

## Observer bias and its causes in botanical records on summits

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### Abstract

Long-term monitoring in protected areas or areas with limited access, such as the Alps, serve as a versatile tool to assess changes in plant communities. In this study, we want to enhance knowledge about factors influencing observer bias in botanical records in the Alps. We repeated historical surveys of vascular plants, with a subset of 48 summits collected by two independent observers. Rates of pseudo-turnover between observers were compared to turnover between historical and recent surveys. Observer-dependent and -independent variables were tested for influence on pseudo-turnover and the number of species missed by one of the observer. Furthermore, the effect of plant characteristics on species detectability was tested. With an average of 13.6%, pseudo-turnover between observers was almost three times smaller than species turnover over one century. Pseudo-turnover and the number of species missed increased with difference in botanizing time between observers and with a longer ascent to the summit, with more species missed in combination with a high species richness on the summit. Species were difficult to detect if they occurred on many summits but with a low abundance, if small in stature and if they belonged to certain taxonomic plant groups. The results of this study confirm that the floristic changes over time found on alpine summits represent an ecological pattern. Comparison to previous studies shows that these factors and their importance change with conditions and environment a study is conducted in. In remote and mountainous terrain, special attendance should be paid to factors closely dependent on observer. To minimize observer bias in floristic studies in general, its possible causes should be specified in advance according to the particular environmental and survey conditions.

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### Keywords

Pseudo-turnover, species detectability, between-observer variability, vegetation records, long-term monitoring, re-survey studies, Summit Flora Project

### Introduction

Ecosystems have been changing rapidly in recent decades due to climate and land-use changes. Revisitation studies are an effective tool to detect, monitor and analyze changes in ecosystem composition. However, research is always vulnerable to undesired influences affecting data quality, and especially in studies based on fieldwork, a certain fraction of variability may be introduced by environmental conditions or observer characteristics. While quantification of observer bias should be included in all studies, a logical further step would be to minimize possible error sources in advance. For this, further investigations about which factors are important for studies in all vegetational surveys and which factors are specific to certain conditions and environment are needed.

While several variables have been tested for influence on data quality by previous studies, conclusions about the direction and magnitude of influence are still generally undecided. Furthermore, factors having a major influence in lowland situations may have a completely different effect in an alpine environment, where remoteness, exposed terrain and mountain climate may pose particular challenges during fieldwork. To date, only few studies have examined observer bias in an alpine field study (VITTOZ & GUISAN 2007; VITTOZ et al. 2010) but no special attention has been paid to which factors related to this particular environment could have an influence on data quality.

The Summit Flora Project (STÖCKLI et al. 2011) is a revisitation study conducted in such an alpine environment. By repeating historical vegetation records of summits that were visited by botanists one century ago, long-term changes in plant community composition, species richness and species distribution can be assessed. For the Summit Flora Project as well as for other field studies, it is important to quantify observer bias and to test which factors are causing it in order to account for them in study design and data analysis, and eventually, minimize variability in field records. The objective of this study is thus to (1) quantify observer bias and variability between field records, (2) discover the main factors causing them, and (3) ensure data quality of the Summit Flora Project data.

## Methods

### Study sites, record protocols and tested variables

The study area of the Summit Flora Project comprises of 124 summits in the southeastern Swiss Alps, of which historical inventories of vascular plant species found approximately a 100 years ago exist. These summits were re-surveyed between end of June and mid-September in 2010 and 2012 by at least one botanist of a team of three permanent and eight temporary field botanists. On a subset of 48 summits, re-surveys were assembled by two independent observers on the same day to analyze the correspondence between simultaneous records.

For each summit, a list of vascular plant species was assembled for the uppermost ten altitudinal meters. Each plant species was recorded with its highest occurrence, along with coordinates, time stamp, altitude and an estimate of the species' abundance. Each of the two observers made an inventory of the whole 10m-area, following the descriptions of the historical records especially from Braun-Blanquet (BRAUN 1913). Variables that could have influenced the composition of species lists in our records were quantified either from data collected in the field, from already existing data or from personal knowledge (Figure 1).

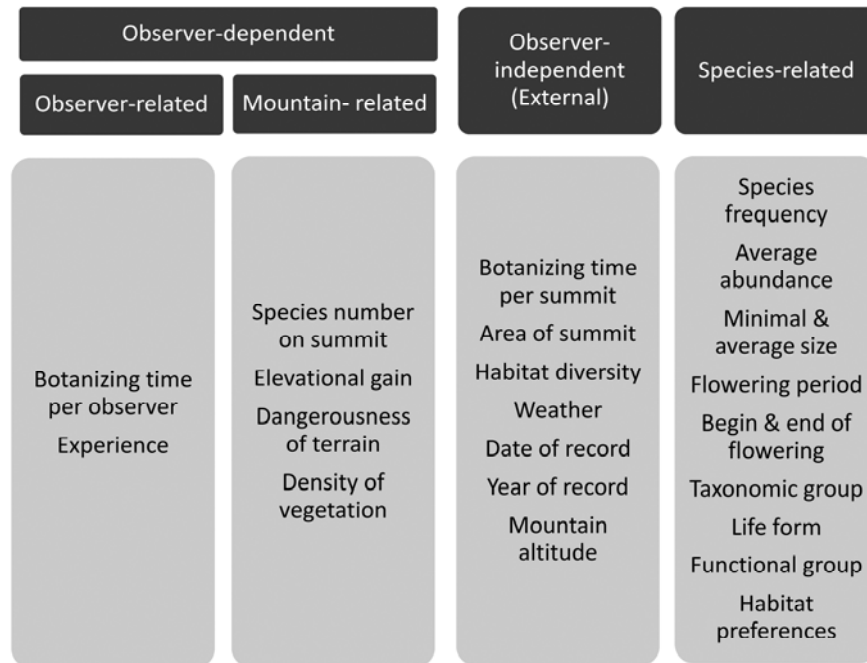


Figure 1: All Variables analysed in this study potentially influencing observer bias.

### Statistical analyses

Species turnover between historical and recent records as well as pseudo-turnover between two records made at the same site *and* the same time were calculated as

$$T = 100 \times \frac{(A + B)}{(S_A + S_B)} \quad (1)$$

(NILSSON & NILSSON 1985), where A and B are the number of species exclusive to each of two records, and  $S_A$  and  $S_B$  are the total number of species in each record. While pseudo-turnover is a relative measure of observer bias including species richness in its calculation, we also calculated the number of exclusive species per summit ( $A + B$  in formula (1)) as an absolute measure of observer bias. Pseudo-turnover and number of exclusive species per summit were analyzed with linear models (models M1 and M2,  $N=48$ ) with observer-dependent and observer-independent (external) variables as explanatory variables (Figure 1). Species detectability (as the probability that a species found on the 48 summits was missed by one of the observers) was analyzed using a GLM (generalized linear model, package 'stats', model M3,  $N=252$ ) with plant characteristics as explanatory variables (Figure 1). Finally, we compared species turnover over time and pseudo-turnover between two observers with paired student's t-test. All statistical analyses were performed in R (version 2.14.1., R Development Core Team, R Foundation for Statistical Computing, Vienna, Austria).

## Results

For the 48 summits analyzed, pseudo-turnover between two contemporary botanists ranged between 0% and 33.3% with a mean of  $13.5\% \pm 7.9$  (SD). Compared to pseudo-turnover, species turnover between historical and recent records was almost three times higher ( $41.4\% \pm 16.3\%$ ;  $t_{\text{paired}} = -11.0$ ,  $df = 42$ ,  $p\text{-value} < 0.001$ ; Figure 2).

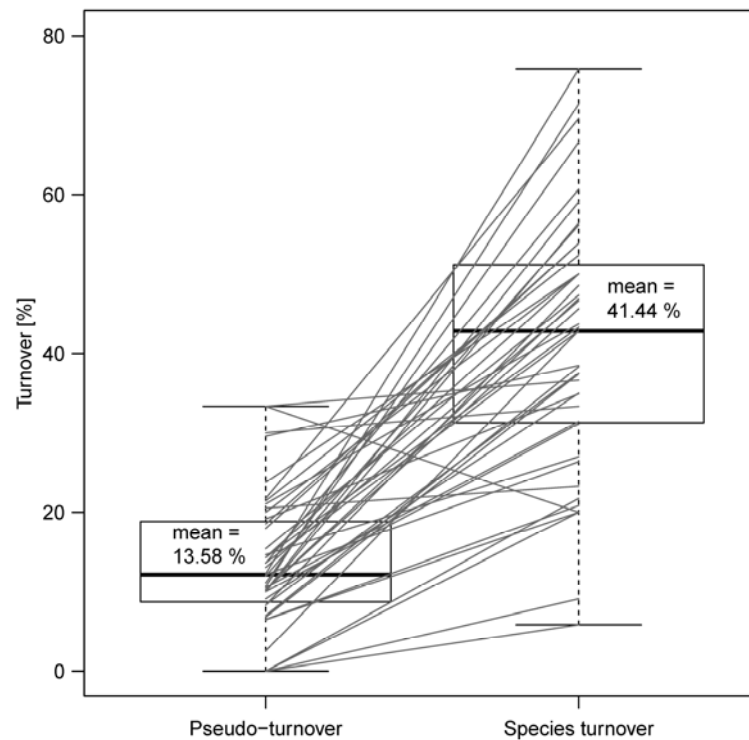


Figure 2: Pseudo-turnover and species turnover for the 48 summits that were recorded by two independent observers. Grey lines connect the same summits.

A large difference in botanizing time between observers was the major cause of a high pseudo-turnover (model M1, Figure 3a). This was confirmed in model M2 showing that more species were missed by one of the observers when difference in botanizing time was high (Figure 3d). Generally, a record took longer to complete (linear regression,  $F_{1,46}=112.4$ ,  $p < 0.001$ ) and recording time differed more between observers (linear regression,  $F_{1,46}=7.42$ ,  $p < 0.001$ ) on summits with higher species richness. A long ascent (in terms of elevational gain) increased pseudo-turnover (model M1, Figure 3b) and the number of species missed by one of the observers on a summit (model M2, Figure 3e), although a long ascent did not seem to have led to time constraints during the record, since there was no significant relationship between ascent length and botanizing time (linear regression,  $F_{1,46} = 0.19$ ,  $p = 0.66$ ) or difference in botanizing time ( $F_{1,46} = 0.56$ ,  $p = 0.46$ ). More species were missed on summits with higher species richness (model M2, Figure 3c), especially when difference in botanizing time between observers was high and the ascent was long (Figures 3d and e).

Species occurring on many mountains (with a high frequency) but with low abundance had a higher chance to be missed (model M3). The taxonomic plant group a species belongs to had a highly significant effect on the probability with which the species was missed, with a tendency that species were more often missed if they belong to Liliaceae/Orchidaceae ( $z = 2.3$ ,  $p = 0.021$ ), Asteraceae ( $z = 1.89$ ,  $p=0.058$ ), Scrophulariaceae (genus *Veronica*) ( $z = 1.76$ ,  $p=0.078$ ) or Juncaceae ( $z = 1.65$ ,  $p = 0.098$ ). Finally, species with a small minimum size had a marginally higher chance of being missed.

## Discussion

### Species turnover vs. pseudo-turnover

Although most records of previous studies were made in much smaller plots of well-defined size and in lowland grassland where vegetation is denser than in alpine terrain, pseudo-turnover in the Summit Flora Project corresponds well with the measured pseudo-turnover in those publications (NILSSON & NILSSON 1985; VITTOZ et al. 2010). Species turnover between historical and recent records is significantly higher than measured pseudo-turnover, confirming that the turnover over time cannot simply be attributed to inter-observer variability or recording protocol alone, but constitutes an ecological pattern.

### Causes of observer bias

The time invested into a record is considered a prevalent source of observer bias. Detection probability generally increases with survey effort (KÉRY et al. 2006; CHEN et al. 2009) and, crucial for many biodiversity studies, rarer species are generally found towards the end of a record (ARCHAUX et al. 2006). It is thus remarkable that in our study, the absolute duration of the record had no effect on observer bias. The absolute duration to find a certain proportion of the species present on a summit seemed to depend on characteristics of the respective summit and thus was an observer-independent variable. Difference in botanizing time, however, depended on the observers working on the mountain. Since each observer decided when the record was finished, a possible negative influence of different searching methods or botanizing technique could be more pronounced on species-rich summits, explaining the significant influence of difference in botanizing time on observer bias in combination with a high species richness.

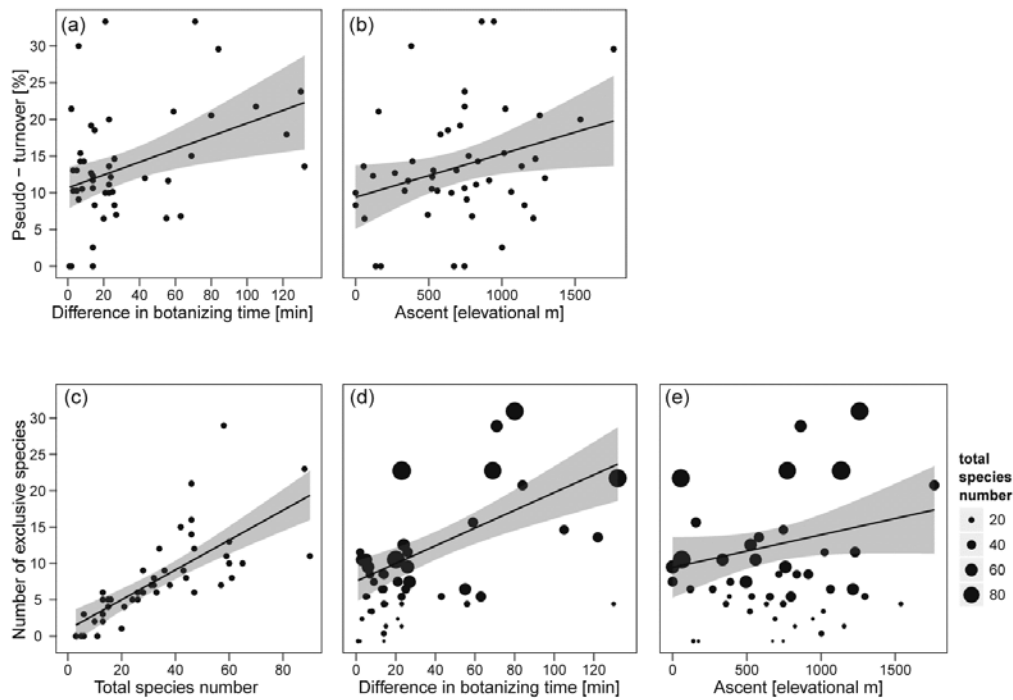


Figure 3: Model results showing significant and marginally significant variables influencing observer bias. 'total species number' refers to the total species number per summit, represented by size of the points in the plot. 95%-confidence intervals are shown in grey.

Our study is to our knowledge the first to make a connection between physical strain and quality of field data, as our data show that a longer ascent (in terms of elevational gain to reach the summit) led to a higher observer bias. Since ascent length was unrelated to altitude of a mountain, species richness, or time spent on a record (all correlations  $p > 0.1$ ), any artifacts related to species richness or time constraints could be excluded. A simple explanation is that a longer ascent is more exhausting to observers, making their record more prone to errors. It is likely that physical fitness interacts with other observer-related traits, such as experience, as experienced observers probably cope better with a long ascent or work more reliably even when tired than less trained observers. Also the finding that ascent length had a particularly large influence on record quality on summits with a high species richness, could be due to more experienced or physically fitter observers being better able to deal with a rich species composition after a strenuous ascent.

In summary, in our study, the factors with a significant influence on observer bias were observer-dependent, either directly (difference in botanizing time) or indirectly in the form of mountain characteristic that influenced observers differentially (ascent length and species number on the summit). It seems that in the alpine environment, the effect of physical and mental abilities of the observers, and how they cope with the demands of mountainous terrain can override the importance of external, observer-independent factors or environmental factors that presumably influenced all observers equally.

#### Species detectability

That frequent species have a higher chance to be overlooked by one of the observers is a simple matter of probability. In agreement with other studies (LEPS & HADINCOVA 1992; RICH & WOODRUFF 1992; KERCHER et al. 2003; VITTOZ & GUIBAN 2007) is the finding that species with a low average abundance are missed more often. As our records covered a relatively large area, and as our protocol did not prescribe to cover each possible spot of it, species that usually occur in a low abundance had matter-of-factly a higher likelihood to get missed. Since many species on our summits occur near their uppermost distribution limit, they often grow vegetatively and are rather small in stature. This inconspicuousness does not only make detection more unlikely, but could also interfere with correct species determination.

That some taxonomic plant groups were particularly often overlooked probably had to do with the reasons stated above. Orchidaceae, Liliaceae and Scrophulariaceae, for instance, often occurred as only one or few individuals per summit. While Asteraceae are a notoriously difficult group for species determination, they were also generally frequent, increasing their chance to be missed. The same may be true for Juncaceae (genus *Luzula* and *Juncus*) which were also often difficult to determine when growing vegetatively.

## Conclusions

The large data set of the Summit Flora Project and a representative subset of summits with two independent records enabled us to calculate the proportion of turnover that could be attributed to inter-observer variability. It also made it possible to find out which factors have a major influence on observer bias in the context of our study. The influence of difference in botanizing time and ascent length show that it is especially important to consider factors that are strongly dependent on the observer in such an extreme environment as alpine summits.

We recommend that issues of botanizing time should be considered closely in every study design. For studies like ours with sample sites of different area and structural complexity, no standardized time frame for the record can be pre-defined, but refined criteria on when to conclude a record could help to reduce inconsistencies between observers. Recommendations about how to deal with inconspicuous, rare and difficult taxa seem to be universally valid for all kind of vegetation studies. In the Summit Flora Project it proved to be helpful to discuss difficult and rare taxa before and during the field season and to establish determination keys for species, genera or families known to be difficult.

This study gives a new understanding of observer bias. We want to point out that most factors causing observer bias are likely to vary in importance depending on the particular environment and conditions a vegetational record is conducted in and thus have to be considered for each study anew.

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