Ecological quality in Swiss lowland meadows: does plant and invertebrate diversity correlate?

Master thesis

Faculty of Science, University of Berne

handed in by

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2018

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Ecological quality in Swiss lowland meadows: does plant and invertebrate diversity correlate?

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Abstract

Extensively-managed meadows registered under Swiss agri-environment schemes as biodiversity promotion areas (BPA) currently make up about 8% of Swiss farmland. In addition to the input-based direct payments, Swiss farmers are further rewarded for hay meadows reaching a certain level of ecological quality (Quality II, abbreviated QII), which is assessed by biodiversity indicators, namely the presence of at least six given plant species. These output-based (QII) payments are thus attributed based on an in-situ assessment of so called QII-indicators. We tested whether the reliance on the mere presence of these QII-indicators was a reliable way to assess the biodiversity quality of a meadow.

For that purpose, in 2017, we correlated the number of QII-indicators to the overall species richness of plants (exhaustive vegetation relevés) and the diversity of invertebrates in 47 extensively-managed meadows across the Swiss lowlands (Plateau). Our invertebrate assessment included species richness and abundance of orthopterans, hoverflies, butterflies, lepidopteran caterpillars, wild bees, ground beetles, rove beetles, spiders, macro-moths, parasitoid wasps, plant- and leafhoppers, and abundance of micro-moths and sawfly larvae.

The number of QII-indicators correlated positively with the botanical diversity (plant species richness), with, on average, nine more plant species in QII-meadows than in the other BPA meadows (i.e. meadows not reaching QII). Invertebrate species richness and abundance also showed positive correlations with the number of QII-indicators. Yet, these correlations were exclusively driven by herbivores (mostly Lepidoptera), whereas no such correlation existed for predatory arthropods.

We thus conclude that the binary quality system (QII vs QI) implemented within BPA meadows promotes meadow biodiversity of plants and primary consumers but fails to promote biodiversity at higher trophic levels. Additional measures seem to be necessary to favour integral food chains. From a practical viewpoint, a more refined BPA incentive system might be envisioned, which incorporates more than two levels of quality or refers to a gradient of quality instead of a simple dichotomic system.

Keywords: indicator, quality, invertebrates, semi-natural grassland, AES, output-based contribution, conservation

1. Introduction

As a response to the dramatic decline in farmland biodiversity, agri-environment schemes (AES) were implemented throughout Europe in the 1990‘s (Van Dyck et al. 2009) to encourage farmers to adopt more nature-friendly farming practices (European Communities 1985, Kleijn and Sutherland 2003). In Switzerland, the main AES instruments dedicated to conservation and restoration of biodiversity are the areas reserved for promoting biodiversity (Biodiversitätsförderflächen in German), hereafter called biodiversity promotion areas and abbreviated BPA. These areas include among other extensively managed meadows and pastures, sown wildflower strips, hedgerows and high-stem orchards. To get direct basic payments, i.e. as part of the minimum cross-compliance rules, Swiss farmers must manage at least 7% of their land as BPA (Bundesrat 2013a). The most common types of BPA are extensively managed and low intensively meadows. They represent about 75% of all BPA in Switzerland (Federal Statistical Office 2015). The management requirements for extensively managed meadows are: no fertilizer, pesticides or herbicides application and minimum one cut per year but not earlier than 15 June (Bundesrat 2013a). This input-based scheme is financially supported with the so called "Quality I" contributions (hereafter called QI). In 2016, Switzerland had ~ 50'000 ha of extensively managed meadows in the lowland (plain and hill agricultural zones) and ~ 31'800 ha in the mountains (BLW 2017). This represented ~ 81 million CHF of input-based contributions (BLW 2017). In addition to the QI contributions, extensively managed BPA meadows can be eligible for the output-based "Quality II" contributions (hereafter called QII) which reward high ecological quality meadows (Bundesrat 2013a). In 2016, ~ 32'000 ha of extensive managed meadows were registered for QII contributions, what led in total to ~ 45 million CHF expenses (BLW 2017). The definition of high quality meadows is established in Art. 59 of the ordinance for direct payment (Direktzahlungsverordnung in German. hereafter called DZV) of Switzerland, which refers to an assessment key based on the plant species growing in the meadow site (see box 1 and Appendix A7). This output-based (also known as results-based) QII system not only contributes to the maintenance of high nature value grasslands, but it also financially motivates farmers to actively restore species-poor grasslands (e.g. through reseeding).

Box 1. The creation and history of the assessment key

The assessment key was created end of 1990s by UNA (Atelier für Naturschutz und Umweltfragen) in close cooperation with Agroscope Reckenholz and Agridea and published in 2001. First an exhaustive list of plant species that could potentially indicate good ecological quality of meadows was created. The list was built by an iterative process of subjective evaluations among experts for or against a plant or plant group. Second, to reduce the number of QII-indicators "pseudospecies" groups were created, containing visually difficult distinguishable plant species with similar quality characteristics. Third, the list was tested for its ability to rank meadows according to their ecological quality (evaluated by experts beforehand) using a data sets of 1390 vegetation relevés from grasslands located all over Switzerland (687 surveys alone to quantify meadows on the Swiss plateau). To define a threshold, i.e. a minimum number of QII-indicators, which would divide grasslands in two categories, with and without quality, a "politically" intended goal was that 30% of current (in 2001) extensively managed Swiss lowland meadows would be eligible for the quality contributions. Accordingly, a threshold of minimum six QII-indicators was set for meadows to qualify as QII meadows, i.e. with ecological quality. Because of differing vegetation due to regionally varying climate two different lists were created; one to be used on meadows in the northern alpine regions and one for central and southern alpine regions (Art. 59. Annex 4 DZV). The key was tested in the field by farmers and future inspectors before its official ratification. This included controlling for the feasibility of the key and the training of participants in identifying the QII-indicators. The practicability was tested in 1999 in different cantons (BE, SG, VD) and got adjusted. To keep it practical and easy to apply also for farmers, a threshold of six plant QII-indicator species needed to be reached within a 3 m radius plot. The final QII-indicator list, for the Swiss lowlands contains 80% forbs (non-grasses) species and 20% grasses. These plants are exclusively positive indicators which only show quality without negative indicators which would indicate meadows with poor quality (Bundesrat 2013b).

In 2001, the ordinance of Eco-quality (Öko-Qualitätsverordnung in German. hereafter called ÖQV) first was published by the government with the reference to the final version of the assessment key which defined how to apply the key and the list of QII-indicators. In 2013, Article 59 DZV overrode the initial ÖQV from 2001. The instructions for applying the key are now stated in the directive to Article 59 and Annex 4 (“Weisung nach Artikel 59 und Anhang 4 der Verordnung über die Direktzahlungen an die Landwirtschaft (Direktzahlungsverordnung DZV), Extensiv genutzte Wiesen, wenig intensiv genutzte Wiesen und Streueflächen der Qualitätsstufe II“ in German, Appendix A7).

As explained in box 1, the eligibility of a meadow for the QII payments is based on a number of easy recognizable QII-indicator plant species. The use of indicators is a basic concept in conservation biology, but it relies on the presumption that the diversity of a limited number of species indicates the diversity of the full taxon and even positively correlates with the diversity of other taxa (Caro and O’Doherty 1999, Favreau et al. 2006). Plants have the advantage of being taxonomically well described, easy to identify in the field and sensitive to environmental conditions (Duelli and Obrist 1998).

Studies investigating surrogate performance of plants on animal taxa showed contrasting results. Some showed that combined multi-taxa richness correlates positive with increasing plant species (Sauberer et al. 2004, Manning et al. 2015) while in terms of abundances the correlations get weaker (Scherber et al. 2010). A more detailed look in the literature shows the importance of plant-feeding invertebrates in such multi-taxa approaches (Manning et al. 2015). In some studies herbivores species richness showed a strong positive correlation with plants (e.g. for a multitaxa herbivore group including phytophagous beetles, heteropterans, dipterans, hymenopterans, leafhoppers and orthopterans: Scherber et al. 2010; for orthopterans: Haddad et al. 2009, Marini et al. 2008; for orthopterans, hymenopterans, lepidopterans, homopterans and heteropterans: Manning et al. 2015; for lepidopterans: Niemelä and Baur 1998, Koch et al. 2013), while in others for some plant feeding groups, like orthopterans (Koch et al. 2013, Niemelä and Baur 1998) or grassland moths (Alison et al. 2017) no correlation was found. Studies analysing different taxa along the trophic cascade including studies with predators are inconsistent in their results, where some find a dilution of correlation (e.g. Jeanneret et al. 2003, Manning et al. 2015, Scherber et al. 2010, Woodcock & Pywell 2010) and even negative correlations (Koricheva et al. 2000) when others find positive correlations, e.g. with spiders and coleopterans (Haddad et al. 2009). These contrasting findings for predators might be due to different plant communities that were tested in different habitat types or experimental setups. Predatory invertebrates are often more prone to diverse habitat characteristics like heterogeneity than plant taxonomic diversity (e.g. Bell et al. 2001, Woodcock et al. 2009).

Before the regulatory approval the surrogate function of the Swiss QII-quality key got quantitatively evaluated for the assessment of vegetation quality of the meadow. However, an investigation about correlations with invertebrate diversity, thus the potential of the key to assess invertebrate quality, has never been done. The aim of this master thesis was to test if the QII-quality assessment key for meadows located in the northern Alps correlates with the biodiversity of invertebrates inhabiting these same meadows. Based on the publications cited above, we hypothesised that: (i) the number of QII-indicators correlate with the species richness of the plants on the meadow, especially with an increase in forb species and decrease of grass species; (ii) there will be an overall positive trend of invertebrate diversity following increasing QII-indicator numbers; but (iii) simultaneous there will be differences in responses between invertebrate taxa and the QII-indicators. In other words, bottom-up effects will lead to positive correlations with invertebrate herbivores while only weak to no correlations with predators. In addition, we hypothesised that the correlations displayed between plants or invertebrates and the number of QII-indicators on a continuous scale will be stronger than the biodiversity differences displayed between the two quality categories, i.e. between meadows with quality (≥ 6 QII-indicators) and without quality (< 6 QII-indicators). To answer the question and test the hypotheses, the quality assessment was performed on 47 meadows in the Swiss lowland and the relationship between number of recorded QII-indicators, and resulting quality categories, with plant and invertebrate sampled in the same meadows were analysed.

2. Material and Methods

2.1. Study sites and design

In 2010, a research team of the Division of Conservation, University of Bern, selected 48 extensively managed meadows across the Swiss Plateau for their study on the effects of different mowing regimes on plant and field invertebrates. All meadows were registered as biodiversity promotion area (BPA) since latest 2004 and were located between 390 and 833 m in altitude. The size of the meadows ranged between 0.3–1.7 ha. The minimal distance between the meadows was 440 m and they were distributed equally in 12 regions with minimum 5 km between two regions (see Buri et al. 2013 for more details). The same meadows were used for this study, except one meadow that was discarded in 2015 and three meadows that were replaced in 2016 (Appendix A1). In addition, some invertebrate groups were not sampled in every meadow, what led, for this study, to different number of meadows being analysed per species group (range N = 32–47, see Table 1).

2.2. Plant and invertebrate sampling

2.2.1. Plant

Plants were surveyed in 2015 and 2017. In 2015 two permanent vegetation plots of 2 m × 4 m were randomly placed 8 m apart in each meadow (though excluding a 10 m buffer zone around the inner edges of the meadow; see van Klink et al. 2017 for more details). In these vegetation plots all plants species and relative cover were recorded. In 2017, the Quality II assessment key was applied between beginning of May and mid-June. In homogeneous meadows (i.e. where the vegetation community seemed visually uniform on the whole meadow area) a subjectively representative area was selected and in it a plot of 6 m diameter was marked. In case of a heterogeneous meadow the area of different vegetation patches was first sketched on a map. Then in each vegetation patch a representative plot was subjectively placed. Following the official procedure (see Appendix A7), the first plot was always located in the patch with, apparently, the highest ecological quality while the second one was always located in the patch with lowest quality. If the second plot reached the threshold of six QII-indicators, no further plots needed to be sampled. In case the second plot did not reach the quality threshold all remaining patches were sampled as well. In addition to the subjective plots as dictated by the assessment key, in each meadow a random plot was added. The centre of the random plot was located between the permanent vegetation plots from the former vegetation survey in 2015 (van Klink et al. 2017) with 2 m buffer to the former plot edge. Nomenclature followed the Flora Helvetica (Lauber et al. 2012).

2.2.2. Orthopteran

Two orthopteran sampling sessions took place in 2017: the first in July and the second in August. The sampling was carried out on sunny days between 9 am and 6 pm. Orthopteran density was measured with a biocenometer following the method described in Buri et al. (2013). The biocenometer is a bottomless cylinder made of a rigid net with a total capture area of 1 m². On each meadow the biocenometer was used 16 times along 2 to 4 parallel transects with a minimum distance of 10 m. A 10 m buffer around the meadow edge was excluded to minimize the edge effects (Knop et al. 2006). Within the biocenometer all individuals got caught, identified, counted and immediately released. Adults were identified up to the species level and juveniles classified into their suborders (Ensifera, Califera). To gain a full picture of the species living in the meadow a qualitative visual and acoustic survey of at least 30 min for one person respectively 2 x 15 min for two persons was additionally performed. The species richness per meadow included the biocenometer data and the species found during the qualitative survey.

2.2.3. Other invertebrate groups

Two full plant surveys took place in 2010 and 2015 (see *Plant survey* section above). Over these five years the vegetation composition and species richness did not significantly change (van Klink et al. 2017). The stable vegetation composition gives evidence that the QII-indicators have not change over the years too. This gives the opportunity to analyse the data of all species groups sampled over the last five years on the same meadows (Table 1) with the QII-indicators sampled in 2017. The sampled invertebrate species groups included orthopterans, hoverflies, butterflies, lepidopteran caterpillars, sawfly larvae, wild bees, ground beetles, rove beetles, spiders, moths, parasitoid wasps, plant- and leafhoppers.

Data for butterflies were sampled along diagonal transects through the centre of the meadow (Bruppacher et al. 2016). Spiders, plant - and leafhoppers were caught with a suction sampler covering 1 m² (5 x 2000 cm^2) of the meadow (Buri et al. 2016). Hoverflies (Diptera: Syrphidae) and wild bees (Hymenoptera: Apoidea: Anthophila) were sampled with three pan trap sets (set of three pan traps in yellow, white and blue attached to wooden poles) per meadow (Meyer et al. 2017).

Ground beetles and rove beetles were sampled during two weeks with four pitfall traps (Ø 9 cm) per meadow. They were installed 10 m apart in a square around the random metal pin and emptied once a week. Parasitoid wasps were collected on two randomly located 25-m transects with 30 sweep netting strokes. Lepidoptera and Hymenoptera caterpillars were caught along predefined 60-m transects diagonal through the meadow with 120 sweep netting strokes. Species richness and abundance was calculated for lepidopteran caterpillars and only abundance for sawfly caterpillars. Adult moths (night active lepidopteran) were sampled with light traps stationed in the centre of the meadow at 1.6 m above the ground. The lights were lit at nightfall for five hours. Species richness and abundance was calculated for macro-moths and only abundance for micro-moths.

In case of more than one year of sampling per species group the data of the last sample year was used for this study. For more information to the methodology please see the references provided in Table 1.

2.3. Statistical analysis

As direct effects of the mowing event on invertebrates were shown by other studies (e.g. Humbert et al. 2012, Buri et al. 2013, Buri et al. 2016, Bruppacher et al. 2016) for all taxa only abundance data before the 15th June, i.e. before the earliest allowed mowing date on extensively managed meadows, were used. In case of more than one sampling before that date, the sessions were merged to a mean. Orthopteran abundance as exception was analysed after one mowing event. Butterfly abundance were standardized to 100-m transect lengths. No standardization was applied to butterfly species richness as number of species reached an asymptote within the range of sampled transects (Bruppacher et al. 2016). Invertebrate species richness was pooled over the entire year of sampling to gain a full picture of the species living in the meadow and being able to exclude mismatches in sampling dates and the different life history traits of organisms.

To get a value for the total invertebrate biodiversity in the meadow we used the multidiversity-index of Allan et al. (2014). It creates standardized species richness values between 0 and 1 for each invertebrate group by scaling them to the maximal observed value across all meadows. Each taxon has given the same weight, independent of the number of species that taxon has. A simple sum of the species richness values would have given higher weight to groups with higher species richness. The concept of the multidiversity-index can also be used for abundance data. It is a scaled metric for total number of individuals independent of the total abundance (van Klink et al. in prep.). Differences among predatory and herbivorous taxa were tested by grouping the invertebrates with the same trophic level and create separate scores for multidiversity and multiabundance (Table 1).

Number of QII-indicators were analysed in relation to plant species richness and plant functional groups cover, as well as species richness and abundance of the single invertebrate groups and multi-indices. The relationships were tested with generalized linear mixed models GLMM using lmer() and glmer() of the lme4 package (Bates et al. 2015). “Region” and “mowing regime” were included as random effect variables. Number of QII-indicators were either the exact number of QII-indicators found in the randomly placed plot or the weighted mean of the subjectively placed plots. For a standardized and representative QII-indicator weighted mean per meadow the subjective vegetation patches were merged together according the proportion of the associated patch within the whole meadow. In addition, since the financial QII contributions are granted for meadows with ≥ 6 QII-indicators the model was analysed for the binary quality system separately, by qualifying the QII-indicator numbers into the two categories of quality (with ≥ 6 QII-indicators) and no quality (with < 6 QII-indicators). P-values were obtained using lmerTest() package (Kuznetsova et al. 2017). Marginal and conditional R^2 were calculated with r.squaredGLMM () of the MuMIn package (Barton 2017) for Gaussian distribution and with sem.model.fits() of the piecewiseSEM package (Lefcheck 2015) for Poisson distributed models, to show the goodness of the model fit. The marginal R^2 represents the variance explained by the fixed, whereas the conditional R^2 represents the variance explained by the fixed and the random effect (Nakagawa & Schielzeth 2013). A Gaussian error distribution was used for multidiversity and multiabundance and invertebrate species richness. For invertebrate abundance, depending on the group Poisson distribution was used and to improve the fitting of the model, shown by the residuals, log transformations were applied. Quadratic functions were tested for all groups, but no model showed a better performance with more than Δ AIC < 2.

Redundancy analyses (RDA) were performed to gain insight in direct interactions of invertebrate groups with single QII-indicators and interactions of QII-indicators among themselves. The RDA is a direct gradient analysis that estimates how much variation of the response variable can be explained by the environmental variables (Paliy & Shankar 2016). It indicates the importance of certain environmental factors explaining the distribution of the species. With this analysis we tried to see if single QII-indicators can explain the variance in invertebrate response. RDA cannot deal with binary data like presence/absence of indicators as environmental variables. It was needed to convert the data into dummy variables, where 1 stands for presence and 0 for absence of an QII-indicator (Legendre & Legendre 1998). The RDA was performed with the ten most frequently encountered QII-indicators. *Anthoxanthum odoratum* (on 70% of the meadows) and the pseudogroup of Asteracea with many flower heads (70%) were the most frequent QII-indicators followed by *Leucanthemum vulgare* (39%), *Centaurea jacea* (39%), *Rhinanthus* spp. (39%), *Tragopogon pratensis* (33%), *Medicago lupulina* (28%), *Helictotrichon pubescens* (23%), *Bromus erectus* (23%) and the pseudogroup of *Knautia* spp. and *Scabiosa* spp. (23%). In average these QII-indicators represent 80% of all QII-indicators occurring in the meadows. The ten QII-indicators are used as environmental variables. The response variables were either species richness or abundance of all invertebrate groups. To keep the abundance data comparable among the groups a transformation was performed to scale all data to the maximum abundance that occurred in the meadows. The scaled abundance had then a range from 0-1. The significance of the model and the canonical axes were calculated with an anova-like permutation test anova.cca() with 999 permutations. The biplot was plotted in scaling = 2 to show correlations among the QII-indicators and invertebrate groups but also among QII-indicators themselves (Ramette 2007). All analyses were performed with R statistical software R version 3.2.2 (R Core Team 2015).

3. Results

Out of the 47 sampled meadows 24 reached at least partly the quality threshold (Appendix A1). 18% of the total meadow area achieved quality. All together we found 31 out of the 47 potential QII-indicator plant species (Appendix A2). The number of QII-indicators ranged from 0 to 18 in the subjectively chosen plots and from 0 to 15 in the random plots (Fig. 1). Comparing the number of QII-indicators of the random plot with the weighted mean calculated out of all subjectively chosen plots showed a strong correlation (marginal $R^2 = 0.79$, conditional $R^2 = 0.827$, $P < 0.001$, Fig. 2).

The following results were all calculated with the QII-indicator values in the random plot as explanatory variable and are presented in detail in Table 2 for species richness and Table 3 for abundance. The detailed graphical output per single species group can be found in Appendix A3 for species richness and Appendix A4 for abundance.

Plant species richness positively correlated with increasing QII-indicator numbers. There were, on average, nine more plant species in meadows with quality (mean ± standard deviation SD = 34.5 ± 6.2) compared to meadows without quality (25.1 ± 4.8; Fig. 3b). Cover of grass negatively correlated with number of QII-indicators, while the opposite trend was found for forb (all non-grasses; Fig. 3c). The mean forb cover was almost double as high in quality meadows (62.3 % ± 23.1) compared to no-quality meadows (34.2 % ± 19.3). Meanwhile, grass cover decreased about almost one third from no-quality meadows (89.9 % ± 29.6) to 64.5 % ± 25.9 in quality meadows (Fig. 3d).

Multidiversity of all invertebrates significantly increased with the number of QII-indicators (Fig. 4a). The multidiversity of the herbivorous feeding guild showed a strong positive relationship with the QII-indicator gradient (Fig. 4c), whereas predators did not correlate significantly (Fig. 4e). Though, comparing meadows with and without quality no differences for the multidiversity of all invertebrates was found (no quality = 0.55 ± 0.10; quality = 0.61 ± 0.09, Fig. 4b). Herbivores and pollinators still showed a significant difference between quality categories (no quality = 0.54 ± 0.11, quality = 0.62 ± 0.12, $P = 0.04$, Fig. 4d) and no difference was detected for multidiversity of predators (no quality = 0.53 ± 0.12; quality = 0.57 ± 0.10, $P = 0.99$, Fig. 4f). Multiabundance of all invertebrates positively correlated with the number of QII-indicators ($P = 0.003$, Fig. 5a). A similar relationship was found for the herbivores ($P = 0.009$, Fig. 5c), though not for predators ($P = 0.174$, Fig. 5e). All multiabundance indices (overall, herbivorous, predatory) showed no difference between the quality categories of the assessment-key (Fig. 5b, 5d and 5f).

In more detail the single species groups showed no or positive correlations with species richness but never negative correlations with the number of QII-indicators. Positive correlations were demonstrated for adult moths and butterflies, their caterpillars and parasitoid wasps. No correlations were shown with orthopterans, wild bees, hoverflies, spiders, plant- and leafhoppers and ground and rove beetles. In terms of abundance butterflies and caterpillars of lepidopterans showed significant positive relationships with the QII-indicator number, whereas hymenopteran caterpillars correlated significantly negative. No correlations were shown with orthopterans, wild bees, parasitoid wasps, moths, hoverflies, spiders, plant- and leafhoppers and ground and rove beetles abundance. The relationships with the quality category were similar to the results above with the QII-indicators gradient, but with decreased statistical power. Rove beetles as an exception had an increase in statistical power and showed a significant negative correlation towards quality meadows. Against expectation no correlation with plant- and leafhoppers and wild bees was found, so further analyses were performed with the overall plant species richness on the meadows (statistical analyses and graphical output in Appendix A6). Analysed with the full vegetation releveé wild bee species richness positively correlated with the overall plant species richness (marginal $R^2 = 0.142$, conditional $R^2 = 0.436$, $P = 0.014$), while their abundance did not show a correlation (marginal $R^2 = 0.001$, conditional $R^2 = 0.511$, $P = 0.834$). Plant- and leafhoppers species richness (marginal $R^2 = 0.097$, conditional $R^2 = 0.159$, $P = 0.075$) and abundance (marginal $R^2 = 0.094$, conditional $R^2 = 0.358$, $P = 0.071$) related marginally positive with the entire plant richness.

The RDA model was calculated with the ten most common QII-indicator plant (or plant group) species. The graphical output can be found in the Appendix A5. The model on species richness was significant ($P = 0.007$) when 33 % of the invertebrate variance was explained by the QII-indicators. Only the first axis was significant and explained 17% of variance ($P = 0.005$). Moths, butterflies and wild bees tend to show a correlation along the first axis, like almost all ten QII-indicators. Among the QII-indicators it is visible that *A. odoratum* is negatively correlated with the other variables. In 44 out of 47 meadows *A. odoratum* was present in the meadow vegetation (19/19 in quality meadows and 25/28 in no quality meadows*)* but only 35 random plots (16/19 in quality meadows and 19/28 in no quality meadows*)* captured the species. The RDA model on invertebrate abundance with the ten most frequent QII-indicators was not significant (*P* = 0.138).

4. Discussion

Ecological quality is a result-based reward for farmers that reach floral quality on Swiss grasslands. The contribution is based on the presence of minimum six defined QII-indicators. As expected, plant species richness and cover of non-grass plants increased with the quality category and thus with the number of QII-indicators. So far it was assumed that meadows with QII-quality would also harbour more invertebrate diversity than meadows without quality. In this regard, we found a positive relation between the species richness of herbivorous invertebrates, especially lepidopterans and the QII-quality key, but no further evidence for a relationship with invertebrates' diversity and abundance. However, on a continuous scale, the number of QII-indicators correlate well with the species richness and abundance of invertebrates herbivores especially with adult and juvenile butterflies and moths. Predators did not show a relationship with the QII-indicators.

The following discussion starts with two subsections on the relative performance of the number of QII-indicators and the quality category to plants (4.1) and invertebrates (4.2), with separated correlations for herbivores (4.2.1) and predators (4.2.2). It is followed by a short discussion comparing the performance of the quality category with the number of QII-indicators on a continuous scale (4.3). Finally, a conclusions and policy implications subsection (4.4) closes the discussion.

4.1. QII-indicators and plants

The main objective of the key was to quickly identify meadows with high ecological quality, represented by high plant species richness. The results demonstrate that the QII-indicators, as well as the quality category successfully perform as assessment tool for the entire plant species richness. With an increase of QII-indicators from 0 to 15 the plant species richness doubled (from 22 to 41 species) while the mean differences from no quality to quality meadows were nine species (from 25 to 34 species). The vegetation showed a shift from grass dominated compositions in meadows without quality towards a more balanced community in quality meadows. Along the surveyed range of QII-indicators (from 0 to 15) forb cover almost doubled (from 37% to 58%), while grass cover decreased by almost one third (from 87% to 68%). This goes in line with Grimes (1973) theory, that extensive management can suppress tall growing grasses and by that create more open space for smaller more stress-tolerant forb species to persist (Marini et al. 2008).

The RDA output though should be interpreted with caution because of the insignificance of the second and all ongoing axis (Legendre et al. 2011). The presence of *A. odoratum* was independent of the quality of the meadow (also see Kaiser et al. 2010) with 100% in quality meadows but at the same time 90% in non-quality meadows. Therefore, to determine QII meadows within the range of established extensive meadows this species is not a crucial QII-indicator.

4.2. QII-indicators and invertebrates

Invertebrate multidiversity and multiabundance (including all groups) showed significant positive relationships with the number of QII-indicators. The multi-invertebrate correlation patterns were mainly driven by nectar and pollen feeding groups while generalist predators did not respond to the QII-indicators.

4.2.1. QII-indicators and herbivores

Invertebrate herbivores correlated well with the number of QII-indicators sampled per plot. This finding confirms the often-reported positive relationship between herbivores and plant diversity (e.g. Koch et al. 2013, Haddad et al. 2009, Woodcock et al. 2009). Direct positive relationships appeared between QII-indicators and lepidopteran larvae and adults. This can be explained by the direct bottom-up effects by the plants on primary consumers, especially on plant-specialized species (Hutchinson 1959). For host-specialized species a higher plant richness, as expressed by increasing QII-indicators expands the likelihood of a plant composition to contain a particular host plant (Haddad et al. 2009). However not all specialized herbivores positively correlated with the QII-indicators, for example plant- and leafhoppers (70% of the species were mono- or oligophagous in our meadows) showed no correlation. The QII-indicators could not capture the diversity and abundance of the mainly grass specialized plant- and leafhoppers (Buri et al. 2016). Although the grass density on QII meadows was reduced about one third compared to meadows without quality, the 60% grass cover in quality meadows seemed to present still enough resources for the plant- and leafhoppers to not show negative interactions with the QII-indicators. The orthopterans showed as expected no correlation neither with species richness, as the study only includes the extensive range of meadows nor their abundance with the QII-indicators (but see Marini et al. 2008). Their independence from particular plant species as food source, as they are predominantly generalist plant tissue feeders, allows their presence also in less species rich meadows (Hochkirch et al. 2016). The abundance of sawfly (Hymenoptera: *Symphyta)* larvae on the other hand correlated negatively with the QII-indicators and the quality category. The diversity and with that the information about their ecological niches or requirements is unknown, as the individuals were not identified.

Pollinators and nectar feeders like hoverflies, wild bees and lepidopterans are mostly categorized as generalists (e.g. Lebeau et al. 2017, Sutter et al. 2017, Uyttenbroeck et al. 2017). Despite their dependence on flowering plants no correlations were found with the number of QII-indicators (except for lepidopteran adults and caterpillars as stated above). Wild bees and hoverflies did not show a connection with the QII-indicators. Broadening the analysis to the entire plant species richness on the meadow, enabled the detection of the assumed positive correlation of wild bee species richness with plants species richness (Appendix A6). The discrepancy of the results between wild bees with the QII-indicators and wild bees with the total plant diversity demonstrates that the plant species considered in the assessment key do not represent the nectar and pollen requirements and preferences of the wild bees. It has already been shown which plants are preferred by wild and rare bee species (Sutter et al. 2017) and these favoured flowers included only partly some QII-indicators. Hence, to reflect wild bee species richness with the QII-key an extension with bee preference flowers could help to improve the assessment of the meadows, but further investigations are needed. Additionally, to have a significant impact on the wild bee abundance, the inclusion of further plant species alone will not be enough, since for strengthening the wild bee abundance, the quantity and temporal heterogeneity of nectar provision must increase simultaneous (Meyer et al. 2017).

4.2.2. QII-indicators and predators

As expected, predators did not show any correlation with the QII-indicators. Earlier studies found that predators are more determinate by structural heterogeneity than taxonomical vegetation richness (Andrey et al. 2014, Woodcock et al. 2009, Birkhofer et al. 2015). The bottom-up effect of taxonomical vegetation richness along the trophic cascade dilutes with increasing levels between producer and consumer and creates a lack of direct dependence of predators on the plants (Scherber et. al 2010, Haddad et al. 2009). Surprisingly, rove beetles showed for both species richness and abundance negative correlations with the quality category. This result did not go in line with the scarce literature, where predatory beetles show no correlation in diversity and abundance with changing plant species richness (Koricheva et al. 2000, Scohier and Dumont 2012). Parasitoid wasps as a special case showed increasing species richness with the number of QII-indicators. This specialized group is strongly dependent on their hosts. Consequently, parasitoid wasps are indirectly reflected by the QII-indicator plants if their hosts are positive correlated with it (Anderson et al. 2010, van Klink et al. in prep.).

4.3. QII-indicator gradient vs. QII quality category

In addition to the analyses on the continuous scale, the relationships between plant or invertebrate diversity (species richness and abundance) and QII-indicators were analysed on a categorical scale. In other words, we tested if the diversity recorded on meadows with QII-quality (i.e. with 6 ≥ QII-indicators) was significantly different than the diversity in meadows without QII-quality. The correlations of the total plant diversity and abundance with the QII-indicators showed similar results between the categorical and continuous scale. However, the invertebrate diversity showed statistically weaker differences for multidiversity of herbivores with the quality categories than with the continuous scale. Differences in the overall invertebrate multidiversity and -abundance were not detectable with the categorical scale, whereas the increasing number of QII-indicators did capture positive correlations.

For the QII-keys' initial purpose, the quick quality assessment of grassland vegetation, the quality category works successfully. However, using the key with the threshold, for describing the quality of invertebrates in the meadow is not efficient. The subdivision of quality in a binary system led for the arthropod community to less precise differences, compared to a continuous use of the QII-indicators as a gradient.

4.4. Conclusions and policy implications

Overall, the study provides clear evidence that the expert-based QII-quality key is an efficient tool for assessing the ecological quality of the BPA meadows vegetation, whereas a direct takeover of the key for assessing grassland invertebrates is not recommended. Invertebrate species richness differences between the quality categories were only detected for adult butterflies, adult macro-moths, rove beetles and parasitoid wasps (4 groups among 11 analysed). In terms of abundance the key is even less effective, as it only captures different abundances of butterflies and lepidopteran caterpillars. However, analyses with the total number of QII-indicators (continuous scale) revealed positive correlations with insect multidiversity especially of herbivorous insects. Invertebrate predators did not show any correlations with neither the categorical key nor the continuous number of QII-indicators. Based on these findings it is not recommended to use the official QII-quality key as assessment tool for invertebrate diversity in BPA grasslands on the Swiss plateau. One option to oppose this deficit could be a subdivision of the current categorical contribution system into several thresholds. This concept is underpinned by the results of this study which showed positive correlations with continuously increasing QII-indicators when the currently used dual categorical system was not able to detect differences in invertebrate diversity. Besides the benefits for the invertebrate diversity a reward on a continuous scale could allow farmers of QI meadows with low QII-indicator numbers to compensate their loss in QI contributions with a first step towards more diverse meadows, while farmers of current QII meadows would have an incentive to reach a next contribution level. However, to define where to set these threshold further investigations with a bigger sample size (data from more meadows) are needed. For some invertebrate species groups the QII-indicator plants are not able to represent their diversity directly as they react on other environmental variables. Species-specific extensions of the key with focus on preferred environmental factors could support the valuation of meadow quality.

5. Acknowledgement

I would first like to thank my thesis advisor PD Dr Jean-Yves Humbert of the Conservation Biology group at University of Berne. PD Dr Humbert helped whenever I ran into trouble, had questions or even when I ran short in help for the fieldwork. In a very nice working atmosphere he allowed the thesis to be my own work, with little steering in the right directions when needed.

I would also like to thank all my helpers in the field that made this project possible in the first place: Nora Rieder, Roman Roth, Yasemin Kurtogullari, Juliette Hayoz and Cristian Fernandes Teiga. Without their spontaneous helpfulness for participating in my fieldwork the survey sessions would probably not have been finished in time. With that I as well want to thank all farmers for their cooperation and their willingness to provide their fields for research.

A special thank goes to Markus Krähenbühl from the LANAT in Berne for his introduction to the practice of applying the quality key in the field and Christian Hedinger from UNA in Berne for his help and personal insights while studying the creation of the quality key.

I would also like to acknowledge Prof. Raphaël Arlettaz the head of the Conservation Biology group at University Berne and I am grateful for his valuable comments on this thesis in various group meetings. With that I want to thank the entire CB group for their constructive inputs and the lovely ambiance during my time there.

Finally, I want to express my gratitude to my family for providing me with unfailing support and continuous encouragement throughout my years of study and through the process of researching and writing this thesis. This accomplishment would not have been possible without them.

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Table 1. List of invertebrate groups included in this study. Not all taxa were identified to species level what led to different analysed parameters per species group (abbreviations are ab = abundance, fr = family richness and sr = species richness). The feeding guild indicates the group in which the respective taxon was included in the multidiversity and multiabundance analyses. Year refers to the sampling year. Numbers of sampled meadows differ per invertebrate group as some groups were not sampled on all meadows. References about already published work on the listed invertebrate data are provided in the last column.

Taxa	Parameter	Feeding guild	Year	N	N quality	N no quality	Reference
Orthopterans	sr, ab	Herbivore	2017	47	19	28	
Rove beetles	sr, ab	Predator	2015	44	18	26	Van Klink et al. in prep.
Ground beetles	sr, ab	Predator	2015	44	18	26	Van Klink et al. in prep.
Caterpillar lepidopterans	sr, ab	Herbivore	2015	44	18	26	Van Klink et al. in prep.
Caterpillars sawflies	ab	Herbivore	2015	44	18	26	Van Klink et al. in prep.
Wild bees	sr, ab	Herbivore	2015	36	14	21	Meyer et al. 2017
Hoverflies	sr, ab	Herbivore	2014	32	13	19	Meyer et al. 2017
Macro-moths	sr, ab	Herbivore	2014	44	18	26	Van Klink et al. in prep.
Micro-moths	ab	Herbivore	2014	44	18	26	Van Klink et al. in prep.
Parasitoid wasps	fr, ab	Predator	2014	44	18	26	Van Klink et al. in prep.
Butterflies	sr, ab	Herbivore	2013	32	13	19	Bruppacher et al. 2016
Spiders	sr, ab	Predator	2012	44	18	26	Buri et al. 2016
Plant- & Leafhoppers	sr, ab	Herbivore	2012	32	13	19	Buri et al. 2016

Table 2. Output of linear mixed effects models with invertebrate and overall plant species richness in relation to (a) the QII-indicator gradient (continuous variable with number of QII-indicators) and to (b) the quality category (yes/no binary variable). Meadows with quality had ≥ 6 QII-indicators while meadows without had less than 6 QII-indicators. Marginal (mar) and conditional (cond) R^2 were computed with a Pearsons correlation coefficient. Multidiversity of herbivores includes pollinators and nectar feeders; multidiversity of predators includes the parasitoids wasps (see table 1).

Response variable	**Slope**	**SE**	**p-value**	**cond R2**	**mar R2**	**Quality mean ±SD**	**No quality mean ±SD**
(a) QII-indicator gradient							
Plants	1.29	0.194	**< 0.001**	0.495	0.492		
Orthopterans	0.04	0.064	0.529	0.136	0.003		
Wildbees	0.22	0.178	0.224	0.239	0.046		
Hoverflies	-0.01	0.09	0.932	0.576	0.006		
Butterflies	0.716	0.145	**< 0.001**	0.747	0.409		
Caterpillar lepidopteran	0.208	0.081	**0.014**	0.394	0.141		
Parasitoid wasp	0.288	0.08	**0.001**	0.37	0.23		
Spiders	0.055	0.182	0.765	0.348	0.002		
Plant- & leafhoppers	0.216	0.161	0.193	0.126	0.055		
Ground beetles	0.03	0.176	0.865	0.116	0.001		
Rove beetles	-0.33	0.204	0.115	0.322	0.061		
Moths	0.921	0.24	**< 0.001**	0.688	0.29		
Multidiversity	0.01	0.004	**0.006**	0.671	0.199		
Multidiversity of herbivores	0.015	0.004	**< 0.001**	0.698	0.315		
Multidiversity of predators	0.001	0.005	0.801	0.487	0.005		
(b) Quality category							
Plants	9.4	1.614	**< 0.001**			34.58 ± 6.24	25.18 ± 4.82
Orthopterans	0.002	0.498	0.997			5.53 ± 1.93	5.71 ± 1.44
Wildbees	1.169	1.442	0.424			11.5 ± 3.86	10.05 ± 4.13
Hoverflies	-0.28	0.709	0.7			6.38 ± 2.33	6.95 ± 2.11
Butterflies	4.717	1.253	**< 0.001**			12.0 ± 3.81	7.71 ± 3.51
Caterpillar lepidopteran	1.223	0.634	0.061			2.94 ± 2.24	1.5 ± 1.71
Parasitoid wasps	1.39	0.68	**0.048**			12.17 ± 1.5	10.39 ± 2.44
Spiders	-0.25	0.745	0.744			9.29 ± 2.73	9.22 ± 2.22
Plant- & leafhoppers	0.283	1.336	0.834			12.54 ± 2.79	12.43 ± 4.07
Ground beetles	-0.2	0.937	0.834			9.03 ± 3.08	9.17 ± 3.10
Rove beetles	-3.71	1.541	**0.021**			11.55 ± 4.29	13.79 ± 5.20
Macro-moths	6.563	2.084	**0.003**			23.78 ± 9.68	19.21 ±7.17
Multidiversity	0.051	0.032	0.126			0.61 ± 0.09	0.55 ± 0.10
Multidiversity of herbivores	0.089	0.04	**0.035**			0.62 ±0.13	0.54 ± 0.11
Multidiversity of predators	0.001	0.041	0.987			0.57 ± 0.11	0.53 ± 0.12

Table 3. Output of linear mixed effects models with invertebrate abundance and plant cover in relation to (a) the QII-indicator gradient (continuous variable with number of QII-indicators) and to (b) the quality category (yes/no binary variable). Meadows with quality had ≥ 6 QII-indicators while meadows without had less than six QII-indicators. Marginal (mar) and conditional (cond) R^2 were computed with a Pearsons correlation Coefficient. Distribution shows the used distributions with either Gaussian error distribution (G) or Poisson distribution (P), further transformations of the response variables are marked by "log" for logarithmic transformations.

Response variable	Distribution	Slope	SE	p-value	cond. R2	mar R2	Quality mean ±SD	No quality mean ±SD
(a) QII-indicator gradient								
Grass cover	G	-2.955	0.789	< 0.001	0.234	0.234		
Forb (non-grass) cover	G	3.100	0.844	< 0.001	0.227	0.227		
Orthopterans	P	0.002	0.015	0.874	0.892	0.000		
Wildbees	P	-0.025	0.019	0.203	0.747	0.020		
Hoverflies (log)	G	-0.009	0.023	0.705	0.154	0.005		
Butterflies	G	0.149	0.039	**< 0.001**	0.545	0.269		
Caterpillar lepidopteran	G (log)	0.144	0.035	**< 0.001**	0.566	0.282		
Caterpillar sawflies	P	-0.124	0.028	**< 0.001**	0.827	0.230		
Parasitoid wasps	G (log)	0.067	0.034	0.058	0.375	0.056		
Spiders	G	-0.176	0.256	0.494	0.323	0.011		
Plant- & leafhoppers	G (log)	0.045	0.031	0.152	0.5	0.058		
Ground beetles	G (log)	-0.004	0.032	0.912	0.326	0.000		
Rove beetles	G (log)	-0.052	0.028	0.076	0.123	0.077		
Micro-moths	G (log)	0.074	0.039	0.068	0.726	0.049		
Macro-moths	G (log)	0.047	0.029	0.111	0.553	0.053		
Multiabundance	G	0.011	0.003	**0.003**	0.579	0.256		
Multiabundance of herbivores	G	0.009	0.003	**0.009**	0.48	0.214		
Multiabundance of predators	G	-0.008	0.006	0.174	0.459	0.053		
(b) Quality category								
Grass cover	G	-25.42	5.934	**< 0.001**			64.45 ± 25.85	89.87 ± 14.79
Forb (non-grass) cover	G	28.127	6.216	**< 0.001**			62.29 ± 23.13	34.16 ± 19.29
Orthopterans	P	-0.06	0.111	0.589			19.78 ± 13.17	19.54 ± 19.89
Wild bees	G	-2.374	2.153	0.281			9.14 ± 7.07	8.71 ± 7.66
Hoverflies (log)	G	-0.046	0.519	0.931			1.65 ± 1.45	1.74 ± 1.34
Butterflies	G	0.888	0.363	**0.021**			2.14 ± 1.11	1.33 ± 0.92
Caterpillar lepidopteran	G (log)	0.814	0.284	**0.007**			8.44 ± 12.46	2.39 ± 3.35
Caterpillar sawflies	G (log)	-0.851	0.26	**0.002**			2.94 ± 2.24	1.5 ± 1.71
Parasitoid wasps	G (log)	0.146	0.281	0.608			77.44 ± 54.49	117.29 ± 136.84
Spiders	G	0.027	1.975	0.989			11.44 ± 7.97	10.93 ± 4.97
Plant- & leafhoppers	G (log)	0.118	0.246	0.635			100.92 ± 74.24	101.71 ± 69.58

Response variable	Distribution	Slope	SE	p-value	cond. R2	mar R2	Quality mean ±SD	No quality mean ±SD
Ground beetles	G (log)	-0.094	0.248	0.708			46.95 ± 58.53	39.90 ± 28.73
Rove beetles	G	-29.83	13.03	**0.027**			48.28 ± 36.99	66.26 ± 47.83
Micro-moths	G	4.754	8.51	0.58			19.17 ± 43.50	7.5 ± 11.24
Macro-moths	G	9.176	5.546	0.108			39.5 ± 32.99	31.86 ± 28.04
Multiabundance	G	0.05	0.029	0.095			0.30 ± 0.08	0.25 ± 0.08
Multiabundance of herbivores	G	0.043	0.027	0.127			0.28 ± 0.07	0.23 ± 0.08
Multiabundance of predators	G	-0.059	0.044	0.186			0.27 ± 0.13	0.31 ± 0.13

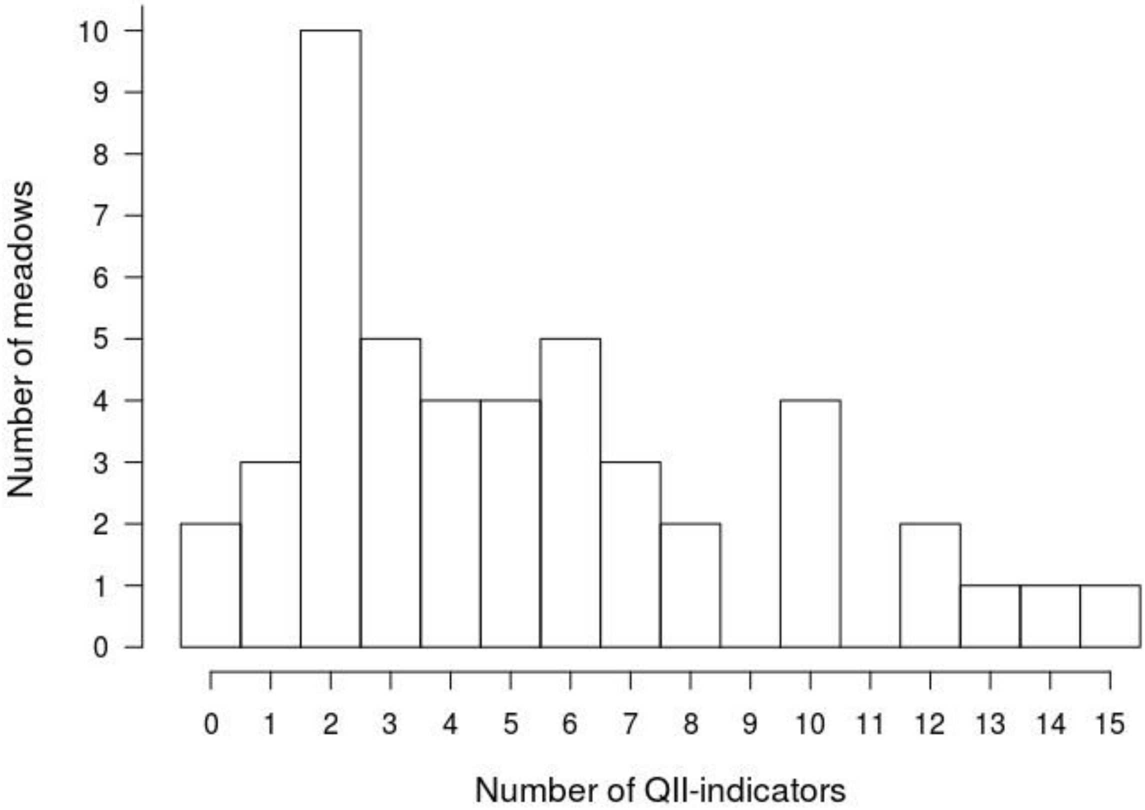


Figure 1. Histogram with the number of plant or plant group QII-indicators per meadow (value from the random plot). 28 random plots contained less than six QII-indicators while 19 meadows contained six or more than six QII-indicators.

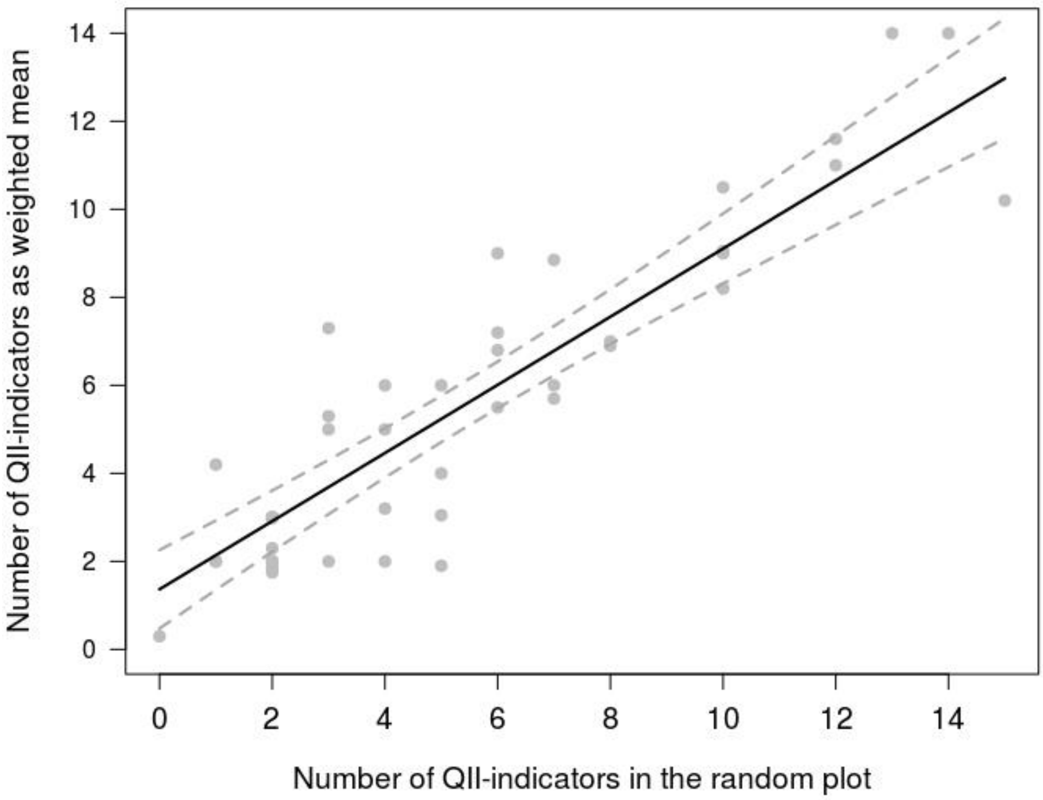


Figure 2. Correlation between the number of QII-indicators as the exact number of QII-indicators found in the randomly placed plot and the weighted mean of the subjectively placed plots. For the weighted mean the number of QII-indicators per subjective vegetation plot were merged together, as a weighted mean according the proportion of the associated patch within the whole meadow. GLMM prediction (black line) and its 95% confidence intervals (within the grey dashed lines) are shown.

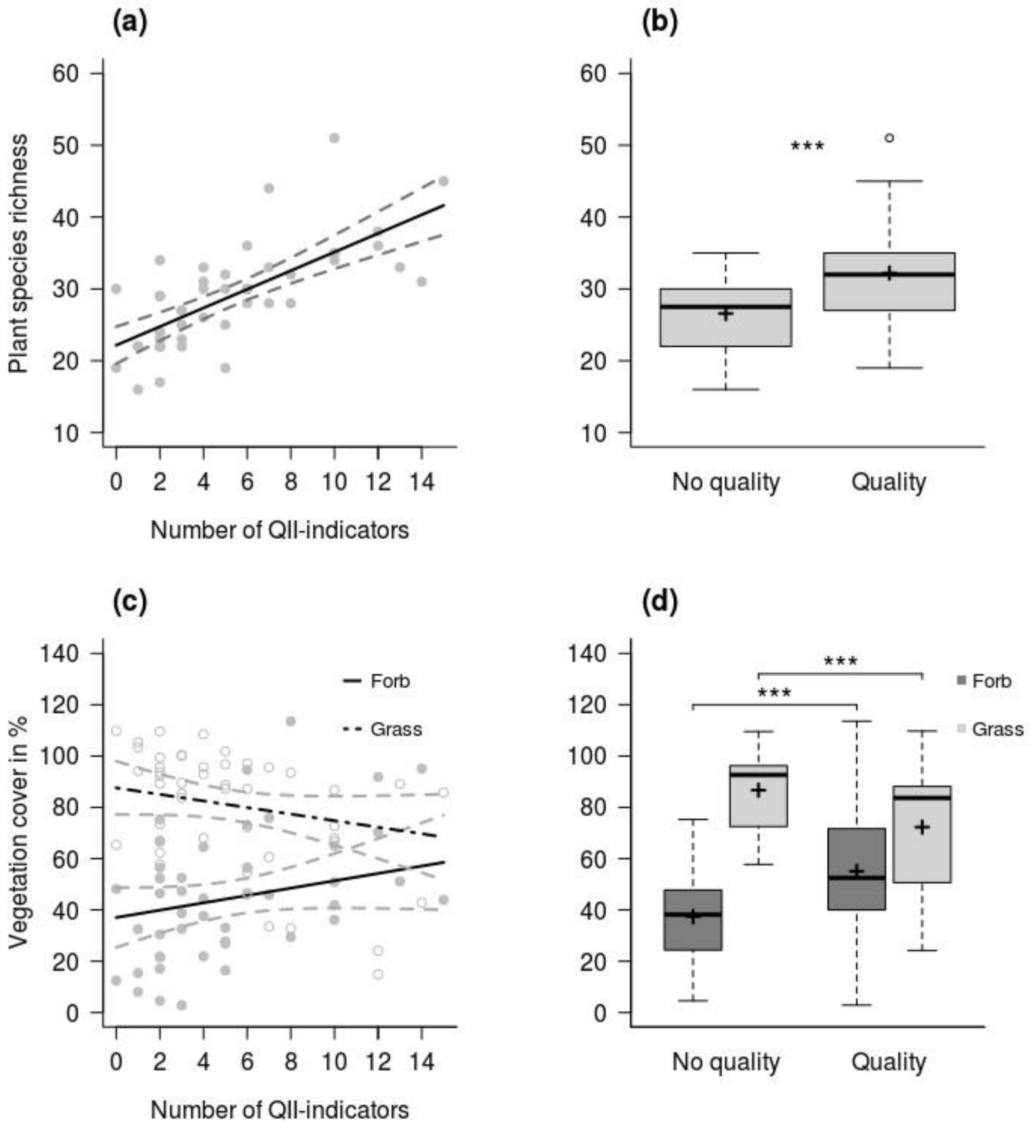


Figure 3. Model predictions of plants in relation to the QII-indicators in the left graphs as QII-indicator gradient and in the right graphs as quality category with ≥ 6 QII-indicators as quality and < 6 as no quality. (a) and (b) show the species richness while (c) and (d) present the percentage cover of grass and forb of the entire vegetation. In the gradient plots, GLMM predictions (black lines) and respective 95% confidence intervals (grey dashed lines) are shown. In (b) and (d), the boxes represent the 75% and 25% quartiles from the median (thick black line), whiskers represent the minimum and maximum values. Outliers are represented as open dots. The crosses indicate the mean. See Table 2 and Table 3 for test statistics. *** $P < 0.001$.

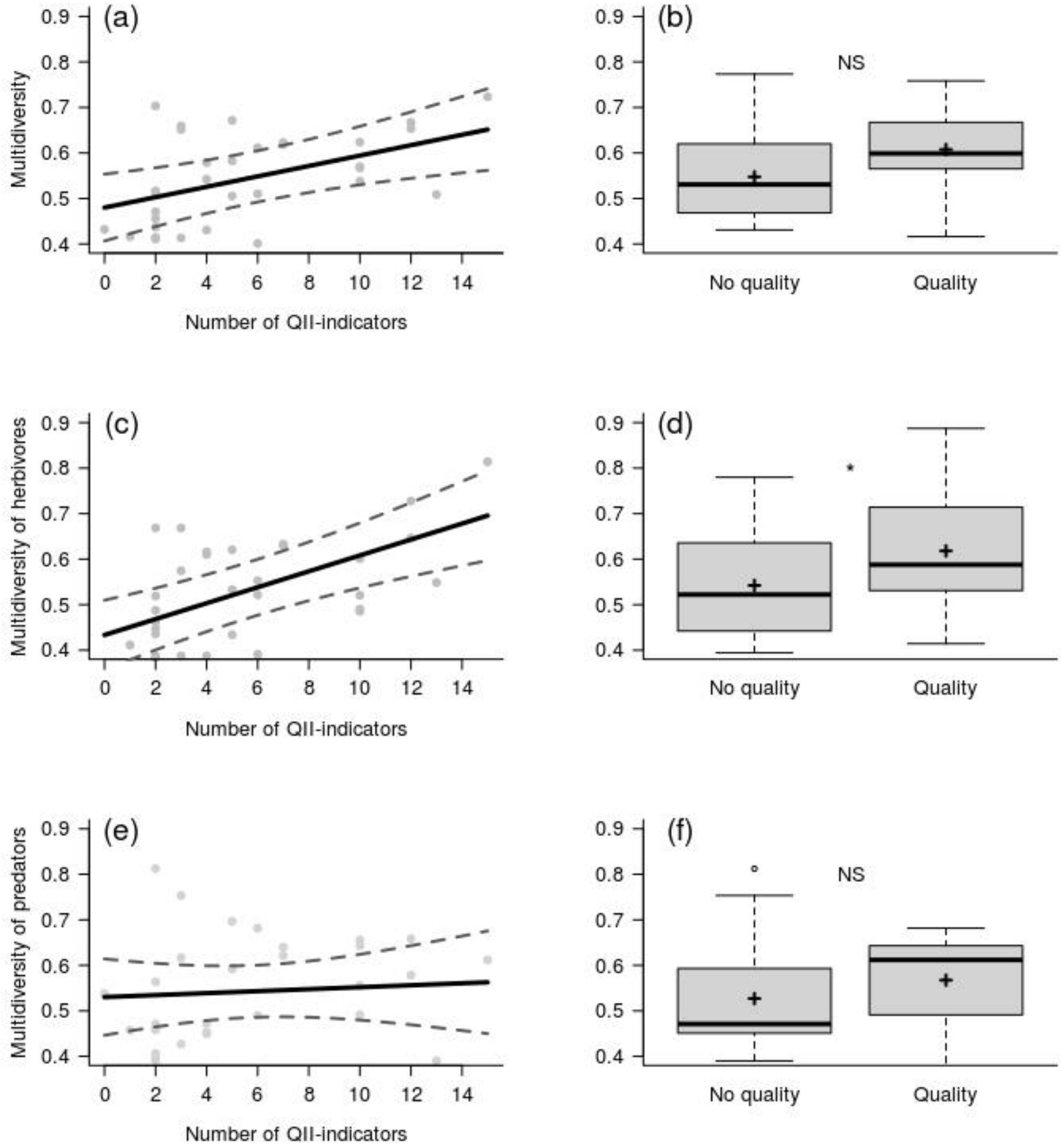


Figure 4. Model predictions of multidiversity in relation to the QII-indicators in the left graphs as QII-indicator gradient and in the right graphs as quality category with ≥ 6 QII-indicators as quality and < 6 as no quality. (a) and (b) show the multidiversity-index for all invertebrates, (c) and (d) show the multidiversity-index for herbivores, while (e) and (f) show multidiversity-index for predators. Properties of the plots as in Figure 3. See Table 2 for test statistics. * $P < 0.05$, NS $P > 0.05$.

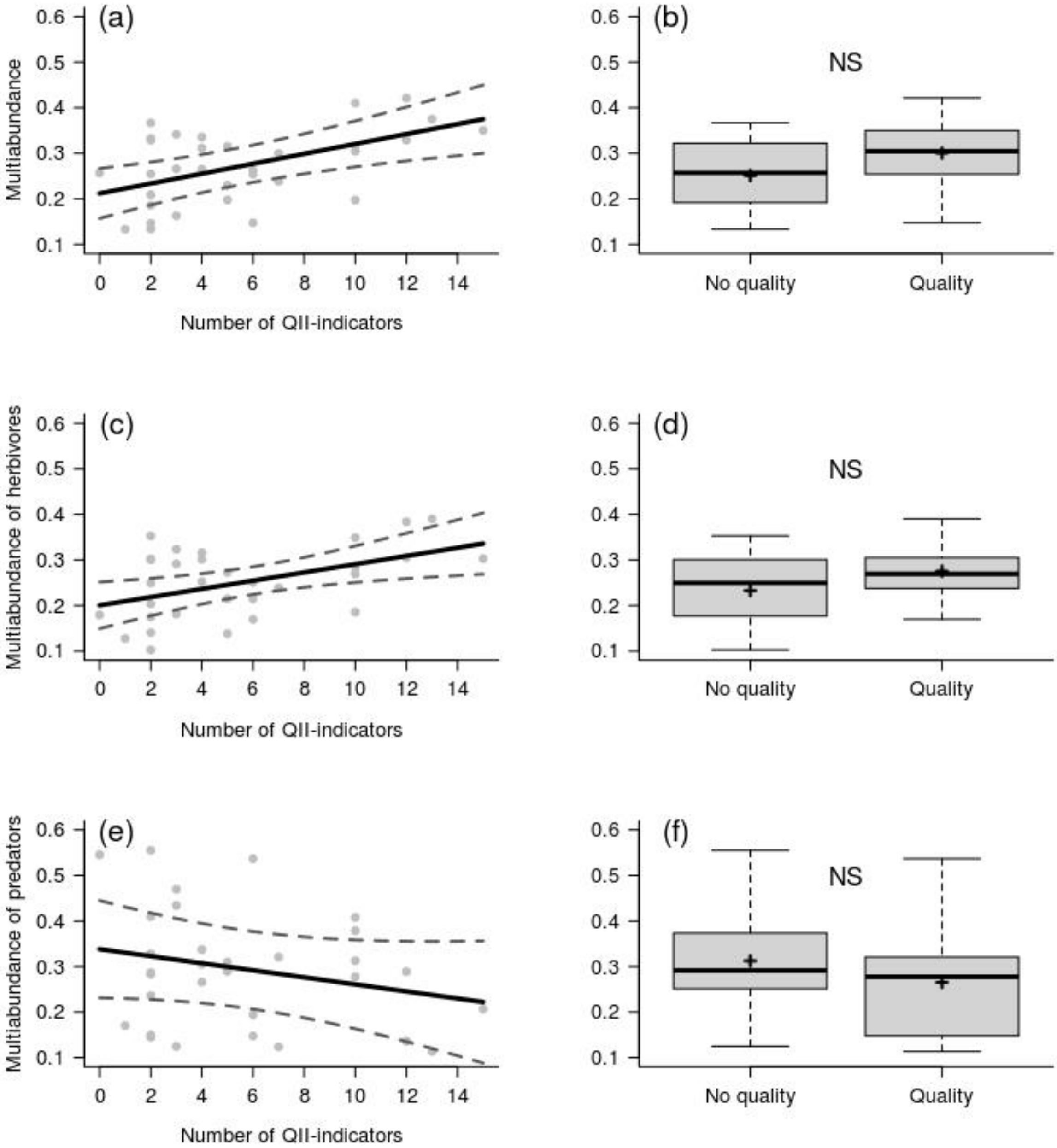


Figure 5. Model predictions of multiabundance in relation to the QII-indicators in the left graphs as QII-indicator gradient and in the right graphs as quality category with ≥ 6 QII-indicators as quality and < 6 as no quality. (a) and (b) show the multiabundance-index for all invertebrates, (c) and (d) show the multiabundance-index for herbivores, while (e) and (f) show multiabundance-index for predators. Properties of the plots as in Figure 3. See Table 3 for test statistics. NS $P > 0.05$.

Appendix

Appendix A1. List of meadows with their respective management regime (for more information on the mowing regime see Buri et al. 2013), geographic coordinates, official agricultural zone and size. The number of QII-indicators found in the random plot and QII-indicator weighted mean (the number of QII-indicators per subjective vegetation plot merged together as a weighted mean according the proportion of the associated patch within the whole meadow) and the percentage of the meadow area that reached QII quality (if ≥ 6, i.e. it reached the quality threshold) are also provided.

Canton	Site	Mowing regime	GPS_E	GPS_N	Agricultural zone	Meadow surface (ha)	N QII-indicator random plot	N QII-indicator weighted mean	% quality per meadow
VD	Avenches	control	567199	197130	valley	0.3	5	6	0.5
VD	Avenches	delayed	570873	198730	valley	0.75	2	3	0
VD	Avenches	refuge	571161	199195	valley	0.37	5	3.05	0.15
VD	Avenches	8weeks	566779	196992	valley	0.53	8	7	1
BE	Belp	control	604636	191062	valley	109.95	3	4	0
BE	Belp	delayed	603162	194392	hill	32.19	0	0	0
BE	Belp	8weeks	605860	193107	valley	1.0512	2	1.75	0
BE	Belp	refuge	605994	193876	valley	0.6024	10	9.05	0.85
NE	Coffrane	control	556134	205777	valley	0.56	6	7.2	0.6
NE	Coffrane	delayed	555521	205676	valley	0.7	6	4	0
NE	Coffrane	8weeks	555492	206936	valley	0.6	6	9	1
NE	Coffrane	refuge	555197	206511	valley	1.07	10	8.2	1
FR	Cousset	control	565053	185881	valley	1.1	15	10.2	0.6
FR	Cousset	delayed	564486	185983	valley	0.9	10	9	1
FR	Cousset	8weeks	564697	185509	valley	0.84	4	6	1
FR	Cousset	refuge	566716	186747	valley	0.67	5	1.9	0
BL	Diegten	control	628587	252760	hill	0.7	13	14	1
BL	Diegten	delayed	629722	254261	valley	0.71	12	11.6	1
BL	Diegten	8weeks	628893	252025	hill	1.64	14	14	1
BE	Grossaffoltern	control	595273	212665	valley	0.7046	2	2.3	0
BE	Grossaffoltern	delayed	595155	213836	valley	0.79	4	5	0
BE	Grossaffoltern	refuge	593108	212537	valley	0.4721	2	1.85	0
BE	Grossaffoltern	8weeks	592093	214070	valley	0.529	5	4	0
BE	Hindelbank	control	612343	209751	valley	1.0365	4	3.2	0
BE	Hindelbank	delayed	608716	211827	valley	0.71	2	3	0
BE	Hindelbank	refuge	609792	208850	hill	0.64	2	2	0

Appendix A1.

Canton	Site	Mowing regime	GPS_E	GPS_N	Agricultural zone	Meadow surface (ha)	N QII-indicator random plot	N QII-indicator weighted mean	% quality per meadow
BE	Huttwil	delayed	631448	217633	valley	1.3944	2	2	0
BE	Huttwil	refuge	629138	217792	hill	1.72	2	3	0
BE	Huttwil	8weeks	630861	216689	hill	0.75	3	2	0
AG	Lupfig	control	655870	255472	valley	0.3	3	5	0
AG	Lupfig	delayed	656487	254980	valley	0.92	4	2	0
AG	Lupfig	8weeks	656960	254803	valley	0.81	2	3	0
AG	Lupfig	refuge	658697	255130	valley	0.4	2	2	0
VD	Nyon	control	502651	141118	valley	0.5	3	5.3	0.3
VD	Nyon	delayed	504395	137106	valley	0.95	7	5.7	0.7
VD	Nyon	8weeks	503623	137136	valley	1.4	1	4.2	0.05
VD	Nyon	refuge	508936	140288	valley	0.8	7	8.85	1
VD	Orbe	control	528474	173681	valley	0.8	10	10.5	1
VD	Orbe	delayed	527588	172621	valley	0.6	3	7.3	0.55
VD	Orbe	8weeks	526781	172289	valley	0.9	7	6	1
VD	Orbe	refuge	528127	174456	valley	0.7	12	11	1
BE	Wohlen	control	595398	205415	valley	1.0503	6	6.8	0.45
BE	Wohlen	delayed	598953	205169	valley	1.0124	0	0.3	0
BE	Wohlen	refuge	596276	202099	valley	0.78	6	5.5	0.7
BE	Wohlen	8weeks	598192	203545	valley	1.7	8	6.9	0.7

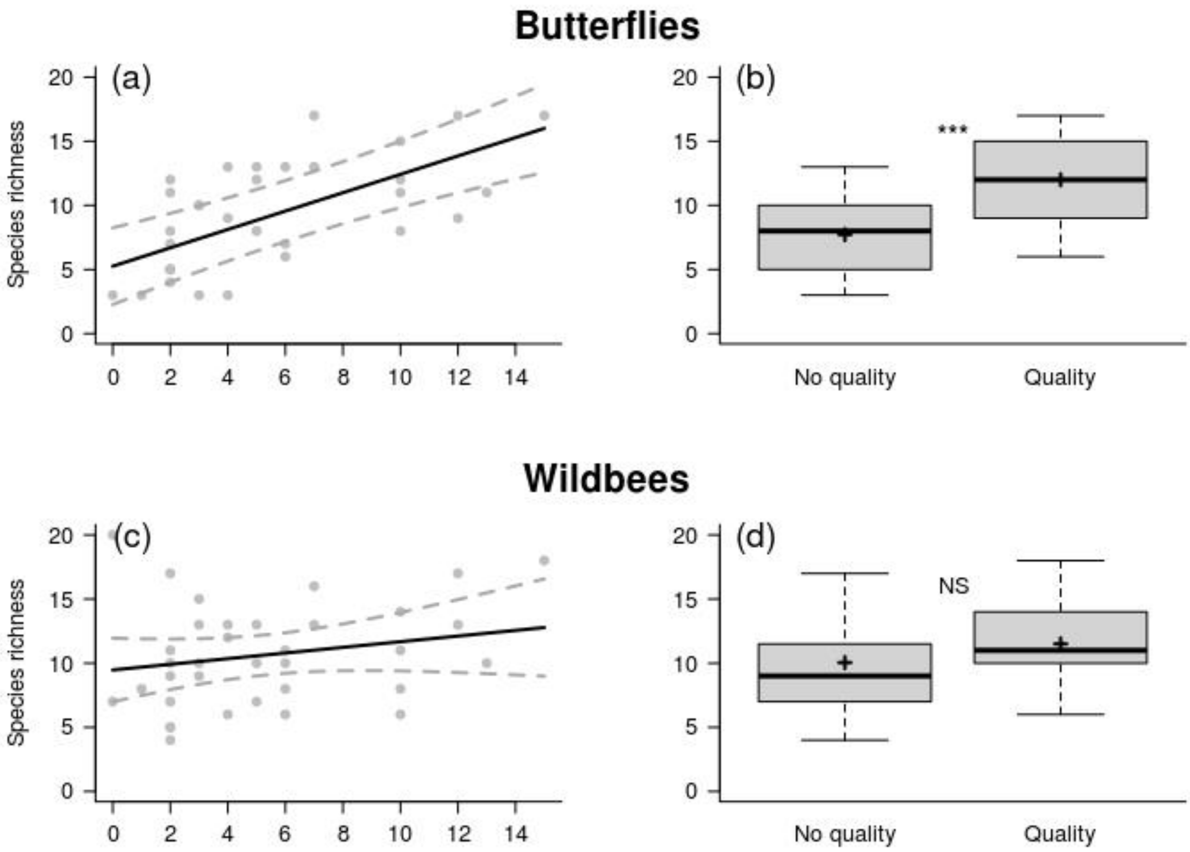
Appendix A2. List of QII-indicators found in the random and subjectively placed plots (in brackets the single species of a pseudogroup). 1^{st} plot represents the patch with subjectively highest quality. The 2^{nd} plot represents vegetation with the subjectively lowest quality. 3^{rd} and 4^{th} plot are patches with subjectively intermediate quality. A complete list of all QII-indicators can be found in Appendix 7.

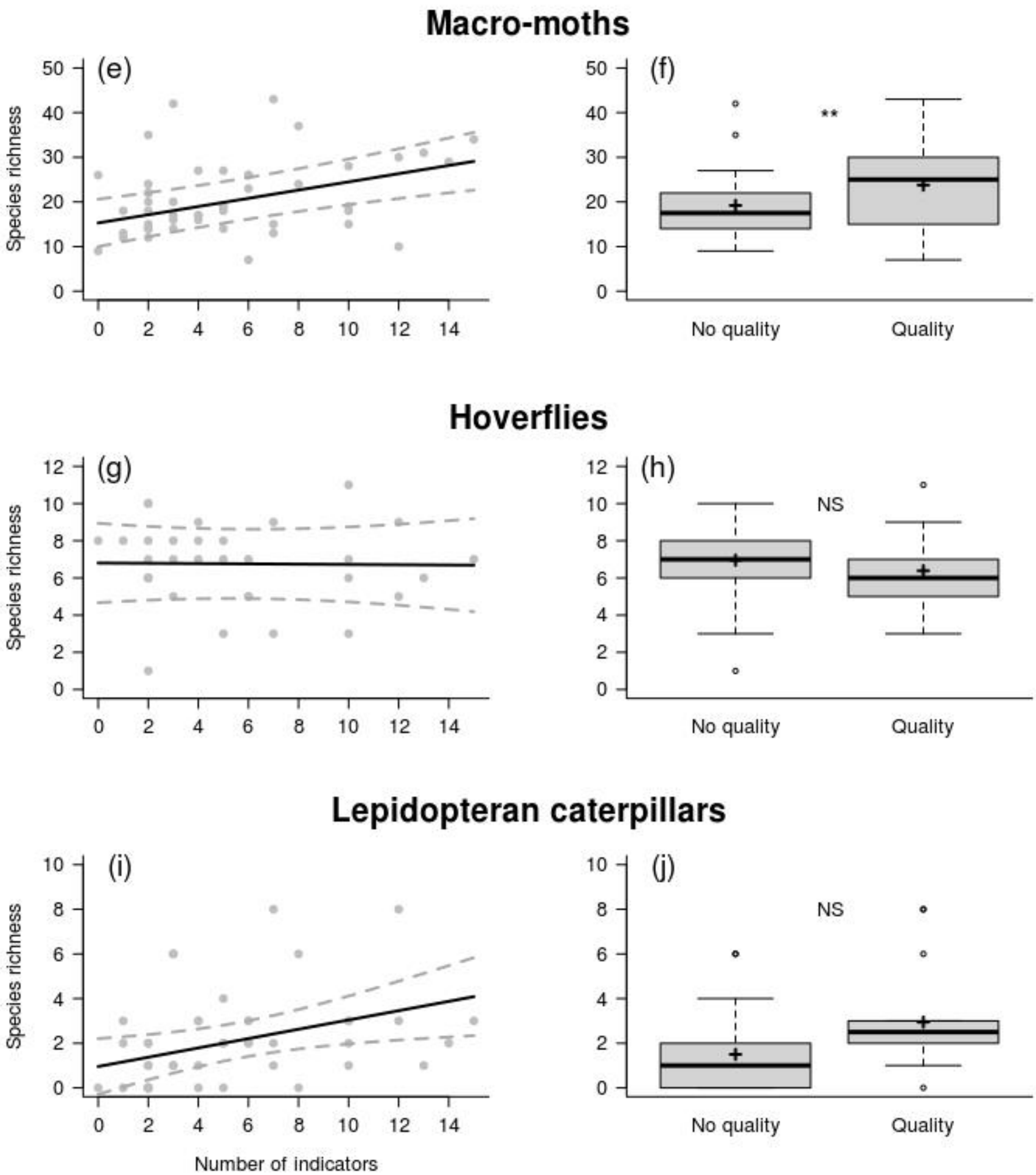
QII-indicators	**Random plot**	**1st plot**	**2nd plot**	**3rd plot**	**4th plot**
Anthoxanthum odoratum	35	40	17	5	3
Asteracea Yellow >1 head *(Crepis biennis, Hieracium murorum, Picris spec)*	34	36	17	4	2
Asteraceae Yellow 1 head *(Helicotrichon pubescens, Hypochaeris radicata, Leontodon hispidus)*	27	21	9	4	1
Briza media	0	2	0	0	0
Bromus erectus	9	9	5	3	0
Campanula patula	0	2	2	0	0
Carex flacca	1	2	0	0	0
Carex spp. *(C. caryophyllea, C. leporine, C. muricata, C. nigra, C. pallescens, C. sylvatica)*	6	8	1	1	1
Centaurea jacea	20	21	10	1	1
Colchicum autumnale	0	1	0	0	0
Fabacea Yellow big *(Lathyrus pratensis, Lotus corniculatus, Anthyllis vulneraria)*	13	19	10	7	1
Festuca spp. *(Festuca ovina)*	3	5	1	0	0
Knautia spp. & *Scabiosa* spp. *(Knautia arvensis, Scabiosa columbaria)*	13	17	8	6	2
Leucanthemum vulgare	21	23	12	4	3
Luzula spp. *(Luzula campestris)*	0	1	2	3	0
Medicago lupulina	11	13	8	2	0

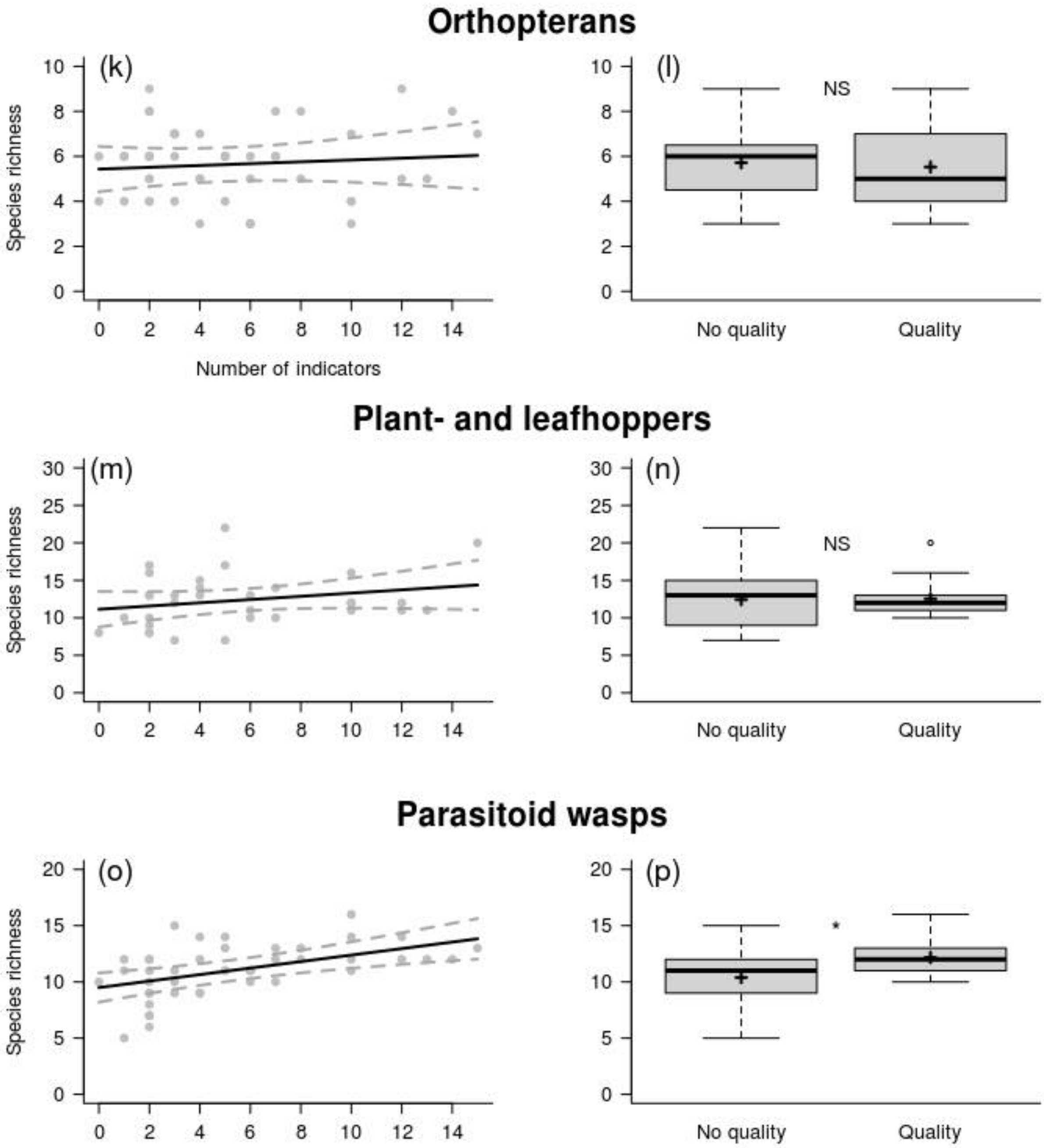
Appendix A2. Second page

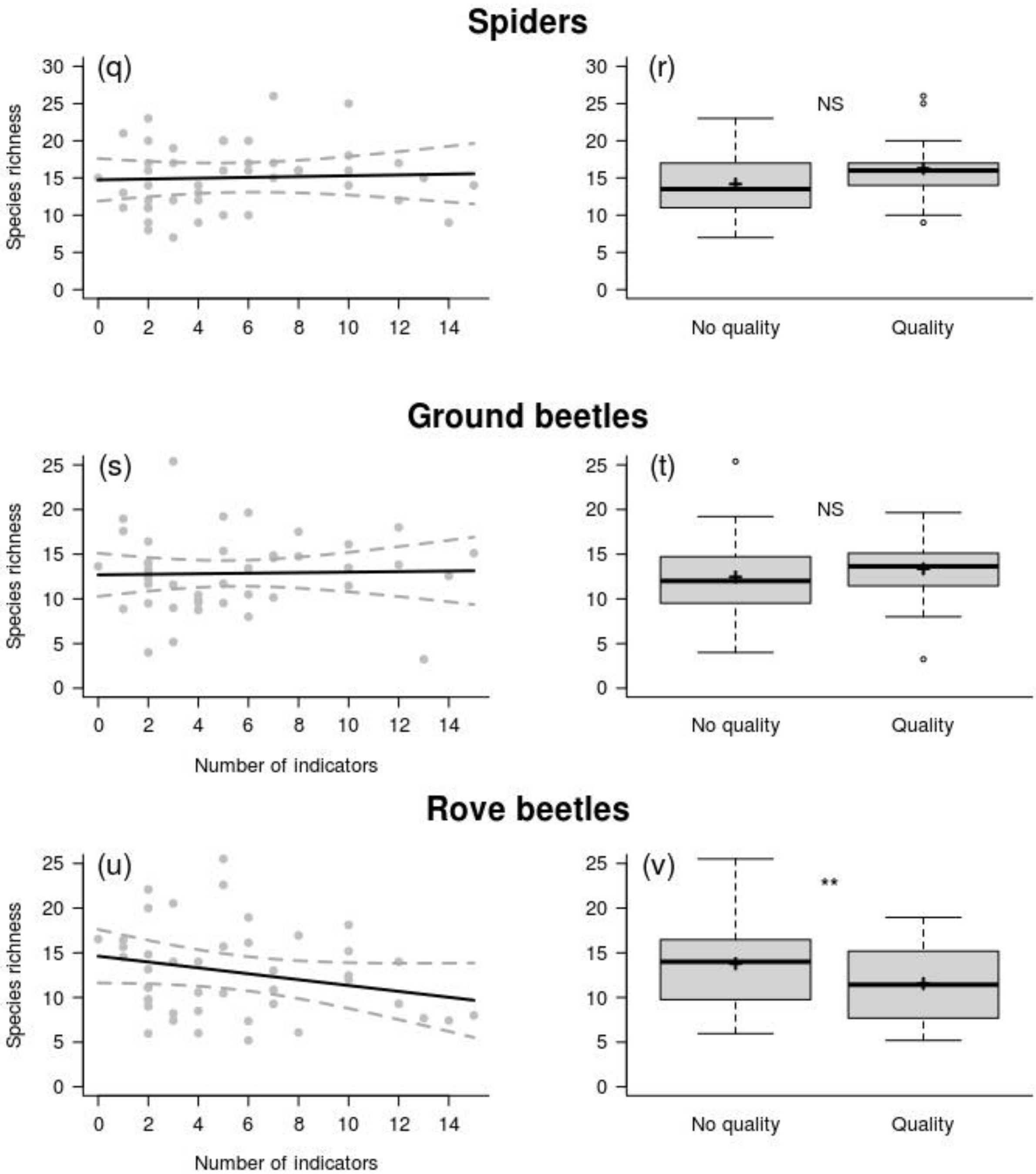
QII-indicators	Random plot	1st plot	2nd plot	3rd plot	4th plot
Onobrychis viciifolia	0	3	0	1	0
Orchidaceae (Orphys apifera, Anacamptis pyramidalis)	0	2	0	0	0
Phyteuma spicatum	0	0	0	1	0
Plantago media	3	4	2	1	0
Primula veris	1	3	1	2	0
Ranunculus bulbosus	9	11	5	1	1
Rhinanthus spp. *(R. alectorolophus, R. minor)*	21	24	11	3	3
Salvia pratensis	5	7	3	3	0
Sanguisorba minor	4	3	2	2	0
Silene spp. *(S. flos-cuculi, S. vulgaris)*	5	7	1	0	0
Tragopogon pratensis	17	19	7	2	2
Vicia cracca	1	1	1	3	0

Appendix A3. Model predictions of species richness of every single invertebrate group in relation to the QII-indicators in the left column as QII-indicator gradient and in the right column as quality category with ≥ 6 QII-indicators as quality and < 6 as no quality. (a-b) butterflies, (c-d) wild bees, (e-f) macro-moths, (g-h) hoverflies, (i-j) lepidopteran caterpillars, (k-l) orthopterans, (m-n) plant- and leafhoppers, (o-p) parasitoid wasps, (q-r) spiders, (s-t) ground beetles, (u-v) rove beetles. In the gradient plots the black lines show the averaged model predictions and the 95% confidence intervals within the grey dashed line. In the right column the boxes represent the 75% and 25% quartiles from the median (thick black line), whiskers represent the minimum and maximum values. Outliers are represented as open dots. The crosses indicate the mean. See Table 2 for test statistics. * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$, NS $P > 0.05$.

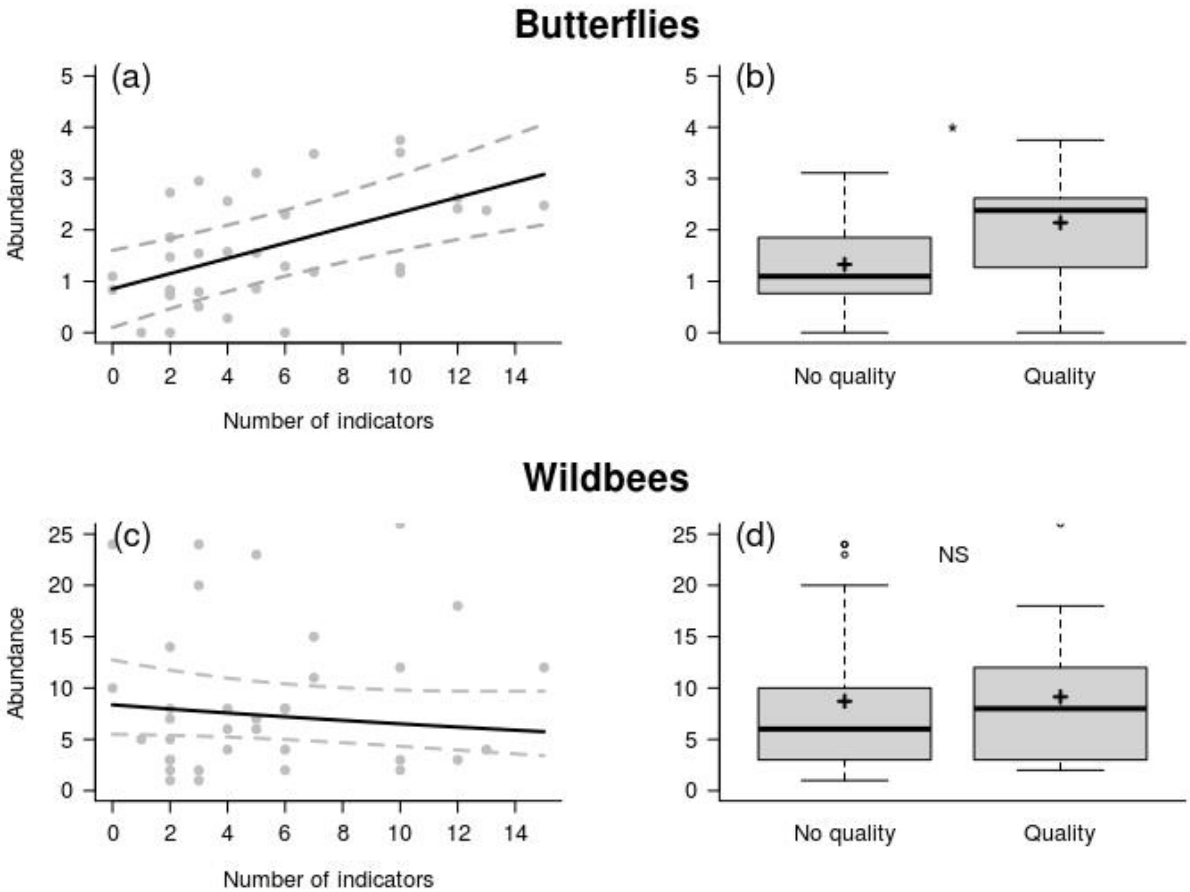


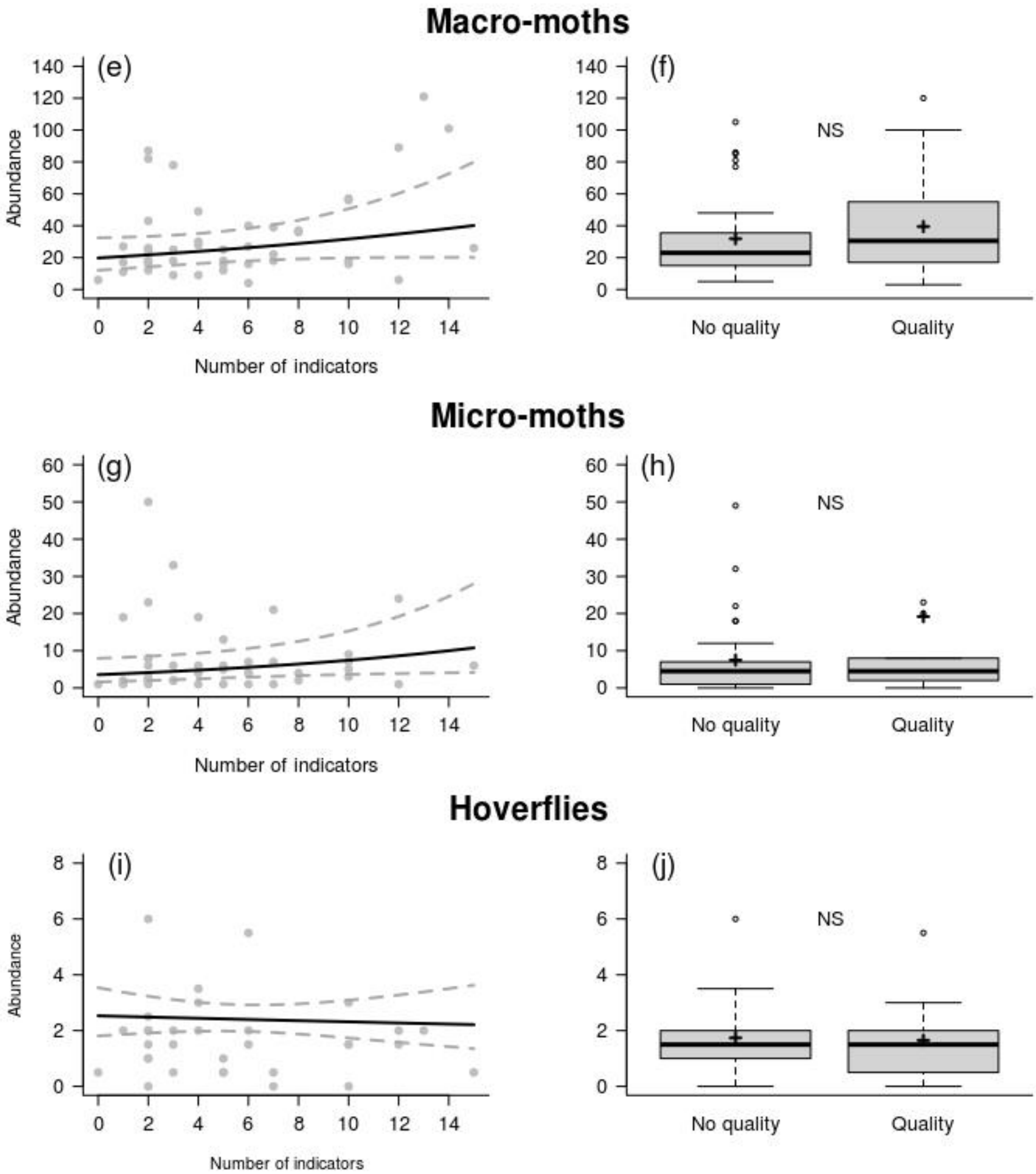

Macro-moths
(e)
(f)
**
Hoverflies
(g)
(h)
NS
Lepidopteran caterpillars
(i)
(j)
NS
Species richness
Number of indicators
No quality
Quality

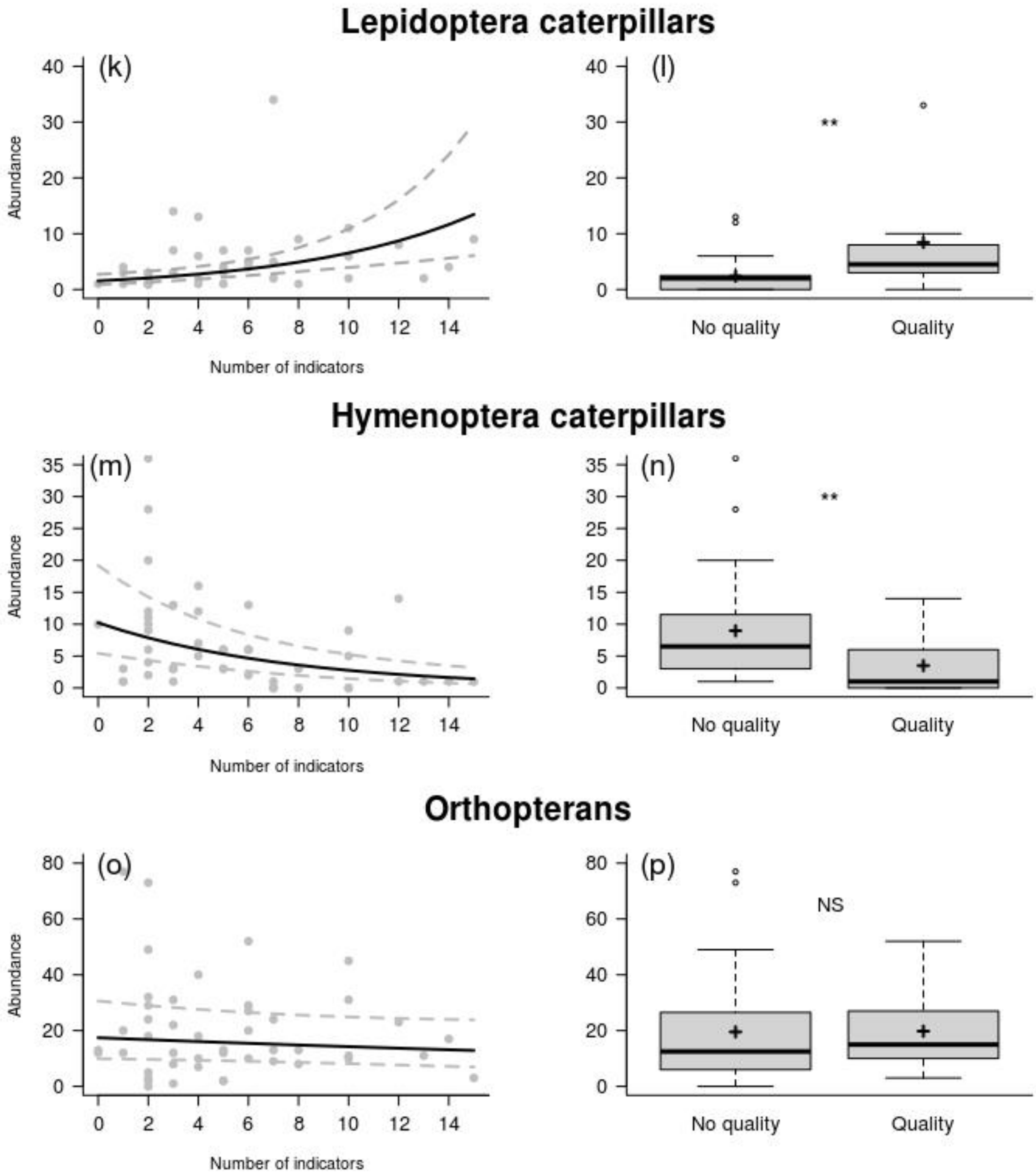

Orthopterans
(k)
(l)
Species richness
Number of indicators
No quality
Quality
NS
0
2
4
6
8
10
12
14
Plant- and leafhoppers
(m)
(n)
Species richness
No quality
Quality
NS
0
5
10
15
20
25
30
Parasitoid wasps
(o)
(p)
Species richness
No quality
Quality
*
0
5
10
15
20

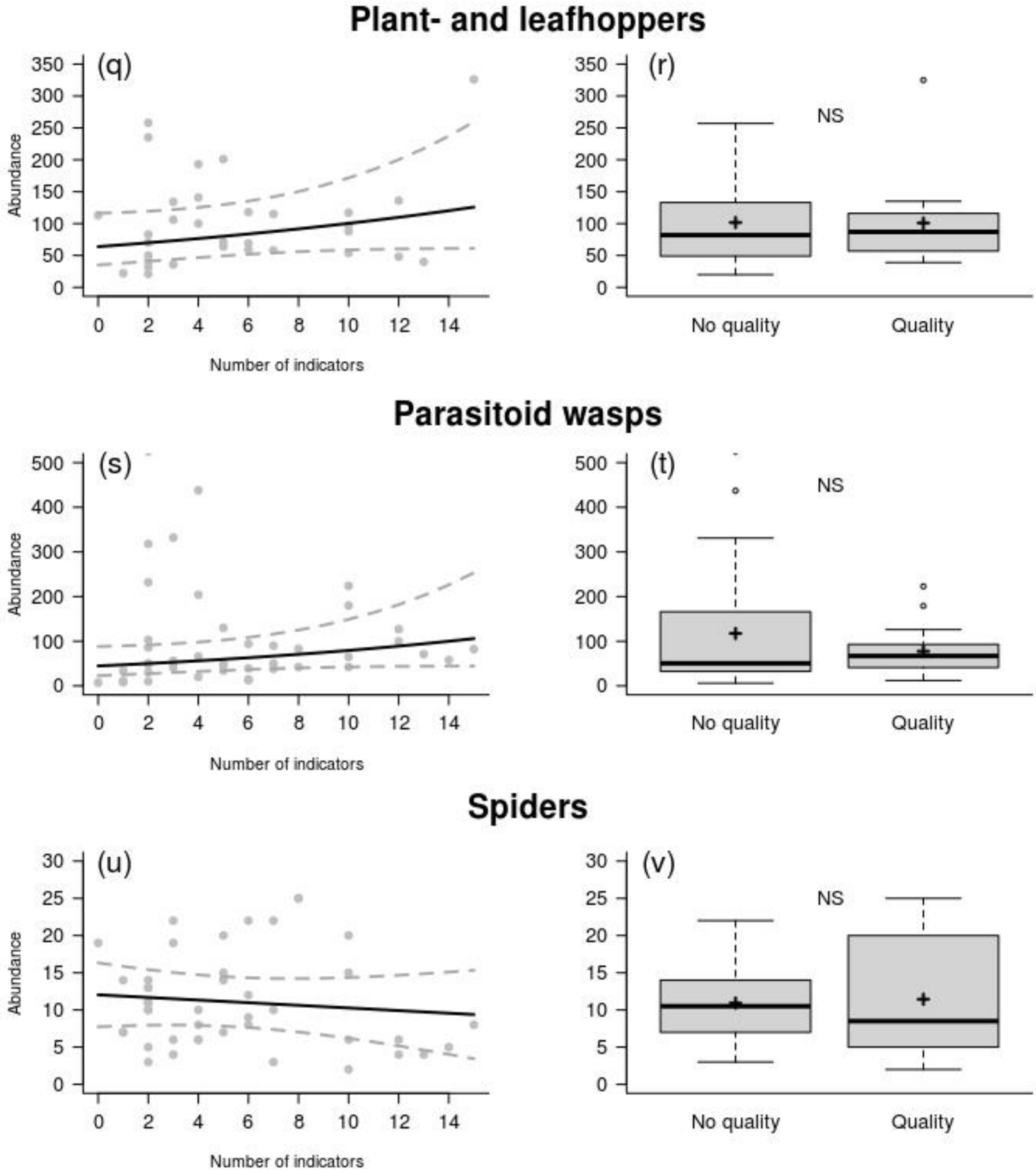

Spiders
(q)
(r)
Species richness
NS
No quality
Quality
Ground beetles
(s)
(t)
NS
Number of indicators
Rove beetles
(u)
(v)
**
Number of indicators

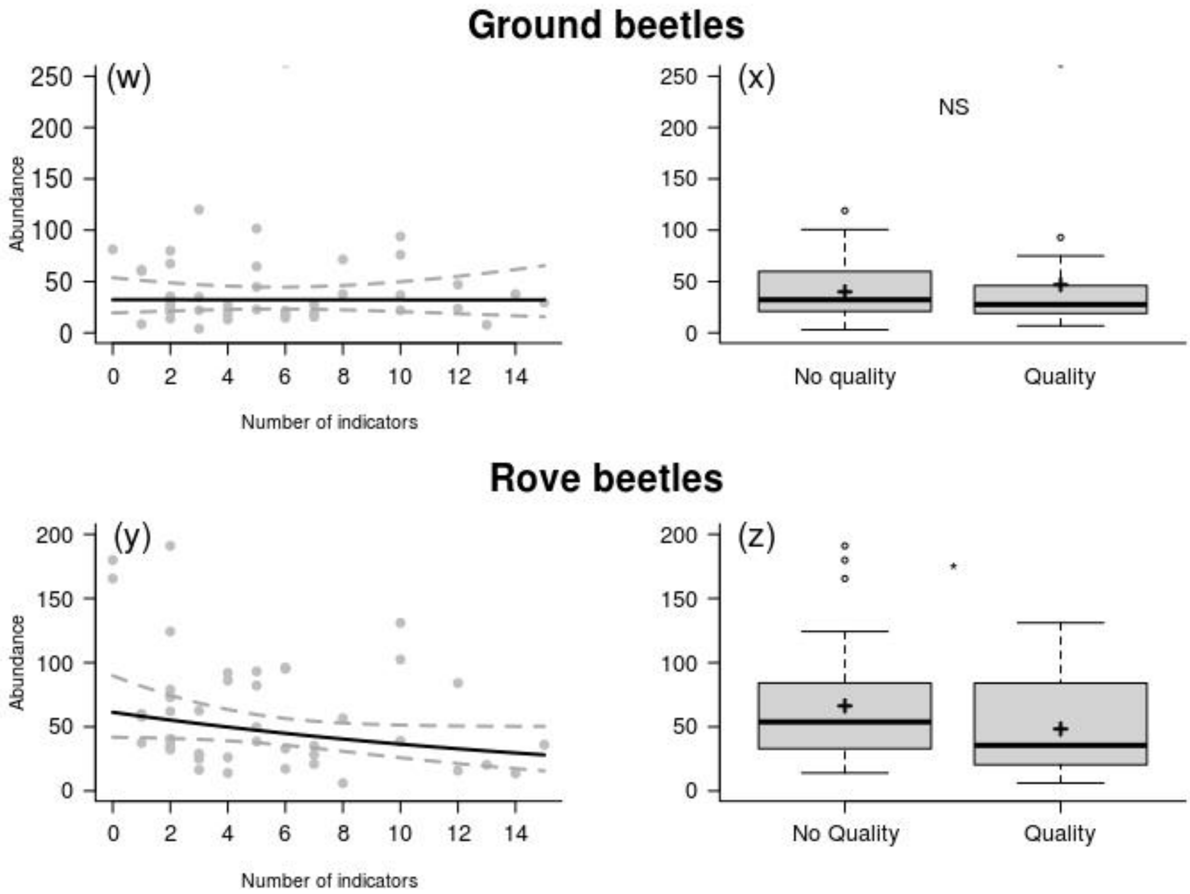
Appendix A4. Model predictions of the abundance of every single invertebrate group in relation to the QII-indicators in the left column as QII-indicator gradient and in the right column as quality category with ≥ 6 QII-indicators as quality and < 6 as no quality. (a-b) butterflies, (c-d) wild bees, (e-f) macro-moths, (g-h) mircro-moths, (i-j) hoverflies, (k-l) lepidopteran caterpillars, (m-n) hymenopteran caterpillars, (o-p) orthopterans, (q-r) plant- and leafhoppers, (s-t), parasitoid wasps, (u-v) spiders, (w-x) ground beetles, (y-z) rove beetles. Single invertebrate groups differ in measure of abundance: butterflies (100 m transect), orthopterans (16 m^2), wild bees and hoverflies (pan traps), ground- and rove beetle (pitfall traps), caterpillars of lepidopteran and hymenopteran (60 m transect), parasitoid wasps (25 m transect), plant- and leafhoppers and spiders (1 m^2), moths (light traps). Properties of the plots as in Appendix 3. See Table 2 for test statistics. * P < 0.05, ** P < 0.01, NS P > 0.05.



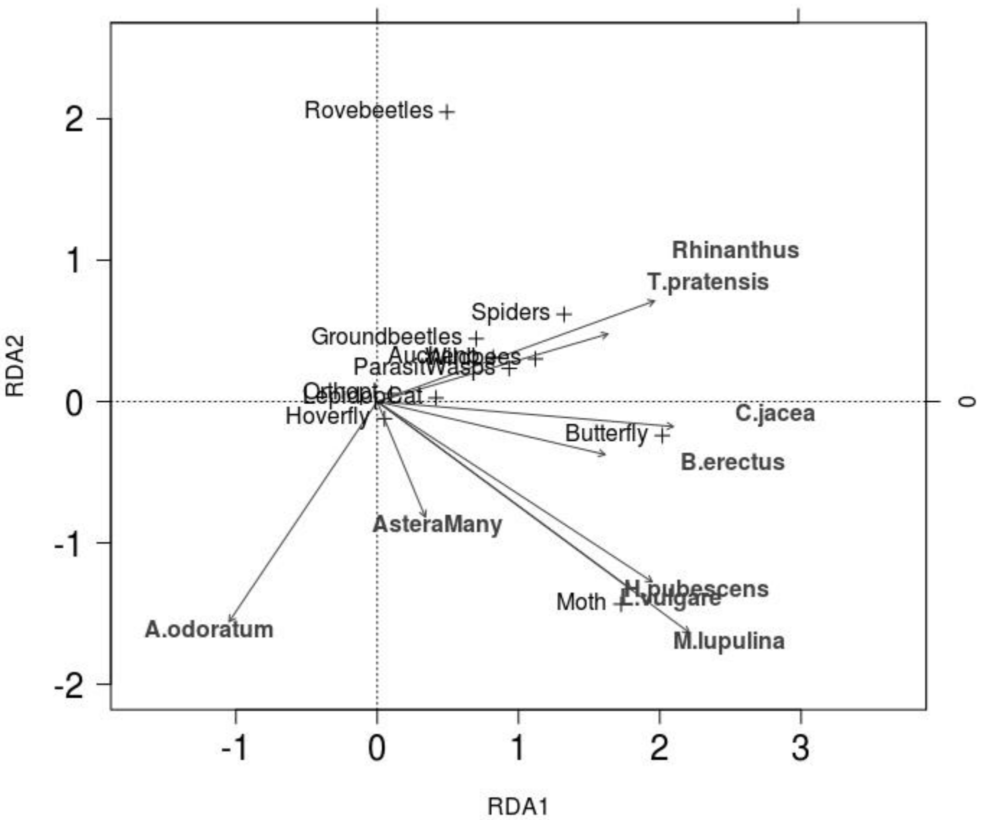

Macro-moths
(e)
Abundance
Number of indicators
(f)
NS
No quality
Quality
Micro-moths
(g)
Abundance
Number of indicators
(h)
NS
No quality
Quality
Hoverflies
(i)
Abundance
Number of indicators
(j)
NS
No quality
Quality


Lepidoptera caterpillars
(k)
Abundance
Number of indicators
0 2 4 6 8 10 12 14
0 10 20 30 40
(l)
**
No quality
Quality
Hymenoptera caterpillars
(m)
Abundance
Number of indicators
0 5 10 15 20 25 30 35
(n)
**
No quality
Quality
Orthopterans
(o)
Abundance
Number of indicators
0 20 40 60 80
(p)
NS
No quality
Quality

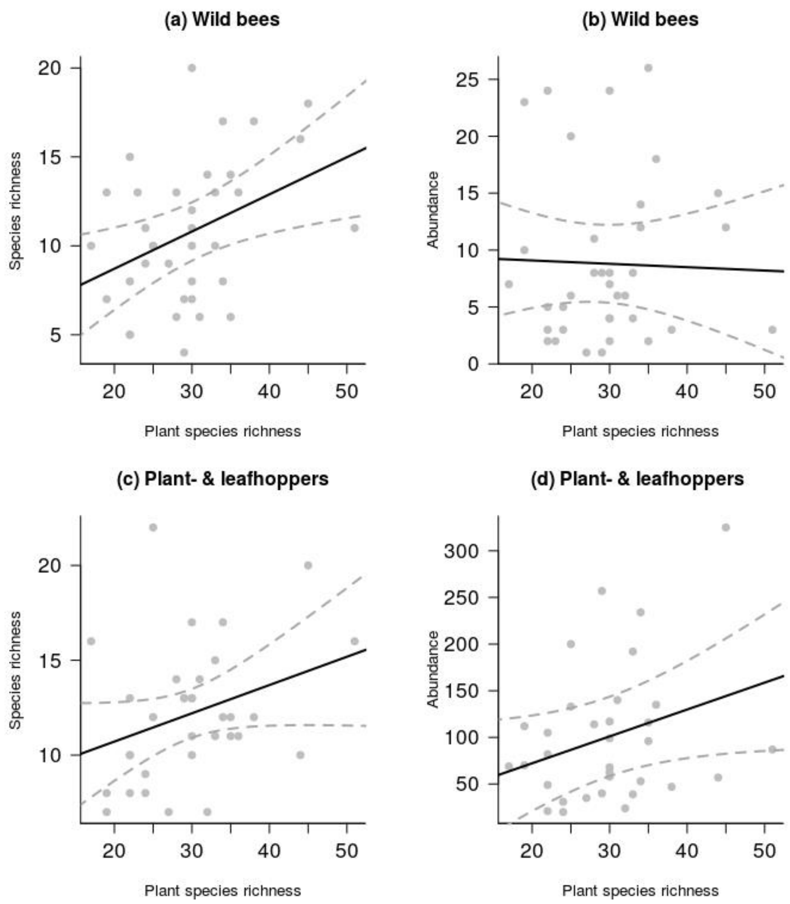

Plant- and leafhoppers
(q)
(r)
NS
Abundance
Number of indicators
No quality
Quality
Parasitoid wasps
(s)
(t)
NS
Abundance
Number of indicators
No quality
Quality
Spiders
(u)
(v)
NS
Abundance
Number of indicators
No quality
Quality


Ground beetles
(w)
Abundance
Number of indicators
(x)
NS
No quality
Quality
Rove beetles
(y)
Abundance
Number of indicators
(z)
*
No Quality
Quality

Appendix A5. Multivariate redundancy analysis (RDA) plots with the ten most common QII-indicators as environmental variables (arrows) and invertebrate species richness (crosses). The model was significant (P = 0.007) and 33% of the variance in the response variables can be explained by the QII-indicators. Only the first axis was significant for explaining 17% of variance (P = 0.005). The second axis was not significant (P = 0.277). This should increase the caution while interpreting the results because we must ignore the non-significant axis for further interpretation (Legendre et al. 2011). The arrow length and direction correspond to the relative variance that can be explained by the environmental variable. The direction of an arrow indicates an increasing magnitude of the environmental variable. The perpendicular distance between orders and environmental variable axes in the plot reflects their correlations. The smaller the angle between the direct line from the centre towards the orders and environmental variables is, the stronger is the correlation.



Appendix A6. Relationship between plant species richness (x-axis) and (a) wild bee species richness, (b) wild bee abundance, (c) plant- and leafhopper species richness, and (d) plant- and leafhopper abundance. Plant species richness derive from the two permanent vegetation plots (16 m^2 in total) survey in 2015. Invertebrates were analysed as response variable with a Gaussian error distribution. Random effects were the site and mowing regime. The black lines show the averaged model predictions and the grey dashed line shows the 95% confidence intervals. Wild bees species richness shows a positive correlation with the overall plant species richness (marginal $R^2 = 0.142$, conditional $R^2 = 0.436$, $P = 0.014$), while abundance shows no correlation (marginal $R^2 = 0.001$, conditional $R^2 = 0.511$, $P = 0.834$). Plant- and leafhoppers species richness and abundance marginally correlate with plant species richness (marginal $R^2 = 0.097$, conditional $R^2 = 0.159$, $P = 0.075$, respectively marginal $R^2 = 0.094$, conditional $R^2 = 0.358$, $P = 0.071$).



Appendix A7. Official document "Weisungen nach Artikel 59 und Anhang 4 der Verordnung über die Direktzahlungen an die Landwirtschaft (Direktzahlungsverordnung, DZV). Bern, Switzerland" with the key instructions and the full list of QII-indicators.

August 2014

Weisungen nach Artikel 59 und Anhang 4 der Verordnung über die Direktzahlungen an die Landwirtschaft (Direktzahlungsverordnung, DZV)

vom 23. Oktober 2013, SR 910.13

Extensiv genutzte Wiesen, wenig intensiv genutzte Wiesen und Streueflächen der Qualitätsstufe II

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1 Einleitung

Die vorliegenden Weisungen zur DZV enthalten die Bestimmungsschlüssel und das Vorgehen zur Beurteilung der Qualitätsstufe II von Biodiversitätsförderflächen (extensiv und wenig intensiv genutzte Wiesen sowie Streueflächen) auf der Basis ihrer botanischen Zusammensetzung.

Die Kriterien beruhen auf pflanzensoziologischen Erhebungen aus der ganzen Schweiz und auf der Beurteilung durch Experten[1]. Sie wurden aufgrund der folgenden Überlegungen erstellt:

- Die Kriterien erlauben es, Flächen mit guter botanischer Qualität zu erfassen. Flächen mit botanischem Verbesserungspotenzial werden ebenfalls erfasst, während Bestände, welche kein Verbesserungspotenzial aufweisen, ausgeschlossen werden.
- Um die Artenvielfalt von Biodiversitätsförderflächen effizient zu erhalten und zu fördern, müssen die Qualitätskriterien in allen Regionen den Bewirtschaftern oder den Bewirtschafterinnen in etwa den gleichen Anreiz und die gleiche Chance bieten, die Mindestqualität zu erreichen. Deshalb wur- den die Schlüssel nach den folgenden zwei Kriterien aufgeteilt:
    1. Die Voraussetzungen für eine hohe Artenvielfalt sind in den Inneralpen (Kantone GR und VS) und auf der Alpensüdseite günstiger als auf der Alpennordseite. Deshalb sind die Schlüssel für die Südseite und die Inneralpen strenger als diejenigen für die Nordseite.
    2. Die Schlüssel sind strenger in Regionen mit hohem biologischem Potenzial. Als solche gelten vor allem höhere Lagen, da Untersuchungen gezeigt haben, dass dort die Wiesen generell eine grössere Artenvielfalt aufweisen. Da Höhenangaben als Abgrenzungskriterien ungeeignet sind, werden zur Bestimmung des biologischen Potenzials Zeigerarten der subalpinen / montanen Stufe verwendet.

  Somit berücksichtigt jede Beurteilung einer Fläche zuerst die Grossregion (Nord oder Süd) und dann das regionsspezifische biologische Potenzial, welches in erster Linie von der Höhenlage der Parzelle bestimmt wird.
- Die Indikatorarten sind wissenschaftlich abgestützt. Es wurden jedoch nur solche Arten ausgewählt, die auch von interessierten Laien erkannt werden können. Es handelt sich sowohl um einzelne Arten als auch um Artengruppen, deren ökologischen Ansprüche und deren Aussehen ähnlich sind (z.B. Seggen, blaue und violette Enziane, gelbblühende grossblütige Kleearten usw.).
- Die Schlüssel enthalten nur „Positivzeigerarten“. Auf „Negativzeiger“, welche auf schlechte Qualität oder auf ein geringes Verbesserungspotenzial hinweisen (z.B. Blacken oder Quecken) wurde verzichtet. Damit sollen die Bewirtschaftenden motiviert werden, bewusst auf qualitätszeigende Arten zu achten.

2 Methode zur Qualitätsprüfung von Biodiversitätsförderflächen (extensiv genutzte Wiesen, wenig intensiv genutzte Wiesen und Streueflächen)

2.1 Einleitung

Im Folgenden wird das Vorgehen im Feld beschrieben, anhand dessen festgestellt wird, welcher Anteil der Parzelle die Mindestanforderungen an die Qualitätsstufe II erfüllt.

Die biologische Qualität variiert häufig innerhalb einer Parzelle. Nur der Anteil der Parzelle, welcher die geforderte Mindestqualität erreicht, berechtigt zu einem Zusatzbeitrag. Die Parzelle muss zusammenhängend und darf nicht zu mehr als 50 Prozent durch Bäume und Sträucher bedeckt sein.

[1] Der Bericht "Definition der biologischen Mindestqualität von Wiesen und Streueflächen des ökologischen Ausgleichs" beschreibt detailliert die Erarbeitung der Qualitätskriterien und enthält eine Autorenliste (erhältlich beim BLW, Mattenhofstrasse 5, 3003 Bern).

Mit der hier beschriebenen Methode wird zuerst das für die Parzelle massgebliche regionale biologische Potenzial festgestellt. Dann wird damit eruiert, welcher Anteil der Parzelle die Mindestanforderungen an die Qualitätsstufe II erfüllt. Die Methode dokumentiert zudem den Kontrollvorgang, damit in Problemfällen Nachkontrollen möglich sind.

Eine korrekte Anwendung der Methode setzt eine gute Kenntnis der Funktionsweise der Schlüssel in Kapitel 3 sowie eine Übersicht über die Wiesen- und Streueflächentypen der jeweiligen Region voraus.

2.2 Vorgehen zur Qualitätsbeurteilung

Die Qualitätsbeurteilung wird auf Antrag des Bewirtschafters oder der Bewirtschafterin durchgeführt.

Der optimale Zeitpunkt ist im ersten Aufwuchs vor dem ersten Schnitt.

Das Vorgehen ist der jeweiligen Situation anzupassen: Botanisch einheitliche Flächen sind rasch beurteilt, inhomogene Flächen erfordern einen erhöhten Aufwand.

2.2.1 Feststellung des regionalen biologischen Potentials

Die Beurteilung der einzelnen Parzelle ist in Kenntnis des **regionalen Potenzials** durchzuführen. Der Begriff „Region“ bezeichnet in diesem Zusammenhang eine *Flächeneinheit* mit ähnlicher Exposition und Höhenlage.

Zur Beurteilung des biologischen Potenzials einer Flächeneinheit wird anhand der vorhandenen Pflanzenarten festgestellt, ob sich diese in einer Höhenlage befindet. Dazu werden in den Schlüsseln (Kapitel 3) höhenzeigende Pflanzenarten der subalpinen / montanen Stufe verwendet (Liste A).

Beim ersten Abschreiten einer Flächeneinheit, zur Gewinnung einer Übersicht, werden Indikatoren der Liste A gesucht. Findet man mindestens drei dieser Arten, werden alle Parzellen dieser Flächeneinheit nach Liste B beurteilt, andernfalls nach Liste C (vgl. Kapitel 3).

Die Feststellung des regionalen biologischen Potentials in einer Flächeneinheit erfolgt nur einmal, und zwar bei der ersten Qualitätserhebung in einer Parzelle dieser Flächeneinheit. Das Resultat dieser Feststellung wird protokolliert. Bei Nachkontrollen wird die selbe Liste (B oder C) wie beim ersten Mal verwendet.

2.2.2 Situationsanalyse der einzelnen Parzelle

Zuerst verschafft man sich durch Abschreiten einen Überblick über die Parzelle. Am Rand der Parzelle stellt sich oft eine abweichende Vegetation ein. Deshalb ist ein **Randstreifen von 5 m Breite für die Flächenbeurteilung wegzulassen[2].**

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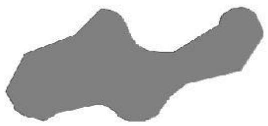
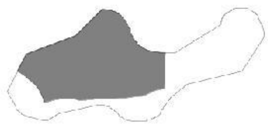
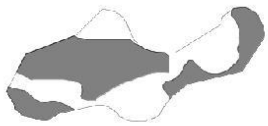
[2] Bei sehr schmalen Parzellen mit nur 5 bis 15 m Breite müssen Randeffekte in Kauf genommen werden. Die Testflächen haben dann u.U. keine Kreis- sondern eine geeignete Rechteckform.

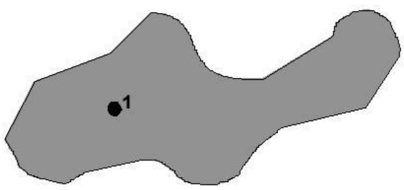
Aufgrund der Übersicht werden 3 Situationen unterschieden:

Situation A	Situation B	Situation C
Die Vegetation ist über die ganze Parzelle einheitlich (ausser ev. am Rand)	Die Vegetation lässt sich deutlich in zwei Zonen aufteilen	Die Vegetation ist uneinheitlich mit mehreren Flecken und Streifen unterschiedlicher Vegetation
		

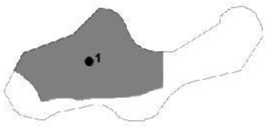
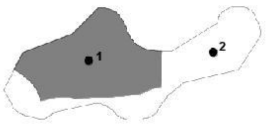
Die Situation A, B oder C wird skizziert.

2.2.3 Beurteilung des Qualitätsanteils

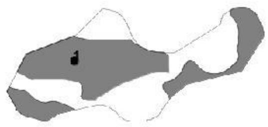
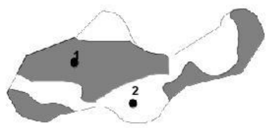
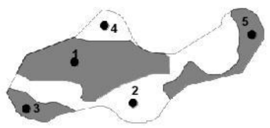
Situation A: Die Vegetation ist einheitlich (homogen)

1.	• Eine kreisrunde Fläche mit einem Radius von 3 m (Testfläche) wird in einen möglichst einheitlichen, repräsentativen Teil der Parzelle gelegt, und die Qualität wird aufgrund des regionalen Schlüssels (Liste B oder C) überprüft (vgl. Kapitel 3). • Die Parzelle wird abgeschritten, um festzustellen, ob die Vegetation tatsächlich homogen ist. Ist dies der Fall, ist die Arbeit abgeschlossen. Die Parzelle erfüllt entweder zu 0 % oder zu 100 % die Mindestanforderungen. • Bei inhomogenen Parzellen ist gemäss Situation B oder C zu verfahren.	

Situation B: Die Vegetation lässt sich deutlich in zwei Zonen aufteilen

1.	• Eine kreisrunde Fläche mit einem Radius von 3 m (Testfläche) wird in den Parzellenteil gelegt, welcher aufgrund der Übersicht die höchste Qualität aufzuweisen scheint. Die Qualität wird aufgrund des regionalen Schlüssels (Liste B oder C) überprüft (vgl. Kapitel 3). • Die Parzelle wird abgeschritten und die Grenze der Zone mit einer Vegetation, welche mit derjenigen der Testfläche vergleichbar ist, in einer Situationsskizze festgehalten.	
2.	• Eine zweite Testfläche (Nr. 2) wird im visuell schlechtesten Teil angelegt und auf Qualität untersucht (damit wird die Spannbreite dokumentiert). Falls hier die Mindestqualität auch erreicht wird, wird die Zone abgeschritten, um festzustellen, ob die Vegetation homogen ist. Ist dies der Fall, ist die Arbeit abgeschlossen, die ganze Parzelle hat die erforderliche Mindestqualität. • Erfüllt die zweite Testfläche die Mindestqualität nicht, ist die in Schritt 1 skizzierte Grenze der Qualitätsvegetation zu verifizieren. • Mit Hilfe der Situationsskizze wird der Anteil der Qualitätsvegetation an der Parzellenfläche geschätzt (Resultat in % und in Aren ausdrücken). Dann ist die Arbeit abgeschlossen.	

Situation C: **Die Vegetation ist uneinheitlich (inhomogen) mit mehreren Flecken und Streifen unterschiedlicher Vegetation**

1.	• Eine kreisrunde Fläche mit einem Radius von 3 m (Testfläche) wird in den Parzellenteil gelegt, welcher aufgrund der Übersicht die höchste Qualität aufzuweisen scheint. Die Qualität wird aufgrund des regionalen Schlüssels (Liste B oder C) überprüft (vgl. Kapitel 3). • Die Parzelle wird abgeschritten und die Grenze der Zone mit einer Vegetation, welche mit derjenigen der Testfläche vergleichbar ist, in einer Situationsskizze festgehalten.	
2.	• Eine zweite Testfläche (Nr. 2) wird im visuell schlechtesten Teil der Parzelle angelegt und auf Qualität untersucht (damit wird die Spannbreite dokumentiert). • Die Parzelle wird abgeschritten und die Grenze der Zone mit einer Vegetation, welche mit derjenigen der Testfläche vergleichbar ist, in einer Situationsskizze festgehalten.	
3.	• Die Testflächen 3, 4 und 5 werden analog angelegt, um die zu Beginn eingetragenen Grenzen zu verifizieren. • Sobald die Grenzen der Flächen mit und ohne Qualität auf der Skizze eingetragen sind, kann der Flächenanteil der Qualitätsvegetation geschätzt werden (Resultat in % und in Aren ausdrücken). Dann ist die Arbeit abgeschlossen.	

3 Mindestanforderungen an die Qualitätsstufe II von extensiv genutzten Wiesen, wenig intensiv genutzten Wiesen sowie Streueflächen

3.1 Einleitung

Dieses Kapitel enthält die Schlüssel zur Bestimmung der Qualitätsstufe II, welche den Anforderungen der DZV entspricht.

Die Anwendungsmethode der Schlüssel ist in Kapitel 2 beschrieben.

3.2 Schlüssel zur Qualitätsbestimmung

Es bestehen zwei Schlüssel zur Bestimmung der Qualitätsstufe II von extensiv genutzten Wiesen, wenig intensiv genutzten Wiesen sowie Streueflächen:

- Der Schlüssel für die Alpensüdseite ist gültig für die Kantone Tessin und Wallis sowie für die Südtäler des Kantons Graubünden.
- Der Schlüssel für die Alpennordseite gilt für die anderen Kantone sowie für die übrigen Gebiete des Kantons Graubünden.

Die Schlüssel bestehen aus zwei Teilen:

1. Der erste Teil dient der Beurteilung des biologischen Potenzials der Region, in welcher sich die Parzelle befindet. Dazu wird Liste A des Schlüssels verwendet. Diese besteht aus höhenzeigenden Arten. Sie erlaubt somit festzustellen, ob es sich um eine Höhenlage handelt. Unter „Region“ wird in diesem Zusammenhang eine Landschafts- oder Flächeneinheit mit ähnlicher Exposition und Höhenlage verstanden (vgl. Kapitel 2.2.1).
2. Gestützt auf das festgestellte biologische Potenzial wird dann mit Hilfe des zweiten Teils des Schlüssels untersucht, inwiefern die Parzelle die Mindestanforderungen erfüllt. Für alle Parzellen der Flächeneinheit wird dieselbe Liste (B oder C) verwendet.

Die lateinischen Namen der Indikatorarten sind für die Alpennordseite auf den Seiten 9 und 10 und für die Alpensüdseite auf den Seiten 14 und 15 aufgeführt.

Wenn verschiedene Arten unter einem Indikator gruppiert sind, werden diese nur einmal gezählt. (Beispiel: Blaue und violette Enziane gehören verschiedenen Arten an, dennoch werden sie als ein Indikator gezählt)

3.2.1 Schlüssel für die ALPENNORDSEITE

<u>**Erster Schritt: Bestimmung des regionalen biologischen Potenzials der Fläche**</u>

Liste A Alpennordseite

Mindestens **3** Indikatoren der Liste A sind auf der Parzelle:

- Alpenhelm
- Arnika*
- Betonie
- Enziane, blau / violett*
- Herbstzeitlose
- Klappertopf
- Mehlprimel*
- Sterndolde
- Sumpf-Herzblatt*
- Teufelskralle
- Trollblume
- Wollgräser*

JA

Die Fläche hat ein hohes biologisches Potenzial.

Benutzen Sie **Liste B** zur Bestimmung der Qualität der Parzelle.

NEIN

Die Fläche hat ein mittleres biologisches Potenzial.

Benutzen Sie **Liste C** zur Bestimmung der Qualität der Parzelle.

Zweiter Schritt: Qualitätstest

Liste B Alpennordseite

Mindestens **6** Indikatoren der **Liste B** sind auf der Testfläche:

Alpenhelm
Arnika*
Aufrechte Trespe*
Betonie
Blutwurz
Dost (inkl. Wirbeldost)
Enziane, blau / violett*
Esparsette*
Primeln, gelb
Glockenblumen
Gräser, borstenblättrig, horstwüchsig* (ohne Festuca rubra)
Habermark
Hainsimsen
Herbstzeitlose
Klappertopf
Knolliger Hahnenfuss*
Kohldistel
Mädesüss
Margerite
Mehlprimel*
Mittlerer Wegerich
Orchideen*
Salbei
Schlaffe Segge
Seggen* (ohne Schlaffe Segge)
Sterndolde
Sumpfdotterblume
Sumpf-Herzblatt*
Teufelskralle
Thymian
Trollblume
Wiesenknopf (kleiner und grosser)
Witwenblumen / Skabiose
Wollgräser*
Zypressenblätterige Wolfsmilch

JA

Die Testfläche weist die erforderliche Mindestqualität auf.

NEIN

Die Testfläche weist die erforderliche Mindestqualität **nicht** auf.

Bitte der kantonalen Fachstelle für Naturschutz die Parzellen melden, die
- 1 oder 2 Arten mit * mit hoher Deckung oder
- 3 Arten mit *

aufweisen.

Liste C Alpennordseite

Mindestens **6** Indikatoren der **Liste C** sind auf der Testfläche:

Alpenhelm
Arnika*
Aufrechte Trespe*
Betonie
Blutwurz
Dost (inkl. Wirbeldost)
Enziane, blau / violett*
Esparsette*
Flaumhafer
Flockenblumen
Glockenblumen
Gräser, borstenblättrig, horstwüchsig* (ohne Festuca rubra)
Habermark
Hainsimsen
Herbstzeitlose
Hopfenklee
Klappertopf
Klee, gelb blühend, grossköpfig
Knolliger Hahnenfuss*
Kohldistel
Korbblütler, gelb, einköpfig (ohne Löwenzahn, Schwarzwurzel, Arnika und Habermark)
Korbblütler, gelb, mehrköpfig (ohne Arnika, Habermark, Gänsedistel, sämtliche Kreuzkräuter)
Kuckuckslichtnelke
Leimkräuter, weiss
Mädesüss
Margerite
Mehlprimel*
Mittlerer Wegerich
Orchideen*
Platterbsen, gelb
Primeln, gelb
Ruchgras
Salbei
Schlaffe Segge
Seggen* (ohne Schlaffe Segge)
Sterndolde
Sumpfdotterblume
Sumpf-Herzblatt*
Teufelskralle
Thymian
Trollblume
Vogel-Wicke
Wiesenknopf (kleiner und grosser)
Witwenblumen / Skabiose
Wollgräser*
Zittergras
Zypressenblätterige Wolfsmilch

NEIN

Die Testfläche weist die erforderliche Mindestqualität **nicht** auf. (→ Meldung an die kantonale Fachstelle, siehe oben)

JA

Die Testfläche weist die erforderliche Mindestqualität auf.

Artenliste für die Alpennordseite

Legende: **+** Indikatoren für Lagen mit mittlerem biologischem Potenzial; **++** Indikatoren für alle Lagen; **+++** Qualitätszeiger für alle Lagen und gleichzeitig Indikatoren der subalpinen und montanen Stufe. * Zeigerarten für NHG-Qualität.

	Liste	Indikatoren	Lateinische Namen	Ausgeschlossene Arten
+++	A, B, C	Alpenhelm (Bartschie)	Bartsia alpina L.	
+++	A, B, C	Arnika*	Arnica montana L.	
++	B, C	Aufrechte Trespe*	Bromus erectus Huds.	
+++	A, B, C	Betonie	Stachys officinalis (L.) Trevis., Stachys pradica (Zant.) Ghreut. Et Pign.	
++	B, C	Blutwurz, Tormentill	Potentilla erecta (L.) Raeusch.	
++	B, C	Dost	Clinopodium vulgare L., Origanum vulgare L.	
+++	A, B, C	Enziane, blau / violett *	Gentiana spp.	Gentiana lutea L., G. punctata
++	B, C	Esparsette*	Onobrychis spp.	
+	C	Flaumhafer	Helictotrichon pubescens (Huds.) Pilg.	
+	C	Flockenblume	Centaurea spp.	
++	B, C	Glockenblumen	Campanula spp.	
++	B, C	Gräser, borstenblätterig, horstwüchsig *	Festuca ovina L. agg., Festuca violacea Gaud. s.l., Festuca valesiaca Schleicher s.l., Festuca varia Haenke s.l., Festuca quadriflora Honck., F. heterophylla Lam., F. halleri All. s.l., Nardus stricta L., Poa bulbosa L., Avenella flexuosa (L.) Parl., Agrostis rupestris All., Agrostis alpina Scop., Stipa spp.,	Festuca rubra L. s.l.
++	B, C	Habermark	Tragopogon spp.	
++	B, C	Hainsimsen	Luzula spp.	
+++	A, B, C	Herbstzeitlose	Colchicum spp.	
+	C	Hopfenklee	Medicago lupulina L.	
+++	A, B, C	Klappertopf	Rhinanthus spp.	
+	C	Klee, gelb blühend, grossköpfig	Lotus spp., Hippocrepis spp., Coronilla spp., Anthyllis spp., Medicago falcata L.	
++	B, C	Knolliger Hahnenfuss*	Ranunculus bulbosus L.	
++	B, C	Kohldiestel	Cirsium oleraceum (L.) Scop.	
+	C	Korbblütler, gelb, einköpfig	Inula salicina L, Inula hirta L., Buphthalmum salicifolium L.,Hypochaeris uniflora, Leontodon hispidus L. s.l. Leontodon crispus Vill., Leontodon helveticus Merat, Leontodon montanus Lam., Leontodon incanus (L.) Schrank s.l., Leontodon saxatilis, Aposeris foetida (L.) Lessing, Crepis bocconei Sell, Crepis alpestris (Jacq.) Tausch, Hieracium intybaceum All., Hieracium pilosella L, Hieracium peletierianum Merat, Hieracium hoppeanum Schultes, Hieracium saus- sureoides Arv.-Touv., Hieracium alpinum L., Hieracium piliferum Hoppe agg.	Taraxacum spp., Scorzo- nera spp., Tragopogon spp., Arnica montana L.

	Liste	Indikatoren	Lateinische Namen	Ausgeschlossene Arten
+	C	Korbblütler, gelb, mehrköpfig	Solidago virgaurea L. s.l., Pulicaria spp., Inula conyza, Inula britannica L, Inula helvetica Weber, Hypochaeris radicata, Hypochaeris maculata, Leontodon autumnalis L., Calycocorsus stipitatus (Jacq.) Rauschert, Picris spp., Crepis praemorsa (L.) Walther, Crepis froelichiana Froehlich, Crepis nemauensis Gouan, Crepis setosa Haller fil., Crepis foetida L., Crepis pyrenaica (L.) Greut., Crepis capillaris (L.) Wallr., Crepis pulchra L., Crepis mollis (Jacq.) Asch., Crepis paludosa (L.) Moench, Crepis conyzifolia (Gouan) Kerner, Crepis biennis L., Crepis nicaeensis Pers., Crepis vesicaria L. s.l., Crepis tectorum L., Hieracium staticifolium All., Hieracium lactucella Wallr., Hieracium angustifolium Hoppe, Hieracium piloselloides Vill., Hieracium bauhinii, Hieracium cymosum L., Hieracium caespitosum Dumort, Hieracium murorum L., Hieracium lachenalii Gmelin, Hieracium bifidum Hornem., Hieracium pictum Pers., Hieracium schmidtii Tausch, Hieracium villosum Jacq., Hieracium villosum Jacq., Hieracium bupleuroides Gmelin, Hieracium glaucum All., Hieracium amplexicaule L., Hieracium humile Jacq., Hieracium tomentosum L., Hieracium prenanthoides Vill., Hieracium umbellatum L., Hieracium laeviga- tum Willd., Hieracium sabaudum L., Hieracium racemosum Willd.	Senecio spp., Sonchus spp., Tragopogon spp., Arnica montana L.
+	C	Kuckuckslichtnelke	Silene flos-cuculi (L.) Clairv.	
+	C	Leimkräuter, weiss	Silene pratensis (Rafn.) Godr., Silene vulgaris (Moench) Garcke s.l., Silene dichotoma Ehrh., Silene nutans L. s.l., Silene rupstris L., Silene pusilla W. et K.	
++	B, C	Mädesüss	Filipendula spp.	
++	B, C	Margerite	Leucanthemum spp.	
+++	A, B, C	Mehlprimel*	Primula farinosa L.	
++	B, C	Mittlerer Wegerich	Plantago media L.	
++	B, C	Orchideen*	Orchidaceae	
+	C	Platterbsen, gelb	Lathyrus pratensis L., L. occidentalis (Fisch. Et Mey.) Fritsch	
++	B, C	Primeln, gelb	Primula acaulis (L.) L., Primula elatior (L.) L., Primula veris L. s.l., Primula auricula L.	
+	C	Ruchgras	Anthoxanthum spp.	
++	B, C	Salbei	Salvia pratensis L.	
++	B, C	Schlaffe Segge	Carex flacca Schreb.	
+++	B, C	Seggen*	Carex spp.	Carex flacca Schreb.
+++	A, B, C	Sterndolde	Astrantia spp.	
++	B, C	Sumpfdotterblume	Caltha palustris L.	
+++	A, B, C	Sumpf-Herzblatt* (Studentenröschen)	Parnassia palustris L.	
+++	A, B, C	Teufelskralle	Phyteuma spp.	
++	B, C	Thymian	Thymus spp.	
+++	A, B, C	Trollblume	Trollius europaeus L.	
+	C	Vogel-Wicke	Vicia cracca	
++	B, C	Wiesenknopf (kleiner und grosser)	Sanguisorba spp.	
++	B, C	Wittwenblumen /	Knautia spp., Scabiosa spp.	
+++	A, B, C	Wollgräser*	Eriophorum spp.	
+	C	Zittergrass	Briza media L.	
++	B, C	Zypressenblätterige Wolfsmilch	Euphorbia cyparissias L.	

3.2.2 Schlüssel für die ALPENSÜDSEITE

<u>Erster Schritt: Bestimmung des regionalen biologischen Potenzials der Fläche</u>

Liste A Alpensüdseite

Mindestens **3** Indikatoren der Liste A sind auf der Parzelle:

- Alpenhelm
- Arnika*
- Betonie
- Enziane, blau / violett*
- Grossblumige Lilien*
- Herbstzeitlose
- Klappertopf
- Mehlprimel*
- Sterndolde
- Sumpf-Herzblatt *
- Teufelskralle
- Trollblume
- Wiesenraute
- Wollgräser*

JA

Die Fläche hat ein hohes biologisches Potenzial.

Benutzen Sie **Liste B** zur Bestimmung der Qualität der Parzelle.

NEIN

Die Fläche hat ein mittleres biologisches Potenzial.

Benutzen Sie **Liste C** zur Bestimmung der Qualität der Parzelle.

Zweiter Schritt: Qualitätstest

Liste B Alpensüdseite

Mindestens **6** Indikatoren der **Liste B** sind auf der Testfläche:

Alpenhelm
Arnika*
Aufrechte Trespe*
Betonie
Blutwurz
Dost (inkl. Wirbeldost)
Enziane, blau / violett* (ohne Gelber Enzian, Getüpfelter Enzian)
Esparsette*
Glockenblumen
Gräser, borstenblättrig, horstwüchsig* (ohne Festuca rubra)
Grossblumige Lilien*
Habermark
Hainsimsen
Herbstzeitlose
Klappertopf
Knolliger Hahnenfuss*
Kohldistel
Labkraut*, gelb
Mädesüss
Margerite
Mehlprimel*
Mittlerer Wegerich
Orchideen*
Primeln, gelb
Salbei
Schlaffe Segge
Seggen* (ohne Schlaffe Segge)
Sterndolde
Sumpfdotterblume
Sumpf-Herzblatt *
Teufelskralle
Thymian
Trollblume
Wiesenknopf (kleiner und grosser)
Wiesenraute
Wollgräser*
Zypressenblätterige Wolfsmilch

JA

Die Testfläche weist die erforderliche Mindestqualität auf.

NEIN

Die Testfläche weist die erforderliche Mindestqualität **nicht** auf.

Liste C Alpensüdseite

Mindestens **6** Indikatoren der **Liste C** sind auf der Testfläche:

Alpenhelm
Arnika*
Aufrechte Trespe*
Betonie
Blutwurz
Dost (inkl. Wirbeldost)
Enziane, blau / violett*
Esparsette*
Flockenblumen
Glockenblumen
Gräser, borstenblättrig, horstwüchsig* (ohne Festuca rubra)
Grossblumige Lilien*
Habermark
Hainsimsen
Herbstzeitlose
Klappertopf
Knolliger Hahnenfuss*
Kohldistel
Labkraut*, gelb
Mädesüss
Margerite
Mehlprimel*
Mittlerer Wegerich
Orchideen*
Primeln, gelb
Salbei
Schlaffe Segge
Seggen* (ohne Schlaffe Segge)
Sterndolde
Sumpfdotterblume
Sumpf-Herzblatt *
Teufelskralle
Thymian
Trollblume
Wiesenknopf (kleiner und grosser)
Wiesenraute
Witwenblumen / Skabiose
Wollgräser*
Zittergras
Zypressenblätterige Wolfsmilch

NEIN

Die Testfläche weist die erforderliche Mindestqualität **nicht** auf.

JA

Die Testfläche weist die erforderliche Mindestqualität auf.

Bitte der kantonalen Fachstelle für Naturschutz die Parzellen melden, die

- 1 oder 2 Arten mit * mit hoher Deckung oder
- 3 Arten mit *

aufweisen.

Artenliste für die Alpensüdseite

Legende: **+** Indikatoren für Lagen mit mittlerem biologischem Potenzial; **++** Indikatoren für alle Lagen; **+++** Qualitätszeiger für alle Lagen und gleichzeitig Indikatoren der collinen und montanen Stufe. * Zeigerarten für NHG-Qualität

	Liste	Indikatoren	Lateinische Namen	Ausgeschlossene Arten
+++	A, B, C	Alpenhelm (Bartschie)	Bartsia alpina L.	
+++	A, B, C	Arnika*	Arnica montana L.	
++	B, C	Aufrechte Trespe*	Bromus erectus Huds.	
+++	A, B, C	Betonie	Stachys officinalis (L.) Trevis., Stachys pradica (Zant.) Ghreut. Et Pign.	
++	B, C	Blutwurz, Tormentill	Potentilla erecta (L.) Raeusch.	
++	B, C	Dost	Clinopodium vulgare L., Origanum vulgare L.	
+++	A, B, C	Enzianen, blau / violett *	Gentiana spp.	Gentiana lutea L., G. punctata L.
++	B, C	Esparsette*	Onobrychis spp.	
+	C	Flockenblume	Centaurea spp.	
++	B, C	Primeln, gelb	Primula acaulis (L.) L., Primula elatior (L.) L., Primula veris L. s.l., Primula auricula L.	
++	B, C	Labkraut*,gelb	Galium verum L. s.l.	
++	B, C	Glockenblumen	Campanula spp.	
++	B, C	Gräser, borstenblätterig, horstwüchsig *	Festuca ovina L. agg., Festuca violacea Gaud. s.l., Festuca valesiaca Schleicher s.l., Festuca varia Haenke s.l., Festuca quadriflora Honck., F. heterophylla Lam., F. halleri All. s.l., Nardus stricta L., Poa bulbosa L., Avenella flexuosa (L.) Parl., Agrostis rupestris All., Agrostis alpina Scop., Stipa spp.,	Festuca rubra L. s.l.
+++	A, B, C	Grossblütige Lilien*	Lilium spp., Paradisea liliastrum (L.) Bertol., Anthericum spp.	
++	B, C	Habermark	Tragopogon spp.	
++	B, C	Hainsimsen	Luzula spp.	
+++	A, B, C	Herbstzeitlose	Colchicum spp.	
+++	A, B, C	Klappertopf	Rhinanthus spp.	
++	B, C	Knolliger Hahnenfuss*	Ranunculus bulbosus L.	
++	B, C	Kohldiestel	Cirsium oleraceum (L.) Scop.	
++	B, C	Mädesüss	Filipendula spp.	

	Liste	Indikatoren	Lateinische Namen	Ausgeschlossene Arten
++	B, C	Margerite	Leucanthemum spp.	
+++	A, B, C	Mehlprimel*	Primula farinosa L.	
++	B, C	Mittlerer Wegerich	Plantago media L.	
++	B, C	Orchideen*	Orchidaceae	
++	B, C	Salbei	Salvia pratensis L.	
++	B, C	Schlaffe Segge	Carex flacca Schreb.	
++	B, C	Seggen*	Carex spp.	Carex flacca Schreb.
+++	A, B, C	Sterndolde	Astrantia spp.	
++	B, C	Sumpfdotterblume	Caltha palustris L.	
+++	A, B, C	Sumpf-Herzblatt* (Studentenröschen)	Parnassia palustris L.	
+++	A, B, C	Teufelskralle	Phyteuma spp.	
++	B, C	Thymian	Thymus spp.	
+++	A, B, C	Trollblume	Trollius europaeus L.	
++	B, C	Wiesenknopf (kleiner und grosser)	Sanguisorba spp.	
+++	A, B, C	Wiesenraute	Thalictrum spp.	
+	C	Wittwenblumen / Skabiose	Knautia spp., Scabiosa spp.	
+++	A, B, C	Wollgräser*	Eriophorum spp.	
+	C	Zittergrass	Briza media L.	
++	B, C	Zypressenblätterige Wolfsmilch	Euphorbia cyparissias L.	

Declaration of consent

on the basis of Article 28 para. 2 of the RSL05 phil.-nat

Name/First Name: Weinrich Maria

Matriculation Number: 16-105-116

Study program: Master of Science in Ecology and Evolution with special qualification in Animal Ecology and Conservation. Universität Bern

Bachelor ☐ Master ■ Dissertation ☐

Title of the thesis: Ecological quality in Swiss lowland meadows: does plant and invertebrate diversity correlate?

Supervisor: Dr Jean-Yves Humbert und Prof Dr Raphaël Arlettaz

I declare herewith that this thesis is my own work and that I have not used any sources other than those stated. I have indicated the adoption of quotations as well as thoughts taken from other authors as such in the thesis. I am aware that the Senate pursuant to Article 36 para. 1 lit. r of the University Act of 5 September 1996 is authorised to revoke the title awarded on the basis of this thesis. I allow herewith inspection in this thesis.

Place/Date Signature