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ASSESSING BIODIVERSITY PRIORITIES IN THE *ALPES VAUDOISES* IN THE FACE OF LAND USE AND CLIMATE CHANGE

Travail de Maîtrise universitaire ès Sciences en comportement, évolution et conservation

Master Thesis of Science in Behaviour, Evolution and Conservation

par

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Abstract

Protected areas play a critical role in protecting biodiversity and threatened species. With global change presenting dynamic threats, the current conservation areas may become less effective at protecting important species. Decision support tools are being increasingly used for spatial conservation prioritization analyses that enable policy makers to include numerous data sources and create results based on specific targets. We used two methods of conservation prioritization to evaluate the current protected area network in the *Alpes Vaudoises*, Switzerland, and to propose optimal conservation networks that would protect the highest level of biodiversity possible. We found that the existing protected areas are not in the optimal locations and that they will become less adequate in the future with climate and land use change. Although the data available for this study site are extensive, they are incomplete, being comprised only of species from insects, amphibians, reptiles and plants. Nevertheless, the results presented here already allow setting priorities for these taxonomic groups, and the proposed analytical framework is ready to be used in future analyses, when more data becomes available and specific targets are identified by all stakeholders.

Résumé

Les zones protégées sont essentielles pour la protection de la biodiversité et des espèces menacées. Les changements globaux présentent des menaces dynamiques, pouvant rendre les zones actuellement protégées moins efficace dans leur principal bût de conservation d’espèces importantes. Les outils d'aide à la décision sont de plus en plus utilisés pour les analyses de priorisation de la conservation puisqu’ils permettent aux chercheurs d'inclure de nombreuses sources de données et de produire des résultats basés sur des cibles spécifiques. Nous avons utilisé deux méthodes de priorisation de la conservation pour évaluer les zones protégées sont en place dans les Alpes Vaudoises en Suisse, et nous avons proposé des régions de conservation optimales qui permettraient de protéger la plus grande proportion possible de biodiversité. Nous avons constaté que les zones protégées existantes ne sont pas localisées dans les régions optimales et qu'elles deviendront moins efficaces en raison du changement climatique et des futurs aménagements du territoire. Malgré la quantité importante de données disponible sur ce site, celles-ci sont incomplètes et ne comprennent que des espèces d'insectes, d'amphibiens, de reptiles et de plantes. Cependant, les résultats présentés ici permettent déjà de fixer des priorités pour ces groupes taxonomiques et le cadre analytique proposé ici est prêt à être utilisé dans de futures analyses, lorsque plus de données seront disponibles et que des cibles spécifiques seront identifiées par les parties prenantes.

Keywords

Conservation Prioritization, Decision Support Tools, Land Costs, Species Distribution Models, Switzerland, Zonation

Introduction

Growing anthropogenic activities related to globalisation and global economic growth are causing biodiversity to face increasing threats in wild areas (Lambin *et al*. 2001). These threats started at the beginning of the Anthropocene era (i.e. Industrial Revolution in the 1800s) and are mainly caused by land use change, human induced climate change, or the introduction of invasive species (Sisk *et al*. 1994). These three factors are playing a key role in the alarmingly high rate of extinctions and biodiversity loss under which wild areas are suffering (Steffen *et al*. 2007). Biodiversity is an important part of ecosystem services providing both provisioning services, such as food and fresh water, and regulating services, which stabilise an ecosystem (Cardinale *et al*. 2012). Therefore, a reduction in biodiversity can cause losses or reductions of certain important ecosystem services that in turn can have a negative impact on human wellbeing (Díaz *et al*. 2006).

Climate change is not a new phenomenon for our planet, but it is now acting at such a fast rate that there is not sufficient time for species to adapt or migrate to more suitable areas (Welch 2005). Climate change influences species ranges and pushes them northward and to higher altitudes (Chen *et al*. 2011; Hickling *et al*. 2006; Parmesan *et al*. 1999; Walther *et al*. 2002), which in turn will cause some species to move out of current protected areas (Araújo 2004). There is a link between climate change and the spread of invasive species, because of their inherent ability to disperse, enabling them to reach new habitats more easily than native species (Beerling *et al*. 1995). This has been seen, for example, in southern Switzerland where milder winters triggered by climate change have caused exotic evergreen plants to dominate the landscape (Walther 2000).

Land use change, especially in combination with climate change, can have substantial negative impacts on biodiversity (Struebig *et al*. 2015). Forest degradation and alteration is expected to cause a decline in species richness and diversity (Gibson *et al*. 2011). For example, due to land use change, 400 bird species are estimated to lose over half of their range globally by 2050 (Jetz *et al.* 2007). This may in turn stress already vulnerable species and push them closer to extinction. Conservation planning is a spatial process of developing conservation areas created to promote nature through locating and managing key sites (Pressey *et al*. 2007). There is an anticipated miss-match between the supply and the demand of ecosystem services if future land use needs are not considered during conservation planning (Stürck *et al*. 2015). This could then result in the conversion of land towards a use that has an adverse effect on biodiversity. Another aspect to consider during conservation planning is land costs, as Naidoo *et al.* (2006) found that plans which included land costs were more effective and had higher biological gains than plans that ignored costs. Conservation planning must balance the costs of conservation with the benefits to wildlife as financial resources are limited (Newburn *et al.* 2005). Incorporating land use change and land costs into conservation prioritization analyses provides a more attainable priority ranking of protected areas that will be more easily implemented (Naidoo *et al*. 2006).

Protected areas are an important tool for conservation as their main goals include protecting vulnerable species or habitats, as well as natural monuments and heritage sites. As means of mitigation, these areas have a variety of regulations which can reduce or restrict activities within their boundaries. Switzerland has nearly 6000 protected areas that cover 10% of the land area of the country (UNEP-WCMC 2016). These reserves have varying degrees of protection, but a large majority of them are designated by The International Union for Conservation of Nature (IUCN) as either a "Strict Nature Reserve" (IUCN Category Ia protection) or a "Habitat/Species Management Area" (IUCN Category IV protection). The first concerns landscapes protected in a self-sustaining way with little intervention, and where human impacts are controlled. The latter are regions set aside to protect a specific habitat or species, sometimes requiring active management to maintain the quality of the landscape. As the world recognised the importance of maintaining biodiversity for the sustainability of the planet, the Swiss government developed the Swiss Biodiversity Strategy in 2009. The objective of this strategy is to conserve biodiversity and their ecosystem services in the long term at both a national and international scale through sustainable development and biological monitoring (Wiedmer & Wisler 2014). Switzerland also agreed to the Aichi Biodiversity Targets in 2010, one of which states that by 2020 at least 17% of the global terrestrial landscape should be managed as protected areas (Leadley *et al*. 2014).

Conservation planning ideally should focus on the irreplaceability of a species or an ecosystem with a focus on endemic and Evolutionarily Distinct and Globally Endangered (EDGE) species (Meir *et al*. 2004). The areas with high endemism or biotic value will be different for each taxon, and thus finding one area where all species of importance overlap is unlikely. In addition, it is rarely the case that one threatened species' range will also contain high diversity (Shafer 1999). When planning a protected area network, a focus needs to be placed on adaptation strategies since the effects of climate change are now inevitable and cause landscapes to be non-static (Heller & Zavaleta 2009). Therefore, it is important to be able to predict the future distributions of species of interest caused by these habitat changes. Adaptive management strategies need to be implemented to re-evaluate the protected area network in a continuous manner, with new methods, additional data, and considering changing and evolving threats (Jenkins *et al*. 2013). Thus, clear conservation goals and targets, as well as conservation prioritization, are needed in reserve design and planning. Creating conservation priorities is a complicated process and can fail if the targets are ill-defined or not specific (Game *et al*. 2013).

Species distribution models (SDMs) have become widely used in conservation planning to predict, in a spatially explicit way, where a species is present based on species observations and on environmental variables (Guisan & Thuiller 2005). They can be used at various steps along the planning process including identifying the problem, defining the objectives, finding the cost-benefit trade-offs, and considering the impacts conservation actions may have on an ecosystem (Guisan *et al*. 2013). SDMs have been used to investigate the effects of climate change (Araújo *et al*. 2011) and the introduction of invasive species (Thuiller *et al*. 2005) on current and future species distributions. This method can help to identify key areas of importance or of potential conflict that need to be considered for conservation planning, but it is only the first step in the process. Prioritization tools for conservation planning help to identify important areas while considering a cost-benefit ratio. The Zonation software (Moilanen *et al*. 2005) is one such quantitative decision support tool used in reserve planning. Zonation can incorporate SDMs with cost maps, future landscape changes, species interactions, and habitat connectivity to find the optimal land to protect based on pre-defined conservation goals. Zonation has been used as a decision support tool for conservation planning on a variety of projects around the globe (Proctor *et al.* 2011; Summers *et al.* 2012; Faleiro *et al*. 2013; Pouzols *et al.* 2014; Kukkala *et al.* 2016), but they have been mainly focused in tropical regions, with almost no studies being conducted in Central Europe (but see Arponen & Zupan 2016; Kukkala *et al*. 2016). A recent study reported that conservation planners could still make better use of SDMs (Tulloch *et al*. 2016), supporting further development of such quantitative tools in conservation planning.

Here, a framework is created with the objective to determine the ability of the current protected area network in the study site to conserve biodiversity, and to investigate the effects of climate and land use change on these areas. This framework will facilitate future conservation area planning when clear conservation goals are made by the local government and when more data becomes available. Two methods of conservation planning will be used to evaluate the current protected area network and to propose new areas for protection. First, priority areas for the expansion of the existing protected area network are identified based on threatened species' current level of protection. Second, the Zonation software is used to combine the effects of climate change, land use change, and land costs to propose optimal conservation areas in the *Alps Vaudoises* region of Switzerland.

Methods

Study area

The western Swiss Alps in the Vaud canton (6°60′ to 7°10′ E; 46°10′ to 46°30′ N) was used for this case study. This area has been the focus of interdisciplinary research for over a decade and has an abundance of environmental and species data available (see http://rechalp.unil.ch). The elevation within this region ranges from 1300 – 3210 m. It has a temperate climate with the annual temperature between 3.5 – 6°C and the annual rainfall ranging from 1400 – 2400 mm depending on altitude and topography. The study area is composed of vegetation varying from deciduous forests at high elevations to mixed and coniferous forest down towards heath, meadows, and grasslands at lower elevations (Randin *et al.* 2006). There are also several towns and agricultural lands present within the study area.

Switzerland has many categories of protected areas with varying degrees of regulations. Here, protected areas were assigned to one of four categories based on their capacity to protect biodiversity. Protected areas that are in the IUCN Category Ia are assigned to Tier 1. Tier 2 encompasses all protected areas that are designated by the IUCN Category IV. Tier 3 is made up of two types of reserves that have nature conservation as their main goal, but have fewer structured regulations than the first two tiers, as they do not have to meet international standards and practices. Finally, Tier 4 includes protected areas that are not designed for biodiversity conservation, but which may indirectly protect nature. The protected areas that are found within the study area are listed in Table S1 (see Supplementary Information) with their assigned tier. In the study area, 18.12% of the land is protected by either Tier 1 (0.02%) or Tier 2 (18.1%) protected areas (Fig 1), which is higher than the percentage for all of Switzerland (10%) (UNEP-WCMC 2016).

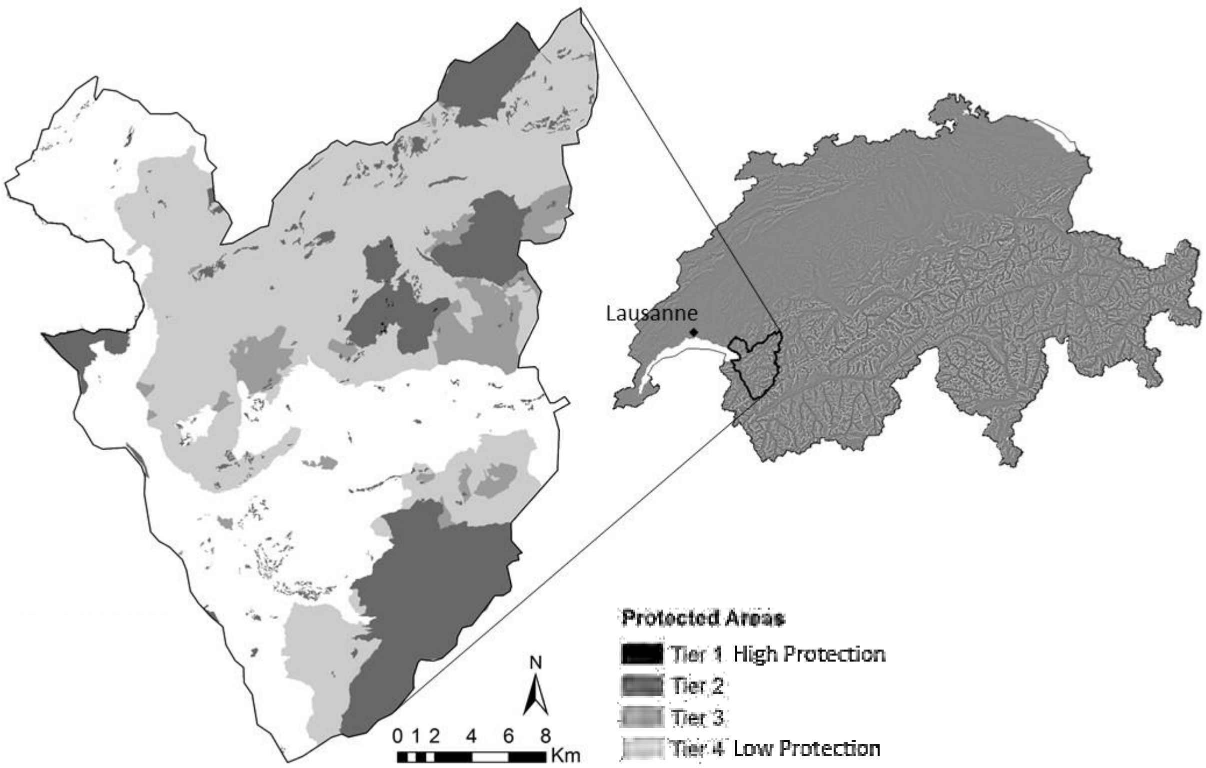

Figure 1: The study site and its position in Switzerland. The current protected areas are shaded in grey with the highest level of protection (Tier 1) given the darkest colour, and the lowest level of protection (Tier 4) shown with the lightest grey.

Analytical framework

Two methods of spatial prioritization for biodiversity conservation were compared through a case study performed in the *Alpes Vaudoises*, to generate a protected area network that optimises protection of biodiversity based on the current and predicted future species distributions. First, species occurrences and environmental data were used to create species

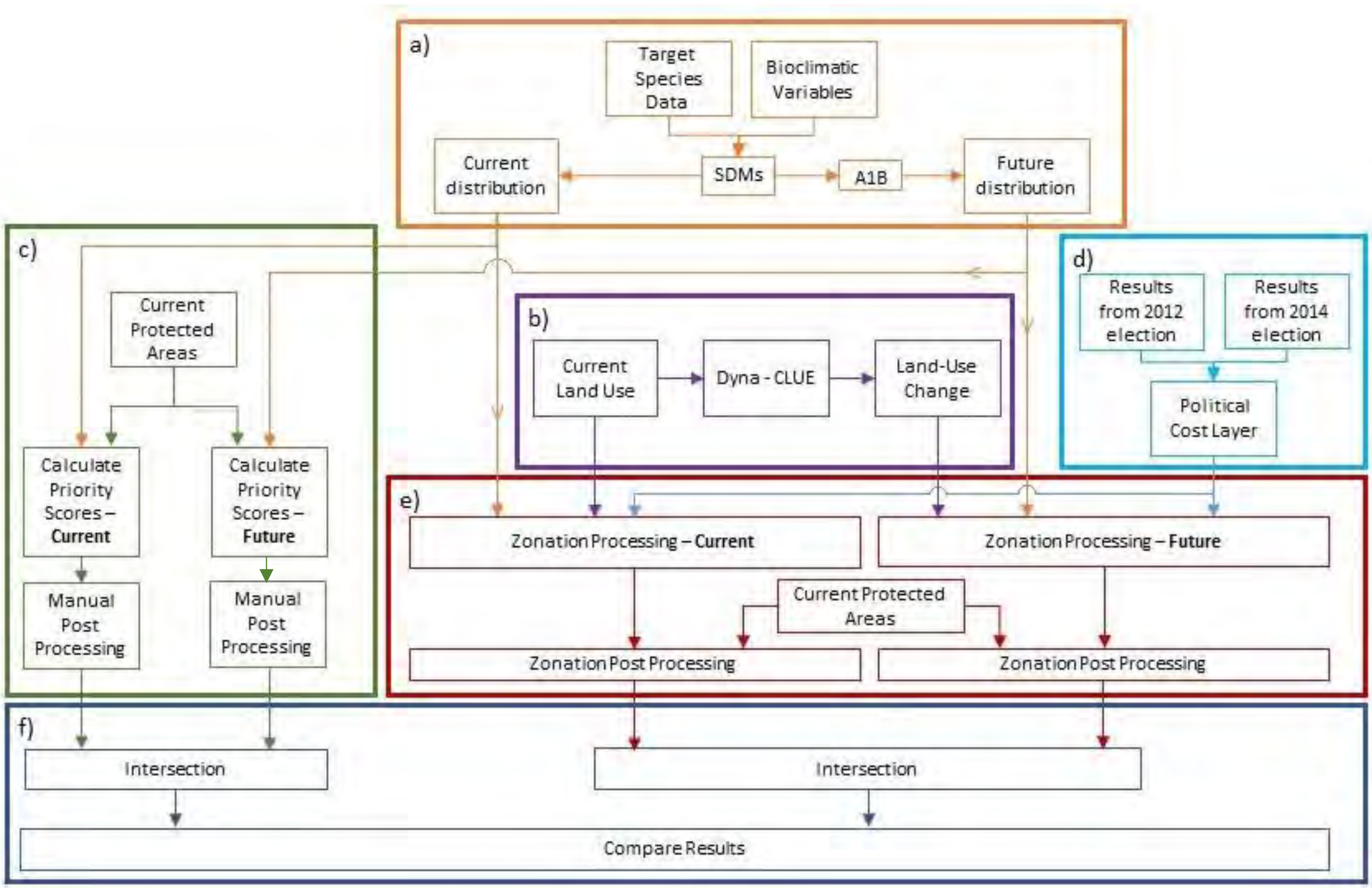

Figure 2: A schematic representation of the framework used for this analysis described in detail in the methods. a) Step 1, gathering species distribution and environmental data and, step 2, creating species distribution models and diversity maps. b) Step 3, calculating priority scores based on species distributions and current protected area network. c) Step 4, sourcing land use change scenarios from external sources. d) Step 5, using election results as a proxy to estimate land cost. e) Step 6, spatial conservation planning using Zonation software. f) Step 7, evaluating priority areas based on intersections of priorities in the present and future time steps.

distribution maps (Fig 2a). Land use change scenarios were obtained from external sources and used to filter SDMs (Fig 2b). Then, from these filtered distributions, a method described by Jenkins *et al*. (2015) was used to establish priority sites for expansion of conservation areas (Fig 2c; Priority scores method). Land costs were considered as political costs where communes with higher opposition to legislature that promoted the environment were given higher costs. These costs were estimated from election results at the commune level (Fig 2d). At the same time, the second prioritization method, the Zonation software, was used to incorporate land costs as well as two methods of implementing land use change scenarios: (i) the land use filter on SDMs (LU filter), and (ii) the removal mask layer with negative weighting (LU mask) (Fig 2e; Zonation solutions). Finally, the results from both the priority ranking method and the Zonation solutions were compared with the existing protected areas, and the best consensus solution for conservation areas was proposed (Fig 2f). All the steps are explained in further detail as follows:

Step 1 – Species distribution and environmental data

Species distributions were based on data from field surveys conducted in the study area. Species occurrence data for plants (including trees and grassland species, n = 627), amphibians (n = 5), reptiles (n = 12), and insects (n = 123; of which lepidopterans n = 82, orthopterans n = 21, and *Bombus* spp. n = 20) were used in this study (Table S2; Appendix 1). Data for other important taxa such as fishes, birds, and mammals is not yet available for the study area and therefore was not included in the analysis. Each species was assigned a threat status according to the Swiss Red Lists provided by the *Office fédéral de l'environnement, des forêts et du paysage* (OFEFP). All statuses are assessed at a national scale (Schmidt & Zumbach 2005; Wermeille *et al*. 2014; Monnerat *et al*. 2007; Moser *et al*. 2002; and Monney & Meyer 2005), except for

Bombus spp. because the hymenopterans national assessment is not yet available. In this case, the IUCN European Red List of Threatened Species was used (IUCN, 2016). The classifications are Data Deficient (DD), Least Concern (LC), Near Threatened (NT), Vulnerable (VU), Endangered (EN), and Critically Endangered (CR) in all cases. The Swiss protection status of each species was outlined by Cardoso (2015) and included species that are explicitly referenced in legislative documents.

Concerning environmental data, ten variables were used in the modelling procedure. Variables for temperature and precipitation were calculated from the mean during the growing season (March to August) from 1981 to 2009 at a resolution of 25 m. This data was then used to project the mean monthly temperatures for the whole study area, a method previously used by Pradervand *et al*. (2014). From this, the maximum temperature and precipitation, the minimum temperature and precipitation, and the sum precipitation were selected to use in the models. Evapotranspiration was calculated based on these precipitation variables and the radiation. Aspect was calculated based on the digital elevation model of the study area. Topography, growing degree days, and slope were retrieved from the Swiss Federal Institute for Forest, Snow and Landscape Research WSL database at 25 m resolution for vegetation, and 50 m for the insect groups.

Two climate change scenarios which couple data from global climate models (GCMs) and regional climate models (RCMs) were used to model future species distributions. The climate scenarios ECHAM5-REMO (Echam) and HadCM3Q0-CLM (Hadley) were developed by the Swiss Climate Change Scenario CH2011 project through the Centre for Climate Systems Modelling (www.c2sm.ethz.ch/). These models are based on high resolution data which incorporates anomalies from all Swiss weather stations (Bosshard *et al*. 2011). It is important to include regional data as Switzerland is warming at a higher rate compared to the rest of the Northern Hemisphere, and this difference is most notable in the Alps (Rebetez & Reinhard 2007). ECHAM5 (from the ECMWF model parametrized by a package developed in Hamburg) is an atmospheric GCM developed by the Max Planck Institute for Meteorology (MPIfM) (Roeckner *et al.* 2003). This is coupled with the atmospheric RCM REMO which was also developed by MPIfM by combining three hydrology models with three ocean models (Jacob & Podzun 1997). HadCM3 (Hadley Centre Coupled Model, version 3) is a GCM that couples atmospheric and oceanic general circulation models and was developed by the Hadley Centre (Gordon *et al.* 2000) with standard sensitivity (Q0). The Community Land Model (-CLM) is the RCM that is coupled with the HadCM3Q0 to add regional land-surface atmosphere interactions and was developed by the Swiss Federal Institute of Technology Zurich.

As future climate is difficult to predict, numerous climate change scenario storylines have been created by several researchers (Moss *et al*. 2010). For this study, we focused on the A1B scenario which predicts rapid economic growth and the global population peaking around 2050 and subsequently declining (IPCC 2001). It also forecasts the introduction of more efficient technology and a balance of fossil fuels and renewable energy sources. Both climate models described above were projected using seasonal temperature and precipitation values to the years 2045 – 2074 (from here on referred to as 2060) under the A1B scenario. To generate the final solution, only the “Hadley” scenario was retained as it predicted a worse case for biodiversity. The analysis using the “Echam” scenario can be found in the supplementary materials (Fig S3-S6; Table S3).

Step 2 – Species distribution models & diversity maps

To model the current and future distributions of the studied species, an ensemble of small models (ESMs) was used, which consists in fitting and averaging many small models with few predictors at a time (typically 2) weighted by their predictive performance (Breiner *et al*. 2015). These ESMs were implemented to avoid overfitting and to improve the modelling of rare species (Lomba *et al*. 2010; Breiner *et al*. 2015). A mean of the following three modelling techniques was used to predict species distributions based on observational data and environmental variables in R v3.2.1 (R Core Team 2015): Generalized Linear Models (GLM; McCullagh & Nelder 1989), Generalized Additive Models (GAM; Hastie & Tibshirani 1986), and Maximum Entropy (MaxEnt; Phillips *et al*. 2006, Phillips & Dudik, 2008) (Fig 2a). GLM and GAM are both statistical methods to predict species distributions using regression techniques with GLMs fitting parametric terms, and GAMs fitting non-parametric terms (Elith *et al.* 2006). MaxEnt is a method developed for presence-only data to estimate probabilities of species distributions by finding the distribution that is closest to uniform (or the most unconstrained), subject to a set of constraints (Phillips *et al*. 2006). It was recently shown to be a special case of GLM where species occurrences are considered as resulting from a Poisson point process (Renner & Warton 2013).

The data for each species was randomly partitioned into 75% for calibration and 25% for validation. For each combination of environmental predictors, GLM, GAM, and MaxEnt were evaluated using a maximisation of the True Skill Statistic (maxTSS), a balanced view evaluation method which takes both omission and commission errors into account (Hanssen & Kuipers 1965). These evaluations were used to create a weighted mean of the predictions to create an ensemble model. Each ensemble model for each combination of predictors was again evaluated by maxTSS, and these evaluations give the best combination of predictors to obtain the final ensemble model which was used for the final evaluation. The full dataset was then used for the projection step where the evaluators for each of the three techniques produce an average weight of the predictions within each of them. Finally, a last prediction for the ensemble model was calculated using the weighted mean across the techniques. A binary presence-absence distribution was obtained for each species. These distributions were then summed, using the *raster* package (Hijmans 2015) in R, across all species of an interest group to create different diversity maps.

Step 3 – Land use change scenarios

Land use data was added to the analysis using one map for the current use and one for the predicted future use (Fig 2b). The baseline land use map was taken from the Swiss land use statistics data from 2009 (SFSO 2013; Fig S1a). The future land use scenario map under the A1 climate change scenario (the scenario family in which A1B is found) was modelled by Price *et al*. (2015) using the Dynamic Conversion of Land Use and its Effects Model (Dyna-CLUE; Verburg & Overmars 2009) framework for the year 2035 (Fig S1b). It was not possible to model the land use change to the same period as the climate change scenarios because the land use models are based on Swiss population growth scenarios which, at the time of this study, were only available until 2035 (Dr. Bronwyn Price, *pers. comm.*). In that study, the land use categories (72 in total) were aggregated from the Swiss land use statistics to include only seven: Closed Forest, Open Forest, Overgrown, Pasture Agriculture, Intensive Agriculture, Urban, and Other (Price *et al*. 2015). The data was obtained with a cell size of 100 x 100 m and was converted in ArcGIS 10.2 (ESRI 2014) to 25 x 25 m, to be used in the Zonation analysis.

The distribution models were then filtered based on these land use maps. This was done by overlaying the species observations with the land use map, and removing any projected presence that occurs in a land use type that has no recorded observations. In this way, the land use filters are different for each species based on its estimated niche. Both methods supplied one current land use map and one future map. These filtered distributions were used in the Priority scores method as well as in the LU filter Zonation analysis.

Step 4 – Priority scores method

The first method to assess priorities for protected area networks was to calculate the priority scores for each species distribution (Fig 2c). This score enables planning to be focused on target species which have the greatest need for protection. This need for protection is defined by the proportion of the species range that is protected under the existing conservation network. Priority scores (*S*) were calculated as described by Jenkins *et al*. (2015) by dividing the area of each species distribution (*A*) that does not fall in a Tier 1 or Tier 2 protected area (*P*) by the total area of the species range (*A*). This score was then summed across all (*n*) modelled species to get the total priority score (eq 1). The filtered SDMs were used for this analysis to incorporate land use change in the priority score calculation. Species were classified as threatened if they were listed as VU, EN, or CR per the designation described in Step 1.

$$S = \sum_{i=1}^{n} \frac{A_i - P}{A_i} \qquad (1)$$

Step 5 – Cost maps calculation

Land cost is an important factor to consider with conservation planning and can be measured as a monetary cost or any other aspect that may influence the feasibility of implementing protection at a site. Here, costs were defined as political costs where municipalities with a tendency to vote against measures that restrict human activity to promote the environment were given a higher cost. This is because it would be more difficult to change the legislation to expand protected areas in these regions. The political costs were calculated by Cardoso (2015) by averaging the opposition results from two votes that had a direct impact on biodiversity conservation, the first was held in 2012 and the second in 2014 (Fig 2d). The communes which had a higher percentage of votes against the measures that would help biodiversity conservation were given a higher political cost, with the highest cost found in the north-east of the study area (Fig S2).

Cardoso (2015) also calculated the monetary acquisition costs for the land in the study area based on the Swiss national VECTOR25 land use data at 25 m x 25 m (Swisstopo 2008). This cost was not included in this analysis, however, as it is the same data as the land use and here we are separately applying that to the analysis. Adding the acquisition cost in addition to the land use would have a repetitive effect on this aspect and would doubly negate areas with a specific land use type.

Step 6 – Spatial conservation planning using the software Zonation

In this step, the Zonation software was used to prioritize areas for protecting biodiversity in the *Alpes Vaudoises* region of Switzerland (Fig 2e). This software uses a meta-algorithm with an iterative ranked cell removal method which begins with a full landscape and then selects the cells which contribute the least to the conservation planning goals, removing these first (Moilanen *et al.* 2005). Therefore, the cells that are removed last have the highest priority to meet the conservation goals. There are two main cell removal rules which determine the order in which pixels are removed: basic core-area Zonation (CAZ) and the additive benefit function (ABF). For CAZ, the minimum marginal loss of biological value (δ) is calculated for each cell and equals the value of the feature which has the highest score based on its proportion of occurrence and its weight. The cell with the lowest δ is removed, meaning that the cell containing species with the largest remaining distribution or the smallest weight is removed before others (Moilanen *et al.* 2005). This value (δ) is recalculated after each cell removal and the proportion of occurrence is reassigned based on the remaining landscape. ABF, in contrast to CAZ, adds all the weights and proportions of features occurring in each cell instead of focusing on the one feature with the highest value (Moilanen 2007). In this study ABF was used because CAZ is not recommended to be performed when incorporating land costs (Moilanen *et al*. 2014). However, the whole analysis was also done using CAZ in parallel to compare results (see Table S3; Fig S8).

In addition to the cell removal rule, Zonation offers the ability to use and adjust numerous parameters to tailor the analysis to various goals including spatial connectivity, feature weights, and uncertainty. To prioritize for future scenarios, the connectivity between different time steps was represented as an ecological interaction, but the interaction is between the present and future distributions of each species. This connectivity is characterised by the dispersal ability of each species as it defines the ability of that species to reach its new distribution. There is currently no substantial information on dispersal ability available for all the modelled species used in this analysis. Therefore, one analysis was done with no dispersal and a parallel analysis was done with unlimited dispersal to give the complete dispersal interval for each species. This way, we ensure that the true dispersal ability of each species is captured within this interval. Engler *et al.* (2009) found that, for this same study area, simulations of plant distributions using limited dispersal gave similar results to those using unlimited dispersal, but both were significantly different from those using no dispersal. Therefore, here we only present the results using unlimited dispersal.

Each feature that is added to a Zonation analysis can be assigned a weight, and the aggregate weight of features in each cell defines its priority during the cell removal process with a higher weight given a higher priority (Moilanen *et al*. 2005). Species feature weights were first assigned based on species IUCN status with CR species given a weight of five, EN species of four, VU species of three, NT species of two, and LC or DD species were given a value of one. Second, an additional two weight points were assigned to any species that are protected under Swiss legislation. This resulted in weights assigned between one and seven for all species. Differential weighting between taxa was not used as we were interested in protecting overall diversity.

Uncertainty in the modelling was addressed by giving lower weights to the future species distributions than to the present, and the lowest in the connectivity between these time steps. SDMs have uncertainty associated with them, but we assume that the uncertainty is equal among species. Projecting into the future carries many more uncertainties, and thus these layers were assigned a lower weight than the present distributions. This method is suggested in the Zonation manual as well as other studies to account for uncertainty in the features (Carroll *et al.* 2010; Kujala *et al.* 2013).

Land use change was added to the Zonation analysis by two methods (LU mask and LU filter). The first method, LU mask, consists in using a removal mask layer to exclude urban areas from the analysis first. This is done because of the almost impossible task of converting urban developed areas into protected areas, and because of the high acquisition cost of this land – 1500 times more expensive than the next highest land use type (Cardoso 2015). To account for prioritization based on the other land use types in the study area, negative weights were given to less favourable land use types. Of the seven land use categories, three were given negative weights: Intensive Agriculture -100, Pasture Agriculture -50, and Other (which includes wetlands, glaciers, and alpine sports facilities, among others) -25. Closed forest, Open Forest, and Overgrown areas were not assigned a weight. The second method of accounting for land use change, LU filter, was done by using SDM filters as previously described (Step 3).

The Zonation analysis was done in a sequential fashion, with new parameters added to the analysis one at a time. The resulting maps and response curves were verified at each step to ensure that there were no setup errors (e.g. all input features were at the same spatial scale, and all file paths were correct), and if errors were noticed they were then easier to remedy. Only the solutions from the final runs with all parameters are included here.

Step 7 – Evaluating priority areas and comparing methods

Manual and automatic post-processing of the results was done to create more practical solutions for comparison and implementation. For the priority score analysis, priority areas were selected based on high scores of threatened and protected species. This was because the priority score method was designed for identifying key areas to protect rare and small ranged species

(Jenkins *et al.* 2015). The current and future scores were summed to create a composite map to select the most important conservation areas (Fig 2f).

For the Zonation analysis, post-processing was done automatically in Zonation to identify the top 18.12% of the landscape to protect. This percentage of the landscape was selected because it is the proportion of the study area currently designated with IUCN protection (either a Tier I or Tier II protected area). A second automated post-processing analysis was conducted in Zonation to assess the effectiveness of the current Tier 1 and 2 protected areas in the study site. This analysis used the same parameters as the previously mentioned analysis, but forced the current protected areas to be retained. The Zonation consensus solution is the spatial overlap between current and future proposed networks using the LU mask (Fig 2f).

Results

Diversity maps

When analysing the diversity map results, we observed that there is currently higher species diversity at the transition zone between the Rhone valley and the Alps in the South-West of the study site, and this becomes more apparent when looking at rare species (Fig 3a, 3c). The future distributions for all species are expected to move westward and to some areas with higher elevations (Fig 3b), but some rare species will continue to inhabit the same areas as are currently occupied (Fig 3d). The diversity patterns vary among the taxonomic groups used. Reptiles are more diverse at lower elevations (Fig S3 d–f), amphibians have a high diversity around lakes and rivers (Fig S3 a–c), and insects have the highest diversity at high elevations (Fig S4). These patterns stay constant for the future time step for these taxonomic groups, but plants are projected to move to higher elevations (Fig S3 g–i).

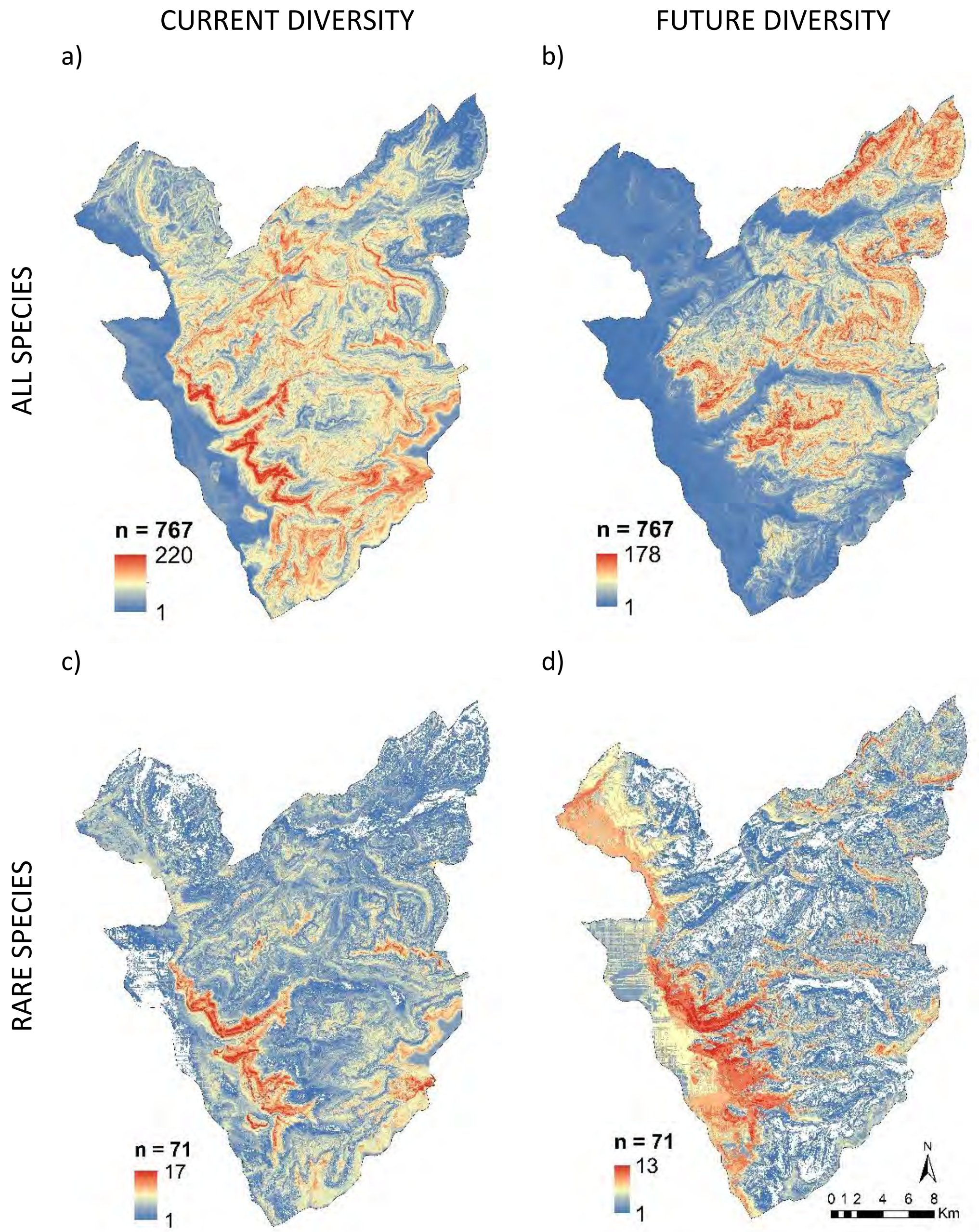

Figure 3: Biodiversity maps represent richness of the modelled species with their current (a, c) and projected future (b, d) distributions. Future refers to the distributions predicted to 2060 using the "Hadley" climate change scenario. A subset of the species was used to create maps of rare species which were identified as being threatened and/or protected (c, d). Species richness is represented here as the number of species with overlapping ranges.

Priority scores method

Looking at the results for the priority scores, we observed that the solutions follow a similar trend as the diversity maps with areas having high diversity given higher scores (Fig 4). Priorities are predicted to decrease in the future time step (Fig 4). The current distributions provide similar priority areas for rare species as for the total (Fig 4a, 4c). The future distributions, on the other hand, indicate a miss-match in priorities between rare and common species (Fig 4b, 4d). As was found with the diversity maps, the priority scores differ spatially for different taxa. At both time steps, amphibians have high priority near waterways (Fig S5 a–c), and reptiles have higher priorities at lower elevations (Fig S5 d–f). The priority scores for plants follow the same trend as for total species because 82% of modelled species were plants (Fig S5 g–i). The insects differ based on elevation with *Bombus* spp. and orthopterans having higher priorities in lower regions and lepidopterans in higher regions (Fig S6).

Zonation solutions

The Zonation solutions presented here used the political land costs, unlimited species dispersal, ABF cell removal rule, and the "Hadley" climate change scenario. The Zonation solutions have over 90% spatial similarity between the land use methods used and the current and future time steps (Fig 5). Although the LU filter and the LU mask methods protect an almost equal proportion of species distributions (Fig 6), the LU filter selects more urban areas which are unfavourable for converting to protected areas. Therefore, the LU mask was used to create the final solution.

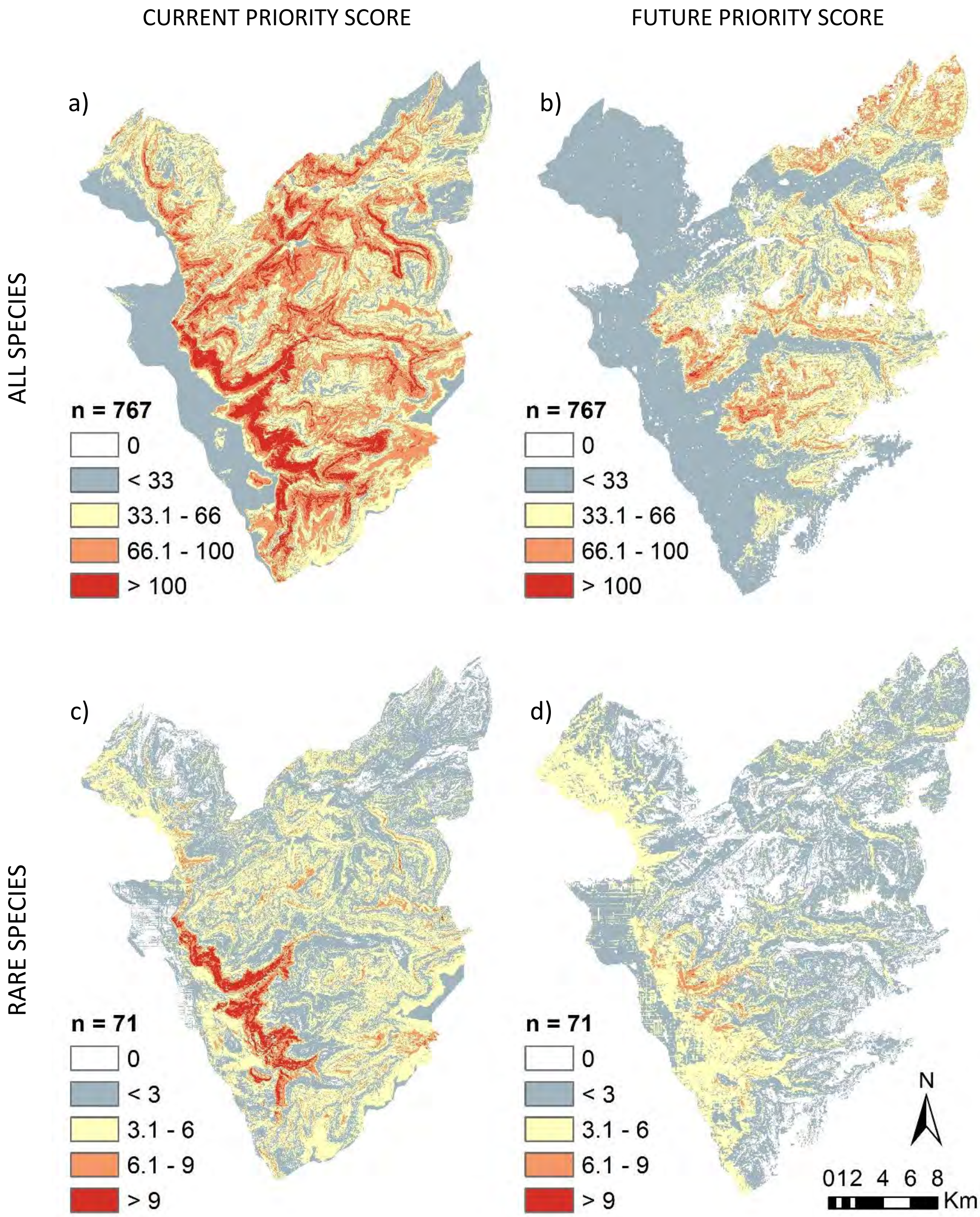

Figure 4: Priority maps showing the sum of species priority scores of the modelled species with their current (a, c) and projected future (b, d) distributions. Future refers to the distributions predicted to 2060 using the "Hadley" climate change scenario. A subset of the species was used to create maps of rare species which were identified as being threatened and/or protected (c, d).

The solutions created by Zonation for the new protected area networks (new PAs) performed better than the Tier 1 and Tier 2 protected areas (existing PAs) for the species distributions at both time steps (Fig 6). Existing PAs cover on average 25% of all species ranges, but one plant species, *Alopecurus pratensis* (LC), currently has none of its range protected. New PAs at the current time step cover 44% of all species ranges, and a portion of all species ranges are within this area. For the future distributions, the existing PAs would become less efficient with a mean of 23% of species ranges compared with the new PAs which would improve and cover a mean of 49%. Concerning the future scenario, the existing PAs would protect 23 fewer species than the new PAs, of which one species is nationally threatened (*Polyommatus damon*, VU), and three are protected by regional or national law (*Traunsteinera globosa*, *Monotropa hypopitys* and *Epipactis purpurata*). The difference in effectiveness between the new and existing PAs is more notable with rare species (Fig 5c–d). There was almost no difference in the performance between the new and existing PAs for amphibians and for *Bombus* spp. at the current time step (Fig S7 a, d). The new PAs however did considerably outperform the existing PAs at both time steps for all other taxonomic groups (Fig S7 b, c, e, f).

Spatial overlap and final solutions

The Zonation consensus solution identifies the areas where the current and future LU mask solutions overlap (Fig 7). The top areas identified by Zonation were selected independently of the existing PA network. The spatial overlap between the new and existing PAs was low at 34% for the current solution and 32% for the future (Table S3). The composite map shows the top priority scores for the current and future time steps and indicates areas that are recommended to be added to the existing PA network (Fig 8).

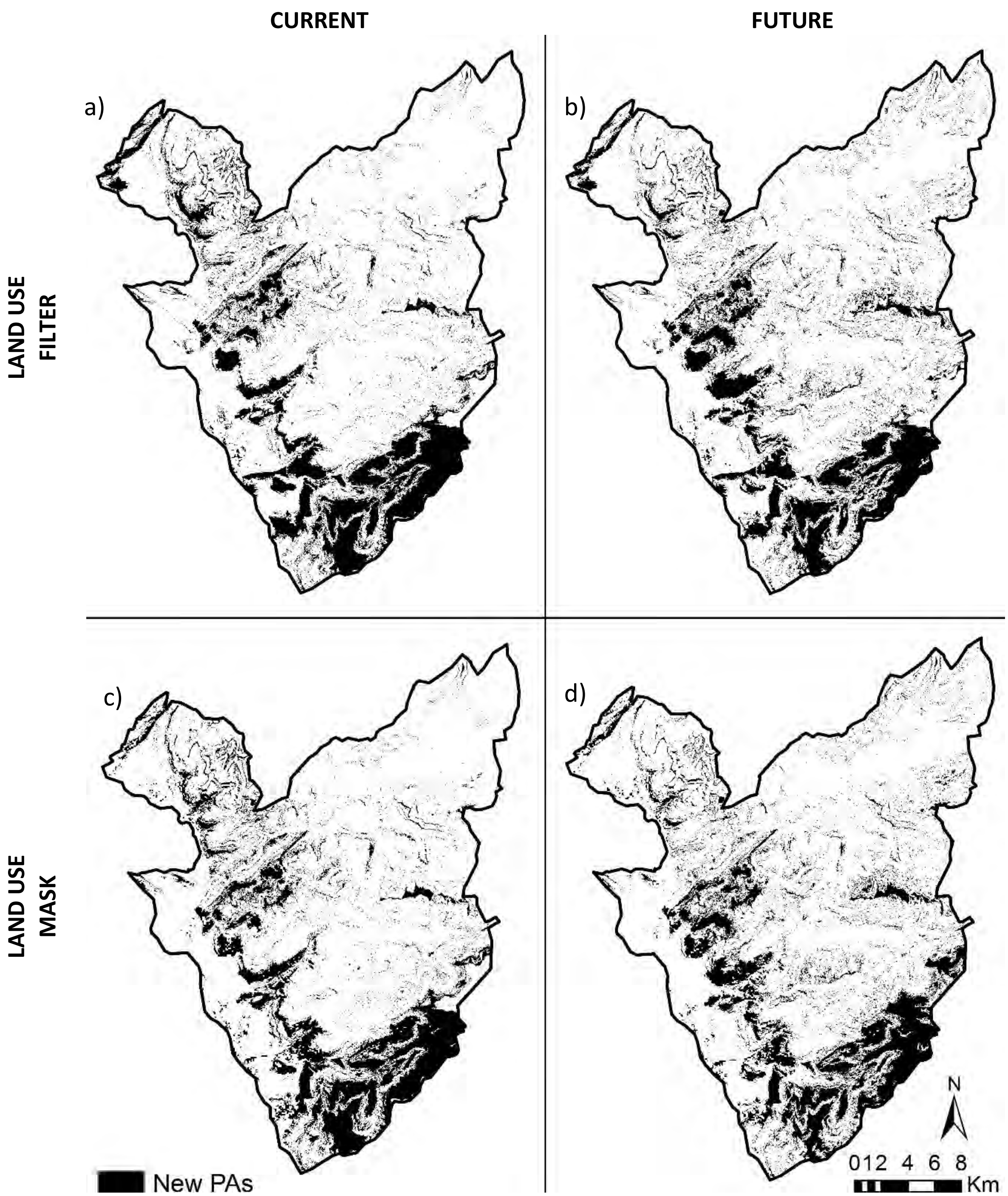

Figure 5: Spatial representation of the Zonation solutions created using the LU filter (a, b) and LU mask (c, d). Future refers to the distributions predicted to 2060 using the "Hadley" climate change scenario. The black areas represent the top priority areas and cover the same proportion of the landscape as the existing Tier 1/ 2 protected areas.

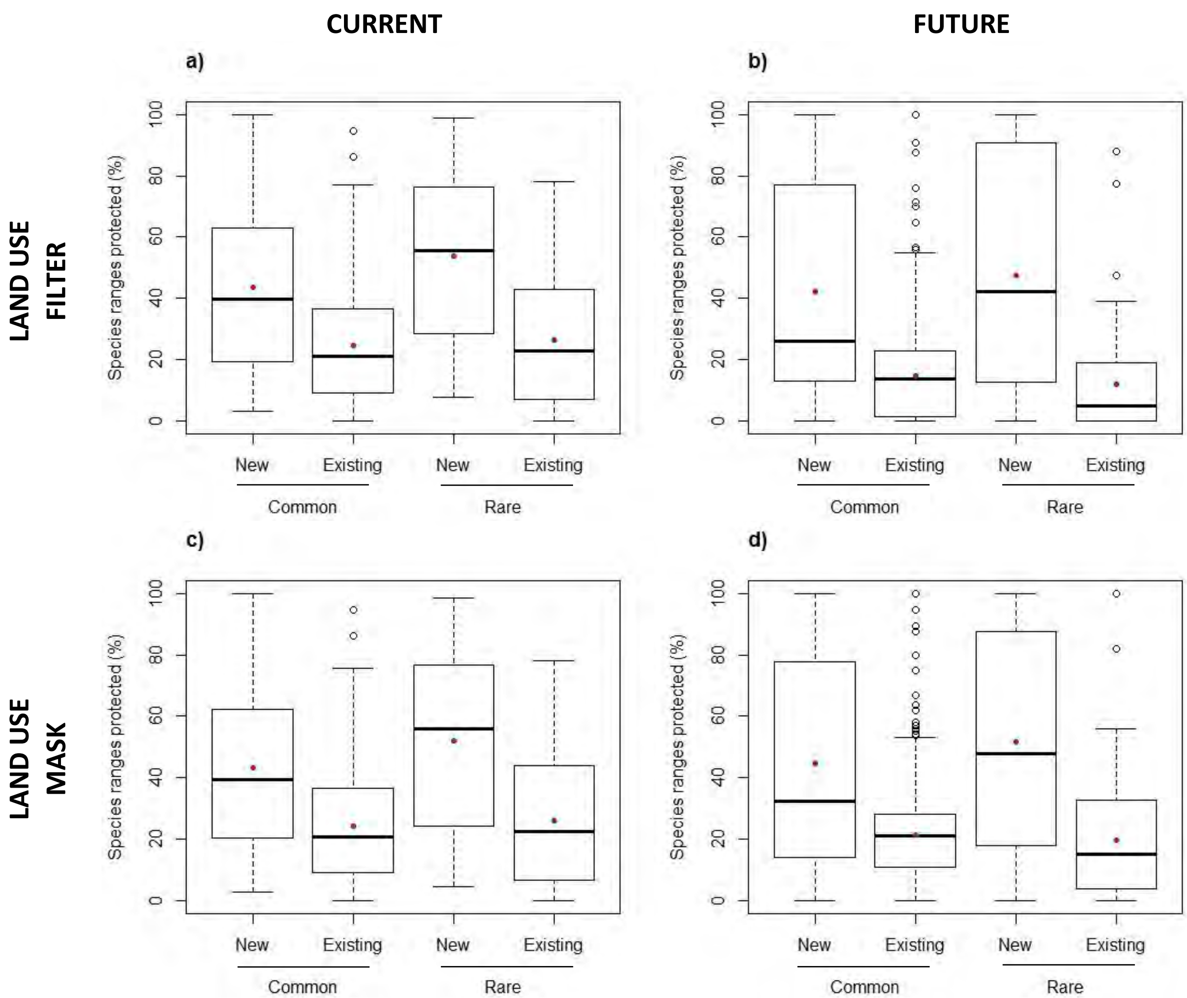

Figure 6: The proportions of species ranges protected by the Zonation solutions created using LU filter (a, b) and LU mask (c, d) compared with the existing protected areas. Rare species are all of those listed as threatened and/or protected, and common species are all other species. Future refers to the distributions predicted to 2060 using the "Hadley" climate change scenario. Open circles indicate outliers, black bars show medians, and red dots indicate means.

The solution maps of the top conservation areas proposed by Zonation using all the various input parameters were compared with each other. There was no difference between solutions using unlimited dispersal and no dispersal, which had a spatial overlap of 100%. The ABF cell removal rule created more similar solutions with each other than the CAZ removal rule when the input parameters were varied (Table S3). With CAZ, solutions were more similar between land use methods than within time steps, however with ABF the opposite is true. The “Hadley” climate change scenario predicted more harsh effects with the existing PAs losing 17 more species than the “Echam” scenario. However, these scenarios produced very similar results with a spatial overlap of 94-96%, indicating that the difference between the two scenarios has a small effect on the solutions.

Discussion

This study was the first to use a decision support tool like Zonation in Switzerland, and in a montane landscape, at such a fine scale and using a high number of taxonomic groups for conservation prioritization. The solutions from both the priority scores and the Zonation analysis indicate that the current protected areas in the *Alpes Vaudoises* are currently not optimally located. This result is more pronounced when species distributions are projected into the future with climate and land use change, with 60 species no longer having any of their range in the protected areas due to local extinction or range translocation. This emphasises the need for using decision support tools for conservation prioritization.

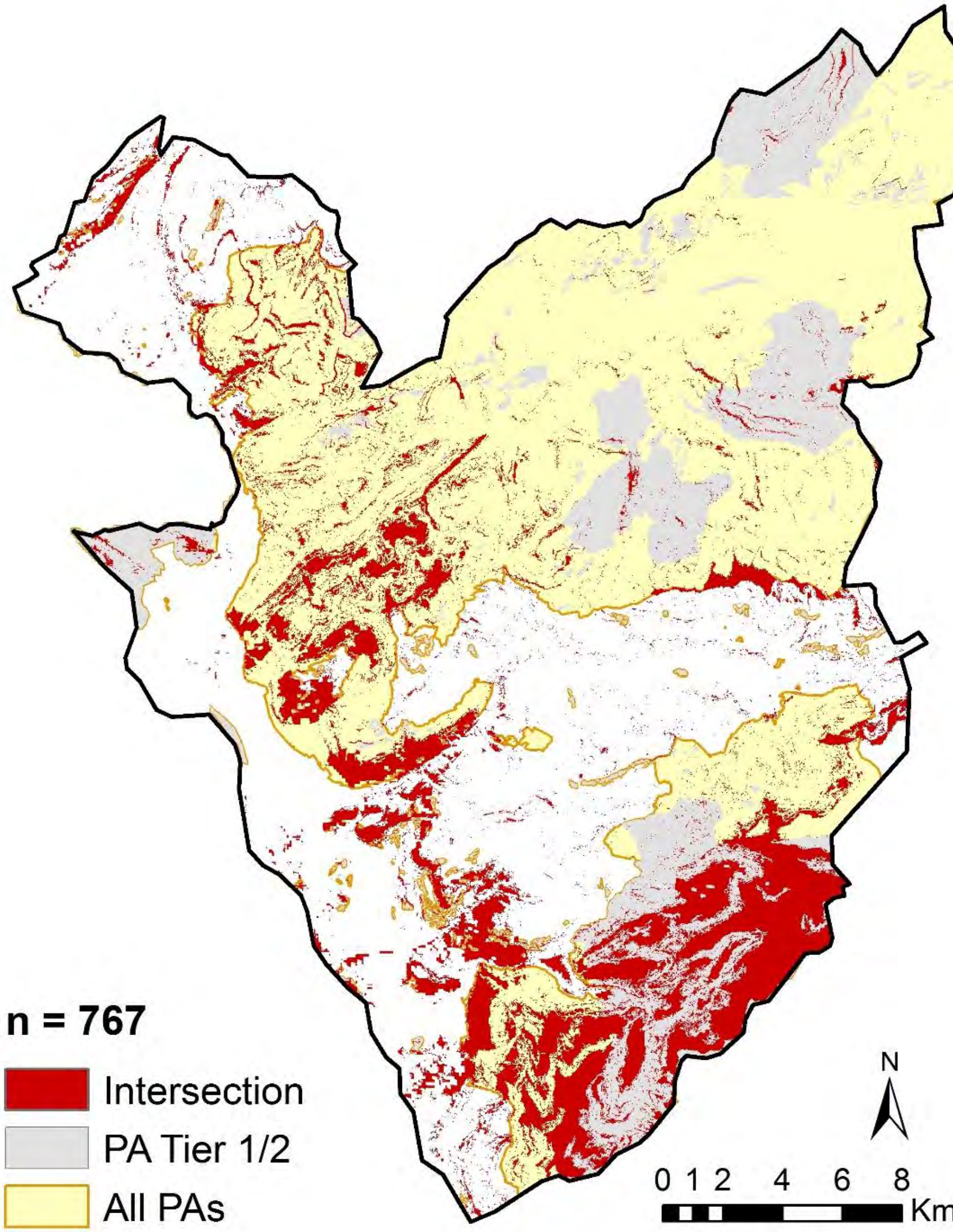

Figure 7: The Zonation consensus solution created by overlaying the current and future LU mask solutions. The overlapping regions are shown in red and represent the areas that are priorities at both time steps. All four tiers of the existing protected areas are shaded in yellow, and within these, the top two tiers are shaded grey.

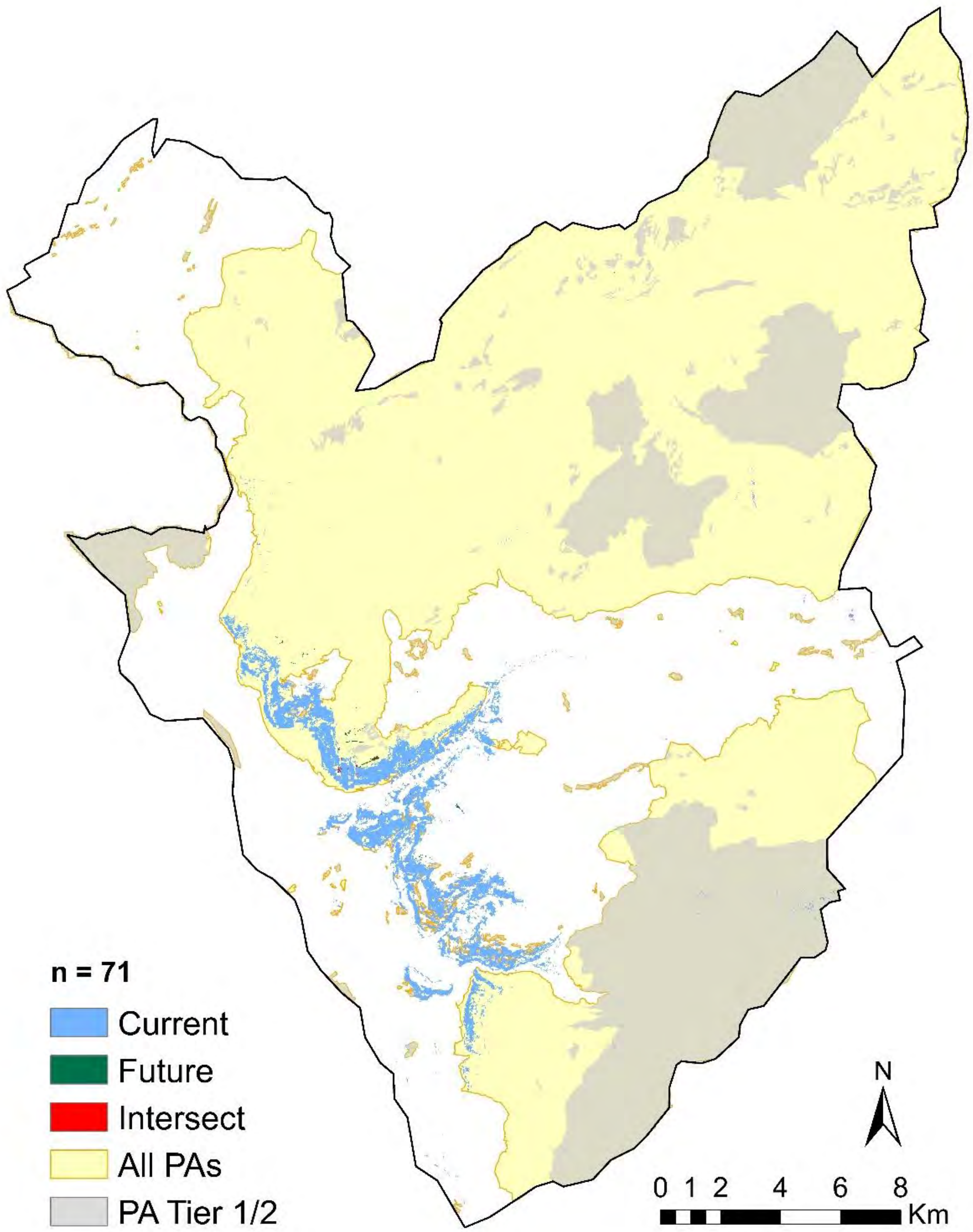

Figure 8: The priority score consensus solution created by overlaying the current (blue) and future (green) priorities for the rare species (threatened and/or protected). The overlapping regions are shown in red and represent the areas that are priorities at both time steps. All four tiers of the existing protected areas are shaded in yellow, and within these, the top two tiers are shaded grey.

Zonation analysis and the priority scores method provide very different solutions that will be useful to address different conservation questions. The Zonation consensus solution (Fig 7), which shows the intersection between current and future top conservation areas, will likely never be implemented in an area like this in Switzerland, as it requires the removal of all protected areas and the creation of completely new protected areas. Nevertheless, this type of solution is useful to question and learn from our past conservation practices, and for managers to consult when planning future development projects, because it supplies key regions where human impacts should be minimised or where future protection should be focused. The priority scores method, however, provides solutions that are more easily implemented as they propose areas that can be added to the current protected area network. The highest priority areas to be included in the network are those where the current and future priorities intersect (Fig 8). Both of these output maps can be useful reference tools for managers and politicians when future infrastructural projects are considered, especially once the additional taxa are included. Both methods incorporate land use and climate change, but the land costs were not added to the priority score analysis as there is currently not a proven method to do so.

There is a decrease in priority scores for the predicted future distributions which could be caused either because species are moving into the existing PA network, or because of local extinctions causing the overall diversity to decrease. The Zonation solutions confirm that the latter is the cause of reduced priority scores as the number of species completely outside existing protected areas increases from 1 to 60. Three locally important species and 17 others are projected to migrate completely out of the existing PAs but maintain a range in the study area. Therefore, they can face higher threats of local extinction due to threats from habitat fragmentation or degradation which have been found to decrease species richness (Wilcox &

Murphy 1985; Gibson *et al*. 2011). These high numbers of local extinctions and species migrations highlight the need for conservation prioritization.

The Zonation solutions with unlimited dispersal and no dispersal gave almost identical results and had complete spatial overlap. This may be because of the small change between the current and future species ranges, and the future ranges were only projected to 2060. If the distributions were projected further into the future, these changes may become more obvious. This is highlighted by the similarity in solutions for the different time steps indicating that there is little change in the distributions. The CAZ cell removal rule has been utilised by most published Zonation studies (but see Lehtomäki *et al*. 2009; Pouzols *et al.* 2014), likely because it is the default value in the software. Our results show that the results obtained when using ABF provided better solutions – protecting a larger proportion of species ranges as well as the total number of species protected – than when CAZ was used for this study site, something that was also found by Cardoso (2015). CAZ is also not recommended to be used when land costs are added as the algorithm loses a clear definition of priorities (Moilanen *et al*. 2014). Zonation has the capacity to decrease the pixilation in the solutions to give more aggregated results through smoothing parameters. This is additionally useful when the goal is to create a new PA network and implement all the areas together or to create protected areas with greater connectivity (Moilanen *et al*. 2014). As this is very unlikely to happen in the study area because of existing bureaucracy and costs involved in recreating the entire protected area network, a method for distribution smoothing was not included in this work. The solutions therefore give a best-case scenario and the top priority sites independent of each other. This will make it more practical in a political environment, like that of Switzerland, where these solutions can be consulted for any future development projects, which may even be on a small scale.

Here, only one climate change storyline was used, A1B, as it presents a harsher degree of change than other scenarios. It is recommended to use more than one climate change scenario because of the uncertainty associated with projecting into the future (Carroll *et al*. 2010). To account for this, two models to predict these climate changes were used, “Echam” and “Hadley”, but it would have been beneficial to include other climate change storylines in the analysis to provide a broader idea of what changes may arise in future. “Hadley” was produced locally in Switzerland and provided more notable changes in the environment than “Echam” and was thus selected for the final maps. However, both models supplied very similar Zonation solutions and priority score solutions with very high spatial overlap, indicating that the projected changes by both models are very similar. Preliminary Zonation runs indicated that adding the land costs had a large effect on the solutions. This may be why areas in the north of the study area were rarely selected for protection, as they had the highest political costs associated with them. Costs have been added to previous Zonation analyses by using land use (Arponen *et al*. 2012) or accessibility (e.g. the distance to roads or settlements) as a proxy for costs (Delavenne *et al*. 2011; Struebig *et al*. 2015). Others have used a combination of costs to create more implementable solutions, like Lagabrielle *et al*. (2011) who created a Conservation Cost Index for their study site by summing four components of land costs. Outlining any additional costs associated with converting land to protection in our study site should therefore be assessed before a similar analysis is done as they effect the results to such a high degree that plans that ignore costs have a lower chance of being implemented (Naidoo *et al*. 2006).

Land use change has not yet been incorporated into a Zonation analysis as a dynamic parameter changing through time steps, and has yet only been modelled externally and added as a static parameter (Faleiro *et al.* 2013; Struebig *et al*. 2015), or not added at all. In this work, two methods for accounting for land use change were used: (i) the land use filter on SDM method (LU filter), and (ii) the removal mask layer and negative weighting (LU mask). Using the LU filter was a good method as it yielded predictions closer to the true distributions, by discounting land use types in which a species was never observed. This method also enabled us to match the future species distributions with the future land use types to account for the changes in land use over time. The LU mask made it more difficult to incorporate land use between different time steps, thus the current and future land use maps were added separately to the current and future Zonation analyses. Globally, there is an increase in land competition caused by an increase in the demand for resources (Summers *et al*. 2015), which will increase the risk of conflict over land uses. The LU mask produced solutions for lower conflicts between human uses and biodiversity conservation as urban areas were removed in the final solutions. Because of the trade-off between minimising conflict and increasing the proportion of species ranges that can be protected, we would recommend combining these methods in future studies. This can be done by using a filter to create a more accurate distribution and adding a mask to remove urban areas that would be difficult to convert into protected areas. Struebig *et* al. (2015) found that including land use change together with climate change in their analysis caused a bigger effect on habitat loss than climate change on its own. Our results highlight this point because the land use methods noticeably changed the Zonation solutions.

The land use changes were less noticeable in the small study area over a short period, and the trends of land use change are seen better on a national scale, e.g. there is more change anticipated in the plateau region of Switzerland compared to the Alpine regions (Price *et al*. 2015). The land use data and the species distributions were modelled using different time and spatial scales, which may have presented inconsistencies within the solutions. With the available data, land use change could only be projected to 2035, but our species distributions were projected until 2060. This therefore provided a conservative estimate of the amount of land use change predicted in the study site. These spatial and temporal variations emphasise the disconnection between researchers in different fields, even between those working in the same regions or study areas. Researchers from all fields working in a common region should form a consensus and use the same climate change scenarios and spatial scales. Guisan *et al*. (2013) suggest the use of 'translators' who can help bridge the gap between researchers and managers. This will facilitate analyses, like this one, which take data from ecology, politics, economics, and geography.

The results from the priority scores show that there is a miss-match in the priority areas between common and rare species. This highlights the importance of setting clear goals with policy makers and scientists before undertaking an analysis like this (e.g. protecting all threatened species, increasing a target species range or population to a desired level, protect biodiversity in general, ensure specific ecosystem services, *etc*.). Setting clear goals with policy makers and including land use and cost information reduces the risk of conflict when trying to implement changes. This is important as there is an "implementation crisis" because the scientific ability to create these results outweighs the ability to apply them, due mainly to disconnect between scientists and the government (Knight *et al*. 2006; Guisan *et al*. 2013). Having a study site like the *Alpes Vaudoises* enables long term relationships to be formed between all the stakeholders in the landscape and this will increase the likelihood of solutions being implemented.

This type of analysis is rarely used in Europe and is more often used in tropical regions. This was the first study to use a decision support tool in a montane landscape that used more than one taxonomic group. Other conservation planning studies have been conducted in mountain ranges, but only for species-specific analyses (Pearce *et al.* 2008; Carroll *et al*. 2010; Januchowski-Hartley *et al*. 2011; Fleishman *et al.* 2014; Wan *et al*. 2014) or for process-based planning (Lagabrielle *et al*. 2009). To date, there have only been three published studies that used decision support tools in Switzerland. Langhans *et al* (2014) used Marxan, a software similar to Zonation, to plan cost-effective rehabilitation of the fresh water system in northern Switzerland. Bolliger et al. (2011) also used Marxan to set priorities to conserve and restore grassland species with limited costs. Arponen & Zupan (2016) assessed hotspots for mammal diversity in continental Europe, which included Switzerland, using the Zonation software. Of the nine total publications that used Zonation in Europe, five were conducted in Finland, where the creators of the software are also based. Decision support tools for conservation prioritization are used less in European countries than in more developing or biodiversity rich countries (e.g. Brazil, Australia). Of the published studies using Marxan in Europe, 68% have been for fresh water or marine protected areas. This infrequent recourse to spatial decision tools may be because in European countries, like Switzerland, there is an existing protected area network, and it is assumed that these areas are already in the optimal places to protect wildlife. However, it has been observed that existing conservation areas are more likely to be in places that are unsuitable for commercial or economic activities, and not necessarily in areas with high biodiversity which therefore creates a biased and unsatisfactory sample of species richness in protected areas (Margules & Pressey 2000).

Switzerland is still far from reaching the Aichi target of having 17% of terrestrial area protected by 2020. With this deadline looming, a recent report by Conservation International (2016) has found that countries with bigger economies are providing less towards these targets and that the targets are likely not going to be met. Because a large majority (63%) of the study area is already protected with some level of protection, increasing the level of protection in some Tier 3/4 areas to Tier 1/2 to meet IUCN criteria might be essential for safeguarding key species. The existing PAs in the study area cover a larger proportion of the landscape than the 17% Aichi target. Switzerland, however, only has 10% cover by protected areas, well below this target. Increasing the coverage in less populated areas like the *Alpes Vaudoises* may help reach the countries' commitment. Alternatively, this framework can be used at a national scale to identify the top 7% of land to convert to protected areas to achieve the Aichi target. To achieve this, though, there needs to be national support towards converting more land to conservation areas.

This study represents a framework for conservation prioritization using decision support tools. With the data that is currently available, the solutions show only a small, but valuable portion of the true biodiversity in the area, so that our conclusions only apply to the groups covered. This framework may however be used again as soon as more data becomes available (e.g. bird, mammal or fish occurrence data), or can be tailored to specific prioritization questions. Zonation also has the capacity to include community level analyses, which would provide more detailed analyses about species interactions. Similar analyses could therefore build in the future on previous community modelling analyses conducted in the same study area (e.g. D'Amen *et al*. 2015a; D'Amen *et al*. 2015b). Creating protected areas alone is often not enough to slow biodiversity loss as competition from invasive species can have a large effect on native species (Glen *et al*. 2013). The SDMs for invasive species known in the study area (56 species) are currently being produced, and will be available to add to future analyses (or see Petitpierre *et al*. 2016). Using decision support tools is just one component of conservation planning which also needs to be addressed through policy, education, and economics (Wilson *et al*. 2005). As species are expected to continually move with the changing climate, this exercise needs to be repeated whenever new data becomes available. This is an ongoing process that will not create one final optimal answer, but will create dynamic optimums which vary with changing threats.

Perspectives and ways forward

While working through this analysis, three main problems were observed. First, the data for most taxonomic groups is not fully available, most notably for mammals and birds, and this limits the priorities that can be set. Second, there is a miss-match in the data from different fields with land use only being available with a different spatial and temporal scale from the species and environmental information that makes the data less comparable. Third, there is a lack of communication between stakeholders in the area, most notably between scientists, politicians, and the public. To solve these problems more research to obtain species distributions is needed, but more importantly communication between and among stakeholders and researchers in the study area needs to be improved. RechAlp, a research platform which supports interdisciplinary research in the *Alpes Vaudoises* study area (http://rechalp.unil.ch), hosted in 2016 an annual transdisciplinary workshop entitled "Which future for the Alps of Vaud?". This workshop constituted a positive first step towards creating dialogue between all the stakeholders in the region and having an avenue to create common goals, share data, and to create consensus on spatial and temporal scales.

This framework improves upon previous methods of conservation planning by incorporating data from multidisciplinary sources and by adding data from multiple taxonomic groups. Zonation is a user-friendly software that requires limited manual pre- and post-processing, and thus can be used with little prior knowledge of geographical information software and other spatial tools. These results highlight the need for the use of decision support tools in conservation planning in Europe, and in a particular case Switzerland, where its use is currently limited. The framework presented here can be easily applied to create solutions for any future goals for this study site. This framework could be improved, however, by adding interactions with invasive species, by including a community level analysis, and by combining land use methods.

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References

Araújo MB, Cabeza M, Thuiller W, Hannah L, Williams PH (2004) Would climate change drive species out of reserves? An assessment of existing reserve-selection methods. *Global Change Biology*, **10**, 1618–1626.

Araújo MB, Alagador D, Cabeza M, Nogués-Bravo D, Thuiller W (2011) Climate change threatens European conservation areas. *Ecology Letters*, **14**, 484–492.

Arponen A, Lehtomäki J, Leppänen J, Tomppo E, Moilanen A (2012) Effects of Connectivity and Spatial Resolution of Analyses on Conservation Prioritization across Large Extents. *Conservation Biology*, **26**, 294–304.

Arponen A, Zupan L (2016) Representing Hotspots of Evolutionary History in Systematic Conservation Planning for European Mammals. In: *Biodiversity Conservation and Phylogenetic Systematics* Topics in Biodiversity and Conservation. (eds Pellens R, Grandcolas P), pp. 265–285. Springer International Publishing.

Beerling DJ, Huntley B, Bailey JP (1995) Climate and the distribution of Fallopia japonica: use of an introduced species to test the predictive capacity of response surfaces. *Journal of Vegetation Science*, **6**, 269–282.

Bolliger J, Edwards Jr. TC, Eggenberg S et al. (2011) Balancing Forest-Regeneration Probabilities and Maintenance Costs in Dry Grasslands of High Conservation Priority. *Conservation Biology*, **25**, 567–576.

Bosshard T, Kotlarski S, Ewen T, Schär C (2011) Spectral representation of the annual cycle in the climate change signal. *Hydrol. Earth Syst. Sci.*, **15**, 2777–2788.

Breiner FT, Guisan A, Bergamini A, Nobis MP (2015) Overcoming limitations of modelling rare species by using ensembles of small models. *Methods in Ecology and Evolution*, **6**, 1210–1218.

Cardinale BJ, Duffy JE, Gonzalez A *et al.* (2012) Biodiversity loss and its impact on humanity. *Nature*, **486**, 59–67.

Cardoso ARP (2015) Spatial data and modelling for the prioritisation of conservation areas in the alpine region of the canton of Vaud. Masters Thesis. Universidade do Porto.

Carroll C, Dunk JR, Moilanen A (2010) Optimizing resiliency of reserve networks to climate change: multispecies conservation planning in the Pacific Northwest, USA. *Global Change Biology*, **16**, 891–904.

Chen I-C, Hill JK, Ohlemüller R, Roy DB, Thomas CD (2011) Rapid Range Shifts of Species Associated with High Levels of Climate Warming. *Science*, **333**, 1024–1026.

Conservation International (2016) Convention on biological diversity: Progress Report towards The Aichi Biodiversity Targets. National commitments fall short of action needed to safeguard nature. *Cancun, Mexico.*

D'Amen M, Pradervand J-N, Guisan A (2015a) Predicting richness and composition in mountain insect communities at high resolution: a new test of the SESAM framework. *Global Ecology and Biogeography*, **24**, 1443–1453.

D'Amen M, Dubuis A, Fernandes RF *et al*. (2015b) Using species richness and functional traits predictions to constrain assemblage predictions from stacked species distribution models. *Journal of Biogeography*, **42**, 1255–1266.

Delavenne J, Metcalfe K, Smith RJ *et al.* (2011) Systematic conservation planning in the eastern English Channel: comparing the Marxan and Zonation decision-support tools. *ICES Journal of Marine Science: Journal du Conseil*, fsr180.

Díaz S, Fargione J, Iii FSC, Tilman D (2006) Biodiversity Loss Threatens Human Well-Being. *PLOS Biol*, **4**, e277.

Elith J, H. Graham C, P. Anderson R *et al.* (2006) Novel methods improve prediction of species' distributions from occurrence data. *Ecography*, **29**, 129–151.

Engler R, Randin CF, Vittoz P *et al.* (2009) Predicting future distributions of mountain plants under climate change: does dispersal capacity matter? *Ecography*, **32**, 34–45.

ESRI: Environmental Systems Research Institute (2014) ArcGIS Desktop: Release 10.2. Redlands, CA: Environmental Systems Research Institute.

Faleiro FV, Machado RB, Loyola RD (2013) Defining spatial conservation priorities in the face of land-use and climate change. *Biological Conservation*, **158**, 248–257.

Fleishman E, Thomson JR, Kalies EL *et al*. (2014) Projecting current and future location, quality, and connectivity of habitat for breeding birds in the Great Basin. *Ecosphere*, **5**, 1–29.

Game ET, Kareiva P, Possingham HP (2013) Six Common Mistakes in Conservation Priority Setting. *Conservation Biology*, **27**, 480–485.

Gibson L, Lee TM, Koh LP *et al.* (2011) Primary forests are irreplaceable for sustaining tropical biodiversity. *Nature*, **478**, 378–381.

Glen AS, Pech RP, Byrom AE (2013) Connectivity and invasive species management: towards an integrated landscape approach. *Biological Invasions*, **15**, 2127–2138.

Gordon C, Cooper C, Senior CA *et al.* (2000) The simulation of SST, sea ice extents and ocean heat transports in a version of the Hadley Centre coupled model without flux adjustments. *Climate Dynamics*, **16**, 147–168.

Guisan A, Thuiller W (2005) Predicting species distribution: offering more than simple habitat models. *Ecology Letters*, **8**, 993–1009.

Guisan A, Tingley R, Baumgartner JB *et al.* (2013) Predicting species distributions for conservation decisions. *Ecology Letters*, **16**, 1424–1435.

Hanssen AJ, Kuipers WJ (1965) On the relationship between the frequency of rain and various meteorological parameters. *Meded Verhand*, 2–15.

Hastie T, Tibshirani R (1986) Generalized Additive Models. *Statistical Science*, **1**, 297–310.

Heller NE, Zavaleta ES (2009) Biodiversity management in the face of climate change: A review of 22 years of recommendations. *Biological Conservation*, **142**, 14–32.

Hickling R, Roy DB, Hill JK, Fox R, Thomas CD (2006) The distributions of a wide range of taxonomic groups are expanding polewards. *Global Change Biology*, **12**, 450–455.

Hijmans RJ (2015) Raster: Geographic Data Analysis and Modeling. R package version 2.5-2. https://CRAN.R-project.org/package=raster

IPCC (2001) *Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change* [Houghton, J.T., Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell, and C.A. Johnson (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 881pp.

IUCN (2016) The IUCN Red List of Threatened Species. Version 2016-3, May 2016. Available at: www.iucnredlist.org

Jacob D, Podzun R (1997) Sensitivity studies with the regional climate model REMO. *Meteorology and Atmospheric Physics*, **63**, 119–129.

Januchowski-Hartley SR, Visconti P, Pressey RL (2011) A systematic approach for prioritizing multiple management actions for invasive species. *Biological Invasions*, **13**, 1241–1253.

Jenkins CN, Pimm SL, Joppa LN (2013) Global patterns of terrestrial vertebrate diversity and conservation. *Proceedings of the National Academy of Sciences*, **110**, E2602–E2610.

Jenkins CN, Houtan KSV, Pimm SL, Sexton JO (2015) US protected lands mismatch biodiversity priorities. *Proceedings of the National Academy of Sciences*, **112**, 5081–5086.

Jetz W, Wilcove DS, Dobson AP (2007) Projected Impacts of Climate and Land-Use Change on the Global Diversity of Birds. *PLOS Biol*, **5**, e157.

Knight AT, Cowling RM, Campbell BM (2006) An Operational Model for Implementing Conservation Action. *Conservation Biology*, **20**, 408–419.

Kujala H, Moilanen A, Araújo MB, Cabeza M (2013) Conservation Planning with Uncertain Climate Change Projections. *PLoS ONE*, **8**, e53315.

Kukkala AS, Arponen A, Maiorano L *et al.* (2016) Matches and mismatches between national and EU-wide priorities: Examining the Natura 2000 network in vertebrate species conservation. *Biological Conservation*, **198**, 193–201.

Lagabrielle E, Rouget M, Payet K *et al*. (2009) Identifying and mapping biodiversity processes for conservation planning in islands: A case study in Réunion Island (Western Indian Ocean). *Biological Conservation*, **142**, 1523–1535.

Lagabrielle E, Rouget M, Le Bourgeois T *et al.* (2011) Integrating conservation, restoration and land-use planning in islands—An illustrative case study in Réunion Island (Western Indian Ocean). *Landscape and Urban Planning*, **101**, 120–130.

Lambin EF, Turner BL, Geist HJ *et al.* (2001) The causes of land-use and land-cover change: moving beyond the myths. *Global Environmental Change*, **11**, 261–269.

Langhans S, Hermoso V, Linke S *et al.* (2014) Cost-effective river rehabilitation planning: Optimizing for morphological benefits at large spatial scales. *Journal of Environmental Management*, **132**, 296–303.

Leadley PW, Krug CB, Alkemade R *et al.* (2014) Progress towards the Aichi Biodiversity Targets: An Assessment of Biodiversity Trends, Policy Scenarios and Key Actions. Secretariat of the Convention on Biological Diversity, Montreal, Canada.

Lehtomäki J, Tomppo E, Kuokkanen P, Hanski I, Moilanen A (2009) Applying spatial conservation prioritization software and high-resolution GIS data to a national-scale study in forest conservation. *Forest Ecology and Management*, **258**, 2439–2449.

Lomba A, Pellissier L, Randin C *et al.* (2010) Overcoming the rare species modelling paradox: A novel hierarchical framework applied to an Iberian endemic plant. *Biological Conservation*, **143**, 2647–2657.

Margules CR, Pressey RL (2000) Systematic conservation planning. *Nature*, **405**, 243–253.

McCullagh P, Nelder JA (1989) *Generalized Linear Models, Second Edition*. CRC Press.

Meir E, Andelman S, Possingham HP (2004) Does conservation planning matter in a dynamic and uncertain world? *Ecology Letters*, **7**, 615–622.

Moilanen A, Franco AMA, Early RI *et al.* (2005) Prioritizing multiple-use landscapes for conservation: methods for large multi-species planning problems. *Proceedings of the Royal Society of London B: Biological Sciences*, **272**, 1885–1891.

Moilanen A (2007) Landscape Zonation, benefit functions and target-based planning: Unifying reserve selection strategies. *Biological Conservation*, **134**, 571–579.

Moilanen A, Pouzols FM, Meller L, Veach V, Arponen A, Leppänen J, Kujala H, (2014) Zonation spatial conservation planning methods and software. Version 4. User Manual. University of Helsinki, Finland. pp. 288

Monnerat C, Thorens P, Walter T, Gonseth Y (2007) Liste rouge des Orthoptères menacés de Suisse. Office fédéral de l'environnement, Berne et Centre suisse de cartographie de la faune, Neuchâtel. L'environnement pratique 0719, 62 p.

Monney J-C, Meyer A (2005) Liste Rouge des reptiles menacés en Suisse. Édit. Office fédéral de l'environnement, des forêts et du paysage, Berne, et Centre de coordination pour la protection des amphibiens et des reptiles de Suisse, Berne, L'environnement pratique, 46 p.

Moser D, Gygax A, Bäumler B, Wyler N, Palese R (2002) Liste Rouge des fougères et plantes à fleurs menacées de Suisse. Ed. Office fédéral de l'environnement, des forêts et du paysage, Berne, Centre du Réseau Suisse de Floristique, Chambésy. Conservatoire et Jardin botaniques de la Ville de Genève, Chambésy. L'environnement pratique. 118 pp.

Moss RH, Edmonds JA, Hibbard KA *et al.* (2010) The next generation of scenarios for climate change research and assessment. *Nature*, **463**, 747–756.

Naidoo R, Balmford A, Ferraro PJ *et al.* (2006) Integrating economic costs into conservation planning. *Trends in Ecology & Evolution*, **21**, 681–687.

Newburn D, Reed S, Berck P, Merenlender A (2005) Economics and Land-Use Change in Prioritizing Private Land Conservation. *Conservation Biology*, **19**, 1411–1420.

Parmesan C, Ryrholm N, Stefanescu C *et al.* (1999) Poleward shifts in geographical ranges of butterfly species associated with regional warming. *Nature*, **399**, 579–583.

Pearce JL, Kirk DA, Lane CP *et al*. (2008) Prioritizing avian conservation areas for the Yellowstone to Yukon Region of North America. *Biological Conservation*, **141**, 908–924.

Petitpierre B, McDougall K, Seipel T *et al*. (2016) Will climate change increase the risk of plant invasions into mountains? *Ecological Applications*, **26**, 530–544.

Phillips SJ, Anderson RP, Schapire RE (2006) Maximum entropy modeling of species geographic distributions. *Ecological Modelling*, **190**, 231–259.

Phillips SJ, Dudík M (2008) Modeling of species distributions with Maxent: new extensions and a comprehensive evaluation. *Ecography*, **31**, 161–175.

Pouzols FM, Toivonen T, Di Minin E *et al.* (2014) Global protected area expansion is compromised by projected land-use and parochialism. *Nature*, **516**, 383–386.

Pradervand J-N, Pellissier L, Randin CF, Guisan A (2014) Functional homogenization of bumblebee communities in alpine landscapes under projected climate change. *Climate Change Responses*, **1**, 1.

Pressey RL, Cabeza M, Watts ME, Cowling RM, Wilson KA (2007) Conservation planning in a changing world. *Trends in Ecology & Evolution*, **22**, 583–592.

Price B, Kienast F, Seidl I *et al.* (2015) Future landscapes of Switzerland: Risk areas for urbanisation and land abandonment. *Applied Geography*, **57**, 32–41.

Proctor S, McClean CJ, Hill JK (2011) Protected areas of Borneo fail to protect forest landscapes with high habitat connectivity. *Biodiversity and Conservation*, **20**, 2693–2704.

R Core Team (2015) R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Randin CF, Dirnböck T, Dullinger S *et al.* (2006) Are niche-based species distribution models transferable in space? *Journal of Biogeography*, **33**, 1689–1703.

Rebetez M, Reinhard M (2007) Monthly air temperature trends in Switzerland 1901–2000 and 1975–2004. *Theoretical and Applied Climatology*, **91**, 27–34.

Renner IW, Warton DI (2013) Equivalence of MAXENT and Poisson Point Process Models for Species Distribution Modeling in Ecology. *Biometrics*, **69**, 274–281.

Roeckner E, Bäuml G, Bonaventura L *et al.* (2003) *The atmospheric general circulation model ECHAM5. Part I: Model description*. Max Planck Institute for Meteorology, Hamburg, Germany.

Schmidt BR, Zumbach S (2005) Liste Rouge des amphibiens menacés en Suisse. Édit. Office fédéral de l'environnement, des forêts et du paysage (OFEFP), Berne, et Centre de coordination pour la protection des amphibiens et des reptiles de Suisse (KARCH), Berne. Série OFEFP : L'environnement pratique. 46 p.

SFSO, Swiss Federal Statistical Office (2013) Land use in Switzerland: Results of the Swiss land use statistics. Neuchatel.

Shafer CL (1999) National park and reserve planning to protect biological diversity: some basic elements. *Landscape and Urban Planning*, **44**, 123–153.

Sisk TD, Launer AE, Switky KR, Ehrlich PR (1994) Identifying Extinction Threats: Global Analyses of the Distribution of Biodiversity and the Expansion of the Human Enterprise. In: *Ecosystem Management*, pp. 53–68. Springer New York.

Steffen W, Crutzen PJ, McNeill JR (2007) The Anthropocene: Are Humans Now Overwhelming the Great Forces of Nature. *AMBIO: A Journal of the Human Environment*, **36**, 614–621.

Struebig MJ, Wilting A, Gaveau DLA *et al.* (2015) Targeted Conservation to Safeguard a Biodiversity Hotspot from Climate and Land-Cover Change. *Current Biology*, **25**, 372–378.

Stürck J, Schulp CJE, Verburg PH (2015) Spatio-temporal dynamics of regulating ecosystem services in Europe – The role of past and future land use change. *Applied Geography*, **63**, 121–135.

Summers DM, Bryan BA, Crossman ND, Meyer WS (2012) Species vulnerability to climate change: impacts on spatial conservation priorities and species representation. *Global Change Biology*, **18**, 2335–2348.

Summers DM, Bryan BA, Meyer WS *et al.* (2015) Simple models for managing complex social–ecological systems: The Landscape Futures Analysis Tool (LFAT). *Environmental Modelling & Software*, **63**, 217–229.

Swisstopo (2008) VECTOR25 Map. Swiss Federal Office of Topography. Wabern, Switzerland.

Thuiller W, Richardson DM, Pyšek P *et al.* (2005) Niche-based modelling as a tool for predicting the risk of alien plant invasions at a global scale. *Global Change Biology*, **11**, 2234–2250.

Tulloch AIT, Sutcliffe P, Naujokaitis-Lewis I *et al*. (2016) Conservation planners tend to ignore improved accuracy of modelled species distributions to focus on multiple threats and ecological processes. *Biological Conservation*, **199**, 157–171.

UNEP-WCMC (2016) Protected Area Profile for Switzerland from the World Database of Protected Areas, May 2016. Available at: www.protectedplanet.net

Verburg PH, Overmars KP (2009) Combining top-down and bottom-up dynamics in land use modeling: exploring the future of abandoned farmlands in Europe with the Dyna-CLUE model. *Landscape Ecology*, **24**, 1167–1181.

Welch D (2005) What should protected area managers do in the face of climate change. *The George Wright Forum*, **22**, 75–93.

Walther G-R (2000) Climatic forcing on the dispersal of exotic species. *Phytocoenologia*, **30**, 409–430.

Walther G-R, Post E, Convey P *et al.* (2002) Ecological responses to recent climate change. *Nature*, **416**, 389–395.

Wan J, Wang C, Yu J *et al*. (2014) Model-based conservation planning of the genetic diversity of *Phellodendron amurense* Rupr due to climate change. *Ecology and Evolution*, **4**, 2884–2900.

Wermeille E, Chittaro Y, Gonseth Y (2014) Liste rouge Papillons diurnes et Zygènes. Espèces menacées en Suisse, état 2012. Office fédéral de l'environnement, Berne, et Centre Suisse de Cartographie de la Faune, Neuchâtel. L'environnement pratique n° 1403, 97 p.

Wiedmer E, Wisler C (2014) Switzerland's Fifth National Report under the Convention on Biological Diversity. Bern, Switzerland.

Wilcox BA, Murphy DD (1985) Conservation Strategy: The Effects of Fragmentation on Extinction. *The American Naturalist*, **125**, 879–887.

Wilson K, Pressey RL, Newton A *et al.* (2005) Measuring and Incorporating Vulnerability into Conservation Planning. *Environmental Management*, **35**, 527–543.

Supplementary figures and tables

a) b)

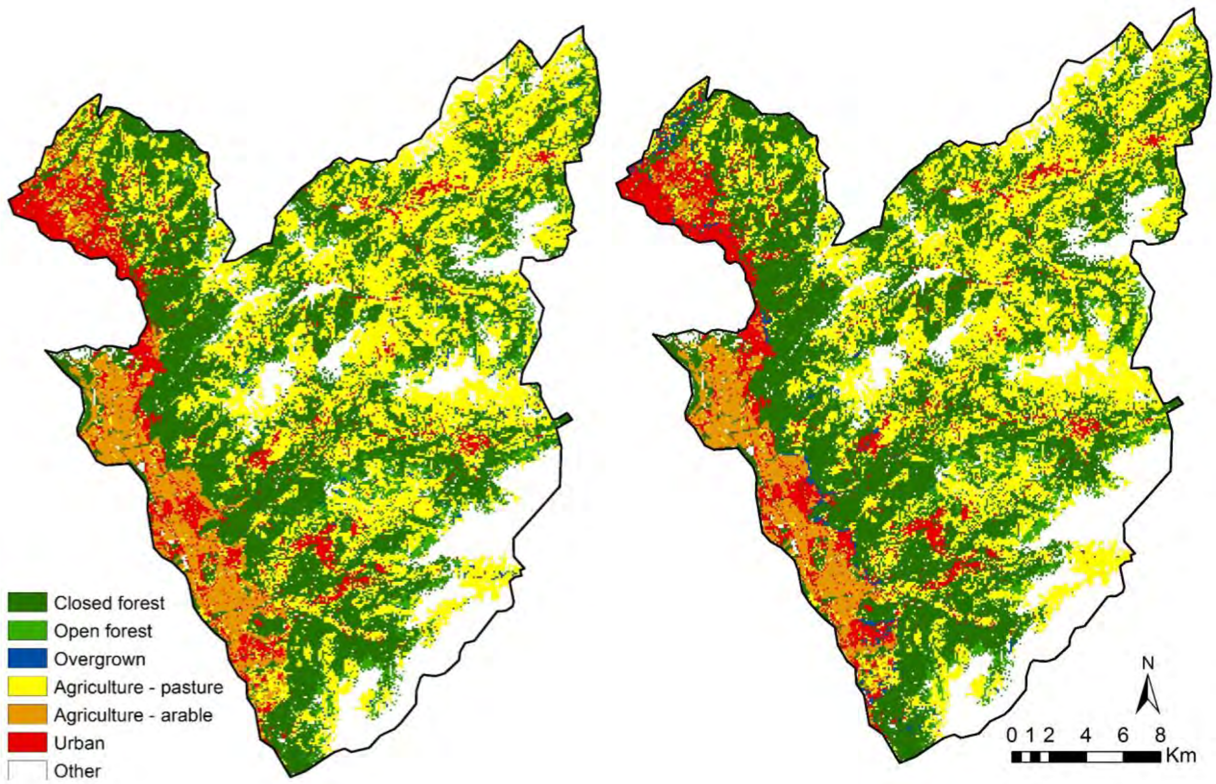

Figure S1: Land use maps (100x100m) acquired from a) Swiss land use statistics data for 2009 (SFSO 2013) and b) the predicted 2035 land use change modelled by Jenkins et al. (2015). The seven land categories are derived from the 72 categories defined by the SFSO.

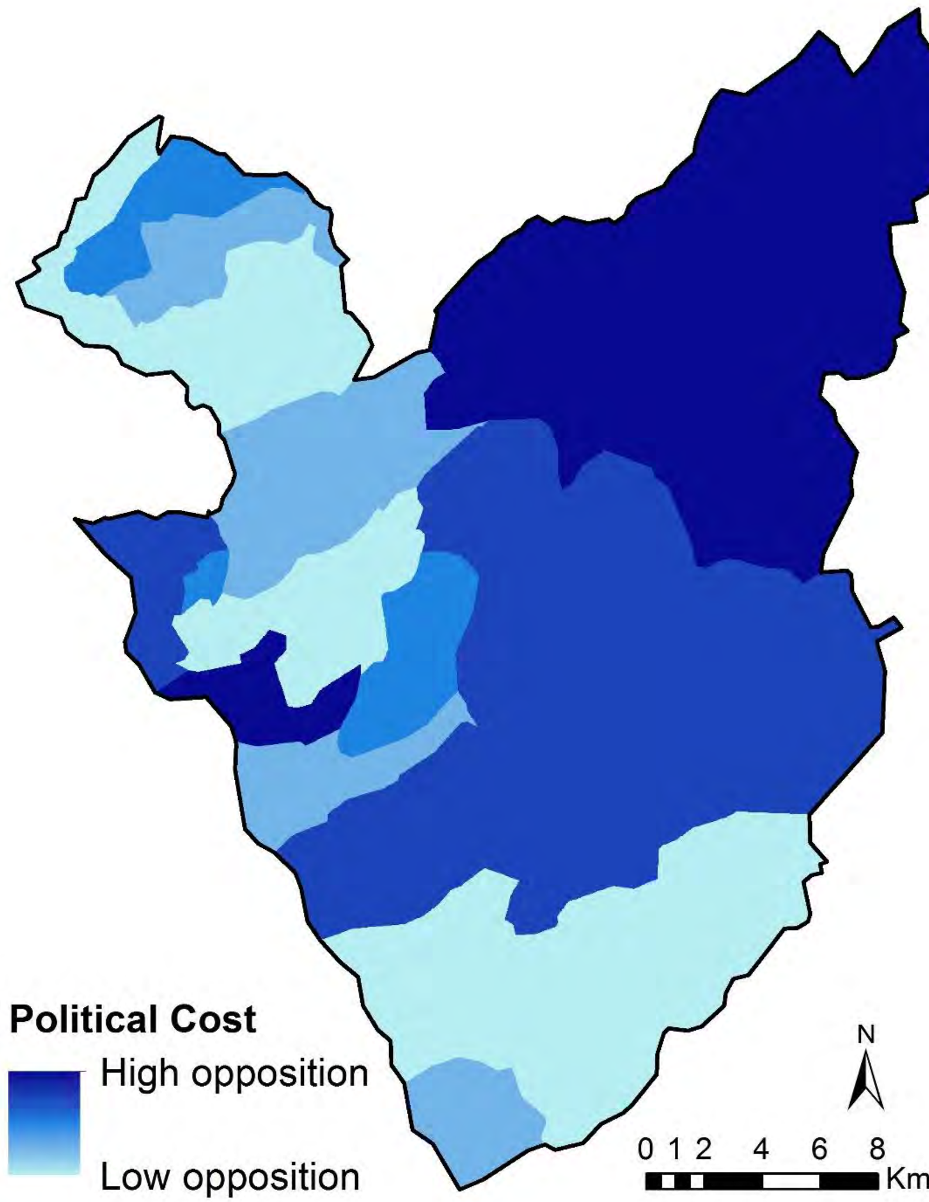

Figure S2: Political costs acquired from Cardoso (2015). The darker regions indicate communes that have a higher political cost as they voted against policy that would support biodiversity in the two most recent elections.

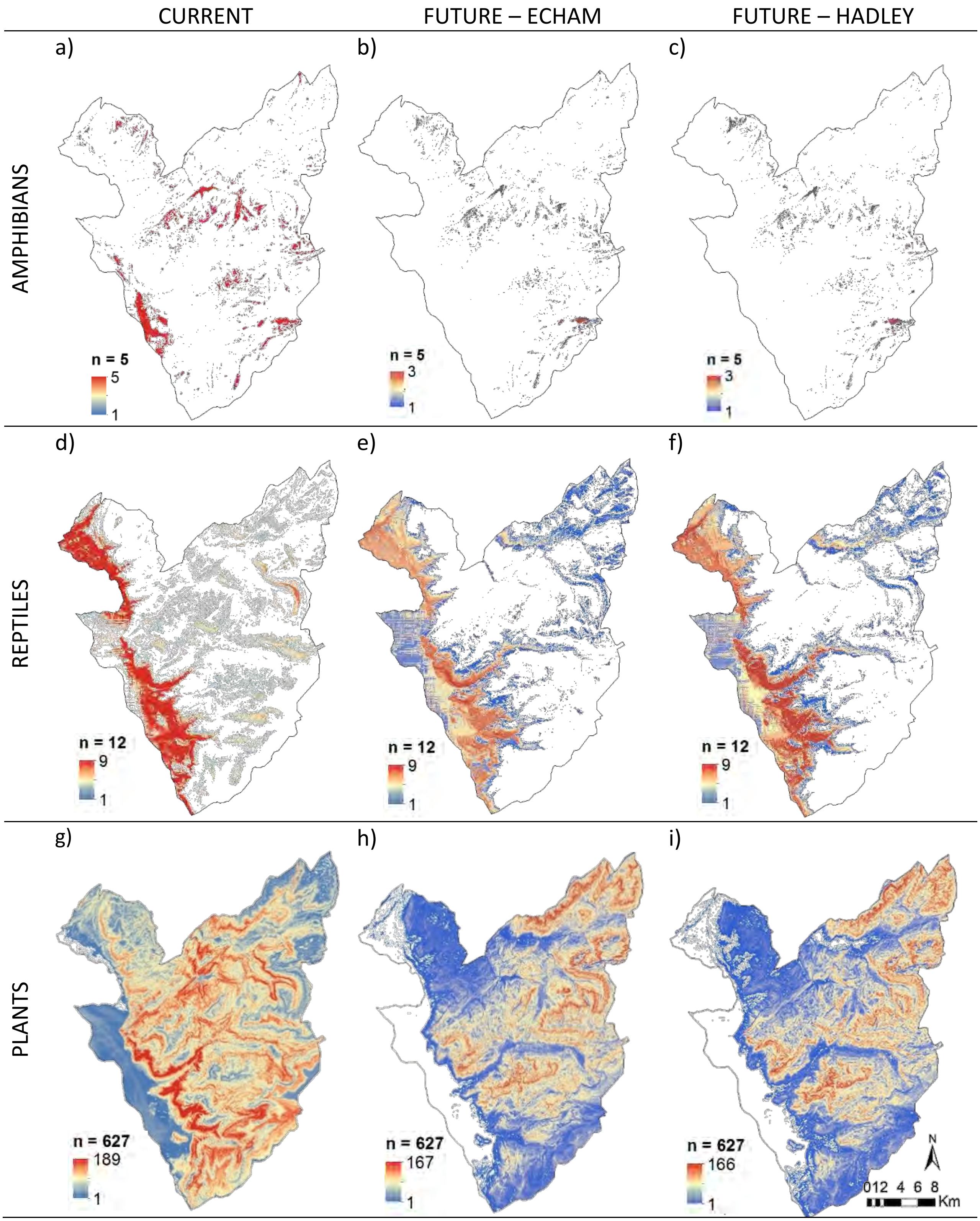

Figure S3: Biodiversity maps represent species richness separated by taxonomic groups at the current time step (a, d, g) and using the predicted 2060 ranges using both climate change scenarios “Echam” (b, e, h) and “Hadley” (c, f, i).

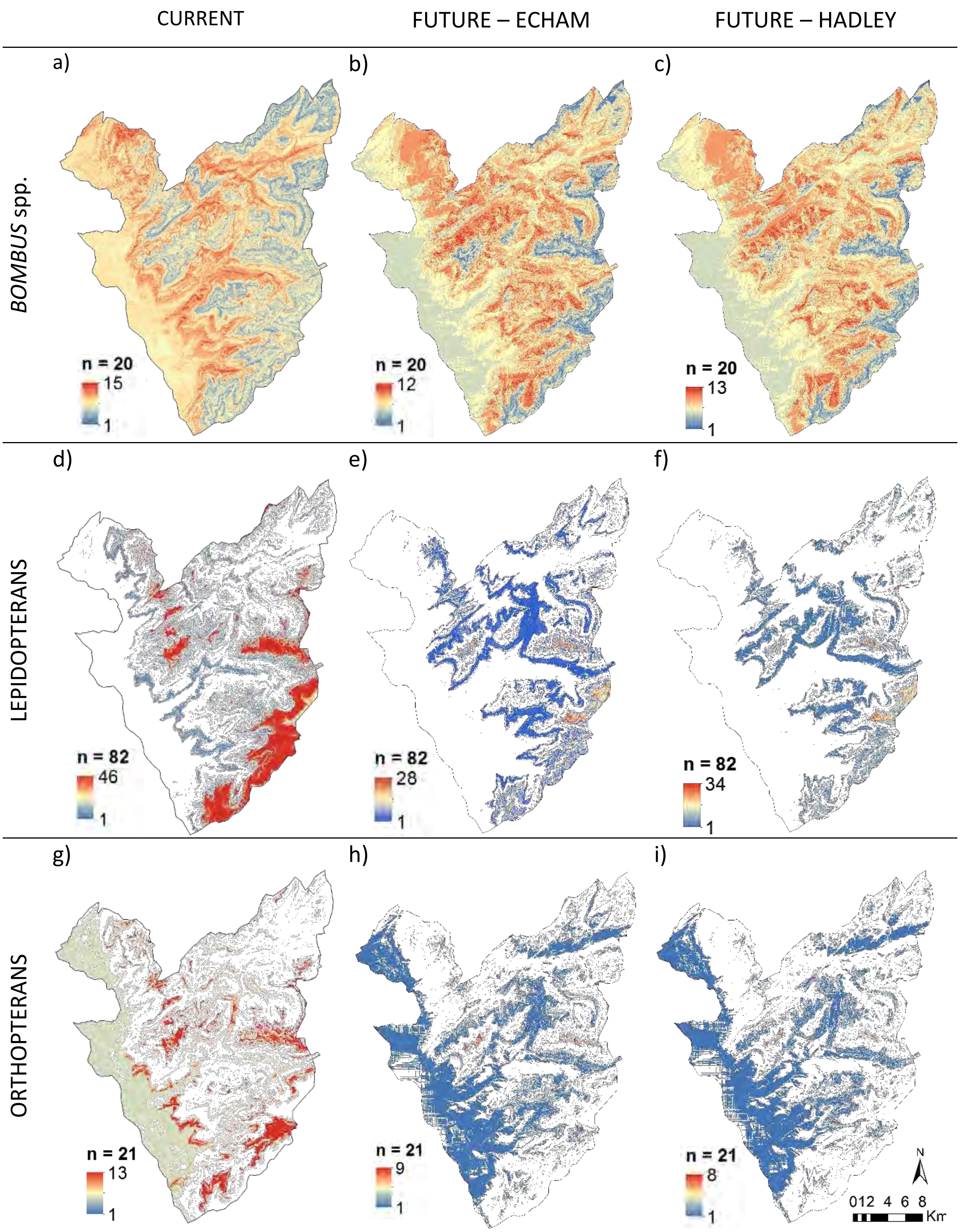

Figure S4: Continuation of Fig S3. Biodiversity maps represent species richness separated taxonomic groups at the current time step (a, d, g) and using the predicted 2060 ranges using both climate change scenarios "Echam" (b, e, h) and "Hadley" (c, f, i).

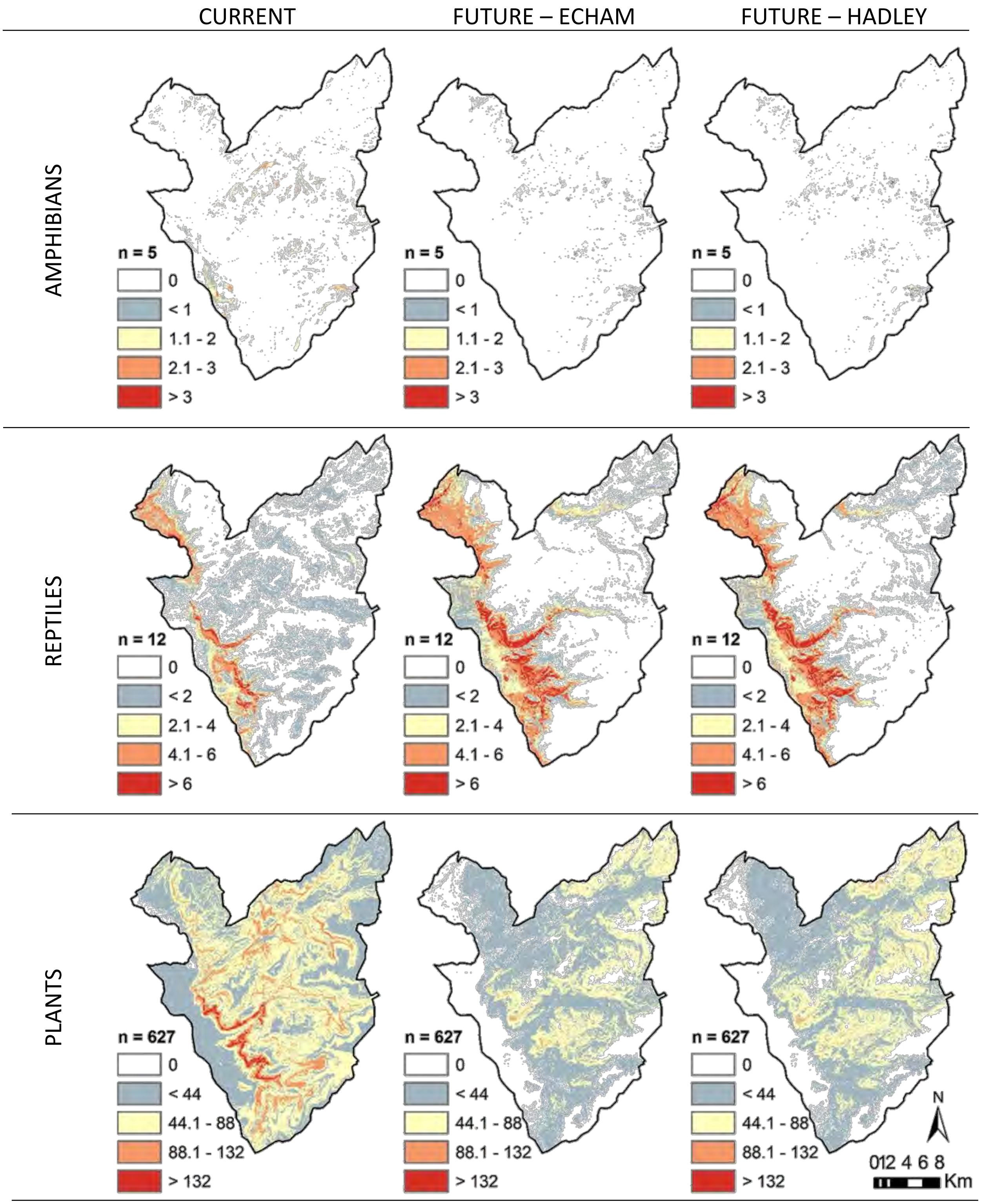

Figure S5: Priority maps showing the sum of species priority scores within each taxonomic group. These were calculated using species ranges from the current time step (a, d, g) and using the predicted 2060 ranges using both climate change scenarios "Echam" (b, e, h) and "Hadley" (c, f, i).

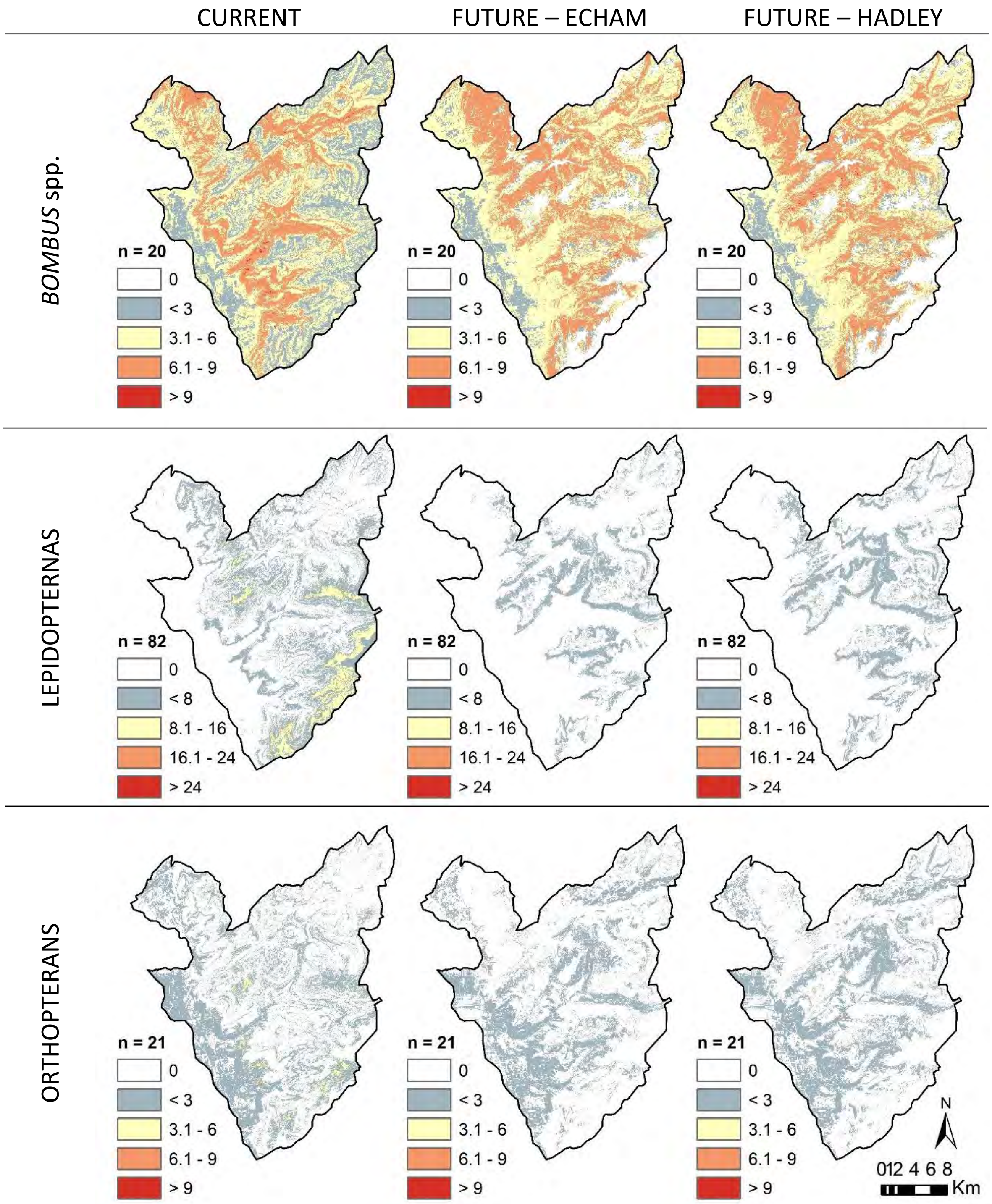

Figure S6: Continuation of Fig S5. Priority maps showing the sum of species priority scores within each taxonomic group. These were calculated using species ranges from the current time step (a, d, g) and using the predicted 2060 ranges using both climate change scenarios "Echam" (b, e, h) and "Hadley" (c, f, i).

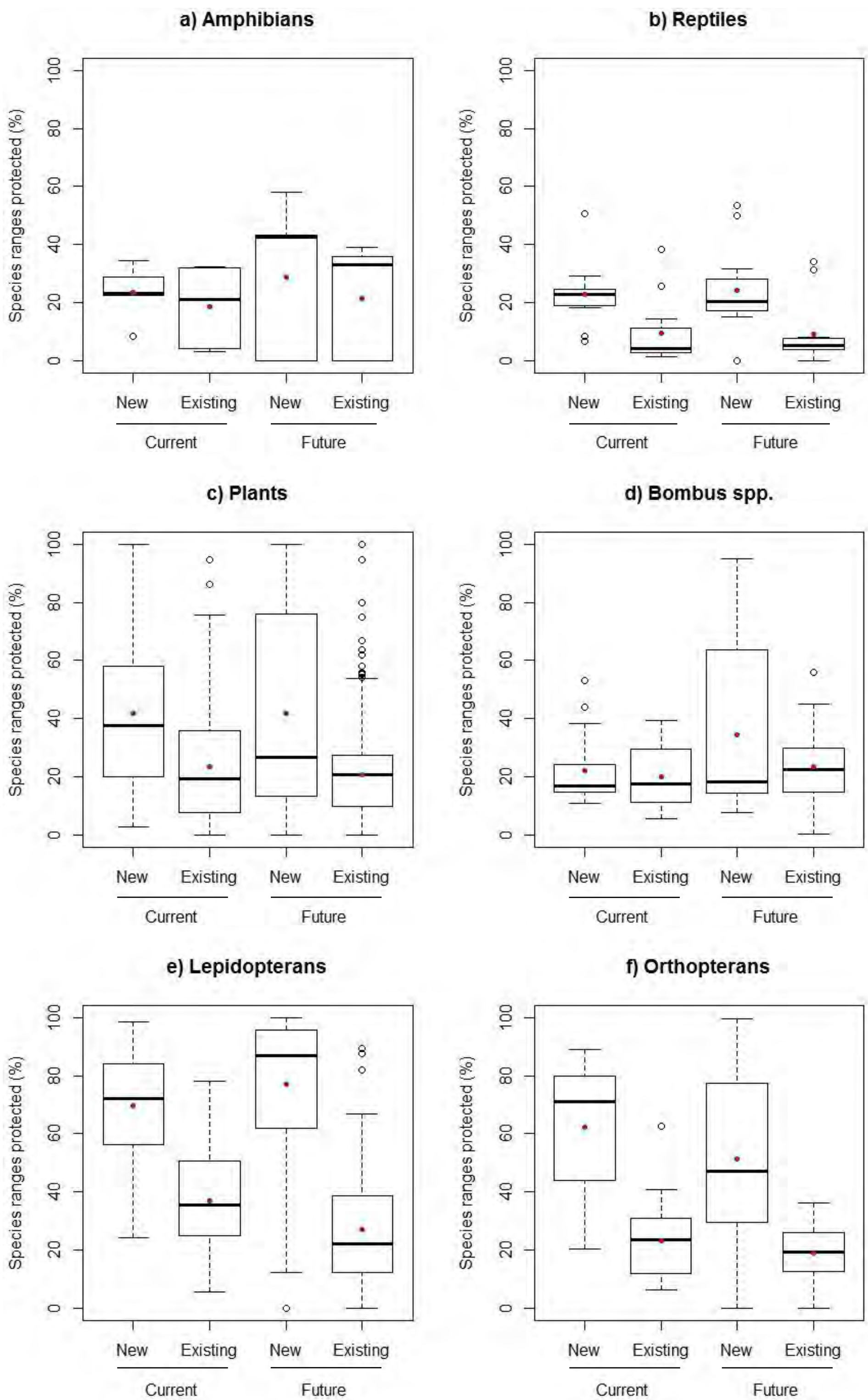

Figure S7: The proportions of species ranges protected by the new Zonation solutions compared with the existing protected areas using LU mask. Future refers to the distributions predicted to 2060 using the "Hadley" climate change scenario. Open circles indicate outliers, black bars show medians, and red dots indicate means.

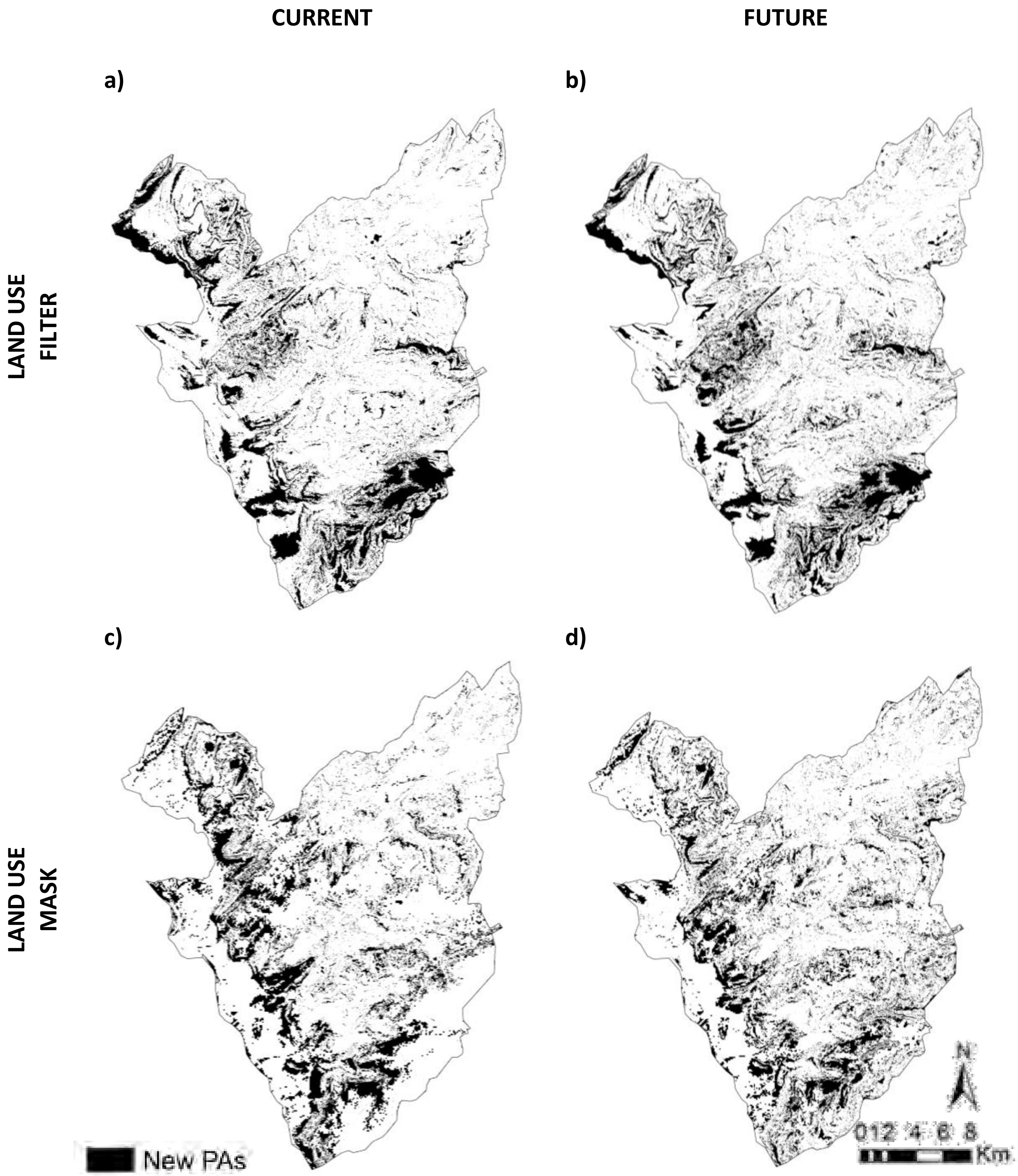

Figure S8: Spatial representation of the Zonation solutions created using the Core-Area Zonation (CAZ) cell removal rule. Both LU filter (a, b) and LU mask (c, d) were used. Future refers to the distributions predicted to 2060 using the "Hadley" climate change scenario. The black areas represent the top priority areas and cover the same proportion of the landscape as the existing Tier 1/2 protected areas.

Table S1: The types of protected areas found within the study site. Tier 1 represents the protected areas with the highest level of protection, and Tier 4 the lowest. The proportion of the study area covered by each tier is shown as a percentage of land cover.

Level of Protection	Type of Protected Area	Land Cover %
Tier 1	UNESCO-MAB Biosphere Reserve	0.02
	Federal Inventory of Raised and Transitional Mires of National Importance	
Tier 2	Ramsar Sites	18.10
	Emerald Sites	
	Federal Hunting Reserves	
	Federal Inventory of Alluvial Zones of National Importance	
	Federal Inventory of Fenlands of National Importance	
	Federal Inventory of Dry Grasslands and Pastures of National Importance	
	Federal Inventory of Reserves for Waterbirds and Migratory Birds of International and National Imp.	
	Federal Inventory of Amphibian Spawning Areas of National Importance	
Tier 3	Forestry Reserves	5.69
	Pro-Natura Preserves	
Tier 4	Natural Landscapes and Monuments of National Importance	39.19
	Gruyère Regional Park	

Table S2: A summary of the total species list (Appendix 1). Numbers represent sums of species. Threatened species are based on the Swiss national Red Lists. Protected species are explicitly referenced in Swiss legislative documents.

Taxonomic Group	No. of species	Threatened species (CR, EN, VU)	Protected Species
Amphibians	5	2	5
Insects	123	3	4
Plants	627	4	47
Reptiles	12	9	6
Total	767	18	62

Table S3: Spatial similarity between Zonation solutions shown by the percentage of overlapping pixels in the proposed protected areas generated using different input parameters. The parameters that were altered were the time steps and climate change scenarios (current, "Hadley" and "Echam"), the land use change method (mask and filter), and the cell removal rule (CAZ and ABF). The percentage of overlap between the new protected areas and the existing Tier 1 and Tier 2 protected areas is shown in the final row.

%	Current Mask CAZ	Current Filter CAZ	Hadley Mask CAZ	Hadley Filter CAZ	Echam Mask CAZ	Echam Filter CAZ	Current Mask ABF	Current Filter ABF	Hadley Mask ABF	Hadley Filter ABF	Echam Mask ABF	Echam Filter ABF
Current Mask CAZ												
Current Filter CAZ	77											
Hadley Mask CAZ	85	82										
Hadley Filter CAZ	76	93	82									
Echam Mask CAZ	85	82	94	81								
Echam Filter CAZ	76	93	81	95	82							
Current Mask ABF	82	86	82	84	82	84						
Current Filter ABF	78	88	80	86	81	86	95					
Hadley Mask ABF	78	84	84	86	83	84	91	91				
Hadley Filter ABF	77	86	81	88	80	86	91	93	94			
Echam Mask ABF	78	84	83	84	84	85	92	92	95	92		
Echam Filter ABF	78	86	80	86	81	87	91	93	92	96	94	
Existing PAs	17	27	21	26	21	26	34	35	32	32	32	32

Appendix 1

All species modelled in the analysis. Threatened level is based on the Swiss national red list level except for *Bombus* spp. (*) which were assessed at European level. Species with legal protection are referenced in Swiss legislative documents.

Group	Species	National Red List	Legal Protection
Amphibians	*Bombina variegata*	EN	Yes
Amphibians	*Bufo bufo*	VU	Yes
Amphibians	*Ichthyosaura alpestris*	LC	Yes
Amphibians	*Pelophylax ridibundus*	NE	Yes
Amphibians	*Rana temporaria*	LC	Yes
Bombus	*Bombus barbutellus*	LC*	
Bombus	*Bombus bohemicus*	LC*	
Bombus	*Bombus Gr terrestris*	LC*	
Bombus	*Bombus hortorum*	LC*	
Bombus	*Bombus humilis*	LC*	
Bombus	*Bombus hypnorum*	LC*	
Bombus	*Bombus lapidarius*	LC*	
Bombus	*Bombus mendax*	NT*	
Bombus	*Bombus mesomelas*	LC*	
Bombus	*Bombus monticola*	LC*	
Bombus	*Bombus mucidus*	NT*	
Bombus	*Bombus pascuorum*	LC*	
Bombus	*Bombus pratorum*	LC*	
Bombus	*Bombus pyrenaeus*	LC*	
Bombus	*Bombus ruderarius*	LC*	
Bombus	*Bombus rupestris*	LC*	
Bombus	*Bombus sicheli*	NE*	
Bombus	*Bombus soroeensis*	LC*	
Bombus	*Bombus sylvestris*	LC*	
Bombus	*Bombus wurfleini*	LC*	
Lepidopterans	*Adscita geryon*	NT	
Lepidopterans	*Aglais urticae*	LC	
Lepidopterans	*Anthocharis cardamines*	LC	
Lepidopterans	*Aphantopus hyperantus*	LC	
Lepidopterans	*Aporia crataegi*	NT	
Lepidopterans	*Argynnis adippe*	NE	
Lepidopterans	*Argynnis aglaja*	LC	
Lepidopterans	*Argynnis niobe*	LC	
Lepidopterans	*Aricia artaxerxes*	LC	
Lepidopterans	*Aricia eumedon*	LC	
Lepidopterans	*Boloria euphrosyne*	LC	

Lepidopterans	*Boloria napaea*	LC	
Lepidopterans	*Boloria pales*	LC	
Lepidopterans	*Boloria titania*	LC	
Lepidopterans	*Brenthis ino*	NT	
Lepidopterans	*Callophrys rubi*	NE	
Lepidopterans	*Carterocephalus palaemon*	NE	
Lepidopterans	*Coenonympha gardetta*	LC	
Lepidopterans	*Coenonympha pamphilus*	LC	
Lepidopterans	*Colias alfacariensis*	NE	
Lepidopterans	*Colias crocea*	NE	
Lepidopterans	*Colias phicomone*	LC	
Lepidopterans	*Cupido minimus*	LC	
Lepidopterans	*Erebia aethiops*	LC	
Lepidopterans	*Erebia cassioides*	NE	
Lepidopterans	*Erebia epiphron*	NE	
Lepidopterans	*Erebia euryale*	LC	
Lepidopterans	*Erebia gorge*	NE	
Lepidopterans	*Erebia ligea*	LC	
Lepidopterans	*Erebia manto*	LC	
Lepidopterans	*Erebia melampus*	LC	
Lepidopterans	*Erebia oeme*	LC	
Lepidopterans	*Erebia pandrose*	LC	
Lepidopterans	*Erebia pharte*	LC	
Lepidopterans	*Erebia pluto*	NE	
Lepidopterans	*Erebia pronoe*	NE	
Lepidopterans	*Erebia tyndarus*	NE	
Lepidopterans	*Erynnis tages*	LC	
Lepidopterans	*Euphydryas aurinia*	EN	Yes
Lepidopterans	*Hesperia comma*	LC	
Lepidopterans	*Lasiommata maera*	LC	
Lepidopterans	*Lasiommata petropolitana*	LC	
Lepidopterans	*Leptidea realisinapis*	LC	
Lepidopterans	*Lycaena hippothoe*	LC	
Lepidopterans	*Lycaena tityrus*	LC	
Lepidopterans	*Macroglossum stellatarum*	NE	
Lepidopterans	*Maculinea arion*	NT	Yes
Lepidopterans	*Maniola jurtina*	LC	
Lepidopterans	*Melanargia galathea*	LC	
Lepidopterans	*Melitaea athalia*	LC	
Lepidopterans	*Melitaea diamina*	NT	
Lepidopterans	*Ochlodes venatus*	LC	
Lepidopterans	*Oeneis glacialis*	NE	
Lepidopterans	*Papilio machaon*	LC	

Lepidopterans	*Parnassius apollo*	NT	Yes
Lepidopterans	*Pieris brassicae*	LC	
Lepidopterans	*Pieris bryoniae*	LC	
Lepidopterans	*Pieris napi*	LC	
Lepidopterans	*Pieris rapae*	LC	
Lepidopterans	*Plebeius argus*	NT	
Lepidopterans	*Plebeius glandon*	NE	
Lepidopterans	*Polyommatus bellargus*	NE	
Lepidopterans	*Polyommatus coridon*	LC	
Lepidopterans	*Polyommatus damon*	VU	
Lepidopterans	*Polyommatus eros*	NT	
Lepidopterans	*Polyommatus icarus*	LC	
Lepidopterans	*Polyommatus semiargus*	LC	
Lepidopterans	*Polyommatus thersites*	VU	
Lepidopterans	*Pontia callidice*	NT	
Lepidopterans	*Pyrgus alveus*	LC	
Lepidopterans	*Pyrgus malvae*	NE	
Lepidopterans	*Pyrgus serratulae*	LC	
Lepidopterans	*Spialia sertorius*	NT	
Lepidopterans	*Thymelicus lineola*	LC	
Lepidopterans	*Thymelicus sylvestris*	LC	
Lepidopterans	*Vanessa atalanta*	LC	
Lepidopterans	*Vanessa cardui*	LC	
Lepidopterans	*Zygaena exulans*	NE	
Lepidopterans	*Zygaena filipendulae*	LC	
Lepidopterans	*Zygaena lonicerae*	NE	
Lepidopterans	*Zygaena loti*	NE	
Lepidopterans	*Zygaena transalpina*	NE	
Orthopterans	*Chorthippus biguttulus*	LC	
Orthopterans	*Chorthippus brunneus*	LC	
Orthopterans	*Chorthippus dorsatus*	LC	
Orthopterans	*Chorthippus parallelus*	LC	
Orthopterans	*Decticus verrucivorus*	NT	
Orthopterans	*Euthystira brachyptera*	LC	
Orthopterans	*Gomphocerippus rufus*	LC	
Orthopterans	*Gomphocerus sibiricus*	LC	
Orthopterans	*Gryllus campestris*	LC	
Orthopterans	*Mecostethus parapleurus*	LC	
Orthopterans	*Metrioptera roeselii*	LC	
Orthopterans	*Metrioptera saussuriana*	LC	
Orthopterans	*Miramella alpina*	LC	
Orthopterans	*Omocestus viridulus*	LC	
Orthopterans	*Platycleis albopunctataalb*	NT	

Orthopterans	*Podisma pedestris*	LC	
Orthopterans	*Polysarcus denticauda*	NT	Yes
Orthopterans	*Stauroderus scalaris*	LC	
Orthopterans	*Stenobothrus lineatus*	LC	
Orthopterans	*Tettigonia cantans*	LC	
Orthopterans	*Tettigonia viridissima*	LC	
Reptiles	*Anguis fragilis*	LC	
Reptiles	*Coronella austriaca*	VU	
Reptiles	*Hierophis viridiflavus*	EN	Yes
Reptiles	*Lacerta agilis*	VU	Yes
Reptiles	*Lacerta bilineata*	VU	Yes
Reptiles	*Natrix natrix*	EN	
Reptiles	*Natrix tessellata*	EN	
Reptiles	*Podarcis muralis*	LC	Yes
Reptiles	*Vipera aspis*	CR	Yes
Reptiles	*Vipera berus*	EN	
Reptiles	*Zamenis longissimus*	EN	
Reptiles	*Zootoca vivipara*	LC	Yes
Plants	*Abies alba*	LC	
Plants	*Acer campestre*	LC	
Plants	*Acer opalus*	LC	
Plants	*Acer platanoides*	LC	
Plants	*Acer pseudoplatanus*	LC	
Plants	*Aceras anthropophorum*	VU	Yes
Plants	*Achillea atrata*	LC	
Plants	*Achillea macrophylla*	LC	
Plants	*Achillea millefolium*	LC	
Plants	*Acinos alpinus*	LC	
Plants	*Aconitum lycoctonum*	LC	
Plants	*Aconitum napellus*	LC	
Plants	*Aconitum paniculatum*	LC	
Plants	*Actaea spicata*	LC	
Plants	*Adenostyles alliariae*	LC	
Plants	*Adenostyles glabra*	LC	
Plants	*Adoxa moschatellina*	LC	
Plants	*Aegopodium podagraria*	LC	
Plants	*Agrostis alpina*	LC	
Plants	*Agrostis capillaris*	LC	
Plants	*Agrostis rupestris*	LC	
Plants	*Agrostis schraderiana*	LC	
Plants	*Agrostis stolonifera*	LC	
Plants	*Ajuga reptans*	LC	
Plants	*Alchemilla pentaphyllea*	LC	

Plants	*Alliaria petiolata*	LC	
Plants	*Allium sphaerocephalon*	LC	
Plants	*Allium ursinum*	LC	
Plants	*Allium vineale*	LC	
Plants	*Alnus glutinosa*	LC	
Plants	*Alnus incana*	LC	
Plants	*Alnus viridis*	LC	
Plants	*Alopecurus pratensis*	LC	
Plants	*Amelanchier embergeri*	NE	
Plants	*Androsace chamaejasme*	LC	Yes
Plants	*Androsace helvetica*	LC	Yes
Plants	*Anemone narcissiflora*	LC	
Plants	*Anemone nemorosa*	LC	
Plants	*Angelica sylvestris*	LC	
Plants	*Antennaria carpatica*	LC	
Plants	*Antennaria dioica*	LC	
Plants	*Anthericum ramosum*	LC	
Plants	*Anthoxanthum alpinum*	LC	
Plants	*Anthoxanthum odoratum*	LC	
Plants	*Anthriscus nitida*	LC	
Plants	*Anthriscus sylvestris*	LC	
Plants	*Anthyllis alpestris*	LC	
Plants	*Anthyllis vulneraria*	LC	
Plants	*Aposeris foetida*	LC	
Plants	*Aquilegia atrata*	LC	
Plants	*Aquilegia vulgaris*	LC	
Plants	*Arabis alpina*	LC	
Plants	*Arabis caerulea*	LC	
Plants	*Arabis ciliata*	LC	
Plants	*Arabis hirsuta*	LC	
Plants	*Arabis pumila*	NE	
Plants	*Arabis turrita*	LC	
Plants	*Arctostaphylos alpina*	LC	
Plants	*Arctostaphylos uva ursi*	LC	
Plants	*Arenaria ciliata*	VU	
Plants	*Arenaria multicaulis*	LC	
Plants	*Arnica montana*	LC	Yes
Plants	*Arrhenatherum elatius*	LC	
Plants	*Artemisia umbelliformis*	LC	Yes
Plants	*Arum maculatum*	LC	
Plants	*Aruncus dioicus*	LC	
Plants	*Asplenium fontanum*	NT	Yes
Plants	*Asplenium ruta muraria*	LC	

Plants	*Asplenium trichomanes*	LC	
Plants	*Asplenium viride*	LC	
Plants	*Aster alpinus*	LC	Yes
Plants	*Aster bellidiastrum*	LC	
Plants	*Astragalus alpinus*	LC	
Plants	*Astragalus frigidus*	LC	
Plants	*Astrantia major*	LC	
Plants	*Astrantia minor*	LC	
Plants	*Athamanta cretensis*	LC	
Plants	*Athyrium filix femina*	LC	
Plants	*Atropa bella donna*	LC	
Plants	*Avenella flexuosa*	LC	
Plants	*Barbarea vulgaris*	LC	
Plants	*Bartsia alpina*	LC	
Plants	*Bellis perennis*	LC	
Plants	*Berberis vulgaris*	LC	
Plants	*Betula pendula*	LC	
Plants	*Betula pubescens*	LC	
Plants	*Biscutella laevigata*	LC	
Plants	*Blechnum spicant*	LC	
Plants	*Botrychium lunaria*	LC	
Plants	*Brachypodium pinnatum*	LC	
Plants	*Briza media*	LC	
Plants	*Bromus benekenii*	LC	
Plants	*Bromus erectus*	LC	
Plants	*Bromus hordeaceus*	LC	
Plants	*Buddleja davidii*	LC	
Plants	*Buphthalmum salicifolium*	LC	
Plants	*Bupleurum ranunculoides*	LC	
Plants	*Calamagrostis varia*	LC	
Plants	*Calamagrostis villosa*	LC	
Plants	*Caltha palustris*	LC	
Plants	*Calystegia sepium*	LC	
Plants	*Campanula barbata*	LC	
Plants	*Campanula cenisia*	LC	
Plants	*Campanula cochleariifolia*	LC	
Plants	*Campanula glomerata*	LC	
Plants	*Campanula latifolia*	NT	Yes
Plants	*Campanula rhomboidalis*	LC	
Plants	*Campanula rotundifolia*	LC	
Plants	*Campanula scheuchzeri*	LC	
Plants	*Campanula thyrsoides*	LC	
Plants	*Campanula trachelium*	LC	

Plants	*Capsella bursa pastoris*	LC	
Plants	*Cardamine heptaphylla*	LC	
Plants	*Cardamine hirsuta*	LC	
Plants	*Cardamine impatiens*	LC	
Plants	*Cardamine pentaphyllos*	LC	
Plants	*Cardamine pratensis*	LC	
Plants	*Carduus defloratus*	LC	
Plants	*Carduus personata*	LC	
Plants	*Carex acutiformis*	LC	
Plants	*Carex alba*	LC	
Plants	*Carex atrata*	LC	
Plants	*Carex capillaris*	LC	
Plants	*Carex caryophyllea*	LC	
Plants	*Carex digitata*	LC	
Plants	*Carex ferruginea*	LC	
Plants	*Carex firma*	LC	
Plants	*Carex flacca*	LC	
Plants	*Carex flava*	LC	
Plants	*Carex humilis*	LC	
Plants	*Carex leporina*	LC	
Plants	*Carex montana*	LC	
Plants	*Carex nigra*	LC	
Plants	*Carex ornithopoda*	LC	
Plants	*Carex pallescens*	LC	
Plants	*Carex panicea*	LC	
Plants	*Carex paniculata*	LC	
Plants	*Carex parviflora*	LC	
Plants	*Carex sempervirens*	LC	
Plants	*Carex spicata*	LC	
Plants	*Carex sylvatica*	LC	
Plants	*Carlina acaulis*	DD	Yes
Plants	*Carlina simplex*	LC	
Plants	*Carpinus betulus*	LC	
Plants	*Carum carvi*	LC	
Plants	*Castanea sativa*	LC	
Plants	*Centaurea jacea*	LC	
Plants	*Centaurea montana*	LC	
Plants	*Cephalanthera damasonium*	LC	Yes
Plants	*Cephalanthera longifolia*	LC	Yes
Plants	*Cephalanthera rubra*	LC	Yes
Plants	*Cerastium latifolium*	LC	
Plants	*Cerastium vulgare*	LC	
Plants	*Cerinthe glabra*	LC	

Plants	*Chaerophyllum aureum*	LC	
Plants	*Chaerophyllum hirsutum*	LC	
Plants	*Chaerophyllum villarsii*	LC	
Plants	*Chrysosplenium alternifolium*	LC	
Plants	*Cicerbita alpina*	LC	
Plants	*Cicerbita plumieri*	NT	
Plants	*Circaea lutetiana*	LC	
Plants	*Cirsium acaule*	LC	
Plants	*Cirsium arvense*	LC	
Plants	*Cirsium eriophorum*	LC	
Plants	*Cirsium oleraceum*	LC	
Plants	*Cirsium palustre*	LC	
Plants	*Cirsium rivulare*	LC	
Plants	*Cirsium spinosissimum*	LC	
Plants	*Cirsium vulgare*	LC	
Plants	*Clematis vitalba*	LC	
Plants	*Clinopodium vulgare*	LC	
Plants	*Coeloglossum viride*	LC	Yes
Plants	*Colchicum autumnale*	LC	
Plants	*Convallaria majalis*	LC	
Plants	*Cornus mas*	LC	
Plants	*Cornus sanguinea*	LC	
Plants	*Coronilla vaginalis*	LC	
Plants	*Corylus avellana*	LC	
Plants	*Cotoneaster integerrimus*	LC	
Plants	*Cotoneaster tomentosus*	LC	
Plants	*Crepis aurea*	LC	
Plants	*Crepis biennis*	LC	
Plants	*Crepis paludosa*	LC	
Plants	*Crepis pyrenaica*	LC	
Plants	*Crepis taraxacifolia*	LC	
Plants	*Crocus albiflorus*	LC	Yes
Plants	*Cruciata laevipes*	LC	
Plants	*Cynosurus cristatus*	LC	
Plants	*Cystopteris alpina*	LC	
Plants	*Cystopteris fragilis*	LC	
Plants	*Dactylis glomerata*	LC	
Plants	*Dactylorhiza maculata*	CR	Yes
Plants	*Daphne laureola*	LC	
Plants	*Daphne mezereum*	LC	
Plants	*Daucus carota*	LC	
Plants	*Deschampsia cespitosa*	LC	
Plants	*Digitalis lutea*	LC	

Plants	*Doronicum grandiflorum*	LC	
Plants	*Draba aizoides*	LC	
Plants	*Dryas octopetala*	LC	
Plants	*Dryopteris carthusiana*	LC	
Plants	*Dryopteris dilatata*	LC	
Plants	*Dryopteris filix mas*	LC	
Plants	*Dryopteris oreades*	NE	
Plants	*Dryopteris villarii*	LC	
Plants	*Elymus caninus*	LC	
Plants	*Elyna myosuroides*	LC	
Plants	*Epilobium alpestre*	LC	
Plants	*Epilobium anagallidifolium*	LC	Yes
Plants	*Epilobium angustifolium*	LC	
Plants	*Epilobium montanum*	LC	
Plants	*Epipactis atrorubens*	LC	Yes
Plants	*Epipactis helleborine*	LC	Yes
Plants	*Epipactis purpurata*	LC	Yes
Plants	*Equisetum arvense*	LC	
Plants	*Equisetum palustre*	LC	
Plants	*Equisetum sylvaticum*	LC	
Plants	*Equisetum telmateia*	LC	
Plants	*Erica carnea*	LC	
Plants	*Erigeron alpinus*	LC	
Plants	*Erigeron uniflorus*	LC	
Plants	*Euonymus europaeus*	LC	
Plants	*Eupatorium cannabinum*	LC	
Plants	*Euphorbia amygdaloides*	LC	
Plants	*Euphorbia cyparissias*	LC	
Plants	*Euphorbia dulcis*	LC	
Plants	*Euphrasia hirtella*	LC	
Plants	*Euphrasia minima*	LC	
Plants	*Euphrasia rostkoviana*	LC	
Plants	*Euphrasia salisburgensis*	LC	
Plants	*Fagus sylvatica*	LC	
Plants	*Festuca alpina*	LC	
Plants	*Festuca altissima*	LC	
Plants	*Festuca gigantea*	LC	
Plants	*Festuca heterophylla*	NT	
Plants	*Festuca ovina*	LC	
Plants	*Festuca quadriflora*	LC	
Plants	*Festuca rubra*	LC	
Plants	*Festuca violacea*	LC	
Plants	*Filipendula ulmaria*	LC	

Plants	*Fragaria vesca*	LC	
Plants	*Fraxinus excelsior*	LC	
Plants	*Galeopsis tetrahit*	LC	
Plants	*Galium album*	LC	
Plants	*Galium anisophyllon*	LC	
Plants	*Galium aparine*	LC	
Plants	*Galium megalospermum*	LC	
Plants	*Galium mollugo*	LC	
Plants	*Galium odoratum*	LC	
Plants	*Galium pumilum*	LC	
Plants	*Galium rotundifolium*	LC	
Plants	*Genista sagittalis*	LC	
Plants	*Gentiana acaulis*	LC	
Plants	*Gentiana asclepiadea*	LC	
Plants	*Gentiana bavarica*	LC	
Plants	*Gentiana brachyphylla*	LC	
Plants	*Gentiana campestris*	LC	
Plants	*Gentiana ciliata*	LC	Yes
Plants	*Gentiana clusii*	LC	
Plants	*Gentiana lutea*	LC	
Plants	*Gentiana nivalis*	LC	
Plants	*Gentiana purpurea*	LC	
Plants	*Gentiana verna*	LC	
Plants	*Geranium pyrenaicum*	LC	
Plants	*Geranium sanguineum*	LC	
Plants	*Geranium sylvaticum*	LC	
Plants	*Geum montanum*	LC	
Plants	*Geum rivale*	LC	
Plants	*Geum urbanum*	LC	
Plants	*Glechoma hederacea*	LC	
Plants	*Globularia cordifolia*	LC	
Plants	*Globularia nudicaulis*	LC	
Plants	*Gnaphalium norvegicum*	LC	
Plants	*Gnaphalium supinum*	LC	
Plants	*Gnaphalium sylvaticum*	LC	
Plants	*Gymnadenia conopsea*	LC	Yes
Plants	*Gymnocarpium dryopteris*	LC	
Plants	*Gymnocarpium robertianum*	LC	
Plants	*Gypsophila repens*	LC	
Plants	*Hedera helix*	LC	
Plants	*Hedysarum hedysaroides*	LC	
Plants	*Helianthemum alpestre*	LC	
Plants	*Helianthemum grandiflorum*	LC	

Plants	*Helictotrichon pubescens*	LC	
Plants	*Helictotrichon versicolor*	LC	
Plants	*Helleborus foetidus*	LC	
Plants	*Hepatica nobilis*	LC	
Plants	*Heracleum sphondylium*	LC	
Plants	*Hieracium bifidum*	LC	
Plants	*Hieracium glaucinum*	CR	
Plants	*Hieracium lactucella*	LC	
Plants	*Hieracium pilosella*	LC	
Plants	*Hieracium prenanthoides*	LC	
Plants	*Hieracium vogesiacum*	NE	
Plants	*Hippocrepis comosa*	LC	
Plants	*Hippocrepis emerus*	LC	
Plants	*Holcus lanatus*	LC	
Plants	*Homogyne alpina*	LC	
Plants	*Hordelymus europaeus*	LC	
Plants	*Humulus lupulus*	LC	
Plants	*Huperzia selago*	LC	Yes
Plants	*Hypericum maculatum*	LC	
Plants	*Hypericum montanum*	LC	
Plants	*Hypericum perforatum*	LC	
Plants	*Hypochaeris radicata*	LC	
Plants	*Ilex aquifolium*	LC	
Plants	*Impatiens noli tangere*	LC	
Plants	*Juglans regia*	LC	
Plants	*Juncus articulatus*	LC	
Plants	*Juncus effusus*	LC	
Plants	*Juncus filiformis*	LC	
Plants	*Juniperus communis*	LC	
Plants	*Juniperus nana*	LC	
Plants	*Kernera saxatilis*	LC	
Plants	*Knautia arvensis*	LC	
Plants	*Knautia dipsacifolia*	LC	
Plants	*Laburnum alpinum*	LC	
Plants	*Lamium montanum*	LC	
Plants	*Lamium purpureum*	LC	
Plants	*Larix decidua*	LC	
Plants	*Laserpitium latifolium*	LC	
Plants	*Laserpitium siler*	LC	
Plants	*Lathyrus niger*	LC	
Plants	*Lathyrus occidentalis*	LC	Yes
Plants	*Lathyrus pratensis*	LC	
Plants	*Lathyrus vernus*	LC	

Plants	*Leontodon autumnalis*	LC	
Plants	*Leontodon helveticus*	LC	
Plants	*Leontodon montanus*	LC	
Plants	*Leucanthemum adustum*	LC	
Plants	*Leucanthemum vulgare*	LC	
Plants	*Ligusticum mutellina*	LC	
Plants	*Ligusticum mutellinoides*	LC	
Plants	*Ligustrum vulgare*	LC	
Plants	*Lilium martagon*	LC	Yes
Plants	*Linaria alpina*	LC	Yes
Plants	*Linum alpinum*	NT	
Plants	*Linum catharticum*	LC	
Plants	*Listera cordata*	LC	Yes
Plants	*Listera ovata*	LC	Yes
Plants	*Loiseleuria procumbens*	LC	
Plants	*Lolium multiflorum*	LC	
Plants	*Lolium perenne*	LC	
Plants	*Lonicera alpigena*	LC	
Plants	*Lonicera caerulea*	LC	
Plants	*Lonicera nigra*	LC	
Plants	*Lonicera xylosteum*	LC	
Plants	*Lotus alpinus*	LC	
Plants	*Lotus corniculatus*	LC	
Plants	*Lunaria rediviva*	LC	
Plants	*Luzula alpinopilosa*	LC	
Plants	*Luzula campestris*	LC	
Plants	*Luzula luzulina*	LC	
Plants	*Luzula multiflora*	LC	
Plants	*Luzula nivea*	LC	
Plants	*Luzula pilosa*	LC	
Plants	*Luzula sieberi*	LC	
Plants	*Luzula spicata*	NT	
Plants	*Luzula sudetica*	LC	
Plants	*Luzula sylvatica*	LC	
Plants	*Lycopodium annotinum*	LC	Yes
Plants	*Lysimachia nemorum*	LC	
Plants	*Lysimachia nummularia*	LC	
Plants	*Maianthemum bifolium*	LC	
Plants	*Malus sylvestris*	NT	
Plants	*Medicago lupulina*	LC	
Plants	*Melampyrum pratense*	LC	
Plants	*Melampyrum sylvaticum*	LC	
Plants	*Melica nutans*	LC	

Plants	*Melica uniflora*	LC	
Plants	*Melittis melissophyllum*	LC	
Plants	*Mentha longifolia*	LC	
Plants	*Mercurialis perennis*	LC	
Plants	*Milium effusum*	LC	
Plants	*Minuartia gerardii*	LC	
Plants	*Moehringia ciliata*	LC	
Plants	*Moehringia muscosa*	LC	
Plants	*Moehringia trinervia*	LC	
Plants	*Molinia caerulea*	LC	
Plants	*Molinia litoralis*	NE	
Plants	*Monotropa hypopitys*	LC	Yes
Plants	*Mycelis muralis*	LC	
Plants	*Myosotis alpestris*	LC	
Plants	*Myosotis arvensis*	LC	
Plants	*Myosotis decumbens*	LC	
Plants	*Myosotis scorpioides*	LC	
Plants	*Myosotis sylvatica*	LC	
Plants	*Myrrhis odorata*	LC	
Plants	*Nardus stricta*	LC	
Plants	*Neottia nidus avis*	LC	Yes
Plants	*Onobrychis montana*	LC	
Plants	*Onobrychis viciifolia*	LC	
Plants	*Ononis procurrens*	LC	
Plants	*Orchis mascula*	LC	Yes
Plants	*Oreopteris limbosperma*	LC	Yes
Plants	*Origanum vulgare*	LC	
Plants	*Ornithogalum pyrenaicum*	NT	
Plants	*Orobanche caryophyllacea*	LC	
Plants	*Orthilia secunda*	LC	
Plants	*Oxalis acetosella*	LC	
Plants	*Oxytropis jacquinii*	LC	
Plants	*Paris quadrifolia*	LC	
Plants	*Parnassia palustris*	LC	
Plants	*Pedicularis ascendens*	LC	
Plants	*Pedicularis foliosa*	LC	
Plants	*Pedicularis verticillata*	LC	
Plants	*Petasites albus*	LC	
Plants	*Petasites hybridus*	LC	
Plants	*Petasites paradoxus*	LC	
Plants	*Peucedanum ostruthium*	LC	
Plants	*Phegopteris connectilis*	LC	
Plants	*Phleum commutatum*	NE	

Plants	*Phleum hirsutum*	LC	
Plants	*Phleum pratense*	LC	
Plants	*Phleum rhaeticum*	LC	
Plants	*Phragmites australis*	LC	
Plants	*Phyllitis scolopendrium*	LC	Yes
Plants	*Phyteuma betonicifolium*	LC	
Plants	*Phyteuma hemisphaericum*	LC	
Plants	*Phyteuma orbiculare*	LC	
Plants	*Phyteuma spicatum*	LC	
Plants	*Picea abies*	LC	
Plants	*Pimpinella major*	LC	
Plants	*Pinguicula alpina*	LC	Yes
Plants	*Pinguicula vulgaris*	LC	Yes
Plants	*Pinus cembra*	LC	
Plants	*Pinus sylvestris*	LC	
Plants	*Pinus uncinata*	LC	
Plants	*Plantsago alpina*	LC	
Plants	*Plantsago atrata*	LC	
Plants	*Plantsago lanceolata*	LC	
Plants	*Plantsago major*	LC	
Plants	*Plantsago media*	LC	
Plants	*Platanthera bifolia*	LC	Yes
Plants	*Poa alpina*	LC	
Plants	*Poa annua*	LC	
Plants	*Poa cenisia*	LC	
Plants	*Poa minor*	LC	
Plants	*Poa nemoralis*	LC	
Plants	*Poa pratensis*	LC	
Plants	*Poa supina*	LC	
Plants	*Poa trivialis*	LC	
Plants	*Polygala alpestris*	LC	
Plants	*Polygala chamaebuxus*	LC	
Plants	*Polygala vulgaris*	LC	
Plants	*Polygonatum multiflorum*	LC	
Plants	*Polygonatum odoratum*	LC	
Plants	*Polygonatum verticillatum*	LC	
Plants	*Polygonum bistorta*	LC	
Plants	*Polygonum viviparum*	LC	
Plants	*Polypodium vulgare*	LC	
Plants	*Polystichum aculeatum*	LC	
Plants	*Polystichum lonchitis*	LC	
Plants	*Populus tremula*	LC	
Plants	*Potentilla aurea*	LC	

Plants	*Potentilla crantzii*	LC	
Plants	*Potentilla erecta*	LC	
Plants	*Potentilla reptans*	LC	
Plants	*Potentilla sterilis*	LC	
Plants	*Prenanthes purpurea*	LC	
Plants	*Primula acaulis*	LC	
Plants	*Primula auricula*	LC	
Plants	*Primula elatior*	LC	
Plants	*Primula farinosa*	LC	Yes
Plants	*Pritzelago alpina*	LC	
Plants	*Prunella grandiflora*	LC	
Plants	*Prunella vulgaris*	LC	
Plants	*Prunus avium*	LC	
Plants	*Prunus spinosa*	LC	
Plants	*Pseudorchis albida*	LC	Yes
Plants	*Pteridium aquilinum*	LC	
Plants	*Pulmonaria officinalis*	LC	
Plants	*Pulsatilla alpina*	LC	
Plants	*Pulsatilla vernalis*	LC	
Plants	*Quercus petraea*	LC	
Plants	*Quercus robur*	LC	
Plants	*Ranunculus aconitifolius*	LC	
Plants	*Ranunculus auricomus*	LC	
Plants	*Ranunculus bulbosus*	LC	
Plants	*Ranunculus ficaria*	LC	
Plants	*Ranunculus friesianus*	LC	
Plants	*Ranunculus glacialis*	LC	
Plants	*Ranunculus lanuginosus*	LC	
Plants	*Ranunculus montanus*	LC	
Plants	*Ranunculus nemorosus*	LC	
Plants	*Ranunculus platanifolius*	LC	
Plants	*Ranunculus repens*	LC	
Plants	*Rhamnus alpina*	LC	
Plants	*Rhamnus cathartica*	LC	
Plants	*Rhinanthus alectorolophus*	LC	
Plants	*Rhinanthus glacialis*	LC	
Plants	*Rhinanthus minor*	LC	
Plants	*Rhododendron ferrugineum*	LC	Yes
Plants	*Rhododendron hirsutum*	LC	
Plants	*Ribes alpinum*	LC	
Plants	*Ribes petraeum*	LC	
Plants	*Ribes rubrum*	LC	
Plants	*Rosa arvensis*	LC	

Plants	*Rosa corymbifera*	LC	
Plants	*Rosa pendulina*	LC	
Plants	*Rubus caesius*	LC	
Plants	*Rubus idaeus*	LC	
Plants	*Rubus saxatilis*	LC	
Plants	*Rumex acetosa*	LC	
Plants	*Rumex alpestris*	LC	
Plants	*Rumex alpinus*	LC	
Plants	*Rumex crispus*	LC	
Plants	*Rumex obtusifolius*	LC	
Plants	*Rumex scutatus*	LC	
Plants	*Ruscus aculeatus*	LC	Yes
Plants	*Sagina saginoides*	LC	
Plants	*Salix alba*	LC	
Plants	*Salix appendiculata*	LC	
Plants	*Salix aurita*	LC	
Plants	*Salix caprea*	LC	
Plants	*Salix hastata*	LC	
Plants	*Salix herbacea*	LC	
Plants	*Salix reticulata*	LC	
Plants	*Salix retusa*	LC	
Plants	*Salix serpillifolia*	LC	
Plants	*Salvia glutinosa*	LC	
Plants	*Salvia pratensis*	LC	
Plants	*Sambucus nigra*	LC	
Plants	*Sambucus racemosa*	LC	
Plants	*Sanguisorba minor*	LC	
Plants	*Sanguisorba officinalis*	LC	
Plants	*Sanicula europaea*	LC	
Plants	*Saxifraga aizoides*	LC	
Plants	*Saxifraga androsacea*	LC	
Plants	*Saxifraga biflora*	LC	
Plants	*Saxifraga caesia*	LC	
Plants	*Saxifraga cuneifolia*	LC	
Plants	*Saxifraga engleri*	NE	
Plants	*Saxifraga oppositifolia*	LC	Yes
Plants	*Saxifraga paniculata*	LC	Yes
Plants	*Saxifraga rotundifolia*	LC	
Plants	*Scabiosa columbaria*	LC	
Plants	*Scabiosa lucida*	LC	
Plants	*Scirpus sylvaticus*	LC	
Plants	*Scrophularia nodosa*	LC	
Plants	*Sedum album*	LC	

Plants	*Sedum atratum*	LC	
Plants	*Sedum maximum*	LC	
Plants	*Selaginella selaginoides*	LC	
Plants	*Senecio alpinus*	LC	
Plants	*Senecio doronicum*	LC	
Plants	*Senecio ovatus*	LC	
Plants	*Sesleria caerulea*	LC	
Plants	*Sibbaldia procumbens*	LC	
Plants	*Silene acaulis*	LC	
Plants	*Silene dioica*	LC	
Plants	*Silene nutans*	LC	
Plants	*Solanum dulcamara*	LC	
Plants	*Soldanella alpina*	LC	
Plants	*Sonchus asper*	LC	
Plants	*Sorbus aria*	LC	
Plants	*Sorbus aucuparia*	LC	
Plants	*Sorbus chamaemespilus*	LC	
Plants	*Sorbus mougeotii*	LC	
Plants	*Stachys alpina*	LC	
Plants	*Stachys officinalis*	LC	
Plants	*Stachys recta*	LC	
Plants	*Stachys sylvatica*	LC	
Plants	*Stellaria graminea*	LC	
Plants	*Stellaria nemorum*	LC	
Plants	*Streptopus amplexifolius*	LC	Yes
Plants	*Succisa pratensis*	LC	
Plants	*Tamus communis*	LC	
Plants	*Taraxacum alpinum*	LC	
Plants	*Taraxacum officinale*	LC	
Plants	*Taxus baccata*	LC	
Plants	*Teucrium chamaedrys*	LC	
Plants	*Teucrium montanum*	LC	
Plants	*Thalictrum aquilegiifolium*	LC	
Plants	*Thesium alpinum*	LC	
Plants	*Thesium pyrenaicum*	LC	
Plants	*Thlaspi rotundifolium*	LC	
Plants	*Thymus polytrichus*	LC	
Plants	*Thymus pulegioides*	LC	
Plants	*Tilia cordata*	LC	
Plants	*Tilia platyphyllos*	LC	
Plants	*Tofieldia calyculata*	LC	Yes
Plants	*Tozzia alpina*	LC	
Plants	*Tragopogon orientalis*	LC	

Plants	*Tragopogon pratensis*	LC	
Plants	*Traunsteinera globosa*	LC	Yes
Plants	*Trifolium badium*	LC	
Plants	*Trifolium campestre*	LC	
Plants	*Trifolium medium*	LC	
Plants	*Trifolium montanum*	LC	
Plants	*Trifolium pratense*	LC	
Plants	*Trifolium repens*	LC	
Plants	*Trifolium thalii*	LC	
Plants	*Trisetum distichophyllum*	LC	
Plants	*Trisetum flavescens*	LC	
Plants	*Trollius europaeus*	LC	Yes
Plants	*Tussilago farfara*	LC	
Plants	*Ulmus glabra*	LC	
Plants	*Ulmus minor*	NT	
Plants	*Urtica dioica*	LC	
Plants	*Vaccinium gaultherioides*	LC	
Plants	*Vaccinium myrtillus*	LC	
Plants	*Vaccinium vitis idaea*	LC	
Plants	*Valeriana dioica*	LC	
Plants	*Valeriana montana*	LC	
Plants	*Valeriana tripteris*	LC	
Plants	*Veratrum lobelianum*	LC	
Plants	*Veronica alpina*	LC	
Plants	*Veronica aphylla*	LC	
Plants	*Veronica arvensis*	LC	
Plants	*Veronica beccabunga*	LC	
Plants	*Veronica chamaedrys*	LC	
Plants	*Veronica officinalis*	LC	
Plants	*Veronica persica*	LC	
Plants	*Veronica urticifolia*	LC	
Plants	*Viburnum lantana*	LC	
Plants	*Viburnum opulus*	LC	
Plants	*Vicia cracca*	LC	
Plants	*Vicia sepium*	LC	
Plants	*Vicia sylvatica*	LC	
Plants	*Vinca minor*	LC	
Plants	*Vincetoxicum hirundinaria*	LC	
Plants	*Viola biflora*	LC	
Plants	*Viola calcarata*	LC	
Plants	*Viola canina*	NT	Yes
Plants	*Viola hirta*	LC	
Plants	*Viola reichenbachiana*	LC	