

The holy trinity of spatial climate change ecology: high-resolution climate data, long-term biodiversity monitoring and physiological experiments. A commentary on Ripley et al. (2019) Invasive grasses of sub-Antarctic Marion Island respond to increasing temperatures at the expense of chilling tolerance.

The effects of climate change on biodiversity are unfolding right in front of our eyes, with the science studying climate change impacts once and for all moving from a predictive to a descriptive one. Ripley et al. (2019) illustrate this new state of affairs elegantly with their research on the grass species of Marion Island, one of the sub-Antarctic islands in the Southern Ocean. There, they compared the physiological response of six out of the nine grass species of the island to warming, and link this to long-term monitoring data of the distribution dynamics of these species across the island. An important assessment, as the island has seen significant warming over the past decades (0.26°C per decade), steadily tilting the balance in favor of more warm-adapted newcomers at the cost of cold-adapted native grasses.

Their findings? The species with the greatest rate of spread over the last decades – the non-native, warm-adapted newcomers - produced leaf area with the lowest biomass cost and had the strongest increase in photosynthesis in response to warming, but they were also most chilling sensitive. Importantly, these most invasive species had photosynthetic rates double those of the non-invasive species at warmer temperatures, showing significantly higher phenotypical plasticity than their native counterparts.

This case-study highlights three distinct data types that are critical for our understanding of how ecosystems are changing – and will change - under climate change: high-resolution environmental data, long-term biodiversity monitoring and physiological experiments (Fig. 1). Indeed, the analysis from Ripley et al. (2019) relies on the long-term (since 1965) repeated biodiversity monitoring on the island, which has shown – with relative certainty and a high resolution – how these native and non-native grasses have behaved on the island over the last decades (le Roux et al. 2013). Secondly, it builds on the weather station data established on the island since the 1950s to quantify the rate of climate warming on the island. Finally, it is their use of physiological experiments that allows data-based predictions of what will happen in the future.

These long-term observational data of climate and biodiversity, in combination with physiological experiments as reported in Ripley et al. (2019) together pave the way towards informed predictions of the distribution of our biodiversity in the future. Here, I argue that, when collected in tandem, on large scales, at high resolutions and in interaction with each other, these three data types can provide the critical baseline data to answer questions on why species are moving and adapting, and predict their fate in a rapidly changing future. Doing this properly needs coordinated efforts, however, as climate change research has traditionally remained scattered, anecdotal and incompatible, compromising opportunities for data synthesis and upscaling (Halbritter et al. 2019). Most importantly, while within each of these three subdisciplines major coordinating efforts are on the way, it is in the interaction between all three that most merit can be found.

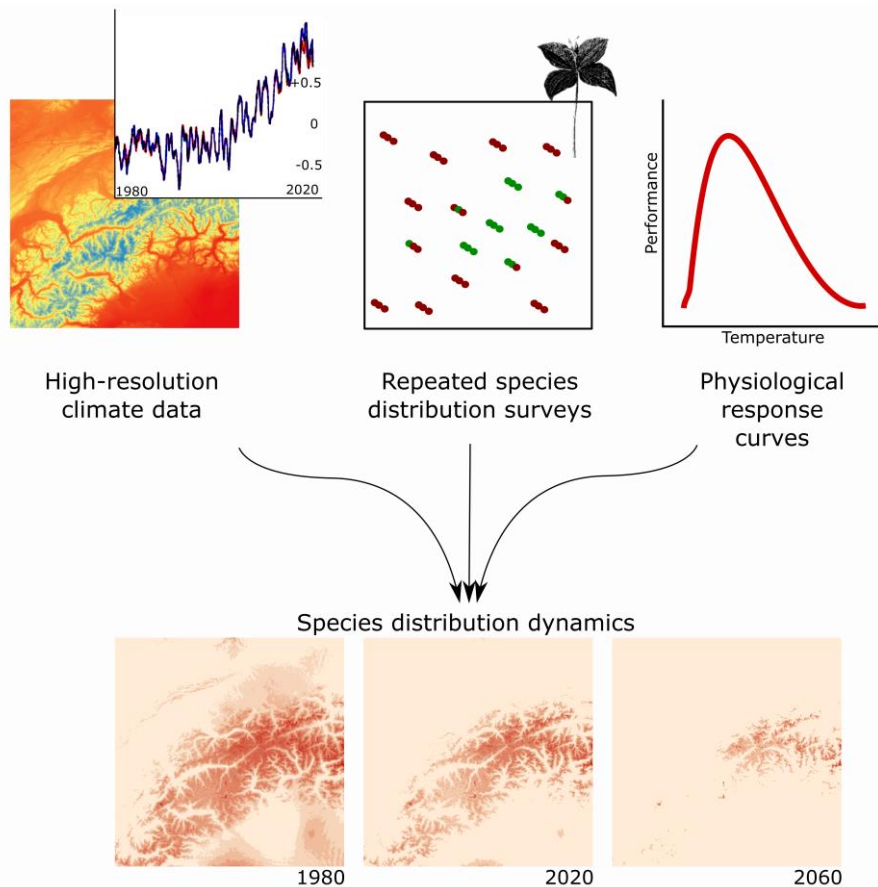


Figure 1: schematic overview of the ‘holy trinity’ of spatial climate change ecology, high-resolution climate data (visualized in space and time), multi-year repeated species distribution surveys and experimentally obtained physiological response curves, which can together inform process-based rather than correlation-driven models to obtain past, present and future species distribution dynamics. Data shown is illustrative only.

Climate data might have advanced the furthest of the three towards long-term, high-resolution large-scale availability, as shown by the presence of a continuous weather station on Marion Island since 1950 (Ripley et al. 2019). Long-term climate data for the whole world is for example available from ERA5 (Copernicus Climate Change Service 2019), while the spatiotemporal extent and resolution of remotely sensed data to downscale these coarse-grained climate models is rapidly increasing (Bramer et al. 2018). Nevertheless, much work still needs to be done to increase the spatial resolution of said climate data at the global scale, and switch from the use of free-air temperatures to in-situ measurements at the level of organisms themselves, especially so for organisms living close to the soil surface like grasses (Lembrechts et al. 2018). This transition to fine-resolution data is timely, as the use of coarse-grained climate data has limited model accuracy and hampered our ability to evaluate the impacts of climate change on species distribution shifts and biodiversity loss (Lembrechts et al. 2019).

Long-term biodiversity monitoring is now finally also reaping the benefits of increasingly long time series, with many initiatives for example coordinating large-scale multi-decadal resurveying of forest plots (Verheyen et al. 2017) or compiling global plant survey data (Bruehlheide et al. 2019). Here again, however, progress could be made through increased global coordination of survey design, a better match between surveys and in-situ microclimate monitoring and an increased investigation of oft-neglected organism groups (e.g. belowground communities).

Finally, it is the interaction between (micro)climatic conditions and physiological parameters at the organism level that ultimately govern species distribution dynamics. As shown in Ripley et al. (2019), for example, warming will increase resource acquisition in warm-adapted non-native, yet not in cold-adapted native grass species, with potential downstream effects on growth, survival and thus their distribution. The understanding of the responses of plants to climate change thus urgently requires the integration of physiological information in distribution models through a correct coupling of physiological experiments with observational data.

In summary, climate change ecology needs high resolution environmental data, measured where it matters for organisms and linked to long-term large-scale data on species community dynamics. Integrating these two will lead to better understanding of past and present changes, and allows careful predictions for the future. Strengthening them even further with physiological experiments allows stepping away from the over-reliance on correlative (rather than process-based) models, which can give those future predictions the extra credibility they need. It is the integration of these data types that will allow climate change ecology to move forward. And that is what we should be aiming for, if we want to tackle the complex and multi-dimensional issues of biodiversity conservation under accelerating global change, as the rate of change demands rapid understanding of and action on species (re)distributions.

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