Global Change Biology

WILEY

Global Change Biology

RESEARCH ARTICLE OPEN ACCESS

Future Climate Shifts for Vegetation on Australia's Coastal Islands

David Coleman | Mark Westoby | Julian Schrader

School of Natural Sciences, Macquarie University, Sydney, Australia

Correspondence: David Coleman (dave.r.coleman@gmail.com) | Julian Schrader (jschrader@posteo.de)

Received: 16 October 2024 | **Revised:** 2 April 2025 | **Accepted:** 15 April 2025

Keywords: climate change | climate refugia | island ecology | plant ecology | plant migration | temperature envelope

ABSTRACT

Small coastal islands serve as replicated units of space that are useful for studying community assembly. Using a unique database holding information on comprehensive vegetation surveys on > 840 small coastal islands fringing the whole continent of Australia, we investigated the extent to which conditions will change for plants on Australia's islands over the next 80 years in terms of their temperature envelopes and inferred changes in vapour pressure deficit (VPD). We found ~40% of island plant populations will experience mean annual temperatures beyond their current envelope. However, envelopes defined by VPD and extreme monthly temperatures are unlikely to be exceeded, highlighting islands' potential to act as climate refugia. Large species with slow life histories and poor dispersal traits were most likely to experience warmer temperatures, although this proved to be driven by correlations of these traits with latitude (closer to the equator) and with smaller range sizes. We found no evidence of warm edge extinction or poleward migration across species in response to 0.5° of warming since the year 2000. These results have applications for monitoring and conservation efforts under climate change for fragmented habitats everywhere.

1 | Introduction

Islands are discrete, finite units of space that house about a quarter of the world's flora, have provided some of the most influential theories in biogeography, species migration and turnover, and now are subject to climate change (Kubota et al. 2015; MacArthur and Wilson 1967; Schrader et al. 2024; Veron et al. 2019; Whittaker et al. 2023). The world's coastal islands will experience warmer temperatures, with likely challenging consequences for their native vegetation (Coleman et al. 2025). However, the response of species to growing outside their current climate envelope is often idiosyncratic depending on the individual species and difficult to generalise (Andrew et al. 2022; Gallagher et al. 2019; Marshall et al. 2008).

Mechanistic understanding of how plants will fare in warmer climates is complex and still being developed. Mechanistic approaches focus on ecophysiological variables such as photosynthetic rates, leaf thermal tolerances and hydraulic parameters (Choat et al. 2018; Crous et al. 2022; Feeley et al. 2020). There are also interactions with plant reproductive success (Sentinella et al. 2020), vulnerability to herbivory (Young et al. 2024) and many other factors. All these are likely to vary across species. But ultimately, plant responses to climate warming can be summarised as three possibilities: (i) populations may be able to tolerate the new conditions in situ, (ii) populations may become locally extinct and/or (iii) populations may be able to migrate polewards (Paquette and Hargreaves 2021). Small coastal islands naturally exhibit high rates of species turnover across a diverse range of flora, located close to source populations on the mainland (Chiarucci et al. 2017; Cody 2006; Flood and Heatwole 1986). Discrete units of habitat such as coastal islands off the Australian mainland offer an opportunity across many climates and environments to assess what proportions of species are expected to become displaced from their present-day climate envelopes. Species so displaced will have to tolerate the change, become locally extinct or migrate polewards.

Quantifying the extent of climate warming that plants will experience in the future depends on the choice of climate metrics from climate projections. Unlike precipitation, which is changing to become more erratic and less predictable (Zhang et al. 2024), temperature metrics such as mean annual temperature (MAT) and maximum temperature of the warmest month (MTWM) are widely used to define the warm edge of species ranges (Benavides Rios et al. 2024; Evans et al. 2015; Feeley et al. 2020; Westoby et al. 2024). In contrast to temperature, much of the mechanistic understanding of plant species population decline and community extinctions due to changes in climate warming invokes vapour pressure deficit (VPD). Increased VPD has been shown to result in tree death, loss of productivity and population extinction (Bauman et al. 2022; Chen et al. 2023; Grossiord et al. 2020; Novick et al. 2024). However, VPD is harder to predict and less commonly used in global climate models (GCMs). For coastal island climates, VPD might be predicted from future temperature projections because of islands' relatively stable and humid climates compared to continental locations, buffered by the surrounding ocean (Byrne and O'Gorman 2018).

Both geographic location and plant traits can contribute to understanding which plant species will experience the strongest climate shifts in the future. For example, island species occurring in narrow temperature ranges may be more vulnerable to warming as more of their range is close to their upper temperature limits (Hatfield and Prueger 2015). Plant traits that are linked to species persistence and extinction under warmer temperatures and higher VPD, such as possessing a lower leaf turgor loss point or higher intrinsic water use efficiency, have yet to be measured over large numbers of species among those growing on Australia's islands (Table S1). However, some traits with high species coverage and associated with the plant economic spectrum (Kattge et al. 2020) have been shown to influence colonisation and extinction probability through recent time on islands (Schrader et al. 2023). For instance, a short, small-seeded herb is more likely to colonise an island and is also more likely to disappear from an island than a tall, longer-lived, larger-seeded, perennial tree. In the high species turnover environment of small continental islands, assessment of which kinds of species are most likely to exceed their climate envelopes can suggest how the vegetation community might shift in response to climate change.

Here we assess how many plant populations on Australia's islands are predicted to experience temperatures above their current day climate envelopes over the next 80 years and discuss how plant species may respond at the continental scale. Estimates are drawn from the A-Islands data set containing vegetation surveys from > 840 small coastal islands fringing the Australian coast (Schrader et al. 2025). Species occurrences on islands are coupled to their temperature envelopes based on their occurrence data over their entire range and climate projections for these islands sourced from the Chelsa Bioclim+ data set (Brun et al. 2022a). Specifically, we quantify the extent of island species populations that will be outside climate envelopes based on MAT, MTWM and mean and maximum annual VPD. We hypothesise that (i) the relatively benign climates of coastal islands will offer protection from future climate extremes for plants, (ii) plants facing the greatest climate shifts can be predicted by location and traits that indicate their responses and (iii) that there will be evidence of net poleward migration of plant species beginning, even in response to the limited climate warming so far.

2 | Methods

2.1 | Island Flora Occurrence Records

Island occurrence records for 1425 species on 843 islands fringing the Australian continent were sourced from the A-Islands database (Schrader et al. 2025). The records were from comprehensive surveys of mostly small (more than 95% < 2 km^2) and coastal (more than 95% < 100 km from the mainland) islands from over the range of environments of Australia's coastline, including monsoonal, tropical, subtropical, temperate and cool temperature, and possessing many different substrates, including sand, coral and rock (Australian Government Department of Climate Change 2009). These species were those within the database that were native to Australia and occurring on at least six islands to analyse species that are common enough for allowing a robust island occurrence range to be calculated. Furthermore, six is the number of records listed as above the minimum threshold for island species distribution models by Benavides Rios et al. (2024). Results for species occurring on more than the minimum six islands compared to a minimum of 10 islands or minimum of 20 islands did not change the overall results and are presented in the Figures S3 and S4. This subset of data contained 39,718 occurrence records (85% of total records in the A-Islands database) of 1425 plant species (30% of total species numbers in the A-Islands database) or ~7% of the total Australian native flora.

2.2 | Species Temperature Envelopes

To access and clean the occurrence data over the entire range of the species (both island and mainland), we followed methods in Gallagher et al. (2019) with minor adjustments to suit our analyses. We conducted the following steps. To define the mainland climate range, occurrence data for the same 1425 plant species was downloaded from the Atlas of Living Australia online portal (ala.org.au; accessed 10 May 2024). Downloads were carried out using the galah R package 2.0.1 (Westgate et al. 2024) with the atlas_occurrences function and occurrences filtered to those occurring in Australia and part of the Atlas of living Australia Species Distribution Modelling data profile https://support.ala.org.au/support/solutions/articles/6000240256-getting-started-with-the-data-profiles.

The data were then filtered sequentially through the following conditions to remove unwanted observations. Numbers in parentheses record how many observations were left at each step: data from resources forming part of the Australian Virtual Herbarium (577,197), observations with geographic coordinates (568,854) and with species names matched back to the original queried names following removal of infraspecific epithets such as subspecies, form, variety, etc. (562,783). Only one unique record for each combination of species name, latitude, longitude, month and year was retained (557,161). Records coming from a cultivated or garden environment were removed using the str_detect function from the Stringr package (Wickham and Wickham 2019) (533,184). Five species that had fewer than six records were also excluded from the analysis to match the threshold applied to the island data set.

To determine the baseline temperature metrics for each species, the mean annual temperature (MAT) and maximum temperature of the hottest month (MTWM), Bioclim variables 1 and 5, were extracted for the coordinates of these records from the Chelsa Bioclim+ data set (Brun et al. 2022a, 2022b). The data set W5E5 v1.0 downscaled with CHELSA v2.0 and represents Bioclim variables at 30 arc sec (1 km) resolution over the earth's surface for the period 1981–2010 (Brun et al. 2022b). The minimum and maximum MAT (Bioclim variable 1) of the occurrences were recorded as the lower and upper temperature envelopes of the species range and the maximum MTWM (Bioclim variable 5) as the upper envelope of hot temperatures for each species. We defined the temperature range size (ΔMAT) as the difference between the maximum MAT and minimum MAT.

2.3 | Species Combined Temperature and VPD Envelopes

VPD values were available for calculating present-day species VPD envelopes; however, future VPD projections for the islands were not accessible. To predict VPD climates on the islands from temperature projections, we explored the relationship between these variables for the period 1981–2010. Mean Annual VPD and Maximum Annual VPD (hereafter referred to as mean VPD and maximum VPD) were extracted from the same data set as above and correlated with MAT and MTWM in a linear model to determine the relationship between these two variables over the island locations in our data set. There were strong linear relationships between MAT and mean VPD ($p < 0.0001$, R^2: 0.95, df: 843, residual standard error = 0.05) and MTWM and maximum VPD ($p < 0.0001$, R^2: 0.93, df: 843, residual standard error = 0.06). These linear relationships were then used to infer future estimates of mean and maximum VPD from the projections of MAT and MTWM over the three future time periods. Combined MAT + mean VPD and MTWM + maximum VPD envelopes for species were defined as the average VPD at the locations of occurrences with the lowest and highest 5% of MAT and MTWM across the species entire range in the period 1981–2010. Like the temperature metrics, VPDs for all locations were sourced from the Chelsa Bioclim+ dataset.

2.4 | Climate Model Selection

We chose to use the GCM projections from the Chelsa Bioclim+ dataset in this analysis to predict the future climates of Australia's coastal islands. This data set is widely used for many different applications involving biological responses to future climates (see citations of Brun et al. (2022a, 2022b)). The data set is made up of global simulations of five earth system models prepared for the Intersectoral Impact Model Intercomparison Project (Lange 2021), projected over three future time periods: 2011–2040, 2041–2070 and 2071–2100. Projections have also been repeated over three socio-economic pathways (SSPs): SSP1 where sustainable emission targets are achieved in the next 30 years, SSP3 where nationalism increases and countries focus on regional security rather than on environmental issues and SSP5 where fossil fuel technologies dominate the development of rapid technological progress (see O'Neill et al. 2016; Table 1). The mean change in MAT and MTWM for these models over each scenario and period was used for analyses throughout the paper and is presented in Figure S1. The Chelsa Bioclim models use statistical downscaling to 30 arcsec using the delta-change method (Hay et al. 2000). To ensure these estimates of future temperatures resulted in similar biological conclusions to those presented here, analyses were rerun using three further climate models sourced from climate models prepared for Australia (Grose et al. 2020) for the most pessimistic scenario (SSP5). These are presented in the Figure S2.

TABLE 1 | Future emission scenarios in the Chelsa Bioclim+ data set.

Socio-economic pathway	Radiative forcing by 2100 ($W\,m^{-2}$)	Scenario description
SSP1	2.6	Optimistic
SSP3	7.0	Intermediate
SSP5	8.5	Pessimistic

2.5 | Assembling Species Traits

We used the near complete data sets for plant growth form, life history and woodiness for all Australian plants (Wenk et al. 2023) and for maximum plant height, seed dry mass and leaf mass per area (LMA) accessed via AusTraits v. 5.0.0 (Falster et al. 2021). For continuous traits, raw observations from many sources were aggregated by Austraits to produce a site-weighted, log-transformed mean value per species. Seed dry mass and LMA values were supplemented by data from TRY (Kattge et al. 2020) by querying for any species without a trait value in AusTraits. Species mean trait values were similarly calculated from TRY data as the mean of log-transformed values.

2.6 | Percent of Island Species Outside Current Temperature Envelopes

We compared the climates of each island with the upper envelope of MAT and MTWM for each species recorded as occurring on that island at any point in the last 70 years. The percent of species-island occurrences above these current observed upper temperature metrics for each model, time period and scenario was then calculated. The average increase in temperature for each island was determined as the mean of the five model temperature projections at each time point; then this temperature was compared to the metrics in the same way as the original five models. The percent of species per island above temperature metrics for each of the time periods was calculated the same way, and the intermediate scenario was presented spatially, given a temperature increase equal to the average of the five models.

2.7 | Structural Equation Models

We used piecewise structural equation models (SEMs) to assess the factors that explained the most variance in island range of species above current MAT in the future. This analysis was carried out using the R package piecewiseSEM (Lefcheck 2016) and fitted linear models with Gaussian error distributions. There may be a correlation between geographic variables such as temperature range size or island location and traits. Some plant traits such as seed mass or plant height have been shown to correlate with latitude and temperature (Andrew et al. 2022; Moles et al. 2009; Weiser et al. 2007). Consequently, the SEM structure was based on a priori hypotheses that plant traits contribute to where a plant grows, the temperature range it inhabits (ΔMAT) and the amount of island range that will be impacted by warmer temperatures. Arguably, the geographic variables may contribute to variation in the trait values rather than the other way around. But if this is the case, the variance contribution (R^2) values do not change—only the direction of the arrows would change. We followed the code and methods outlined in Lefcheck (2016) to construct a traits composite variable, fitting a linear model to the percentage of range of each species that was outside their current climate envelope. The traits composite variable was composed of plant height, seed mass and LMA for species where all three of these trait values were known. The mean latitude of species was defined as the mean latitude of all islands where the species occurs according to the A-Island data set. ΔMAT was determined as explained above in the *Percent of island species outside current temperature envelopes* section. The data for the average percent loss over the three time periods in the intermediate scenario are presented in the main text of the paper. The intermediate scenario was chosen to maximise the spread among species percent of range outside temperature metrics and reduce the number of species that had lost 100% of their range. To show that little changed in terms of the relative contributions of the various effects depending on the scenario, this SEM was remade using the SSP5 scenario following the same method (Figure S5).

For all models, we calculated the independent contribution (R^2) of each single predictor variable using the R-package hier.part (Walsh et al. 2020) and the corresponding significance levels (*p*-values).

2.8 | Northward Extinction/Southward Migration Analysis

A-Island occurrence data were divided into two groups, pre and post the year 2000 (post-2000 included the range 2000–2018) and limited to observations where the island had been sampled in both periods—a data set of 317 islands from all coastal states in Australia. We chose the year 2000 to retain a reasonable proportion of the data in the latter period (~20%) but also at a late enough time that climate warming in comparison to the earlier time period was as large as possible. Then, the highest (closest to the equator) and lowest (furthest from the equator) latitude for each species in each period was recorded and the difference calculated. Finally, species were grouped by categorical traits of woody/herbaceous, fleshy/dry fruits and annual/perennial life history. These traits were chosen as representative of dispersal and persistence abilities of species, in order to determine if some groups of species may be responding to climate warming earlier than others. Both the northern-most (warm) and southern-most (cool) margins were tested for significant differences between the two periods using paired *t*-tests and a Bonferroni corrected significance level of 0.01.

All analyses were implemented in the statistical software R v 4.4.1 (R Core Team 2023), and data and codes to support this analysis are available via Figshare (Coleman 2025).

3 | Results

3.1 | Species Envelopes Will Be Exceeded for Island Plants in the Future for MAT but Not for VPD and MTWM

On average, ~40% of the populations of plant species on islands are likely to experience temperatures above their current observed maximum MAT under both the SSPs 3 and 5 in the 2071–2100 period (Figure 1). The proportion of species populations predicted to experience temperatures above their uppermost MAT increased linearly over the next 80 years in all models for both the SSPs 3 and 5 but peaked and then flatlined at 10% after the period 2041–2070 in the optimistic scenario. In contrast to envelopes based on MAT alone, $<10\%$ of plant populations will experience both warmer MAT and higher VPD than their uppermost temperature envelope. A similar result was found for envelopes based on MTWM and MTWM with maximum annual VPD, where $<5\%$ of species were predicted to experience temperatures outside these current climate envelopes.

In the tropics of northern Australia in the 2071–2100 period (Figure 2A), most islands were predicted to experience higher MATs than the current observed MAT envelope for nearly all the plants growing on these islands. This concentration of climate change affected plants in the tropics seemed to occur despite warming proceeding at roughly equal rates around most of the Australian coastline (Figure S2). But envelopes of MAT combined with VPD as well as MTWM with VPD showed fewer of these tropical islands to present unprecedented climates for species, with only moderate proportions of species per island outside their current climate envelope by 2100—mostly $<50\%$ per island.

3.2 | Proximity to the Tropics and Smaller Temperature Range Size Drives the Proportion of Exceeded Temperature Envelopes More Than Traits

Overall, 53% of the variation in plant species populations experiencing warmer temperatures than current MAT envelopes in the future could be explained by plant traits, by the observed

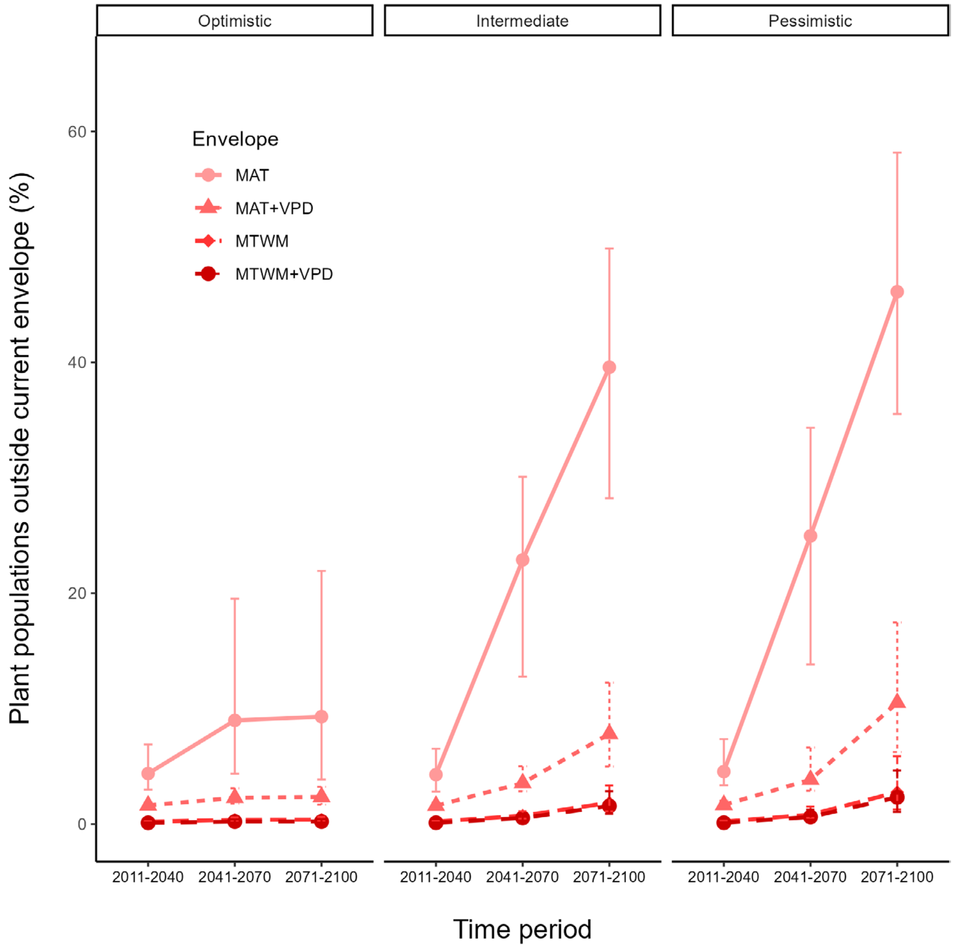

FIGURE 1 | The percent of plant populations across Australia's islands that will experience temperatures outside of four different measures of current climate envelopes: Current mean annual temperatures (MAT), both MAT and mean annual VPD, maximum temperature of the warmest month (MTWM) and both MTWM and maximum annual VPD over the next 80 years. Each projection is the mean number of island plant populations outside their envelope from the five global climate models in the Chelsa Bioclim+ data set (Brun et al. 2022a). The projections occur over three 30-year time periods and for three Shared Socioeconomic Pathways: An optimistic scenario, SSP1 with 2.6 W m^{-2} warming by 2100, an intermediate scenario SSP3, 7.0 W m^{-2} warming by 2100 and a pessimistic scenario, SSP5 with 8.5 W m^{-2} warming by 2100. Error bars represent the highest and lowest estimates of the five climate models in the Chelsa data set (see Table S2 for more details about the models).

temperature range for each species ΔMAT and by mean latitude of the species range (Figure 3A). The proportional contributions of the three variables of traits, mean latitude and ΔMAT remained equivalent for species outside the envelope based on MAT and VPD, except for the contribution of mean latitude, which reduced by half. Most of the variation explained by traits of plant height, seed mass and LMA was via correlations with ΔMAT and the mean latitude of species (roughly 6%) with larger trait values representing smaller temperature range sizes and mean latitudes closer to the equator.

3.3 | There Was Little Evidence for Range Limits of Plants Shifting in Recent Years

Although islands were on average 0.5°C warmer after the year 2000 compared to the ~50 years prior (Figure 4B), the cool and warm (southerly and northerly) edges of species ranges demonstrated both expansion and contraction but showed little directional change considered across all species (Figure 4A). Some plants shifted their range by up to 12° of latitude or more than 1000 km; however, most boundaries shifted by just a few degrees or < 300 km. These individually large shifts are likely due to the sparse sampling of islands between the two time periods, but average out across all species. Temperature increases across the islands in this study post 2000 were similar regardless of the metric used—cool edge temperatures (MTCM) increased just as much as MAT and MTWM.

4 | Discussion

The extent to which plant species on islands will be displaced from their present-day climate envelopes depends on the climate metric used. For MAT, roughly 40% of species populations on islands will find themselves outside their current envelope by 2100 in both the intermediate and pessimistic scenarios. But this result differs markedly when considering mean annual VPD as the climate threshold. Less than 10% of plants that grow on islands will experience both MAT and VPDs above their climate envelope. Our findings show that islands tend to encompass more benign climates within species ranges, considering that

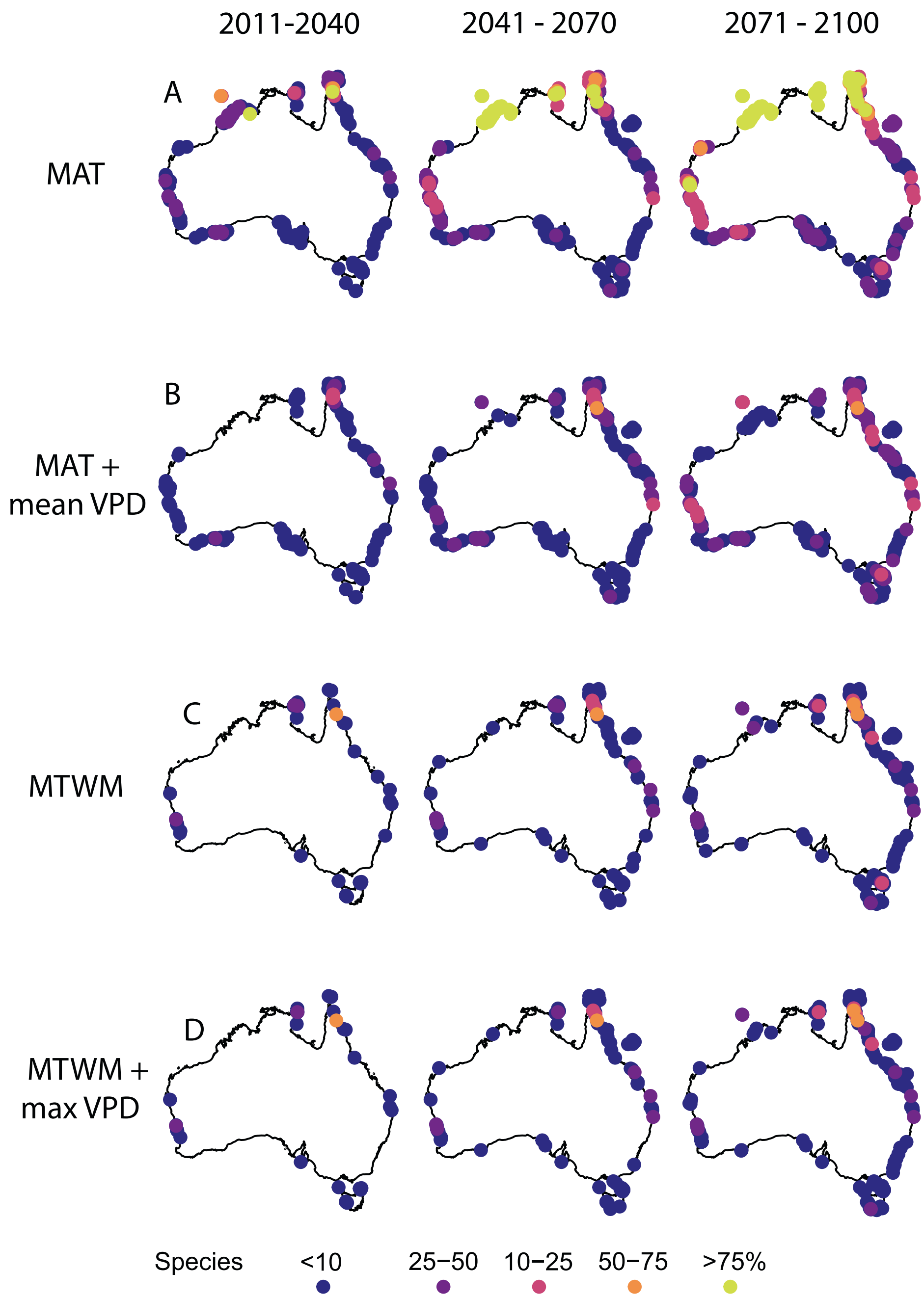

FIGURE 2 | The percent of species per island that will experience temperatures outside of four different measures of current climate envelopes: (A) mean annual temperatures (MAT), (B) both MAT and mean annual VPD, (C) maximum temperature of the warmest month (MTWM) and (D) both MTWM and maximum annual VPD with a rise in temperatures equivalent to the average of the five model predictions for the Intermediate climate scenario Socio-Economic Pathway 3 with a radiative forcing of 7.0 $W\,m^{-2}$.

MTWM on islands will continue to rise by 3°–4° in the pessimistic scenario (Figure S1B).

How might plants respond to these warmer climates? There is some evidence that plant populations on islands that exceed their MAT envelope will be able to tolerate these new conditions. Firstly, about half of cultivated Australian native species planted outside their native range can tolerate climates beyond their MAT envelope (Bush et al. 2018), suggesting that current temperature envelopes do not necessarily represent the absolute tolerance of species to higher temperatures in the future (Laughlin and McGill 2024). Secondly, VPD appears to be a more critical threshold than MAT for species persistence and survival (Bauman et al. 2022; Chen et al. 2023; Novick et al. 2024). For the even fewer island plant populations moving beyond their current MTWM and VPD limits, evidence suggests these variables are more critical thresholds than MAT. Studies of local extinctions of populations that have already occurred due to anthropogenic climate warming show that increases in hottest temperatures during the year are more strongly associated with local extinctions than are rises in MAT (Bauman et al. 2022; Hatfield and Prueger 2015; Román-Palacios and Wiens 2020). If VPD or MTWM are more critical envelopes

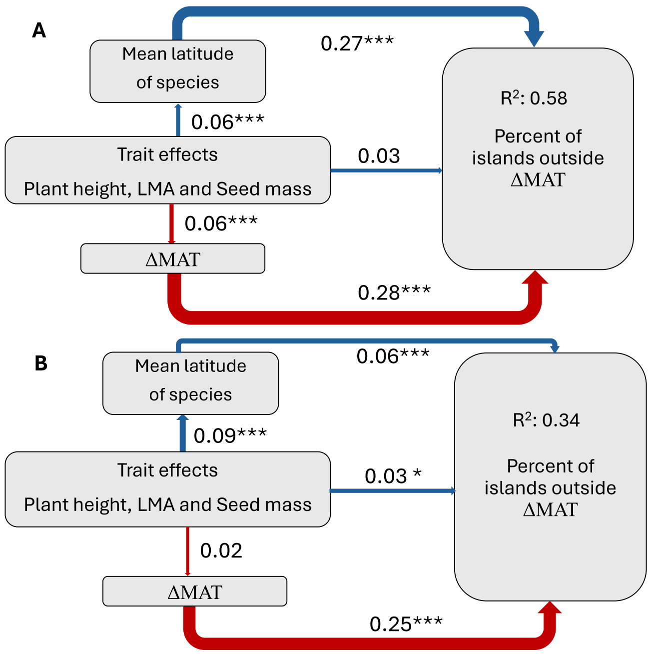

FIGURE 3 | Structural equation models showing the direct and indirect effects of factors influencing the percentage of islands projected to experience (A) warmer MAT than current maximum MAT ($n = 421$) and (B) both warmer MAT and higher VPD ($n = 177$) than in their current range over the next 80 years. Numbers and arrow widths indicate relative contributions of variance of the factor explained by each relationship. Asterisks indicate significance: ***$p < 0.001$. Red arrows denote negative relationships, blue arrows are positive relationships, and grey arrows represent non-significant relationships. Trait effects are a composite variable made up of mean maximum plant height, leaf mass per area and seed mass and numbers of species in each model limited to those which had data for all three traits.

for species, then coastal islands will be important future habitat refugia for plants in the coming century.

However, if considering islands as climate change refuges, the high rate of species turnover on these islands should be considered (Cody 2006; Flood and Heatwole 1986; Keppel et al. 2012; Morrison 2017). Plant populations on small islands generally operate as part of a metapopulation and require replenishment of seeds and propagules to sustain populations or recolonise islands over the longer term (Freckleton and Watkinson 2002; Hanski 1998). Determining whether island populations are self-sustaining, and if not, what measures are required to make them so will be important for the viability of these locations as habitat refugia.

We found that most climate-impacted species (based on MAT envelopes) are found on islands along Australia's northern tropical coastline (Figure 2A); a fact which is concerning given that tropical plants worldwide are considered more vulnerable to warming as they are near their upper thermal limits (Laughlin and McGill 2024; Sentinella et al. 2020). If less heat-tolerant than temperate species, tropical island plants may need to migrate, tracking their climate niche between islands. Indeed, most climate-impacted species (based on MAT envelopes) are found on islands along Australia's northern tropical coastline (Figure 2A) where many are regional endemics with narrow observed temperature ranges (Andrew et al. 2022; Gallagher et al. 2019). This is partly due to Australia's northern coast acting as a 'climate ceiling' for temperature. While some native species occur in countries closer to the equator, they typically grow in areas with lower MAT than in Australia (Gallagher et al. 2019). Given Australia's high plant endemism, many species may already be adapted to the warmest tolerable conditions, but this hypothesis requires further testing. For island plants along Australia's northern coast, movement might be hindered. These islands are oriented east–west with large gaps between archipelagos, limiting migration.

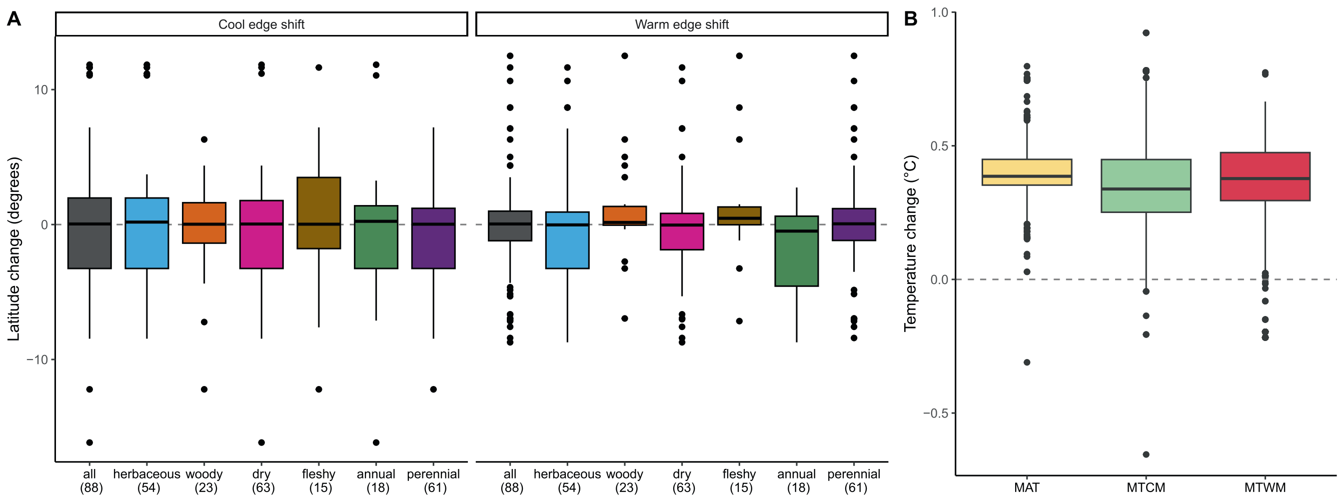

FIGURE 4 | (A) Shifts in minimum latitude (southerly limit or cool edge) and maximum latitude (northerly limit or warm edge) of 88 island species comparing occurrence records 1950–2000 to records from 2000 to 2018 (pre and post the year 2000), grouped by categorical traits. Box plots represent the interquartile range and median; whiskers are the smallest value at most 1.5 * interquartile range. Numbers on the axis labels refer to numbers of species in each trait group that displayed latitudinal shifts between the two time periods. The dashed line represents 0° of latitude. No significant difference was observed for any group between the two time periods (tested using paired t-tests with a Bonferroni corrected significance level of 0.01). (B) Change in mean temperatures pre and post the year 2000 across 844 fringing coastal islands in the A-Island data set.

Can the plants that will experience the most change be characterised in terms of geographic range or plant traits? In combination with latitudes closer to the equator, our data show species with smaller range sizes will experience temperatures above their MAT over a greater proportion of their range (Figure 3A). However, when VPD is also considered, the correlation with mean latitude reduces by half (Figure 3B). This is also evident in the contrasting patterns when comparing the spatial distribution of MAT envelopes with others (Figure 2A vs Figure 2B), where the concentration of species outside their envelope in the tropics is greatly reduced. Such a strong contrast between temperature envelopes of increased MAT without corresponding shifts in VPD will make plant community turnover on tropical coastal islands key locations to identify the most critical climate metrics for plants in the future.

Plant traits may also help predict how vegetation may change for islands most impacted by warmer temperatures. Woody species with higher LMA and larger seed mass will tend to lose proportionally more of their range (Figure S1) because they tend also to have smaller range sizes and occur at latitudes closer to the equator. These traits are associated with species that persist longer on islands but also are less likely to recolonise (Schrader et al. 2023). If these species disappear from islands, island vegetation may shift towards smaller, shorter-lived species that are strong colonisers over the next 80 years as the climate warms (Barton and Fortunel 2023).

There was little evidence for change among any group of plant species in recent years compared to the latter half of the previous century. This is not surprising given that most island surveys in the later time period (55%) were conducted in the years 2000–2010 before climate change had any great impact on island plant populations (Sippel et al. 2020). The null result correlates with studies of mainland national parks that recorded very few native species migrating in recent decades (Wenk et al. 2024). This and other results in the literature showing little tracking of temperature envelope over recent decades may be the result of dispersal limitations, which would cause species to lag behind their changing climate envelope (Alexander et al. 2018; Mallen-Cooper et al. 2023). It is also possible that any such subtle effect from temperature on the latitudinal ranges of species may be obscured by the stochasticity and high turnover rates of plants on small coastal islands (Cody 2006; Flood and Heatwole 1986). Furthermore, if VPD and temperature extremes of MTWM drive local extinctions at the warm edge (Román-Palacios and Wiens 2020), then there may be smaller net change in the geographic range of plants on islands. As the climate warms, revisiting islands would be of great benefit in detecting evidence of contraction of the warm edge or possible poleward migration of individual species and vegetation communities; little net change in climate envelopes could confirm islands as refugia from extinction due to heat waves.

5 | Conclusion

We have applied established climate change scenarios to the question of how many island species might find themselves displaced from existing temperature envelopes across a whole continent over the next 80 years. Our results identify coastal islands as potential climate refugia for species but also suggest a likely shift from longer-lived woody vegetation to shorter-lived species with higher colonisation probability. We could find no evidence of consistent poleward migration of plant species as yet. Continuing to resurvey the vegetation of islands offers a valuable opportunity for refining conservation strategies for these important habitats and in shaping our understanding of how vegetation communities everywhere are likely to respond to climate change.

Author Contributions

David Coleman: data curation, formal analysis, investigation, writing – original draft. **Mark Westoby:** conceptualization, supervision, writing – review and editing. **Julian Schrader:** conceptualization, data curation, supervision, writing – review and editing.

Acknowledgements

Open access publishing facilitated by Macquarie University, as part of the Wiley - Macquarie University agreement via the Council of Australian University Librarians.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data and code that support the findings of this study are openly available in Figshare at https://doi.org/10.6084/m9.figshare.28837541. Vegetation surveys were obtained from the A-Islands database accessible from Zenodo at https://zenodo.org/records/10775810. Current and future climate projections were obtained from the Chelsa+ bioclim dataset at https://www.doi.org/10.16904/envidat.332.

References

Alexander, J. M., L. Chalmandrier, J. Lenoir, et al. 2018. "Lags in the Response of Mountain Plant Communities to Climate Change." *Global Change Biology* 24, no. 2: 563–579. https://doi.org/10.1111/gcb.13976.

Andrew, S. C., R. V. Gallagher, I. J. Wright, and K. Mokany. 2022. "Assessing the Vulnerability of Plant Functional Trait Strategies to Climate Change." *Global Ecology and Biogeography* 31, no. 6: 1194–1206. https://doi.org/10.1111/geb.13501.

Australian Government Department of Climate Change. 2009. "Climate Change Risks to Australia's Coast." https://www.dcceew.gov.au/climate-change/policy/adaptation/publications/climate-change-risks-australias-coasts.

Barton, K. E., and C. Fortunel. 2023. "Island Plant Functional Syndromes and Competition With Invasive Species." *Journal of Biogeography* 50, no. 4: 641–653. https://doi.org/10.1111/jbi.14568.

Bauman, D., C. Fortunel, G. Delhaye, et al. 2022. "Tropical Tree Mortality Has Increased With Rising Atmospheric Water Stress." *Nature* 608, no. 7923: 528–533. https://doi.org/10.1038/s41586-022-04737-7.

Benavides Rios, E., J. Sadler, L. Graham, and T. J. Matthews. 2024. "Species Distribution Models and Island Biogeography: Challenges and Prospects." *Global Ecology and Conservation* 51: e02943. https://doi.org/10.1016/j.gecco.2024.e02943.

Brun, P., N. E. Zimmermann, C. Hari, L. Pellissier, and D. N. Karger. 2022a. "CHELSA-BIOCLIM+ A Novel Set of Global Climate-Related Predictors at Kilometre-Resolution." EnviDat. https://doi.org/10.16904/envidat.332.

Brun, P., N. E. Zimmermann, C. Hari, L. Pellissier, and D. N. Karger. 2022b. "Global Climate-Related Predictors at Kilometer Resolution for the Past and Future." *Earth System Science Data* 14, no. 12: 5573–5603. https://doi.org/10.5194/essd-14-5573-2022.

Bush, A., R. A. Catullo, K. Mokany, A. H. Thornhill, J. T. Miller, and S. Ferrier. 2018. "Truncation of Thermal Tolerance Niches Among Australian Plants." *Global Ecology and Biogeography* 27, no. 1: 22–31. https://doi.org/10.1111/geb.12637.

Byrne, M. P., and P. A. O'Gorman. 2018. "Trends in Continental Temperature and Humidity Directly Linked to Ocean Warming." *Proceedings of the National Academy of Sciences of the United States of America* 115, no. 19: 4863–4868. https://doi.org/10.1073/pnas.1722312115.

Chen, N., Y. Zhang, F. Yuan, et al. 2023. "Warming-Induced Vapor Pressure Deficit Suppression of Vegetation Growth Diminished in Northern Peatlands." *Nature Communications* 14, no. 1: 7885. https://doi.org/10.1038/s41467-023-42932-w.

Chiarucci, A., S. Fattorini, B. Foggi, et al. 2017. "Plant Recording Across Two Centuries Reveals Dramatic Changes in Species Diversity of a Mediterranean Archipelago." *Scientific Reports* 7, no. 1: 5415. https://doi.org/10.1038/s41598-017-05114-5.

Choat, B., T. J. Brodribb, C. R. Brodersen, R. A. Duursma, R. López, and B. E. Medlyn. 2018. "Triggers of Tree Mortality Under Drought." *Nature* 558, no. 7711: 531–539. https://doi.org/10.1038/s41586-018-0240-x.

Cody, M. L. 2006. *Plants on Islands: Diversity and Dynamics on a Continental Archipelago*. University of California Press.

Coleman, D. 2025. "Shifts in Climate Envelopes for Plants on Australia's Islands (Version 1) [Dataset]." figshare. https://doi.org/10.6084/m9.figshare.28837541.

Coleman, D., M. Westoby, and J. Schrader. 2025. "Island Plant Species Distributions Contracted at the Cooler Edge Compared to Mainland." *Ecology Letters* 28, no. 4: e70099. https://doi.org/10.1111/ele.70099.

Crous, K. Y., J. Uddling, and M. G. De Kauwe. 2022. "Temperature Responses of Photosynthesis and Respiration in Evergreen Trees From Boreal to Tropical Latitudes." *New Phytologist* 234, no. 2: 353–374. https://doi.org/10.1111/nph.17951.

Evans, T. G., S. E. Diamond, and M. W. Kelly. 2015. "Mechanistic Species Distribution Modelling as a Link Between Physiology and Conservation." *Conservation Physiology* 3, no. 1: cov056. https://doi.org/10.1093/conphys/cov056.

Falster, D., R. Gallagher, E. H. Wenk, et al. 2021. "AusTraits, a Curated Plant Trait Database for the Australian Flora." *Scientific Data* 8: 254. https://doi.org/10.1038/s41597-021-01006-6.

Feeley, K., J. Martinez-Villa, T. Perez, A. Silva Duque, D. Triviño Gonzalez, and A. Duque. 2020. "The Thermal Tolerances, Distributions, and Performances of Tropical Montane Tree Species." *Frontiers in Forests and Global Change* 3: 25. https://doi.org/10.3389/ffgc.2020.00025.

Flood, P. G., and H. Heatwole. 1986. "Coral Cay Instability and Species-Turnover of Plants at Swain Reefs, Southern Great Barrier Reef, Australia." *Journal of Coastal Research* 2, no. 4: 479–496.

Freckleton, R. P., and A. R. Watkinson. 2002. "Large-Scale Spatial Dynamics of Plants: Metapopulations, Regional Ensembles and Patchy Populations." *Journal of Ecology* 90, no. 3: 419–434. https://doi.org/10.1046/j.1365-2745.2002.00692.x.

Gallagher, R. V., S. Allen, and I. J. Wright. 2019. "Safety Margins and Adaptive Capacity of Vegetation to Climate Change." *Scientific Reports* 9, no. 1: 8241. https://doi.org/10.1038/s41598-019-44483-x.

Grose, M. R., S. Narsey, F. P. Delage, et al. 2020. "Insights From CMIP6 for Australia's Future Climate." *Earth's Future* 8, no. 5: e2019EF001469. https://doi.org/10.1029/2019EF001469.

Grossiord, C., T. N. Buckley, L. A. Cernusak, et al. 2020. "Plant Responses to Rising Vapor Pressure Deficit." *New Phytologist* 226, no. 6: 1550–1566. https://doi.org/10.1111/nph.16485.

Hanski, I. 1998. "Metapopulation Dynamics." *Nature* 396, no. 6706: 41–49. https://doi.org/10.1038/23876.

Hatfield, J. L., and J. H. Prueger. 2015. "Temperature Extremes: Effect on Plant Growth and Development." *Weather and Climate Extremes* 10: 4–10. https://doi.org/10.1016/j.wace.2015.08.001.

Hay, L. E., R. L. Wilby, and G. H. Leavesley. 2000. "A Comparison of Delta Change and Downscaled GCM Scenarios for Three Mountenous Basins in the United States." *JAWRA Journal of the American Water Resources Association* 36: 387–397. https://doi.org/10.1111/j.1752-1688.2000.tb04276.x.

Kattge, J., G. Bönisch, S. Díaz, et al. 2020. "TRY Plant Trait Database—Enhanced Coverage and Open Access." *Global Change Biology* 26, no. 1: 119–188. https://doi.org/10.1111/gcb.14904.

Keppel, G., K. P. Van Niel, G. W. Wardell-Johnson, et al. 2012. "Refugia: Identifying and Understanding Safe Havens for Biodiversity Under Climate Change." *Global Ecology and Biogeography* 21, no. 4: 393–404. https://doi.org/10.1111/j.1466-8238.2011.00686.x.

Kubota, Y., T. Shiono, and B. Kusumoto. 2015. "Role of Climate and Geohistorical Factors in Driving Plant Richness Patterns and Endemicity on the East Asian Continental Islands." *Ecography* 38, no. 6: 639–648. https://doi.org/10.1111/ecog.00981.

Lange, S. 2021. "ISIMIP3b Bias Adjustment Fact Sheet, Inter-Sectoral Impact Model (p. 40)." https://www.isimip.org/documents/413/ISIMIP3b_bias_adjustment_fact_sheet_Gnsz7CO.pdf.

Laughlin, D. C., and B. J. McGill. 2024. "Trees Have Overlapping Potential Niches That Extend Beyond Their Realized Niches." *Science* 385, no. 6704: 75–80. https://doi.org/10.1126/science.adm8671.

Lefcheck, J. S. 2016. "piecewiseSEM: Piecewise Structural Equation Modelling in r for Ecology, Evolution, and Systematics." *Methods in Ecology and Evolution* 7, no. 5: 573–579. https://doi.org/10.1111/2041-210X.12512.

MacArthur, R., and E. O. Wilson. 1967. *The Theory of Island Biogeography*. Princeton University Press.

Mallen-Cooper, M., W. K. Cornwell, E. Slavich, M. E. B. Sabot, Z. A. Xirocostas, and D. J. Eldridge. 2023. "Limited Range Shifting in Biocrusts Despite Climate Warming: A 25-Year Resurvey." *Journal of Ecology* 111, no. 10: 2194–2207. https://doi.org/10.1111/1365-2745.14169.

Marshall, J. D., J. M. Blair, D. P. Peters, G. Okin, A. Rango, and M. Williams. 2008. "Predicting and Understanding Ecosystem Responses to Climate Change at Continental Scales." *Frontiers in Ecology and the Environment* 6, no. 5: 273–280. https://doi.org/10.1890/070165.

Moles, A. T., D. I. Warton, L. Warman, et al. 2009. "Global Patterns in Plant Height." *Journal of Ecology* 97, no. 5: 923–932. https://doi.org/10.1111/j.1365-2745.2009.01526.x.

Morrison, L. W. 2017. "Insular Plant Turnover Across a 22-Year Interval: A Critical Retrospective of the Roles of Pseudoturnover and Cryptoturnover." *Journal of Biogeography* 44, no. 5: 1007–1017. https://doi.org/10.1111/jbi.12866.

Novick, K. A., D. L. Ficklin, C. Grossiord, et al. 2024. "The Impacts of Rising Vapour Pressure Deficit in Natural and Managed Ecosystems." *Plant, Cell and Environment* 47, no. 9: 3561–3589. https://doi.org/10.1111/pce.14846.

O'Neill, B. C., C. Tebaldi, D. P. van Vuuren, et al. 2016. "The Scenario Model Intercomparison Project (ScenarioMIP) for CMIP6." *Geoscientific Model Development* 9, no. 9: 3461–3482. https://doi.org/10.5194/gmd-9-3461-2016.

Paquette, A., and A. Hargreaves. 2021. "Biotic Interactions Are More Often Important at Species' Warm Versus Cool Range Edges." *Ecology Letters* 24: 2427–2438. https://doi.org/10.1111/ele.13864.

R Core Team. 2023. *R: A Language and Environment for Statistical Computing. (Version 4.3.2) [Computer software]*. R Core Team. https://www.R-project.org/.

Román-Palacios, C., and J. J. Wiens. 2020. "Recent Responses to Climate Change Reveal the Drivers of Species Extinction and Survival." *Proceedings of the National Academy of Sciences of the United States of America* 117, no. 8: 4211–4217. https://doi.org/10.1073/pnas.1913007117.

Schrader, J., D. Coleman, I. Abbott, et al. 2025. "A-Islands: A Vascular Plant Dataset for Biodiversity Research and Species Monitoring on Australian Continental Islands." *Journal of Vegetation Science* 36, no. 2: e70019. https://doi.org/10.1111/jvs.70019.

Schrader, J., P. Weigelt, L. Cai, et al. 2024. "Islands Are Key for Protecting the World's Plant Endemism." *Nature* 634, no. 8035: 868–874. https://doi.org/10.1038/s41586-024-08036-1.

Schrader, J., I. J. Wright, H. Kreft, et al. 2023. "ETIB-T: An Equilibrium Theory of Island Biogeography for Plant Traits." *Journal of Biogeography* 50, no. 1: 223–234. https://doi.org/10.1111/jbi.14526.

Sentinella, A. T., D. I. Warton, W. B. Sherwin, C. A. Offord, and A. T. Moles. 2020. "Tropical Plants Do Not Have Narrower Temperature Tolerances, but Are More at Risk From Warming Because They Are Close to Their Upper Thermal Limits." *Global Ecology and Biogeography* 29, no. 8: 1387–1398. https://doi.org/10.1111/geb.13117.

Sippel, S., N. Meinshausen, E. M. Fischer, E. Székely, and R. Knutti. 2020. "Climate Change Now Detectable From any Single Day of Weather at Global Scale." *Nature Climate Change* 10, no. 1: 35–41. https://doi.org/10.1038/s41558-019-0666-7.

Veron, S., M. Mouchet, R. Govaerts, T. Haevermans, and R. Pellens. 2019. "Vulnerability to Climate Change of Islands Worldwide and Its Impact on the Tree of Life." *Scientific Reports* 9, no. 1: 14471. https://doi.org/10.1038/s41598-019-51107-x.

Walsh, C., R. Mac Nally, and M. C. Walsh. 2020. "Package 'hier. Part.' R Project for Statistical Computing."

Weiser, M. D., B. J. Enquist, B. Boyle, et al. 2007. "Latitudinal Patterns of Range Size and Species Richness of New World Woody Plants." *Global Ecology and Biogeography* 16, no. 5: 679–688. https://doi.org/10.1111/j.1466-8238.2007.00323.x.

Wenk, E., D. Coleman, R. Gallagher, and D. Falster. 2023. "A Near-Complete Dataset of Plant Growth Form, Life History, and Woodiness for All Australian Plants." https://doi.org/10.1101/2023.12.19.572473.

Wenk, E., T. Mesaglio, D. Keith, and W. Cornwell. 2024. "Curating Protected Area-Level Species Lists in an Era of Diverse and Dynamic Data Sources." *Ecological Informatics* 84: 102921. https://doi.org/10.1016/j.ecoinf.2024.102921.

Westgate, M., M. Stevenson, D. Kellie, and P. Newman. 2024. "galah: Biodiversity Data from the GBIF Node Network." (Version 2.0.1) [Computer software]. https://CRAN.R-project.org/package=galah.

Westoby, M., S. C. Andrew, R. V. Gallagher, and J. Schrader. 2024. "Species Gain and Loss per Degree Celsius." *Oikos* 2024, no. 4: e10556. https://doi.org/10.1111/oik.10556.

Whittaker, R. J., J. M. Fernandez-Palacios, and T. J. Matthews. 2023. *Island Biogeography: Ecology, Evolution, and Conservation*. Oxford University Press.

Wickham, H., and M. H. Wickham. 2019. "Package 'stringr'." http://stringr.tidyverse.org, https://Github.com/Tidyverse/Stringr.

Young, M. L., K. C. Dobson, M. D. Hammond, and P. L. Zarnetske. 2024. "Plant Community Responses to the Individual and Interactive Effects of Warming and Herbivory Across Multiple Years." *Ecology* 105, no. 11: e4441. https://doi.org/10.1002/ecy.4441.

Zhang, W., T. Zhou, and P. Wu. 2024. "Anthropogenic Amplification of Precipitation Variability Over the Past Century." *Science* 385, no. 6707: 427–432. https://doi.org/10.1126/science.adp0212.

Supporting Information

Additional supporting information can be found online in the Supporting Information section.