



## **Project of Strategic Interest NEXTDATA**

### **Deliverable D1.7.1**

### **Analysis of terrestrial biodiversity and ecosystem changes in high-elevation regions**

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## Main Objectives

Topic of this study is the assessment of changes in biodiversity and ecosystems in high-altitude mountain areas, by statistical analysis and comparisons of the data collected during the project with earlier data, made available in the course of the project.

In this framework, this study aimed to apply and to improve monitoring and data storage methodologies, devoted to explore relationships between animal biodiversity, climate and land use at different spatial scales in alpine protected areas. Long term purpose is to create the baseline against which to assess future changes with a monitoring program that is planned to be repeated every five years.

The study is characterised by 2 different steps:

- the conduction of the new monitoring campaign;
- the identification, collection and analysis of previous data on terrestrial biodiversity in the western Italian Alps.

This monitoring project was promoted by Gran Paradiso National Park in 2006 and continued with the cooperation between ISAC-CNR and other two protected areas in the NW Italian Alps, the Orsiera Rocciavré Natural Park and the Veglia Devero Natural Park.

During the year 2013, we developed the following activities:

- 1) the conduction of the new monitoring campaign, devoted to the collection of data about animal biodiversity along altitudinal gradients;
- 2) the execution of laboratory activities, devoted to the analysis of the entomological material and the compilation of the databases, created during the previous year;
- 3) the preparation of the working protocol and the creation of the necessary databases for 3 National Parks, that during this year adopted the same monitoring protocol;
- 4) the analysis of datasets about the distribution of animal biodiversity in mountain ecosystems.

### **1. Conduction of the new monitoring campaign (April-October 2013)**

Field activities have been carried out in fixed plots, already subjected to monitoring during the period 2007-2008 and in 2012. They represent the implementation and continuation of a previous existing *in situ* project, promoted by Gran Paradiso National Park (PNGP) in 2006 and continued with the cooperation between ISAC-CNR and other two protected areas in NW Italian Alps, Orsiera Rocciavré Natural Park (PNOR) and Veglia Devero Natural Park (PNVD).

Aim of the research is to develop an historical dataset, on the base of already existing data, and to improve some of the methodologies applied to the monitoring of animal biodiversity.

Monitoring activities during 2013 have been carried out in all the 3 Parks (Gran Paradiso National Park, Orsiera-Rocciavré Natural Park, Veglia Devero Natural Park). Thirteen altitudinal transects were set covering an altitudinal range of 1000 meters, chosen from 500 to 2700 m a.s.l. interesting three vegetation belts (montane, subalpine, alpine).

Sampling units are circular plots (100 m radius), for a total of 74 sampling stations, where monitoring activities have been carried out to provide presence and relative abundance data of species belonging to taxa, selected as bio-indicators.

Selected taxa are: Lepidoptera Rhopalocera (butterflies), Orthoptera (grasshoppers/crickets), birds, surface-active macro-arthropods (Coleoptera Carabidae, Coleoptera Staphylinidae, Araneae, Formicidae).

For each taxonomic group we used semi-quantitative census techniques that are, as much as possible, easy to apply, standardized, cheap and repeatable. Birds were monitored by means of point counts and each plot was visited twice during the reproductive season, for a total of

148 (74 plots\*2) counts, done during the period between the end of April and the beginning of July. We sampled butterflies using linear transects along one diameter of the plot (200 m in length), walked at uniform speed, executed one per month from May to September, for a total of 370 (74\*5) transects. Grasshoppers/crickets were also monitored using linear transects, three times per plot, during the period between the middle of July and the end of September, for a total of 222 sampling (74\*3). We collected surface-active arthropods using pitfall traps (plastic cups, diameter of 7 cm, filled with 10 cc of white vinegar). We placed 5 traps per plot and collected them every 15 days, in the period between the end of May and the middle of October, for a total of ca. 3700 pitfall traps (74\*5\*10).

All field activities were done during mid April-mid October 2013. During the same period, we collected micro-climatic data, through the positioning of temperature data-loggers (iButton DS1922), one per each sampling station, located in field at the beginning of the sampling season.

## **2. Laboratory activities**

We finished the determination of the material collected in 2012 (January-March 2013). After field work (October 2013-nowadays), we started the laboratory analysis of the collected material.

In the case of the selected groups of surface-active macro-arthropods (Coleoptera Carabidae, Coleoptera Staphylinidae, Araneae, Formicidae), we started the identification at the morpho-species level. All specimens were stored and preserved in alcohol 70%, waiting for the identification at the species-level, executed by expert taxonomists.

We have now sorted 75% of the material collected during 2013 in the 3 protected areas.

During the laboratory analysis of pitfall traps, we applied the protocol for the measurement of arthropod biomass, experimented in 2012. Therefore, for each pitfall trap we have now data about the weight and the volume occupied by the total captured arthropods.

In the case of butterflies and grasshoppers/crickets, we started the identification of collected specimens and the preparation of a reference-collection. We have now identified about 70% of the collected specimens.

We stored the data collected during the field campaign 2012 in the appropriate databases. Datasets are now ready for the following taxonomic groups: birds, butterflies, carabids, staphylinids, spiders.

For the campaign 2013, only the datasets for birds are now ready, because the determination of the other taxonomic groups is not yet finished (butterflies, grasshoppers/crickets, surface active macro-arthropods). Temperature data from 2012 and 2013 are now in the appropriate databases and ready for the analysis and for the comparisons between micro-climatic data from 2007 and 2008.

### Body size variation along altitudinal gradients

Body size is a key functional trait both within and among species that influences population abundance, geographic distribution, species interactions and physical performance (Fisher et al., 2010). The most well-known trend is the tendency of individuals within the geographical range of a species to be larger in body size under colder climatic conditions (Millien et al., 2006). Much effort has been invested in the study of latitudinal variation, as a proxy for temperature. In contrast, analogous altitudinal variation has been studied much less frequently. However, altitudinal variation occurs over much shorter distances, facilitating gene flow from adjacent areas and thus making local genetic differentiation probable only

under conditions of strong selection. It is consequently easier to separate the relative role of genetic and environmental causes of phenotypic variations (Blanckenhorn, 1997).

Our sampling design covers a long altitudinal gradient, offering the possibility to an in-depth analysis between body size and altitude. We used carabids, as a target group, collected through pitfall traps during 2012 field season. We chose five species, which are spread over the altitudinal gradient and between the three protected areas: *Calathus melanocephalus*, *Carabus depressus*, *Pterostichus externepunctatus*, *Pterostichus multipunctatus* and *Pterostichus flavofemoratus*.

To get information both on Condition Factor (CF) and on Fluctuating Asymmetry (FA) we selected seven **body size measures**

- total body length (TBL);
- left elytron length (LEL);
- right elytron length (REL);
- left hind femur length (LHFL);
- right hind femur length (RHFL);
- maximum elytra width (c. abdomen width);
- maximum thickness of the body;

and two **body mass measures**

- ethanol-fresh mass (EFM);
- ethanol dry-mass (EDM).

At present, we have finished the measurement of 159 individuals of *C. melanocephalus*, 372 of *C. depressus* and we have started the measurement of the *P. multipunctatus*.

To reduce bias each body size measure was repeated by three different operators.

### 3. Monitoring protocols and common databases

In 2013, three other protected areas decided to share the objectives of the monitoring activities promoted by PNGP in 2006 and to follow the sampling protocols already adopted by PNGP, PNOR and PNVD. These protected areas are Stelvio National Park (CPNS), Val Grande National Park (PNVG), Dolomiti Bellunesi National Park (PNDB). During spring 2013 (March-April), we formed the personnel of these Parks, in order to obtain comparable data and we created the appropriate databases for common data storage.

In the following Table (Tab. 1), we show the monitoring activities carried out by each Park.

	Transects	Plots	Temperature	Birds	Butterflies	Grasshoppers	Macro-arthropods
PNDB	2	11	X		X	X	X
CPNS	6	30	X	X	X	X	X
PNVG	3	17	X	X	X	X	X

Tab. 1. Monitoring activities carried out by each Park. Transects represent the number of altitudinal gradients under study, and Plots the total number of monitored sampling stations.

As soon as the identification of the collected specimens and the quality of the collected data will be properly evaluated by each Park, the common data will be stored in the prepared databases, with the data from PNGP, PNOR and PNVD.

## 4. Data analysis

### 4a) Simulation of temperature increase scenarios

Detailed information on biodiversity and vulnerability drivers is needed to assess the effects of temperature rise, but they are still largely lacking, in particular for mountain invertebrates. In this framework, species distribution models represent essential tools to estimate the impact of temperature changes and to develop adequate conservation strategies.

Therefore, we modelled the effect of climate warming on species richness and community composition using a multi-taxa approach, in order to assess the risk of modifications in alpine animal biodiversity in response to temperature rise.

As a starting database, we used the high-resolution biodiversity data, collected in field during the first sampling season of the Biodiversity Monitoring Program (2007), executed in the 3 protected areas (PNGP, PNOR, PNVD). In our modelling procedure, we first modelled each species, using Maxent software (Phillips et al., 2006), and then we analysed the results at species and community level, accounting for differences between ecological categories.

We developed three realistic temperature increase scenarios, coming from the current knowledge about temperature changes in the Alps:

- 1 Degree, in which minimum, mean and maximum temperature are all equally increased by 1° C;
- 1.5Min, in which, minimum temperature is increased by 1.5° C, maximum by 0.5° and mean by 1°;
- 1.5Max, in which minimum temperature is increased by 0.5°, mean by 1°, maximum by 1.5°.

Our choices were mainly based on the results by Beniston (2006), who observed a larger increase of minimum temperature, and by Ciccarelli et al. (2008), who detected the same increase but for maximum temperature.

In order to buffer the effect of temperature increase and hypothesize species' responses in a more realistic way, we applied different level of environmental constraints, considering also habitat type and geographic area. We consequently combined the environmental variables at our disposal in different ways, obtaining three model classes with an increasing number of environmental constraints:

- Temp, which considers only temperature-derived variables and altitude to model species distribution.
- Tempark, which considers temperature-derived variables, altitude and geographical location.
- All, which considers temperature-derived variables, altitude, geographical location and vegetation cover.

All our analyses were based on 304 species: 45 Carabidae, 80 Lepidoptera Rhopalocera, 99 Araneae, 40 Staphylinidae and 40 Birds. Among them, 41 were endemic and 91 vulnerable.

For each species we run three Maxent model classes (Temp, Tempark, All), for a total of 912 current distribution datasets. The outputs of the Maxent species distribution models for current conditions were then used as baselines for assessing the response to temperature increase. For each model class, we run the three different scenarios, for a total of 2736 future distribution outputs.

### Species distribution

The comparisons between each scenario and the corresponding baseline showed high variability in the species response to temperature increase, in particular depending on the position and breadth of the climatic niche and on the species range. The majority of modeled species did not show much response to the temperature increase, but, as a general pattern, we

observed that species already restricted to high altitude and with limitation to dispersal (brachyptera and with low vagility), which we defined as *vulnerable*, were the most affected ones (Fig. 1).

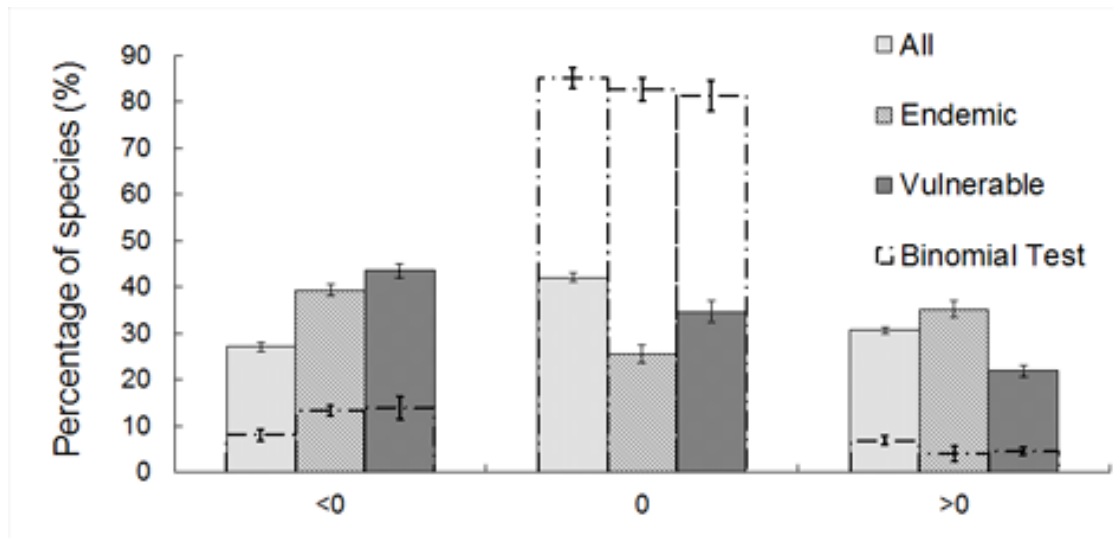


Fig. 1. Percentage of species that showed a decrease (<0), an increase (>0) and no variation (0), in the number of occupied plots. Dotted lines represent *varying* (>0 and <0) and *not varying* (0) species after a two-tailed binomial test. In such a test, the number of successes was represented by the occupied plots, after the temperature increase; the number of trials is the total number of plots in the study area (62); the probability of success is the proportion of occupied plots before modelling. Bar charts represent mean value and error bars the standard error among model classes and scenarios.

Moreover, the comparison with the non-vulnerable species highlights significant differences in all scenarios and model classes (Mann-Whitney test, all p-values<0.05; Fig. 2).

Indeed, species that are habitat specialists and poor dispersers are negatively influenced by environmental change (e.g., Dirnböck et al. 2011).

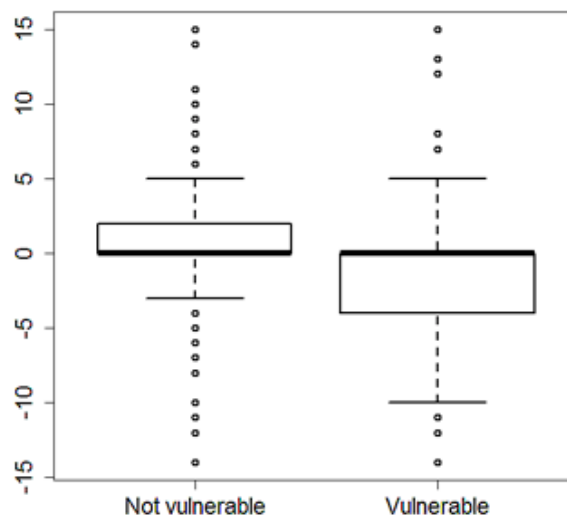


Fig. 2. Box plots of the number of plots gained or lost for vulnerable species in the Tempark model class, 1.5Min scenario. Vulnerable species gained significantly fewer plots ( $-1.6 \pm 0.2$ ) than non-vulnerable ones ( $0.7 \pm 0.1$ ) for all scenarios and model classes. The box shows the median, the first and the third quartile of the distribution, whiskers represent minimum and maximum values and outliers are plotted as circles.

## Species richness

As a general trend, we observed an increase of species richness in the alpine belt (Fig.3). According to our simulations, meadows potentially experience the largest change in faunal composition under temperature increase, with a robust pattern for butterflies, staphylinids, spiders and all taxa pooled together. However, the increase of species richness is presumably transitory because the decline of arctic-alpine species that go out of their distribution range will subsequently reduce alpine biodiversity (Lesica and McCune, 2004). Moreover, such an increase in species richness could be detrimental for some localised and specialised taxa. The colonisation of the alpine belt by species from lower altitude could exacerbate competition (Pauli et al., 2007; Gottfried et al., 2012).

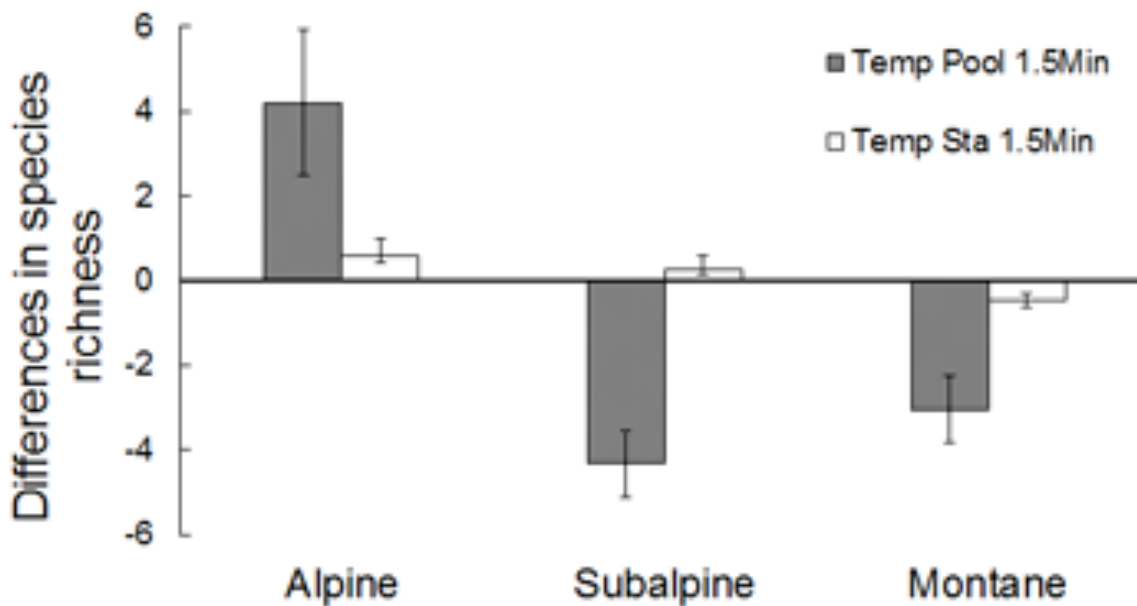


Fig. 3. Bar chart of the differences between projected and current species richness per plot (y-axis) in the three vegetation belts (x-axis), for the Temp model class, 1.5Min scenario. Bar charts represent mean value and error bars the standard error among plots, for all taxa pooled together (grey) and for staphylinids (white).

We observed differences in the changes of species richness of the different taxonomic groups. Carabids collected inside our monitoring programme did not show any relationship with temperature (Viterbi et al., 2013) and, as a consequence, they did not display any change under the various temperature increase scenarios. Butterflies are heliothermic and for many species the distribution is strongly influenced by temperature: for all scenarios and model classes, butterflies showed a higher proportion of occupied plots for higher temperatures and were the taxon with the highest proportion of increasing species. Spiders suffer from temperature increase, showing a decrease in the number of occupied plots. In our monitoring program, spiders were highly localized and most species were present in a small number of plots; therefore, variations of microclimatic conditions can reduce the areas of occurrence.

## Differences between model classes and scenarios

Comparing the three model classes, we found that the number of species with changing distributions was lower with a larger number of environmental constraints and the more pronounced effects on species turnover were found when only variables linked to temperature were considered. Indeed, *varying species* in each scenario significantly differed

between model classes using a binomial test (All =  $25.7 \pm 4.4$ , Tempark =  $43.7 \pm 4.4$ , Temp =  $67.7 \pm 8.4$ ;  $20.64 < \chi^2 < 27.82$ ,  $p < 0.001$ ).

Even if there is uncertainty in land use change (Dirnböck et al., 2003), our results suggest that the effects of temperature increase are buffered by the other environmental variables, resulting in a lower decrease in species richness and a lighter change in community composition.

Comparing the three scenarios, we observed a higher number of *varying species* after binomial test in the 1.5Min scenario (1.5Max =  $37.3 \pm 10.7$ , 1.5Min =  $56.7 \pm 14.6$ , 1Degree =  $43.0 \pm 11.3$ ) in each model class, but differences were significant only in Temp ( $\chi^2 = 8.56$ ,  $p = 0.02$ ).

Differences between scenarios are not as marked as the model classes' ones. Anyway, the 1.5Min scenario displayed the largest number of *varying species*, indicating that the minimum daily temperature can be an important limiting factor for species distribution (Coulson et al., 1995; Sykes et al., 1996). Considering that minimum temperature have increased at a faster rate than maximum temperature during the latter half of the 20th century (Vose et al., 2005), variations in biodiversity patterns larger than the ones predicted here could occur.

### Community composition

In terms of community composition, we observed significant modifications, implying that plot composition changes in a coherent way and that differences between vegetation belts are retained also for increased temperatures.

The median change in plot scores from current to projected conditions was significantly different from zero along the first axis of a Correspondence Analysis, in the majority of the tested combinations (54 combinations of taxa, model classes, scenarios; Wilcoxon Test with  $p < 0.01$  in all cases except one). High altitude communities become more similar to the low altitude ones (Fig. 4).

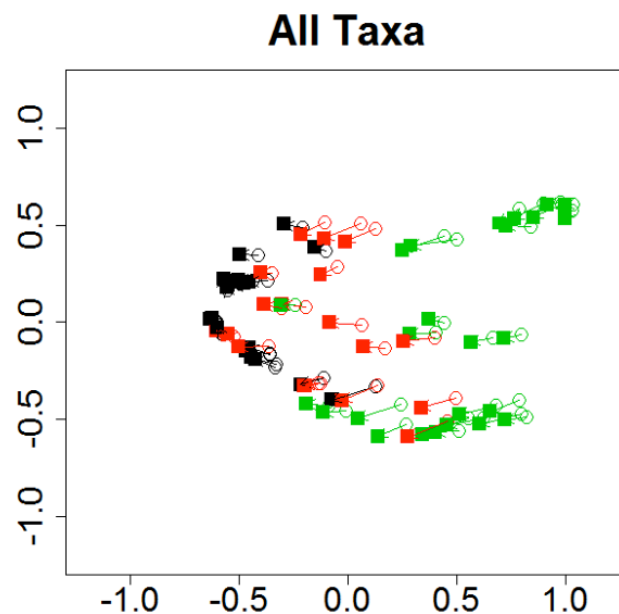


Fig. 4. Correspondence Analysis (CA) for the Tempark model class in the 1.5Min scenario, for all taxa pooled together. Open circles indicate the current situation and filled square the projection. Arrows indicate the shift of each plot. Different colours mean different vegetation belts (green = alpine, red = subalpine, black = montane). The first axis is positively correlated with altitude and negatively with minimum temperature.



Plots were distributed from the montane to the alpine belt along the first axis, with significant differences in plot scores across belts (Kruskal-Wallis Test,  $df = 2$ , all  $p < 0.0001$ ; Fig. 5a) that were retained in the projected plots (Kruskal-Wallis Test,  $df = 2$ , all  $p < 0.0001$ ; Fig. 5b).

Differences between pairs of plots (current minus projected) across vegetation belts along the first axis showed an interesting pattern (Fig. 5c): in all the significant differences, the lowest values have been reached in the montane belt.

As a mirror of the changes in species richness, in the montane belt the community composition seemed to be more stable while the subalpine and alpine belts showed the highest turnover, due to species shifts. In the upper two belts, new species forge new ecological relationships with each other and with the previously occurring species; the character of species interactions as well as the fundamental ecosystem processes can be transformed in unforeseen ways (Walther et al., 2002).

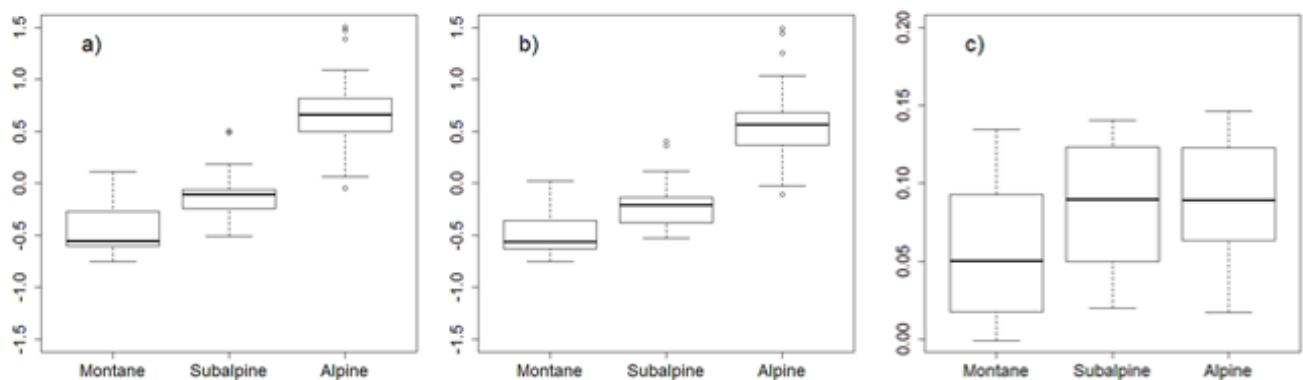


Fig. 5. Analysis of plot scores along the first axis, obtained from CA of all taxonomic groups pooled together with the All model class in the 1.5Min scenario. Plots are grouped based on vegetation belt. Values for plot scores are represented separately for a) the current situation and b) the projection. Differences between c) current and projected scores show differences in the rate of change across belts. The box shows median values and the first and third quartiles, whiskers indicate minimum and maximum values and outliers are plotted as circles.

## Conclusion

Our results provide insights into the vulnerability of the alpine ecosystems, because even a moderate temperature increase has the potential of influencing animal biodiversity. We observed only small changes in the overall biodiversity patterns, but different responses depending on taxonomic group and degree of specialization.

In particular, a marked increase in species richness is likely to occur in the cooler areas, such as the alpine belt, and for some taxa, while it is highly probable to witness a significant decrease in the number of vulnerable species, with a consequent change in community composition.

Our conservative approach will allow for comparing, in the near future, model results with real changes in species response. Long-term field data are indeed essential for revising and fine-tuning model predictions and for designing effective conservation strategies.

### 4b) Biodiversity pattern in time and between taxa

These activities are only at a preliminary stage. We are analysing collected data, following three main research approaches.

### 1. Comparison of biodiversity pattern between sampling seasons

The main purpose is to identify the taxa (or the functional groups) and the habitat types (or the altitudinal range), that suffer the highest amount of change between sampling seasons.

Field data from 2007, 2008 and 2012 are already available and stored in the appropriate datasets for butterflies, birds, carabids and staphylinids. Using both univariate and multivariate techniques, we are now analysing the pattern of change between time periods.

### 2. Ecological indicators

We are trying to identify species or group of species, which could be used as surrogate of biodiversity, in order to develop monitoring protocol as simple and as representative as possible. Field data from 2007 will be used as training datasets, while the data coming from 2012 will be used to test the validity through time of the observed patterns.

### 3. Temporal trend

Along two altitudinal transects in PNGP, data about butterflies, birds and temperature have been collected for the whole time period, from 2006 to 2013. These time series are now available and ready for the analysis. Main objective are twofold. At first, to analyse pattern of change, searching for congruence between taxa and temperature and at the same time, comparing the amount of change at different altitude. Secondly, to analyse if the general sampling design of our monitoring protocol (2 years of sampling followed by 4 years stop) is detailed enough to identify the main changes in species distribution and community composition.

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