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Ecology in a Changing Climate: Two Hemispheres, One Globe
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S29: Species invasions, environmental change and the future biogeography of freshwater fishes

Date Tuesday, August 18, 2009
Time: 8:30-10:15am
Location: Plaza P2

Symposium Chairperson
Julian Olden, University of Washington, United States (olden@u.washington.edu)

Symposium Speakers
Julian Olden, University of Washington, United States (olden@u.washington.edu)
Emili García-Berthou, Universitat de Girona, Spain (emili.garcia@udg.edu)
Mark Kennard, Griffith University, Australia (m.kennard@griffith.edu.au)
Fabien Leprieur, Antenne au Muséum National d'Histoire Naturalle, France (leprieur@cict.fr)
Pablo Tedesco, Muséum National d'Histoire Naturelle (pablo.tedesco@mnhn.fr)
Kirk Winemiller, Texas A&M University, United States (k-winemiller@tamu.edu)

Symposium Schedule

8:30 Species invasions, environmental change and the future biogeography of freshwater fishes - Julian Olden

8:45 Global-scale patterns of freshwater fish diversity: a starting point to predict future changes - Pablo Tedesco

9:00 Patterns and processes in non-native fish species richness - Fabien Leprieur

9:15 The biogeography of nowhere: Species invasions and the fading antiquity of globe fish faunas - Julian Olden

9:30 Are successful fish invasions only from species-rich into species-poor communities? Examination of evidence from three continents - Kirk Winemiller

9:45 Invasive fishes in the Iberian Peninsula: linking ecology and biogeography - Emili García-Berthou

10:00 Systematic conservation planning of eastern Australian rivers to manage and maintain bioregional variation in fish biodiversity - Mark Kennard

1. Species invasions, environmental change and the future biogeography of freshwater fishes

Julian D. Olden
School of Aquatic and Fishery Sciences, University of Washington, Seattle, WA, USA; olden@u.washington.edu

Humans have a penchant for introducing species to areas beyond their native range, giving the potential for these non-indigenous species to become biological invaders. The continuing globalization of economies and trade has greatly facilitated this process, where invasive species are spreading at unprecedented rates, crossing oceans and colonizing formerly remote regions of the world. In contrast to most terrestrial species, freshwater fishes are uniquely constrained because their ability to respond to environmental change is limited to movement defined by the connectivity of water. In recent times, however, humans have dramatically enhanced the ability of fish species to overcome these natural biogeographic barriers to movement either through intentional transport and other colonization routes created by anthropogenic activities. As a result, human-mediated species introductions have dramatically reshuffled the present-day biogeography of freshwater fishes and threaten the unique biological antiquity of many regions of the world. My presentation will provide an overview of the patterns and dominant drivers of freshwater fish diversity at different spatial and temporal scales, thus serving as an introduction to the collection of presentations in the special symposium. Current conservation threats and challenges will also be discussed. Speakers in this symposium will discuss the current and future challenges to conserving the biogeography of long-evolved native species in light of rapidly expanding populations of invasive species and continued global change. Together, this symposium aims to enhance our knowledge of the linkages between natural and human-induced environmental change and patterns of freshwater fish biogeography at global, continental and regional scales.

2. Global-scale patterns of freshwater fish diversity: a starting point to predict future changes

Pablo A. Tedesco[1], Fabien Leprieur[1], Hans Dürr[2], Olivier Beauchard[3], Sébastien Brosse[4], Bernard Hugueny[1], and Thierry Oberdorff[1]
[1] UMR BOREA, Muséum National d'Histoire Naturelle, Département Milieux et Peuplements Aquatiques, Paris, France; [2] Department of Physical Geography, Faculty of Geosciences, Utrecht University, Utrecht, The Netherlands; [3] Ecosystem Management Research Group, University of Antwerp, Antwerpen, Belgium; [4] UMR ECOLAB, Université de Toulouse, Toulouse, France

Understanding the causes of variability in plant and animal diversity at the global scale has been a major focus of biogeography and macroecology in recent decades. Despite the dozens of hypotheses that have been put forward on the subject, the question of what drives patterns of global freshwater fish biodiversity remains unanswered. Here, we built and explored a database including the distribution of more than 90% of the described freshwater fish species over 926 river basins covering nearly 80% of the land surface, to test three major hypotheses proposed to explain large-scale variation of species richness - species richness-area, species richness-energy and historical hypotheses. We analysed diversity patterns both in term of total species richness (i.e. number of native species by drainage basin) and endemic species richness (i.e. species restricted to a single river basin) in relation to >20 environmental, climatic and historical variables measured at the drainage scale. Based on current ecological thinking, we expect total species richness to be explained by drainage area and habitat heterogeneity (richness-area hypothesis), by climate, hydrology and productivity (species-energy hypothesis), and by history and isolation (historical hypothesis). It is likely that the diversity of native and endemic species is influenced by a combination of factors supporting multiple hypotheses, and that there is no close correspondence between centres of maximal diversification and centres of intense species endemism. Results from our study have important implications in applying global environmental change scenarios on freshwater fish diversity.

3. Patterns and processes in non-native fish species richness

Fabien Leprieur [1], Olivier Beauchard [2], Simon Blanchet [3], Thierry Oberdorff [1], Sébastien Brosse[3].
[1] UMR 5178 « Biologie des Organismes et Ecosystèmes Aquatiques », Muséum National d'Histoire Naturelle, Paris, France ; [2] Ecosystem Management Research Group, University of Antwerp, Antwerpen (Wilrijk), Belgium ; [3] UMR 5245 « Laboratoire d'Ecologie Fonctionnelle », Université Paul Sabatier, Toulouse, France

Identifying the factors determining non-native species richness (hereafter NNSR) is a keystone challenge for predicting species invasions and ecological damage. However, the relative importance of ecological and human activity-related factors considered for explaining NNSR might depend upon both the spatial scale (grain and extent) and the historical context of the area surveyed. Here, using a worldwide database of freshwater fish occurrences at broad spatial grains (river basins), we tested if the relative influence of human and ecological determinants of fish NNSR at the extent of the biogeographic realm was consistent (i) with that observed worldwide and (ii) among the different biogeographical realms. Then, at a much smaller spatial extent (Europe), we tested for an effect of introduction history on the observed gradient of NNSR. Our results revealed that the prominent role of human activity in shaping the global pattern of NNSR cannot be directly extrapolated to the biogeographical realms. Further, the relationships between human and ecological determinants of NNSR vary strikingly across biogeographic realms, revealing a strong context-dependency of the determinants of NNSR. Particularly, the human-related factors play a predominant role in explaining patterns of NNSR in economically developed realms, while in the other realms environmental characteristics of the river basins best explained geographical patterns of NNSR. At the European extent, distinguishing between exotic (originating from outside Europe) and translocated (originating from Europe) revealed contrasting richness gradients. In addition, the relative influence of human and ecological determinants of NNSR vary according to the place of origin of non-native species (i.e. exotic vs. translocated). In the face of future species introductions, our study suggests that both the spatial scale and the introduction history of the surveyed area should be considered when analyzing patterns and processes in non-native species richness.

4. The biogeography of nowhere: Species invasions and the fading antiquity of globe fish faunas

Julian D. Olden
School of Aquatic and Fishery Sciences, University of Washington, Seattle, WA, USA; olden@u.washington.edu

Humanity's migrations across, and subsequent modification of, the landscape have had innumerable effects on the many organisms in which we share this world. Mounting evidence suggests that the dual processes of human-mediated extirpation of native species and the introduction of nonnative species have resulted in significant changes in freshwater fish faunas. The idea that the transport and release of nonnative fishes by humans will continue relatively unabated into the future has prompted several scientists to term the coming era in Earth's history the 'Homogocene'. The world envisioned is one where the barriers to fish species dispersal are largely broken down by human actions, resulting in the widespread introduction of ubiquitous nonnative species into areas containing rare, and often unique, native species. There is no doubt that fish species are being intentional and accidental moved around the world at an unprecedented rate and these species are finding themselves in streams, rivers and lakes that they could never have established under their own accord. It is also depressingly clear that the scale of human enterprise is large enough greatly to accelerate the pace at which endemic fishes are driven extinct, either globally or locally. What is not so clear is what these species convulsions will do to patterns of freshwater fish biogeography in the future. Here, I demonstrate that a long and continuing history of species introductions is threatening the antiquity of freshwater fish faunas across the globe. Empirical data is presented that provides clear evidence for the homogenization of fish species pools among distant regions in response to the unbridled introduction of nonnative species via human activities. These results emphasize that the success of future global conservation efforts will require the reconciliation of historical patterns of native biogeography with the emerging and rapidly expanding spread of invasive fish species.

5. Are successful fish invasions only from species-rich into species-poor communities? Examination of evidence from three continents

Kirk O. Winemiller
Department of Wildlife and Fisheries Sciences, Texas A&M University, College Station, Texas, 77843-2258, USA

Certain regions of the world, North America, Europe and Australia in particular, have experienced large numbers of introductions of non-indigenous fish species, whereas other regions report scant records of non-indigenous fishes in natural surface waters. Some of this geographic variation can be explained by different types and levels of economic activities, including aquaculture, sportfishing and the ornamental fish hobby, that determine the number of *attempts* to introduce non-indigenous species, either intentional or accidental. Another factor is species tolerances to abiotic conditions within the receiving habitat, with physiological tolerance of cold temperatures within temperate regions being a primary limiting factor. In spite of the fact that temperate-zone fishes should be more tolerant of generally warm temperatures in the topics when compared to tropical fishes' very limited tolerance of cold winter conditions in temperate regions, the dominant global pattern is that more tropical fish populations have become established within temperate regions than have temperate fishes within the tropics. Moreover, instances of successful establishment of non-indigenous tropical fishes within tropical habitats are comparatively rare. Several ichthyological databases and compendia were analyzed for records indicating successful establishment of non-native fish populations within lotic ecosystems. The regions examined were North America, Northern South America, Western Africa, and Southern Africa. Data also were examined to determine of non-indigenous fishes had become established in reservoirs or other constructed lentic habitats. The overwhelming trend is that invasions into lotic waters are successful when the receiving fish fauna contains fewer native species than the donor fauna, and this is true for tropical, subtropical, and temperate regions. Usually, the donor fauna contained substantially more species than the receiving fauna. This pattern suggests that coevolved ecological interactions within species-rich tropical rivers and streams prohibit establishment of non-native species that are relative ecological generalists from less-rich faunas.

6. Invasive fishes in the Iberian Peninsula: linking ecology and biogeography

Emili García-Berthou
*Institute of Aquatic Ecology, University of Girona, E-17071 Girona, Spain.*http://ciencies.udg.edu/egb.html

Freshwater fish are a fascinating taxon for biogeography and a very diverse, highly threatened group from the conservation point of view. Freshwater ecosystems are very rich in species but among the most altered and threatened ecosystems in the world and for these reasons invasive species have been particularly damaging in inland waters. Freshwater fish in the Iberian Peninsula reflect both this native biodiversity and the strong impact of invasive species. I will address these two points by summarizing the biogeography of fishes in the Iberian Peninsula and our research on the process of biotic homogenization of its fauna and the ecological impact, genetics, and life history traits of introduced mosquitofish (*Gambusia holbrooki*). The Iberian Peninsula has a rich native fish fauna, with many endemisms, superseded by many introduced fishes, mostly of European (many species widespread in Europe are not native to the Iberian Peninsula) or North American origin. The mosquitofish was first introduced to Europe through Spain and unpublished genetic data reflect well the routes of introduction. Mosquitofish is now abundant in most Mediterranean wetlands and slow-flowing waters and has been shown to displace endemic, endangered cyprinodontiform fishes (*Valencia hispanica* and *Aphanius* spp.). This poeciliid fish also displays variation in life history traits along a latitudinal gradient from France to southern Spain that might explain why it has not yet invaded northern Europe. Overall, our research exemplifies both the enormous knowledge gaps on fundamental questions of fish ecology and biogeography (e.g., ecological impacts of introduced species, life history variation along latitudinal gradients, role of parasites, and implications of biotic homogenization) and the opportunities that invasive species offer to bridge the gap between ecology and biogeography (e.g., performing ecological studies at large scales and adding a temporal dimension to biogeographical studies).

7. Systematic conservation planning of eastern Australian rivers to manage and maintain bioregional variation in fish biodiversity

Mark J. Kennard [1], Virgilio Hermoso [2], Simon Linke [2], Julian D. Olden [3], Bradley J. Pusey [1]and Janet L. Stein [4].

[1] Australian Rivers Institute, Griffith University, Nathan, QLD, Australia; [2] The Ecology Centre, School of Integrative Biology, University of Queensland, St. Lucia, QLD, Australia; [3] School of Aquatic and Fishery Sciences, University of Washington, Seattle, WA, USA; [4] The Fenner School of Environment and Society, Australian National University, Canberra, ACT, Australia

Systematic conservation plans aim to efficiently select a comprehensive and representative set of areas to ensure the long-term persistence of species. Plans that maintain bioregional integrity of species distributions may offer the best chance of conserving critical ecological and evolutionary processes. Unfortunately, these principles have not been applied to freshwater biodiversity conservation in Australia. Here, we use a simulated annealing algorithm (implemented using Marxan software) to identify and prioritise a minimum set of river basins to represent bioregional variation in the distribution of 109 native fish species across 230 coastal river basins in eastern Australia. We evaluated a number of planning scenarios in which the costs (i.e. management and restoration costs) of including particular basins in a reserve design were estimated according to basin area, intensity of human disturbances, or number of introduced fish species in each basin. Multivariate regression trees identified distinct freshwater bioregions comprising river basins that were strongly concordant (model $R^2 > 0.75$) in terms of their environmental characteristics (e.g. hydrology, basin topography) and fish species composition. Systematic conservation planning analyses revealed that overall a relatively small number (~20%) of basins need to be managed to preserve bioregional integrity, but their identity varied according to the cost surrogate used. In contrast, 14 basins with high species endemism were consistently selected despite their high potential costs. Analysis of conservation priorities over the entire region yielded less costly reserve designs (i.e. fewer basins required) than plans that maintain bioregional integrity, but these may be less effective in maintaining long-term evolutionary potential and adaptive capacity of species. Our broad-scale analysis provides an essential spatial context to underpin more detailed conservation assessments within high priority basins and a foundation for developing freshwater fish management strategies in a region of Australia expected to undergo considerable future anthropogenic environmental change.