Evolutionary ecology of species ranges in aquatic environments

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Factors influencing species distributions have been categorised as "historical" or "contemporary" (1,2). Historical evolutionary and phylogeographic factors have operated to generate regional species pools, and are associated with colonisation, speciation, and selective extinction events (3). Contemporary biogeographic and ecological factors operate to determine distributions within regions, and include environmental abiotic variables such as temperature and salinity, and biotic factors such as trophic resource availability and abundance of natural enemies, such as predators, competitors and pathogens. This 'historical vs. contemporary' dichotomy provides a useful temporal subdivision for investigating factors that structure species distributions, but it overlooks important ecological variables that facilitated historical colonisation, speciation and extinction. Similarly it does not allow for ongoing flexibility of regional geographic boundaries and species pools. Perhaps instead species distributions are best considered as ongoing manifestations of micro-evolutionary adaptation to local ecological regimes (fit to environment), dispersal constraints (how far can propagules travel) and increasingly human intervention (overharvesting, habitat change, alien introductions). Here we introduce a mini-series of papers related to these issues that emerged predominantly during the 2015 Aquatic Biodiversity & Ecosystems conference (Liverpool, UK) that brought together marine and freshwater biologists.

In aquatic systems temperature is the ultimate factor determining species distributions (4), although multiple proximate factors are in involved in setting range limits, particularly dispersal capability, habitat quality and the outcomes of biological interactions themselves modulated by temperature (5). Consequently, the range of thermal tolerance (metabolic plasticity) is likely to predict the potential range of species over thermal gradients. Ability to tolerate enemies is also potentially relevant, as we may expect that capacity to mount immunological responses to combat pathogens and parasites will in part determine species ranges. Cioffi and colleagues (6) provided novel tests of these ideas using *Deronectes* water beetles. The authors showed distributions can be partially explained by differences in metabolic plasticity and immunocompetence, alongside thermal tolerance, dispersal ability and body mass.

Dispersal ability shapes distributions of aquatic organisms, alongside ecological traits that facilitate successful colonisations, such as adult body size and anti-predator behaviour (7). Past environmental changes have altered availability of essential habitat and driven extinctions (3). Present day species ranges may therefore be dependent on ability to subsequently disperse from historical refugia. A useful example is provided by the magnificently high species richness of fish present in the Coral Triangle (Indo-Australian Archipelago) of the Indo-Pacific. Here, reef species diversity is positively associated with persistence of reef habitat during sea level changes over the last 3 million years (8). This concept of the Coral Triangle acting as source of contemporary species diversity across the Indo-Pacific was further investigated by Evans and colleagues (9) who used molecular data to estimate relative ages of populations in each of 46 reef-associated species. Focal species were more likely to have older populations closer to the Coral Tringle, consistent with the region being a centre of survival from which they have dispersed and colonised the wider region.

Ongoing shifts in aquatic species distributions are clear from responses to climate change (10), and from records of species invasions following deliberate (aquaculture, fishery improvement, aquarium trade) or accidental translocations (11). One consequence of such shifting distributions is that indigenous species may fall into "evolutionary traps" that reduce fitness due to preferential use of poor quality resources. Hale and colleagues (12) discuss evolutionary traps, using the example of Kemp's Ridley sea turtles that have shown shifts in distribution over recent decades into regions with greater human activity. The authors also consider river-sea migratory fish, such as salmonids, and speculate that human disruption of migration through dam construction may lead to loss of intraspecific phenotypic diversity.

Undoubtedly an appreciation of evolutionary and ecological processes is required to understand broader patterns of species distribution, and to predict responses to global change. Fortunately knowledge of distributions and physical environments of aquatic organisms is now more accessible than ever via online resources such as the Ocean Biogeographic Information System (http://www.iobis.org/) and the Global Biodiversity Information Facility (http://www.gbif.org/). These will become even more critical over coming decades by enabling evidence-based conservation to be implemented in light of the inevitably shifting distributions driven by global change. The contributions in this mini-series forms part of a broader literature that will help to interpret observed biogeographic changes as they progress.

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