# Biogeography of Parasites

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"Essentially, all models are wrong, but some are useful." - George Box

Biogeography is a top-down view of the distribution of organisms through geological time and aims to record and understand these spatial variations across environments (Lomolino *et al.*, 2010). The term came into existence in the 1800’s as advances in technology allowed biologists and naturalists to travel to the far reaches of our planet; documenting, collecting and describing the various plants and animals they stumbled across. Over the years, the field has expanded and refined our understanding of the global distribution of species due to an understanding of continental movement; improved methods for molecular systematics; and has advanced our ability to compile, visualize, and analyse geographic information (Lomolino *et al.*, 2010).

One of the fundamental components of biogeography is searching for drivers of spatial variation in the biodiversity of a region or ecosystem (rohde 1992). Therefore, extensive accounts of the distribution of species that occur in these regions is key to understanding how biodiversity is distributed. To date, studies of large-scale patterns have focussed primarily on free living, terrestrial, vertebrate organisms (see pappalardo et al 2019 for refs). This is, in part, due to the extensive availability of range maps and the blah blah blah (see for reasons). In contrast, the biogeography of parasites have very few empirical studies investigating large scale patterns of their diversity.

Our knowledge of parasite diversity, in general, lags far behind that of free-living organisms. Recognition that study effort is the best predictor of the number of known parasite species per host (Nunn, Altizer, Jones, & Sechrest, 2003; Walther, Cotgreave, Gregory, & Clayton, 1995) and of parasite discovery rates (Jorge & Poulin, 2018) implies that the current picture of parasite biodiversity is incomplete and likely biased towards parasites of charismatic megafauna. As a result, there are very few parasite species for which accurate range maps are available based on geographic occurrence data (e.g., African ticks: Cumming, 1999), and sophisticated maps of infection probability are typically only available for some parasites of high public health relevance (e.g., Soares Magalhaes, Clements, Patil, Gething, & Brooker, 2011).

Thus far, most studies that estimated parasite geographic range assumed that if a host–parasite association is reported, the entire geographic range of the host can be considered the potential area of occurrence for the parasite (Brierley, Vonhof, Olival, Daszak, & Jones, 2016; Han, Kramer, & Drake, 2016; Harris & Dunn, 2010), a method we refer to as “host filling”. This approach can overestimate parasite distribution ranges (e.g., see detailed studies on ticks: Cumming, 1999; fleas: Shenbrot, Krasnov, & Lu, 2007), and thus generates a misleading picture of global parasite diversity.

### Latitudinal, longitudinal and environmental trends

Most groups of animals, whether terrestrial, freshwater or marine, show general changes in species numbers from high to low latitudes (Hillebrand, 2004; Chaudhary, Saeedi and Costello, 2016, 2017), along longitudinal gradients () and with various other geographical (e.g.: depth, altitude) and/or environmental (e.g.: precipitation, temperature) gradients. The increase of species diversity from the poles toward the tropics is the single most interesting pattern in biodiversity and the reasons for this pattern has fascinated ecologists for over a century (Pianka, 1966; Rohde, 1984, 2002; Hillebrand, 2004; Chaudhary, Saeedi and Costello, 2016).

Among marine parasites, latitudinal gradients in diversity with an increase in diversity towards the equator, have been shown for genera of Monogenea and Digenea (Rohde, 1984, 2002). However, these data have not been corrected for sampling bias (Chaudhary, Saeedi and Costello, 2017). Although several robust patterns have been revealed, studies that have corrected for these biases have shown we are far from achieving a clear understanding of the mechanisms behind the geographic variation of parasites (Guilhaumon *et al.*, 2012). Researchers have hypothesized that large-scale patterns in parasite richness should mirror those of their hosts, as parasites and their hosts are involved in intimate interactions. However, these researchers have revealed only weak and inconsistent evidence in favour of marine parasite latitudinal diversity gradients (Poulin and Morand, 2004).

Longitudinal gradients?

Depth gradients?

Statistical models? Such as: GAM’s ? GLMM ? (Jorge and Poulin, 2018)

(Poulin and Pérez-Ponce de León, 2017) - Global analysis reveals that cryptic diversity is linked with habitat but not mode of life

R.

A further consideration is that across a parasites geographic range, it will be exposed to communities of potential host species that change in composition and relative density from one locality to the next. This can result in different host use by a parasitic species across its geographic range. Host specificity can therefore be measured as host use by a parasite across these changing localities. The concept of species turnover across localities is not new to ecologists and have been measured using alpha, beta and gamma diversity measures. Alpha (α) diversity measures local species diversity, while gamma (γ) diversity gives us a diversity measure across a species’ geographical range. Beta (β) diversity measures the difference in species composition, or turnover, among localities within its geographical space.

These concepts can be applied to parasitic host specificity. α - Diversity refers to a parasites host range at a particular locality, while γ - diversity measures the host range across a parasites entire geographic range. β - Diversity therefore measures turnover in host use of a parasite across localities within its geographic range. Therefore, particular parasite species can show high specificity at a local scale while being generalists on a global scale, or vice versa. These measures can then be applied to phylogenetic and ecological indices to gain a finer scale understanding of host specificity across its geographic range.

Next, we investigate patterns of parasite sharing among chondrichthyans in relation to phylogeny, ecology and biogeography, and parasite phylogenetic host specificity. We predict that parasite sharing will be highest among closely related, ecologically similar hosts that live in close proximity, as these factors should favour parasite transmission.

Biogeography

What is it?

How does it apply to parasites?

* Hosts and their parasites are intrinsically linked.

How is it measured?

* Longitudinal, Latitudinal gradients (depth?)
  + General and within parasites
* Species distribution models
  + General and within parasites
* Parasite geographic specificity measures

Specific questions:

* What are the longitudinal and latitudinal trends of marine parasites and their hosts? Is it similar?
* With respect to SDM’s, which env variables play the most nb role between hosts and parasites, is it the same
* Does range size/geographic location correlate with host specificity. And are there trends between host specificity and geographic distribution. i.e, are parasites in the equator/smaller ranges more specific than temeperate/larger ranged parasites?

## Methods

## References