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gradients intersect in the alpine zone, organisms that endure diurnal and seasonal extremes in temperature and water availability, high winds and elevated UV-radiation during a contracted growth season are exposed to rapid environmental shifts. Among animals, the survival and reproduction of ectotherms is likely to be especially sensitive to displacement of climate isoclines [2,3].

Although most ecosystems will be impacted in some way, arctic, alpine and boreal biomes are predicted to be particularly vulnerable to the ecological impacts of anthropogenic climate change when compared with other systems [4–6]. Growing evidence suggests that global warming results in rapid temperature increases at higher elevations [7]. This is reflected by rising treelines and snowlines, and reduction in snowpack depth and longevity [8 –10]. For alpine species, the consequences of such changes include upward shifts in both lower and upper elevational range limits where the landscape permits, increasing inter-species competition at higher elevation, reduction in richness at lower elevation and shifts in phenology [11–14].

Alpine habitat exists at increasing elevations from the poles towards the equator and in total is estimated to currently cover approximately 2.64% of Earth's total land area outside Antarctica (3.56 Mkm^2) [15,16]. Temperature decreases by approximately 0.65°C for every 100 m of elevation subject to geographic, seasonal and diurnal variance [17,18]. In mountainous areas, this results in the

transferring the ensemble models to future climate change scenarios to predict how their optimal habitat might grow, shrink and/or fragment over the next 50 years of climate change.

2. Material and methods

2.1. Collection of species location records

For 12 grasshopper species, location records were collated from insect collections, journal articles, theses, books and Crown Pastoral Lease Tenure Reviews (CPLTR) (electronic supplementary material S1) published between 1967 and 2016. These 12 endemic New Zealand grasshoppers consist of 10 high-elevation species: *Alpinacris crassicauda*, *Alpinacris tumidicauda*, *Brachaspis collinus*, *Brachaspis nivalis*, *Paprides dugdali*, *Paprides nitidus*, *Sigaus australis*, *Sigaus campestris*, *Sigaus piliferus* and *Sigaus villosus*, and two low-elevation relatives: *Sigaus childi* and *Sigaus minutus*. Given the range of sources used to obtain location data, our sample does not suffer from the common bias of only collecting from sites close to access roads. In particular, our location data benefit from the use of CPLTR that are produced by Land Information New Zealand and contain conservation reports and ecological surveys carried out by the Department of Conservation on pastures throughout Te Waipounamu (South Island), New Zealand. Additional records were retrieved from our specimen collections at Massey University. World Geodetic System 1984 (WGS84) coordinates (latitudes and longitudes) were obtained for each location record using NZ Topo Map [40]. Location records for two additional endemic lowland grasshopper species (*Phaulacridium marginale* and *Phaulacridium otagoense*) were included in the dataset, but not modelled in this study [37]. Both of these species have low-elevation distributions and provided additional location searches and absence data that increase the accuracy of the ENMs. Coordinates were reduced to two decimal places and duplicate records within species were removed, in order to ensure only one record per approximately 1 km^2 for each species. Coordinates 7.8(Sy)20(s)19.1(tem)-

that scored greater than a predetermined cut-off value in greater than 50% of models was ranked as a 1, and all other pixels as 0. When comparing binary vectors between current and future models, Biomod2 ranks pixels as either, 'Never occupied' (pixels were unoccupied and remain unoccupied between models), 'Always occupied' (pixels were occupied and remain occupied between models), 'Lost' (pixels were occupied but become unoccupied in the future RCP scenario) or 'Gained' (pixels that were unoccupied in the current model become occupied in the RCP model). From this information range change statistics were calculated with two contrasting models. The dispersal model assumed the species in question will occupy any pixels 'gained' in future models, implying no limitation on dispersal and/or establishment; the model essentially treats potential habitat as realized habitat. At the other extreme, the non-dispersal model precluded occupation of disconnected 'gained' pixels, which means nearby but separate habitat patches as well as more distant patches (e.g. on a separate island) are assumed to be uncolonized. We also applied FRAGSTATS, implemented in R package 'SDM Tools' v. 1.1-221 [57] (see McGarigal [58] for a detailed description of FRAGSTATS metrics), to the binary files to estimate fragmentation statistics that can be compared between different RCP scenarios from their current niche models. Pixels that are connected within each of the binary files are given unique patch identities, and the area and number of these patches calculated for each scenario. We excluded small patch fragments that were less than 0.1 km^2 from the fragmentation statistics analysis. Methods and scripts implemented in this study can be found in the electronic supplementary material S5 and S6.

3. Results

After filtering, nine of the 12 grasshopper species had more than 30 location records as 'present' (table 1). A minimum of 30 occurrences are recommended for ENMs, below which model accuracy decreases, and variance of model accuracy increases [50–52]. The majority of evaluation scores averaged across the three model runs were greater than 0.9 ROC (65/120), but for the four most