Island biology: looking towards the future

Christoph Kueffer¹, Donald R. Drake² and José María Fernández-Palacios³

¹Institute of Integrative Biology, ETH Zurich, Universitätsstrasse 16, 8092 Zurich, Switzerland
²Department of Botany, University of Hawaii, Honolulu, HI 96822, USA
³Island Ecology and Biogeography Research Group, La Laguna University, Tenerife, Spain

Oceanic islands are renowned for the profound scientific insights that their fascinating biotas have provided to biologists during the past two centuries. Research presented at Island Biology 2014—an international conference, held in Honolulu, Hawaii (7–11 July 2014), which attracted 253 presenters and 430 participants from at least 35 countries¹—demonstrated that islands are reclaiming a leading role in ecology and evolution, especially for synthetic studies at the intersections of macroecology, evolution, community ecology and applied ecology. New dynamics in island biology are stimulated by four major developments. We are experiencing the emergence of a truly global and comprehensive island research community incorporating previously neglected islands and taxa. Macroecology and big-data analyses yield a wealth of global-scale synthetic studies and detailed multi-island comparisons, while other modern research approaches such as genomics, phylogenetic and functional ecology, and palaeoecology, are also dispersing to islands. And, increasingly tight collaborations between basic research and conservation management make islands places where new conservation solutions for the twenty-first century are being tested. Islands are home to a disproportionate share of the world’s rare (and extinct) species, and there is an urgent need to develop increasingly collaborative and innovative research to address their conservation requirements.

1. Introduction

Oceanic islands have long served as model systems for research in biogeography, ecology, evolution and conservation. They were crucial for the formulation of evolutionary theory by Darwin [1] and Wallace [2], and MacArthur and Wilson’s [3,4] dynamic theory of island biogeography is by far the most widely discussed theory in biogeography. Sherwin Carlquist’s seminal publications [5,6]—in particular his classic Island Biology, published exactly 40 years ago—formulated hypotheses specific to island biology that remain valuable today. Key research questions focus on long-distance dispersal, characteristics that facilitate the establishment or persistence of small populations on isolated islands (including evolutionary shifts in breeding systems, e.g. [7]) and diversification processes [8]. Up to one-quarter of global plant diversity is endemic to islands [9].

One reason that islands make ideal model systems for studying universal processes such as adaptive radiation, parallel evolution, community assembly and ecosystem development is that they are globally distributed and isolated geographical spaces characterized by often comparable conditions; this allows observations to be replicated at regional or planetary scales [10]. Another is that islands combine relatively simple biotas with high within-island or within-archipelago abiotic heterogeneity resulting from large elevational ranges, steep climatic gradients, varied geological origins, geological dynamism and strong connectivity between marine and terrestrial ecosystems.

Despite the unique research opportunities and great scientific advances that islands have already furnished, island biology may not have reached its full potential. We see four obstacles that have hindered progress:

(1) Until recently, relatively few islands and taxonomic groups have dominated the island biology literature,
(2) Biogeographic analyses have traditionally been based on relatively simple data, such as species numbers from individual islands,
(3) Many modern research approaches such as genomics, functional traits, community ecology and palaeoecology have not been widely adopted, and
(4) Although oceanic islands are global priorities for biodiversity conservation, basic research and applied conservation have often not been effectively connected.

However, as detailed below, the Island Biology 2014 conference showed impressively that the field is overcoming these obstacles and entering a phase of rapid development.

2. Island biology becomes global
Island biology is experiencing a major new wave of research, with diverse, in-depth studies occurring on island groups worldwide. Research has expanded beyond traditional strongholds and is now flourishing in new regions. Macaronesia is a hotspot, with intensive research in the Canary Islands, Azores and recently Cape Verde. Among French Pacific islands, new research suggests New Caledonia was once completely submerged, and the biota of this Gondwanan relict formed through a series of re-colonization and local diversification events [11]. Likewise, new geological and phylogenetic data increasingly allow reconstruction of the fascinating story of the Western Indian Ocean [12], where a tightly linked regional biogeography involves the mini-continent Madagascar, continental fragments of the Seychelles, Aldabra atoll dominated by giant tortoises and oceanic Mascarones. The conference also helped expand island biology by connecting the international community to burgeoning research on Japan’s outlying islands and arctic and subantarctic islands. While many islands remain underexplored, expertise and data are increasingly available from some of the least known islands, such as the Gulf of Guinea islands.

Paralleling this geographical expansion of research, the taxonomic breadth of island biology has widened to include freshwater biota, prokaroytes, fungi and blind cave arthropods. Bryophytes and ferns are emerging as model groups for biogeography and potential early warning systems for detecting climate change impacts. We are experiencing the emergence of a truly global, comprehensive island research community (e.g. [10,13–16]).

3. Modern biology disperses to islands

(a) Macroeconomy and macroevolution
Two conference sessions demonstrated how the emergence of new data is facilitating more comprehensive meta-analyses than previously seen. Increasingly comprehensive species lists from around the world allow investigation of the determinants of the taxonomic structure of island biotas: for instance, which taxa are particularly prominent on islands, which of them radiated, whether islands are indeed characterized by a relatively more uneven (disharmonic) representation of taxa than continents and how this affects phylogenetic diversity. Analysing species distributions among islands and along chronosequences within archipelagos helps clarify the role of vicariant speciation and reconstruct the time-sequence of radiations and community assembly. With the help of detailed molecular phylogenetic data, analyses can be further improved by identifying lineages resulting from single versus multiple colonization events, determining arrival times and ages of lineages, and tracing source biotas and dispersal routes. Future steps will further refine species distribution data by assigning species to different habitats and linking them to functional trait and population genetics data.

(b) Genetics
Island biology has long employed phylogenetics, but population genetics and genomics are providing new insights. Genetic research is revealing the mechanisms involved in the evolution of beak size in Darwin’s finches [17] and the enormous plasticity of Metrosideros species: trees that dominate Hawaiian habitats from new lava to bogs to rainforests, but in which most of the plasticity is within species [18]. Growing databases (e.g. http://www.demiurge-project.org/) of fine-scale population genetics data can be used to investigate the genetic basis of radiations or test hypotheses about gene-level adaptations of small and isolated populations. Such information about the genetics of rarity will potentially be of huge significance for conservation biology.

(c) Palaeoecology
Palaeoecology is greatly expanding our understanding of island ecology. Many islands have only relatively recently been colonized and suffered large reductions in their biotas. Palaeoecology is revealing that many species that are now rare or extinct were abundant in pre-human ecosystems and that land use, introduced species and fire often played important roles in their decline. Of particular importance for conservation are new data on extinct keystone animals, helping inform strategies for restoration and re-wilding. Some of the most dramatic advances from palaeoecology, however, come from data showing how dynamic pre-human island ecosystems were. Vegetation on many islands fluctuated strongly in response to climate changes, contradicting the common opinion that islands experienced buffered climates with minimal fluctuations, and providing a new perspective on the challenges for island species to persist in isolation. Finally, palaeoecology continues to add evidence to long-standing questions such as insular dwarfism or gigantism. The conference devoted a session to palaeontological records of extreme body size in island dinosaurs and mammals.

(d) Community ecology
Community ecology has seen major conceptual advances recently through the integration of population biology, coexistence theory, phylogenetic data and functional ecology; these developments are now reaching island biology. Islands, through their simplicity, replication and chronosequences, are ideal for studying the interplay of ecological and evolutionary processes in community assembly, as demonstrated in exemplary work on the assembly of Hawaiian spider communities [19]. The simplicity of island communities also makes them systems of choice for applying network analyses to examine plant–animal interactions at multiple trophic and geographical scales. If macroecological and multi-island comparative analyses advance in parallel by addressing multi-species patterns
at a habitat level, community ecology on islands should soon yield major breakthroughs.

4. Integrating basic and applied ecology

Islands urgently require effective conservation management. Many species face extinction, natural areas are small and fragmented and alien species dominate most ecosystems [20]. Conservation has a long tradition on islands, and there are success stories; the conference highlighted many examples of eradication of alien species and restoration of seabird islands. However, an arresting conference session revealed that many Hawaiian forest birds continue to decline rapidly, and solutions remain elusive.

Increasingly, basic and applied ecology are tightly integrated in island research. After initial failures, invasive species eradication programmes now incorporate population models and analyses of multi-trophic interactions. Research on plant–animal interactions, such as seed dispersal or pollination, compare little-disturbed, novel and restored ecosystems, and palaeoecological research provides conservation baselines and informs ecological restoration. Thus, although islands remain hotspots of biodiversity loss, they also hold promise as grounds for innovative conservation approaches needed in the novel ecosystems of human-transformed landscapes [20]. Effective solutions will, however, often require interdisciplinary research involving the social sciences. Several talks on climate change highlighted how societal responses to climate change could indirectly threaten island biodiversity, e.g. when sea-level rise displaces human populations from coastal areas, forcing them into previously uninhabited areas inland. Analyses of the ecological legacy of traditional societies on islands can inform us about sustainable land use [21].

5. Conclusion

Islands are reclaiming their role as ideal model systems for the latest research questions and methods in ecology, evolutionary biology, biogeography and conservation. It is becoming feasible to do research that integrates processes at vastly contrasting temporal and spatial scales, from local coexistence and species interactions, to regional species assembly and rapid evolutionary processes, to large-scale macroecological and species interactions, to regional species assembly and rapid evolutionary processes, to large-scale macroecological patterns and long-term biogeographical processes. Islands could provide model systems where new conservation solutions for the unknown novel ecosystems of the twenty-first century are tested through coordinated interaction between basic and applied research, and adaptive management [20].

The conference demonstrated much recent progress towards this vision. Yet gaps—and therefore opportunities—persist. For instance, functional ecology remains poorly developed because functional traits of most island species are unknown, limiting possibilities to study species coexistence and link community and ecosystem ecology. Although ecosystem ecology is well established on some islands, little research has addressed whether island ecosystems differ fundamentally from continental ones, e.g. in spatial biodiversity patterns or efficiency of biochemical cycles. Such research questions could reveal how ecosystem function can be maintained in species-poor communities.

The conference illustrated island biology’s great potential, and the quantity and innovative nature of the work presented by young researchers emphasized the vigour of the field. Our goal was for this meeting to launch a series of international island biology conferences, bringing together researchers who, by the very nature of the islands they study, face geographical barriers to communication. The meeting also provided opportunities for conservation practitioners from local agencies—people rarely able to attend international meetings—to see presentations from other islands around the world and exchange ideas with many scientists whom they would not otherwise meet. We should stand together not only to embrace unique research opportunities, but also to forge momentum that is desperately needed to save the biological treasures on islands. Literally, thousands of endemic island species survive as only a few individuals or small and fragmented populations—and for most of them very little is known about their basic biology. What is unequivocally clear, however, is that most of these species will disappear from the wild in this century unless we markedly intensify our conservation efforts.

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Endnote

1Abstracts of all communications are available at https://sites.google.com/a/hawaii.edu/islandbiology2014/home/scientific-program.

References


