7 — Impacts on the biodiversity of widely distributed birds and vascular plants: species richness and turnover

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● bird and plant species
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– Projected changes in species composition (i.e., turnover) of birds and vascular plants, two important components of biodiversity, are widespread across Switzerland, with especially strong turnover at both low and middle (~2000 m asl) elevations by the end of the century under the A1B scenario.

– Areas with large changes in number of species and turnover in composition do not completely coincide because areas initially with few species can experience high turnover with the influx of just a few species, as in Graubünden and Valais.

– Uncertainty in the turnover of species composition that is associated with different climate models decreases with increasing time as impacts become stronger. Uncertainty in turnover is initially found both in high and low elevations in the first simulation period (2020), but predominately in mountainous areas in the third simulation period (2090).

– By using an approach that should better capture the limits on species distributions imposed by warm, dry conditions, these projections suggest that low-elevation cantons will be among the most highly impacted by climate-driven changes in species distributions.

‹ Climate change alters the species composition of bird communities in Switzerland (wigeons rising from a marsh near Kerzers, March 2013; photo: Hansruedi Weyrich/weyrichfoto.ch).

7.1. INTRODUCTION

There is increasing concern regarding the effects of climate change on the survival and future distribution of animals and plants, since warming climate moves tolerable conditions to higher elevations, potentially increases ecosystem productivity, and can alter interactions among species. These effects may diminish or alter the distribution of ecosystem services that depend on key species. Some species, such as birds, might have relatively little difficulty tracking the changing climate conditions that they prefer. Other species that are not very mobile and do not disperse widely (some insects, many terrestrial vertebrates, and plants) face substantial challenges. The conversion of productive habitat to highways, settlement, and intensive agriculture and the fragmentation of remaining habitat impact biodiversity negatively and further exacerbate effects of climate change by presenting substantial barriers to successful dispersal of species to newly suitable areas.

Modeling studies conducted at coarse resolution suggest that, depending on dispersal ability, 15–37% of species in studied continental areas may be irretrievably on the path to extinction by 2050 (Thomas et al., 2004) and this number may increase to 50% for high mountain species in Europe (Engler et al., 2011, Dullinger et al., 2012). The distributions of some species are currently responding to climate change (Thomas and Lennon, 1999; Parmesan and Yohe, 2003), often in ways that are consistent with forecasts from species distribution models (Araújo et al., 2005; Chen et al., 2011). These changes suggest that management and conservation decision-making can benefit from assessments of climate change impacts, so as to facilitate policy adaptation to potential future climates. Conclusions from earlier modeling studies of climate change impacts on biodiversity in Switzerland are limited because wide-ranging species are modeled exclusively with distribution data from within

Switzerland (Pearman et al., 2011). Because this practice does not capture warm, dry conditions that limit species ranges, projected impacts on species distributions at low elevations are underestimated and estimates of impact intensity are biased toward high elevations where increasing numbers of species find future conditions suitable. In this chapter, updated projections of expected change in species assemblages are provided by focusing on wide-ranging species, using species distribution data of European extent, and incorporating the most recent regional climate models for Switzerland.

7.2. METHODS

State-of-the-art species distribution models (SDMs; Guisan and Zimmermann, 2000) are applied for selected species of **birds** and **vascular plants**. These two groups are often used in scientific study, management, and monitoring of biological diversity. Here these SDMs are calibrated with data on climate and known locations of occurrences of each species across Europe, and then validated with independent data from Switzerland. Validated models are applied to maps of projected future climate for Switzerland and the surrounding area. An ensemble approach (Araújo and New, 2007) is used for modeling each species individually. This includes calibration of models using four different algorithms. The European extent of the calibration data allows comprehensive capture of the relationship between climate and distribution limits of each species.

Species data for calibration come from the Atlas of European Breeding Birds (Hagemeijer and Blair, 1997) and from the Atlas Floreae Europaeae (Jalas and Suominen, 1972–2005), both at approx. 50 km × 50 km resolution. Independent validation data come from approximately 410 sites (1 km^2 in size) of the Swiss Biodiversity Monitoring Program (BDM; Weber et al., 2004). The climate data come from: (1) the WorldClim database (Hijmans et al., 2005) providing the current climate of Europe at 10 min and 30 sec resolution (approximately 1 km × 1 km) and (2) future climate simulations by six regional climate models (RCMs) covering Switzerland under the A1B scenario, and downscaled to a resolution of 1 km × 1 km, for the period 2010 to 2100 (Lautenschlager et al., 2009; Chapter 3). Five of six climate models are also used in CH2011 (2011). These additional sources (WorldClim data and additional RCMs) are used because of the need to calibrate models and project future species distributions outside of Switzerland. For this report, the assessment is restricted to species which already occur in Switzerland currently, and whose current distribution in Switzerland at a resolution of 1 km × 1 km is well represented by the European-scale models. This is done because it is only possible to validate model performance for currently resident species. Accordingly, immigration of new species into Switzerland, though likely, is not considered. Specifically, the selection of species comprises only those with at least 25 occurrences in the calibration data that are at the European extent, at least 10 occurrences in the BDM validation data set, and sufficient model performance on the validation data (AUC ≥ 0.7). For the projections, SDMs are applied to both the current climate and the six future RCM-simulated climates for the A1B scenario, averaged for the time periods 2011–2030, 2041–2060, and 2081–2100 over all of Switzerland. These periods deviate slightly from the standard CH2011 periods (Chapter 3) and are referred to by the central years 2020, 2050, and 2090, respectively. The 20-year period is selected to avoid averaging over a period that includes substantial climate change and, thus, could interact with modeled variability in the climate tolerances of species. The use of SDMs implies that equilibrium states are modeled, but convergence to equilibrium is species specific and not directly accounted for.

The susceptibility of current species assemblages to climate change is assessed by comparing simulated current and future species composition. Susceptibility is quantified for each 1 km^2 grid cell in terms of species turnover, a quantity calculated as 1–S where S is the Sorensen similarity index (S). This index quantifies the similarity between the lists of species at two different sites or, alternatively, at a single site at two distinct points in time. Turnover attains its minimum value 0 when the species assemblage persists unchanged; conversely, the maximum value 1 indicates that there are no species in common between the present and future period. Additionally, the uncertainty in turnover is considered. It is estimated from the variation among the six different RCMs by calculating for each square kilometer the standard deviation of turnover divided by its mean. The distribution of turnover values is examined on the canton level. The projected turnover here is a lower bound because only species already occurring in Switzerland are considered. As a consequence, invading species will further increase turnover.

7.3. RESULTS

Of the 395 **bird species** and 1943 **plant species** for which there are 25 or more occurrences in the respective atlases of European species distributions, 111 bird species and 218 plant species are recorded in at least 10 sites of the BDM monitoring program. Using this independent dataset, models for a total of 79 avian species and 135 plant species performed sufficiently well (AUC ≥ 0.7) to give reliable projections of species distributions. The simulated current distributions of the study species indicate that relatively few have suitable climate at high elevations. Change in the absolute number of analyzed bird and plant species that find suitable climate in the future is highest in the lowlands of Switzerland (Figure 7.1). The differences in simulated species composition between current and future time periods indicate substantial turnover of both bird and plant species (Figure 7.2 a, d). Species turnover is noticeable by 2020 and becomes strongest by the third simulation period, approximately 2090 (Figure 7.2 c, f), and is most pronounced in high elevation areas of the southern Valais and in easternmost Switzerland in the Canton Graubünden (Figure 7.2 c,f). In these areas current climate is classified as suitable for few or none of the study species. Thus, any increase in the potential number of species in the future implies substantial turnover. Additionally, some areas of low turnover are scattered throughout the highest elevations (>2000 m asl) of the Alps (Figure 7.2 c,f), where only few species find suitable climate under both current and simulated future climate conditions.

The relative uncertainty in turnover values, owing to variation among climate simulations, decreases with time. For both birds and plants the highest uncertainty in projected turnover occurs in mountainous areas. Overall, uncertainty in turnover due to uncertainty in climate models is somewhat greater for birds than for plants.

Species turnover depends strongly on elevation (Figure 7.3). For birds (Figure 7.3) and plants (Figure 7.3 b), maxima in turnover occur at multiple elevations, with a main peak centered at 2000 m asl. Low turnover is projected at about 1000 m asl and 3700 m asl for both birds and plants. This is likely because upward movement of the potential distribution of low-elevation species does not lead to great losses around 1000 m asl and few species move into areas around 3700 m asl because climate at these very high and exposed elevations does not become warm enough. Average projected turnover values for individual cantons also show large variation and some cantons have bimodal distributions of turnover values (Table 7.1 a, b). Some small cantons at low elevation and having relatively little elevation range appear to experience high projected species turnover, as do some larger cantons, suggesting that a number of factors influence mean turnover projections within cantons.

7.4. IMPLICATIONS

The results suggest that many of the most widely distributed species in Switzerland will be affected by changing climate by 2090. Turnover in species composition among these species will be substantial, both in the low-lying cantons and in mountain areas, and most pronounced at about 2000 m of elevation. Likely two processes are reflected in these patterns. First, at low elevations and in cantons with little elevation range, climate change results in the loss of suitable conditions for native species because of increased temperatures that exceed the conditions experienced by these species in the warmest areas within their European distribution. At higher elevations (~2000 m asl), climate becomes suitable for many species that were originally restricted to the lowlands, while the previous resident species still may escape to higher elevations. Above 2000 m asl, few of the study species have suitable climate during the original time period, so conclusions are limited. Nonetheless, these areas are already projected by more specialized studies to suffer high local extinction rates or show high turnover (Engler et al., 2011; Pearman et al., 2011). These elevations are high enough that only a few species will find suitable conditions by 2090. At approximately 2000 m asl the average turnover for birds and plants is ca. 0.5 and 0.4 respectively, meaning that ca. 50% and 40% of the study species are projected to differ between the current period and the end of the century.

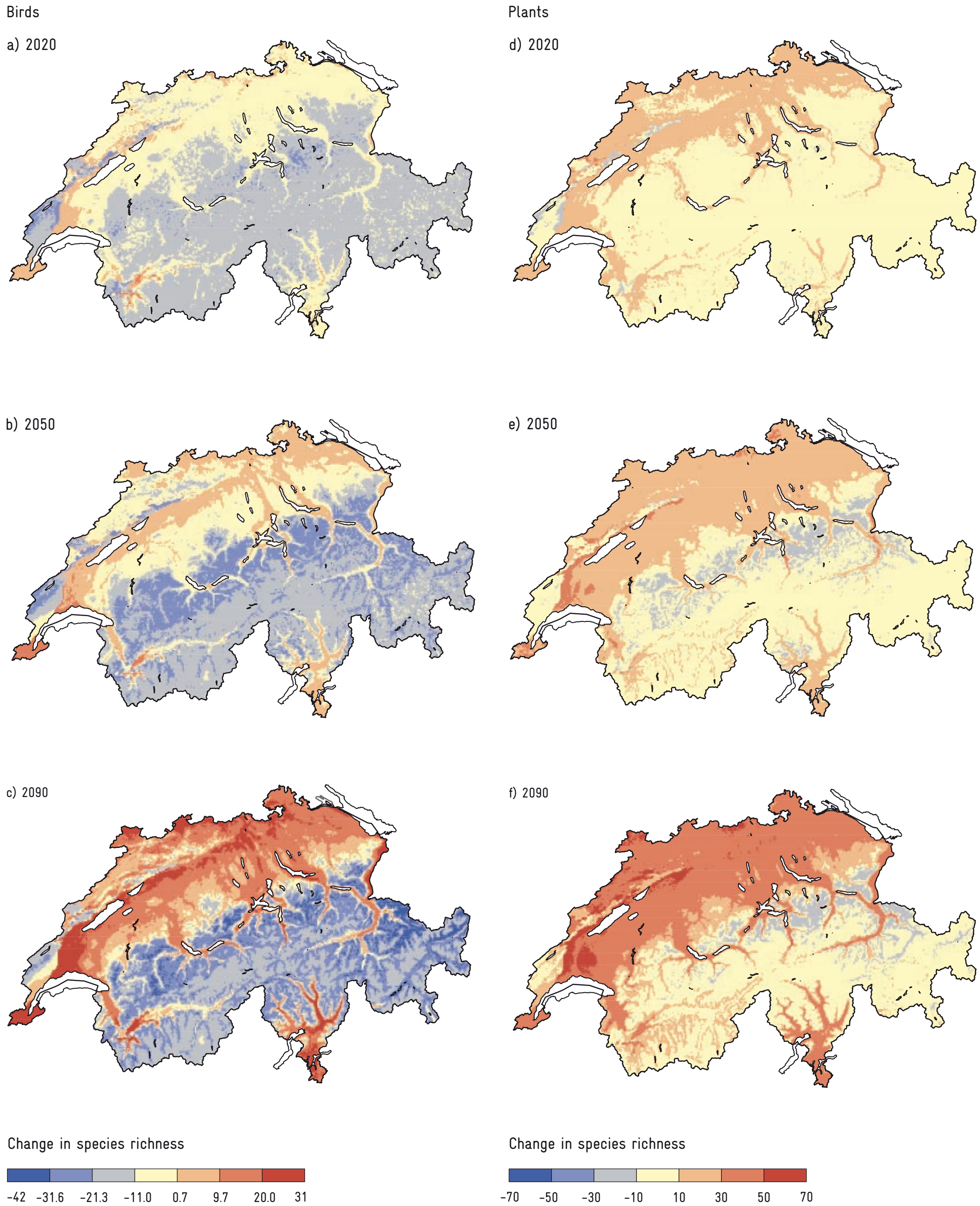

Figure 7.1: Mean change in the number of study species with suitable climate conditions under the A1B scenario at 2020 (a, d), 2050 (b, e), and 2090 (c, f). Results for birds (a, b, c) and plants (d, e, f) are shown. The resolution is 1 km × 1 km. The mean was calculated from application of the distribution models to current climate and to six regional models of future climate. Only the results for species that currently breed in Switzerland and have passed the selection criteria (see text) are shown. The potential arrival of species that might newly breed in Switzerland is not addressed because the models could not be validated at a resolution of 1 km × 1 km. The largest changes in terms of absolute numbers of breeding species occur in relatively low elevation areas because these areas originally have the largest number of species.

The general pattern of loss of suitable conditions for resident species at low elevations and increasingly suitable conditions for widely distributed species at high elevations likely carries over to additional species. The ones that are currently found at mid-elevations will likely lose suitable conditions at the bottom of their elevation range, while finding newly suitable areas nearby at higher elevations. Overall, because of decreasing land area at higher elevations, many of these species will have less total area with suitable conditions, and will as a consequence experience decreases in population sizes. How ecosystems and their services will be affected by these changes in species composition remains largely unanswered.

These initial results may be useful to canton agencies that are charged with natural resource conservation. Cantons at low elevations and/or having high projected rates of turnover need to evaluate the risk that new immigrating species (not studied here) may succeed in replacing the many species for which climate conditions will no longer be suitable. Cantons with low average levels of turnover in species composition likely have large elevation ranges, but vertical movement of species may need to be facilitated, e.g., through maintenance of sufficient habitat continuity to allow species with limited dispersal capacities to respond to changing distributions of suitable climates.

The substantial levels of turnover in species composition across many cantons, especially at low and moderately high elevations, signal the importance of identifying which species and biotic communities provide important ecosystem services, for instance for recreation, pest control, or valuable commodities. Studies with a more detailed focus on these particular species (Chapter 8 for some examples) can better identify risks of ecosystem service loss, as well as candidate species that are suited to new climate conditions and supply similar services.

A number of limitations must be taken into consideration in the interpretation of these results. Most importantly, for methodological reasons, the analysis is restricted to species that are broadly distributed in the data from both Europe (≥25 occurrences) and Switzerland (≥10 occurrences). Further, the study focuses on species represented by models with high validation performance on independent data. While broadly distributed species are largely responsible for the overall geographic pattern of species richness in Switzerland (Pearman and Weber, 2007), the species studied here constitute a small fraction of the entire Swiss flora and fauna. Other species, in the same or other groups, will respond to climate change differently, e.g., some may be more affected due to narrower climate tolerances, but the overall patterns are likely to remain similar. The focus on widely distributed species, for which models also transfer successfully between European (50 km) and Swiss (1 km) scales, means that the estimates of turnover are a lower bound. Immigration of additional species not yet resident in Switzerland will likely increase turnover, with these effects concentrated in lower elevations.

The approach also assumes that climatic requirements of species remain stable over time and do not change in response to changing species composition. This is certainly only partially true. Similarly, technical limitations here prevent the study of effects of changing landscape composition, although some species may be locally more limited by land cover, conversion of habitat to agriculture, infrastructure development, and habitat degradation than they currently are by climate.

Further, to interpret the results as reflecting the distribution of species, one must assume that species are distributed in equilibrium with the distribution of modeled suitable climate, both initially and in the future. This is certainly not true for long-lived trees, for which inevitable extinction may follow only after a long period (extinction debt; Dullinger et al., 2012). The assumption may be more reasonable for fugitive plant species having ample dispersal capabilities and short life cycles, and for many bird species.

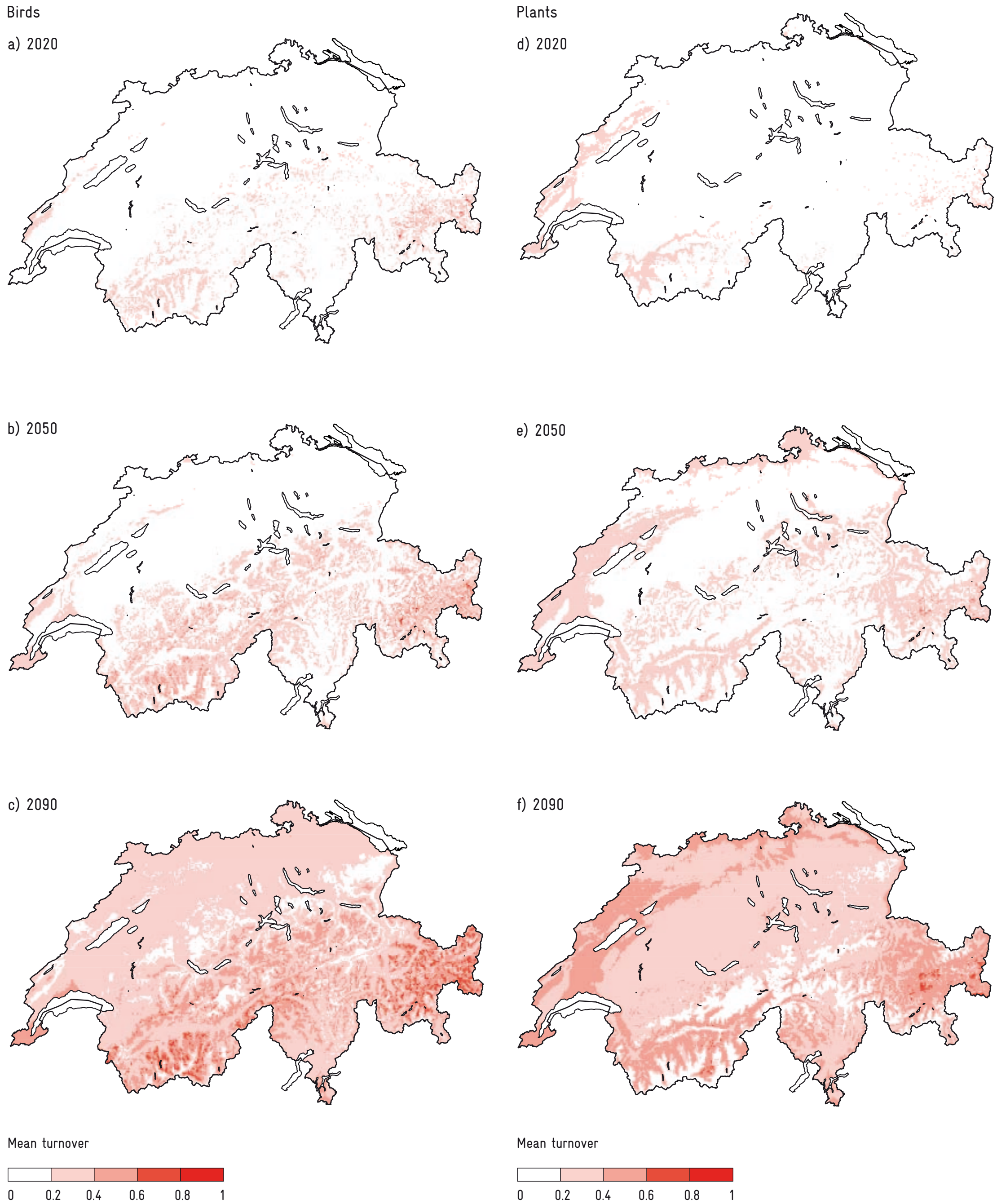

Figure 7.2: Mean turnover in species composition for climate conditions under the A1B scenario at 2020 (a, d), 2050 (b, e), and 2090 (c, f) as compared to current simulated distributions of suitable climate conditions. Turnover is defined as 1–S, where S is the Sorensen Index of similarity. Results for birds (a, b, c) and plants (d, e, f) are shown. The resolution is 1 km × 1 km. Mean turnover for each pixel was calculated by averaging across the results of model application to six different regional climate simulations. A value of zero (0) for a pixel indicates there has been no change in which species are simulated to have suitable climate, while a value of one (1) indicates that the species that are modeled to find suitable climate currently or in the future form two distinct groups with no shared members. Turnover is independent of the absolute number of species, which may vary widely.

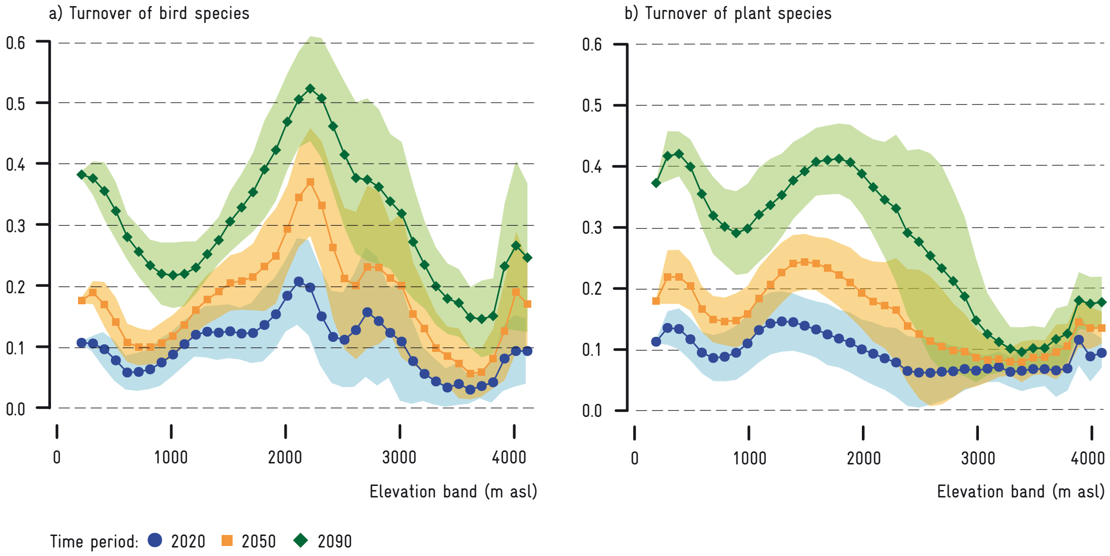

Figure 7.3: Values of mean turnover, averaged over all 1 km² cells in 100 m elevation bands in Switzerland for (a) 79 widespread bird species and (b) 135 widespread species of vascular plants. Turnover is defined as 1–S, where S is the Sorensen Index of similarity. Error bars show plus/minus one standard deviation for turnover values within elevation bands. The mean turnover for an individual cell is obtained by calculating six estimates of 1–S that come from extension of species distribution models to six estimates of potential future climate under the A1B scenario. All species distribution models are calibrated with European scale data and are validated to perform well at a resolution of 1 km × 1 km of the downscaled climate data for Switzerland.

Table 7.1a: Turnover for bird assemblages and associate statistics by canton as of 2090 under the A1B scenario. The table presents mean turnover across all 1 km^2 cells (pixels) in each canton, the standard deviation (sd) across all cells in each canton, the number of cells in each canton (n), and the absolute elevation range within each canton. The turnover value for each cell in a canton is itself a mean over the distribution models for each species and six different regional climate simulations. Lower turnover scores signify more similarity between modeled current and future species composition. Cantons marked with * have distinctly bi-modal frequency distributions of turnover values.

Canton	Mean Turnover	sd	n	Elevation Range (m)
Genf*	0.481	0.045	282	137
Graubünden	0.389	0.137	7110	3220
Wallis	0.387	0.131	5222	3939
Uri	0.368	0.113	1073	2827
Basel-Stadt	0.361	0.028	36	211
Tessin	0.353	0.106	2809	2766
Obwalden	0.328	0.114	491	2305
Glarus*	0.318	0.108	687	2731
Schaffhausen	0.314	0.021	296	530
Waadt	0.304	0.075	3214	2407
Thurgau	0.303	0.031	988	520
Bern	0.295	0.099	5959	3377
Nidwalden	0.294	0.100	277	1967
Aargau	0.293	0.038	1402	545
Zürich	0.281	0.042	1727	765
Schwyz	0.278	0.097	909	2066
Neuenburg	0.278	0.061	805	1000
Basel-Land	0.273	0.044	519	816
Jura	0.272	0.036	836	749
Solothurn	0.270	0.044	779	961
St. Gallen	0.265	0.084	2026	2435
Freiburg	0.261	0.052	1671	1633
Luzern	0.245	0.055	1500	1635
Zug*	0.245	0.055	237	974
Appenzell I. Rh.	0.208	0.073	172	1550
Appenzell A. Rh.	0.182	0.028	245	1277

Table 7.1b: Turnover for assemblages of vascular plants and associate statistics by canton as of 2090 under the A1B scenario. The table presents mean turnover across all 1 km^2 cells (pixels) in each canton, the standard deviation (sd) across all cells in each canton, the number of cells in each canton (n), and the absolute elevation range within each canton. The turnover value for each cell in a canton is itself a mean over the distribution models for each species and six different regional climate simulations. Lower turnover scores signify more similarity between modeled current and future species composition. Cantons marked with * have distinctly bimodal frequency distributions of turnover values.

Canton	Mean Turnover	sd	n	Elevation Range (m)
Genf*	0.491	0.042	282	137
Basel-Stadt	0.457	0.028	36	211
Neuenburg*	0.426	0.053	805	1000
Schaffhausen	0.399	0.034	296	530
Waadt	0.395	0.069	3214	2407
Jura	0.377	0.037	836	749
Aargau	0.377	0.043	1402	545
Solothurn	0.373	0.041	779	961
Thurgau	0.370	0.051	988	520
Basel-Land	0.362	0.046	519	816
Graubünden	0.360	0.127	7110	3220
Tessin*	0.338	0.094	2809	2766
Freiburg	0.330	0.047	1671	1633
Zürich*	0.327	0.068	1727	765
Wallis*	0.321	0.157	5222	3939
Bern	0.318	0.078	5959	3377
Nidwalden	0.315	0.060	277	1967
Luzern	0.307	0.046	1500	1635
Zug*	0.299	0.046	237	974
Obwalden	0.291	0.066	491	2305
St. Gallen	0.288	0.075	2026	2435
Schwyz*	0.288	0.063	909	2066
Glarus	0.276	0.080	687	2731
Uri*	0.260	0.102	1073	2827
Appenzell I. Rh.	0.244	0.059	172	1550
Appenzell A. Rh.	0.215	0.028	245	1277