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The International Biogeography Society: enabling a dynamic discipline

Introduction

Biogeography is a dynamic and burgeoning field that seeks to understand the role of historical factors in shaping biodiversity and to develop predictive capacities for gauging how biodiversity will respond to our rapidly changing world. The focus is frequently on circumstances leading to these distributions, and consequently on ecological and/or historical factors that have played a role in shaping them. Biogeography integrates information across fields of evolutionary biology, ecology, geology, and geography: for example, selection within a given environment, in concert with isolation that might be achieved through geological or ecological events imposed on the organism, or the activities of the organism itself, have all acted at some level to mold ancient and recent distributions. The complexities of these interactions and emerging patterns of biotic distribution have been of interest to biologists since the time of Wallace and Darwin and before.

Biogeography has changed enormously over the last half century (Lomolino and Brown 2009). Starting from a largely descriptive field it became a rigorous science in the 1960s and 1970s with the testing of explicit hypotheses. Notable milestones included the advent of vicariance biogeography in concert with the development of cladistics and understanding of plate tectonics (Nelson and Platnick 1981) and the development (MacArthur and Wilson 1967) and subsequent experimental testing (Simberloff and Wilson 1970) of the theory of island biogeography. The advent of molecular tools in the late 1980s again revolutionized the field by providing new information on relationships and their origins (Riddle et al. 2008). Today, the field is poised for yet another revolution, this time stemming from the massive amounts of data that are becoming available through rapidly developing technologies, including high throughput DNA sequencing and accessible online databases, that allow us to infer new details of the processes involved in biogeography.

Major growth areas in biogeography

The newly available technologies have facilitated growth in very different aspects of biogeography. The advances are enabling the field to move far beyond testing scenarios of geographic subdivision and understanding processes in one space and time. Rather, we can now look at processes underlying biogeographic patterns and, importantly, develop predictions of how biogeographic patterns might be shaped in the future: How will species respond to changes in climate and land use? What will be the impact of invasive species? How will resulting changes in species composition affect community stability and ecosystem function?

Phylogenetics and phylogeography

The genomic revolution was initiated in the mid-1980s (Kuska 1998, McKusick and Ruddle 1987), taking off in the 1990s and still continuing (Fleischmann 1995, Hughes and Field 2005). The abundance of markers now available from newly developed genomic tools has provided the potential for detailed insights into biogeographic patterns, including the temporal framework of colonization, fragmentation, or diversification of lineages (e.g., Jetz et al. 2012b, Moore and Donoghue 2009), and associated demographic changes involved (e.g., Knowles 2009), as well as the genetics of adaptation and other mechanisms (e.g., Elmer and Meyer 2011, Hohenlohe et al. 2010, Martin et al. 2012) that allow insights into the interplay between geologic and climatologic history and the biology of organisms.

Microbial biogeography and metagenomics

In addition to a direct examination of biogeographic scenarios (Whitaker et al. 2003), the wealth of molecular data presents the opportunity to assess the role of microbes in biogeography and how bacterial and fungal genes may be involved in shaping evolutionary history. These approaches have also provided understanding of the mechanisms of speciation across multiple scales (Lopez-Garcıa and Moreira 2008), and both in terrestrial environments and in the ocean (Follows et al. 2007). Concomitantly there has been a tremendous increase in the number of metagenomic studies sequencing the DNA from environmental samples. Numerous 'megasequencing' projects aim to characterize environments such as the world's oceans (Rusch et al. 2007), and other environments (Gilbert 2010); these advances are paving the way for genomic studies of entire communities and ecosystems.

Macroecology

The field of macroecology, which examines the relationships between organisms and their environment at large spatial scales to determine statistical patterns of abundance, distribution and diversity, also started as descriptive and pattern-based (Brown 1995). New conceptual and analytical approaches, together with the rapid development of phylogenetic data and tools for paleoclimatic modeling, have changed the field with a renewed focus on mechanisms (Keith et al. 2012, Lorenzen et al. 2011). At the same time, theoretical tools are providing avenues for allowing predictive capabilities. For example, maximum information entropy (MaxEnt) (Jaynes 1982) is a powerful tool that allows prediction of a universal species-area relationship based on simple ratios of state variables across space (Harte et al. 2009); deviations from this universal prediction can serve as indications of systems departing from equilibrium. Overall, macroecological approaches hold much promise for helping understand biotic responses to global change (Kerr et al. 2007, Nogués-Bravo and Rahbek 2011).

A key role for bioinformatics and data science

As new technologies develop and our ability to address the dynamic nature of biodiversity advances, so too does the availability of massive amounts of data and increasingly sophisticated tools that can analyze the data (Parr et al. 2012), which in turn opens up a world of opportunity for understanding biogeographic patterns (e.g., Storch et al. 2012). Information on environmental variables is now extraordinarily sophisticated, with global information on topography, hydrography, soils, bioclimate, etc. (Jetz et al. 2012a). Geographic information on biodiversity as a whole has lagged, with understanding of even the best known species being much coarser than other environmental information, a phenomenon termed the "Wallacean shortfall" (Brown and Lomolino 1998, Whittaker 2005). However, considerable progress has been made in recent years. In particular, one effort to address this shortfall is the *Map of Life*[1] which aims to provide fine scale species occurrence information by integrating across as many different data types as are available, including regional checklists, expert range maps, modeled distributions, and phylogenetic information (Jetz et al. 2012a). Major regional efforts to integrate geographically relevant biological data include the *Atlas of Living Australia*[2], which provides spatial biodiversity information together with innovative tools and REBIOMA[3] for Madagascar.

The amount of freely available data for specimens worldwide, especially museum-based records, is increasing rapidly. Major specimen data aggregators include the *Global Biodiversity Information Facility*[4], the *Paleobiology Database*[5], and *Ocean Biogeographic Information System*[6] (Sedberry et al. 2011). Regional aggregators include *Canadensys*[7], the *US Virtual Herbarium*[8], and *New Zealand Virtual Herbarium*[9]. There are also increasing numbers of occurrence databases including *MaNIS*[10], *FishNet2*[11], *HerpNet*[12], and *ORNIS*[13]. Notable species account and information databases are *AmphibiaWeb*[14],

1 http://www.mappinglife.org/
2 http://www.ala.org.au/
3 http://www.rebioma.net/
4 GBIF; all biodiversity, http://data.gbif.org/
5 http://paleodb.org/
6 OBIS; http://www.iobis.org/
7 http://data.canadensys.net/
8 http://www.wiu.edu/USvirtualherbarium/
9 http://www.virtualherbarium.org.nz/home
10 mammals; http://manisnet.org/
11 fish; http://www.fishnet2.net/
12 herps; http://www.herpnet.org/
13 birds; http://www.ornisnet.org/
14 amphibians; http://amphibiaweb.org/

FishBase[15], and *Neotoma*[16]. Additional repositories include *Dryad*[17] for data and *MorphBank*[18] for images. Many of these have apps or interfaces to allow easy access for the public (e.g., *AmphibiaWeb*). Other bioinformatics efforts aimed at integrating and serving data on biodiversity include *Data Observation Network for Earth*[19], the *Encyclopedia of Life*[20], *GEO Biodiversity Observations Network*[21], initiatives connected to the *Convention on Biodiversity*[22] and the *Intergovernmental Platform on Biodiversity and Ecosystem Services*[23] including the IUCN list of threatened and endangered species, and the Global Invasive Species Database. In addition to information on specimens and associated ecological data, the availability of genetic and genomic data has exploded over the last decade or so (Parr et al. 2012), with massive amounts of data available through the *National Center for Biotechnology Information* (NCBI, e.g., Genbank and the Gene Expression Omnibus[24]) There are also multiple efforts underway to harness genomic data to provide biogeographic information (Davies et al. 2012).

In addition to developing accessibility of existing data, several efforts are underway to enhance data acquisition, including the use of citizen scientists and crowd-sourcing for digitization of specimen labels (Hill et al. 2012). Additional citizen science efforts are focused on natural history observations (e.g., *iNaturalist*[25] and *eBird*[26]). Clearly, the enormity of the data that is becoming available holds immense promise, although the pitfalls of using these data uncritically is already well recognized (Anderson 2012). Of key importance is to ground the data analysis and interpretation within a solid scientific structure (Peterson et al. 2010).

Role of the International Biogeography Society

The field of biogeography is clearly booming. The role of the *International Biogeography Society* (the Society) is to serve as a home for researchers in the field, and provide a framework that facilitates optimal use of the new resources and developing tools, while maintaining foundations in organismic biology and our interdisciplinary focus. Therefore, as the Society moves ahead, I see four key needs. First, to provide a forum to enable access to, and information on the appropriate use of, emerging tools and data. Second, to foster a solid understanding of organisms and of the environmental conditions under which they occur. Third, to promote global connections and facilitate capacity in underdeveloped countries so as to allow the promise of the new approaches to reach the far ends of the globe. And, fourth, to cultivate interdisciplinarity such that the predictive capabilities of the field can be used to inform management and policy.

A forum for information on new tools and data

The availability of data, and associated tools and technologies for dealing with massive amounts of information, are overwhelming. An important role for the Society will be to disseminate the availability of this information broadly, and across taxonomic (from microbes to mammals), geographic (worldwide, including both marine and terrestrial habitats), and temporal (paleontological as well as neontological) boundaries. We aim to provide workshops at Society events that inform members on state-of-the-art tools and accessibility, and how (and perhaps more importantly, how not) to use them.

Foundation in organismal biology

Given the deluge of data, as outlined above, it is tempting to focus on the tools and analyses at the expense of time-consuming data-gathering and understanding mechanisms. The risk is that research then becomes removed from the biology of the organisms and the environment in which they live (Ricklefs 2012).

15 fish; http://www.fishbase.org/
16 Pliocene-Quaternary fossils; http://www.neotomadb.org
17 http://datadryad.org/
18 http://www.morphbank.net/
19 DataONE, http://www.dataone.org/
20 EOL; http://www.eol.org/
21 GEO BON; http://www.earthobservations.org/geobon.shtml
22 CBD; http://www.cbd.int/
23 IPBES; http://www.ipbes.net
24 http://www.ncbi.nlm.nih.gov/
25 http://www.inaturalist.org/
26 http://ebird.org/

Role of taxonomy and museums — Taxonomy and systematics are critical to understanding the organisms at which we are looking. Museums have and continue to serve as the primary foundation for specimen identification and for assessment of changing patterns of distribution over space and time. Without these collections, our understanding of biodiversity becomes one-dimensional as we lose the temporal, and to a large extent also the geographic, element. Given current funding constraints both within the USA, as well as other countries throughout the world (Shen 2012), the Society aims to provide a forum for support and assistance for museums worldwide so that we do not lose the resources that serve as our foundation.

Role of field-based research — Fieldwork is essential for developing insights into how natural systems work, and making observations that allow us to question and reconsider the interaction between species and their environment. Detailed field-based research allows the development of general knowledge that is broadly exportable (Billick and Pierce 2011).

Global connections

Biogeography is a global discipline, and a broadly international focus is key to the Society in order to address issues and questions that are global in nature. However, access to tools and expertise varies widely across the globe. As the home for research in biogeography, the Society can foster regional activities across the globe, and facilitate interaction and connection between regions.

Interdisciplinarity

Biogeography is an innately interdisciplinary and integrative field. Over recent years, general theories of biodiversity dynamics have relied on insights from the field of biogeography. Moving to the future, the developing predictive capacity of the science allows us to begin to advise policy makers more realistically as they face the challenge of adapting to global change. Therefore, it is becoming increasingly important for the Society to foster effective communication across disciplines. Given the rapidity and unpredictability of the changing landscape, the interdisciplinary nature of biogeography, and the importance of incorporating taxonomy and field-based research into broad geographic constructs, has never been more critical.

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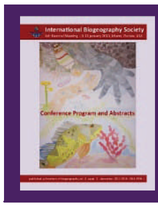

The abstract book of the 6th IBS Biennial Meeting is already available at http://escholarship.org/uc/item/3kb4c5jr and http://www.biogeography.org/html/Meetings/2013/program.html.

