Bimodal seasonal activity of moths and elevation, weather and land use as drivers of their diversity

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ABSTRACT

Moths are an important part of terrestrial insect diversity and contribute substantially to ecosystem functioning. Yet, how their activity varies with the season and how different biotic and abiotic factors (elevation, weather, land use) are simultaneously linked to moth community characteristics are still poorly understood.

We analysed a vast moth community dataset from Switzerland collected by a single expert across 50 years containing data of 2.8 Mio moth individuals (1,045 species), covering the whole yearly cycle. Using regression models, we related moth community characteristics (total abundance, species richness, biomass) to season, elevation, weather and land use (landscape composition).

Moth community characteristics showed a clear bimodal seasonal cycle with an activity peak in early spring and one in summer. The different peaks could be clearly linked to moth species with different overwintering stages, i.e. the spring peak was driven by species overwintering as pupae or adults. Along the elevational gradient, we found increases of all moth community characteristics, levelling of at around 2000 m asl. Also, moth activity increased significantly with increasing temperatures and was higher in landscapes with higher proportions of forests.

Based on a moth dataset of unseen extent, we present a well resolved seasonal activity pattern and quantify the role of elevation, landscape composition (forests) and weather (temperature) in driving moth community characteristics. These results will help to better understand variation in moth activity across different temporal and spatial scales and to design targeted conservation efforts, e.g. in lower elevation sites.

INTRODUCTION

Moths make up the largest share of the species-rich insect group of lepidopterans, but have been receiving less research interest compared to the popular butterflies (New, 2004). This is despite their important role in ecosystems such as pollinators (Knop et al., 2017; Walton et al., 2020) or food source for bats (Vaughan, 1997) and birds (Evans et al., 2024). Moth communities cover species with various ecological strategies, resulting in community changes along biotic and abiotic gradients. Also, moths are susceptible to various global change drivers such land use intensification (Mangels et al., 2017), climate change (Hunter et al., 2014) or light pollution (Knop et al., 2017; van Grunsven et al., 2020). The latter is related to their nocturnal activity and their attraction to artificial light sources, which allows to quantify and characterise activity of nocturnal moths using light trap sampling (Jonason et al., 2014). Yet, how moth activity varies over the season and which parameters drive their abundance, species richness and biomass is still poorly understood. Here, we studied how these moth community characteristics change over the course of the year and how they are related to different biotic and abiotic drivers (elevation, weather, land use).

In temperate regions, insects have distinct seasonal cycles, but these cycles have been insufficiently quantified because observational studies, including studies on moths, often have temporally limited sampling schemes. Consequently, often a unimodal activity pattern is assumed, with one single activity peak of adults during the vegetative period, similar to diel activity peaks. However, recent evidence on different insect groups indicates that neither diel (Knop et al., 2023; Xu et al., 2021; Zoller et al., 2020) nor seasonal activity (Mellard et al., 2019) show unimodal patterns by default. In the case of moths, it is also highly unlikely that there is only a single activity peak of adults during the vegetative period, given their high species richness and their different overwintering strategies, with species overwintering as egg, larvae, pupae, and adults. However, except for a few studies that analysed the intra-annual variability of moth activity over part of the seasonal cycle (Busse et al., 2022; Jonason et al., 2014; Roth et al., 2021) and indicate variability in activity peaks, a comprehensive analysis of moth activity peaks over the entire year is missing so far, most likely due to the lack of suitable data. Insufficient understanding of intra-annual variation of insect communities is problematic (Montgomery et al., 2021), as important population changes of species due to global change might be missed, namely of those active early or late in the season, resulting in biased conclusions on susceptibility of moth communities to global change and its consequences for the provision of ecosystem services.

Besides changes in moth community characteristics across the season, moth communities are driven by various biotic and abiotic factors. These factors might vary spatially between sampling sites, but also temporally between days of sampling. For example, the proportion of suitable habitats in a landscape surrounding a sampling site (e.g. forests) is often positively linked to moth abundance and species richness (e.g. Kühne et al., 2022). Also, it has been found that elevation is a driver of moth communities, with highest richness at mid-elevation sites (Beck et al., 2017). Furthermore, weather conditions (temperature, precipitation) are crucial factors linked to moth activity, which vary on a daily basis and result in more individuals and species of moths being caught during nights in which temperature is higher (Beck et al., 2010; Jonason et al., 2014; Knop et al., 2018). However, large-scale studies on how moth communities are driven by these abiotic and biotic factors are still rare, and their relative importance is so far not well resolved. Better knowledge on the most important drivers of moth community characteristics is however crucial to design specific and efficient conservation measures.

In this study, we analyzed a vast dataset collected by a single expert across 50 years and throughout the seasons in Switzerland, spreading across a large elevational gradient. Based on macro-moth abundance, species richness and estimated biomass from this dataset, we addressed the following research questions:

1. How do moth abundance, richness and biomass change with seasons? How are these patterns influenced by species with different overwintering stages (egg, larva, pupa, adult)?
2. How do moth abundance, richness and biomass vary with weather conditions (temperature, precipitation)?
3. How do moth abundance, richness and biomass change along an elevation gradient?
4. How does landscape composition relate to moth abundance, richness and biomass?

METHODS

Moths dataset

The data were collected with light traps across a 50-year timespan by one of the main experts of the group in Switzerland, Dr. Ladislaus Rezbanyai-Reser (ZOBODAT, 2014–2023), with the purpose to describe the macro-moth communities (including abundance distribution and phenology) at different sites (cf. Rezbanyai-Reser, 2018b). The dataset, which is hosted by *info fauna* (The Swiss Topic Center on Fauna), contains species-level abundance data of macro-moths (Table S1.1 in Supporting Information). The light trap samples allow characterisation of local nocturnal moth communities (Truxa & Fiedler, 2013). All attracted moths were collected and killed with a sampling fluid (mostly chloroform). Light traps were operated in two different ways (Fig. S1.1): Fixed traps, which were installed for a long period (mostly several months) and emptied daily over the whole period in which they were active, and manual traps, which were installed only in single selected nights and which were only active for some hours (sampling duration of 1–13 hours). For fixed trapping, there was a commonly used trap model ("type 1", used in 154 site–year combinations) and a more rarely used trap model ("type 2", used in 10 site–year combinations). The number of traps installed at a site and the lamps used differed between sampling procedures, sites, and years. The number of traps varied from one trap up to four simultaneously active traps at a single site (Fig. S1.2), but moth data were only available for the pooled samples of all active traps. Three lamp types can be distinguished, which were used differently often: 150–160W mercury mixed-light lamps (150–160W HWL), 80W mercury mixed-light lamps (80W HWL) and 125W mercury vapour lamps (125W HQL) (Fig. S1.3). When several traps were active, several lamp types might have been used, resulting in a joint category 150–160W HWL/125W HQL.

The dataset holds data from 171 sites spread across an elevational gradient between 193m asl. and 2454m asl. in Switzerland (Fig. S1.4) and from 49 years (1972–2021; no samples in 2019), entailing 663 unique site and year combinations. A total of 37,461 nights were monitored, in which 2,814,187 individuals of 1,045 nocturnal macro-moth species (Table S1.1) were caught (day active species that were accidentally collected were excluded from analyses). Some sites with manual traps were in proximity and normally ran simultaneously in the same nights (34 site groups including 94 sites, distances between simultaneously active sites ranging from 38m to 6.1km). These sites were still treated as separate sites, but their grouping was accounted for in the statistical models. For fixed traps, we assumed that stretches of 10 or more nights without a single record were due to inactivity of a trap (e.g., due to misfunctioning) and we excluded them from analyses (1614 nights, leaving 35,847 nights). Fixed traps were on average active for 194 nights per year (range: 5–362 nights) with July 24 being the mean sampling day of the year (range: Feb 3 – Aug 28); manual traps in a site were on average active for 8 nights per year (range: 1–71 nights) with July 16 being the mean sampling day of the year (range: Feb 3 – Nov 11) (Fig. S1.5). To test how weather conditions during sampling affect moth activity and thus sampling numbers, we determined the temperature and precipitation for each sampling night. We used gridded daily temperature and precipitation data (1.25 degree minute grid; approx. 2.3 km × 1.6 km) provided by MeteoSwiss (https://www.meteoswiss.admin.ch) and used the values of the closest grid cell. Mean temperature and total precipitation of the two sampling days enclosing the sampling night were used (2 days average/total).

Landscape composition

Landscape composition at the study sites was determined based on aerial photo interpretation for the whole of Switzerland at four time steps (1979–1985, 1990–1998, 2004–2009, 2012–

2019), which attributed each hectare a categorical land-use and land-cover value ("Arealstatistik", Bundesamt für Statistik, 2021). We determined the cover of four broad land-use types (forests, grasslands, croplands, sealed area) (Table S1.2) in the surroundings of the study plots. For forest and grassland cover, we expected positive relations to moth community characteristics, as they may provide valuable habitats (Archaux et al., 2018). For cropland cover, we expected negative relations to community characteristics as the barely provide habitats and might even be detrimental e.g. due to higher amounts pesticide being present (Archaux et al., 2018; Brühl et al., 2021). Cover of sealed area was used as a proxy of urbanisation, for which we might expect negative effects e.g. due to light pollution (van Grunsven et al., 2020), but could also envision positive relations e.g. due to availability of more diverse food plants (Hall et al., 2017). The cover of these land-use types was determined in a 500m radius around the plots. Starting from the centre point of the hectare of the study site, we included hectares, whose centre point was within the 500m radius of the focal centre point (81ha). The 500m radius was chosen as it covers dispersal distances of many moth species and is a relevant scale for the different land-use types that were involved (Fuentes-Montemayor et al., 2011). Furthermore, it limits spatial autocorrelation among study sites. These land-use covers were attributed to the average year of the aerial photos that were included. For years that fell between the four observation time points, land-use covers were interpolated linearly from the land-use covers in the two adjacent time points. For sampling years prior to the first year with land-use data available (~1982) or after the last year with land-use data available (~2015), proportions of the closest year were used, following a conservative scenario of no change.

Statistical analyses

All statistical analyses were performed in R version 4.2.0 (R Core Team, 2022). All code used for analyses is available from the online repository located at https://github.com/nefff1/moths-CH-Reser.

For each sampling night, we determined three community characteristics: total abundance (sum of individuals across all species), species richness (number of species), and total biomass. Total biomass was estimated from species-level dry mass, which was determined from forewing length through allometric equations (Kinsella et al., 2020). Species-level wingspan data, which are more readily available than forewing-length data, were assembled from Jonko (2002–2022) (*n* = 981) and completed with data from other sources (Fibiger, 1990; Potocký et al., 2018; Ronkay et al., 2001) (*n* = 12). Based on data for a subset of study species (Cook et al., 2022), a linear relation between forewing length and wingspan was determined and used to estimate forewing length for all study species. These data were finally used to estimate species dry mass. For species where forewing length could not be retrieved (*n* = 13), dry mass was estimated from congeneric species.

The three community characteristics were used as response variables in the regression models. We used a zero-inflated negative binomial response distribution for abundance and richness (log link) and a hurdle gamma distribution for biomass (log link), which yielded high agreements between posterior predictive and empirical data distributions (Fig. S1.6). All models included a smoothing term for the day of the year to quantify seasonal patterns, a smoothing term for the elevation of the study site (mean elevation of the study site measured at a hectare) as well as linear terms for weather parameters for the sampling night (temperature and precipitation). To check how the seasonal patterns are influenced by species with different overwintering strategies, we divided the dataset by overwintering stage (egg, larva, pupa, adult) and ran the same models for these data subsets. Overwintering stages were gathered from several trait collections (Cook et al., 2022; Mangels et al., 2017; Potocký et al., 2018) and completed based on additional moth trait databases (Jonko, 2002–2022; Ziegler, 2005–2022). To analyse the relation of abundance, richness, and biomass to landscape composition, we included cover of the different land-use types (forest, grassland, cropland, sealed area) as predictor variables.

Furthermore, all models had a set of fixed and random factors to account for the sampling design. Fixed effects were trap type (fixed type 1, fixed type 2, or manual), lamp type (four nominal factor levels), number of traps (ordinal factor with four levels) and a two-level nominal factor denoting whether the site was sampled in the previous night to account for persisting attraction of light traps. Additionally, there was a smoothing term accounting for the sampling duration, which was only included for manual traps and if data on sampling duration was available (2800 out of 4024 manual sampling nights). We chose a smoothing term over a linear effect as we expected moth activity to be changing over the course of a night (e.g. Ma & Ma, 2013). The random structure was composed of the site ID (n = 171), the site ID and year combination (n = 663), a factor accounting for the sampling night, where proximate sites operated in the same night are grouped together (n = 34,390), and a spatio-temporal grouping factor of study sites to account for among-region and year variability (n = 249). The latter was defined such that all sites in a year that were within 20km of each other were grouped. In all models, continuous predictor variables were standardised to mean 0 and standard deviation 1 prior to analyses. Sum-to-zero contrasts were used for nominal factor variables.

The basic structure of all models was built through ‘brms’ (Bürkner et al., 2022) and then manually adapted to meet the specific requirements (covariate for sampling duration only included if data was available) by directly changing the underlying Stan code of the model. The final models were run through ‘rstan’ (Guo et al., 2022) (4 Markov chain Monte Carlo chains with 2000 iterations each, including 1000 warm-up iterations). Priors followed standard settings of the ‘brms’ package representing weakly informative priors (details available in the online repository for the code). Model results were evaluated based on posterior distributions of model predictions.

We used the mean and 95% symmetric credible intervals (CIs) based on 2.5% and 97.5% quantiles to summarise posterior distributions. To check whether the four chains mixed well, we calculated Rhat statistics for estimates of intercepts, fixed effect slopes and spline coefficients (smoothing terms) through the package ‘rstan‘ (Guo et al., 2022). The standard threshold of 1.1 was met by all values of all final models.

RESULTS

Seasonal patterns in moth community characteristics

All three community characteristics showed a clear seasonal pattern with two distinct peaks (Fig. 1). The first peak, which was clearly lower (richness) or slightly lower (abundance, biomass) than the second peak, was at the end of March (March 24 for all community characteristics). The second peak was mid-July (July 12 for abundance and biomass, July 8 for richness) and for abundance and biomass was followed by a plateau peaking again mid-August (August 10 for abundance, August 12 for biomass). The single peaks could be reconstructed for subsets of the dataset defined by species overwintering stages (Fig. 1). At the same time as the first peak, there was a peak of species overwintering as pupa and of the few species overwintering as adults. At the time of the second peak, species overwintering as larva had a coinciding peak. Also, all community characteristics of species overwintering as pupa had a second peak at this time, which however was for abundance and biomass clearly lower than the first peak. Species overwintering in the egg stage, which tend to be rarer than those overwintering as larva or pupa, had their peak late in the year (between October 22 and November 3). Around the same time, the decline of overall community characteristics was slightly mitigated.

Sampling night specifics and moth community characteristics

Several sampling night specifics were related to the three investigated community characteristics (abundance, richness, biomass) (Fig. 1, Fig. S1.7, Table S1.3). With respect to weather conditions, there was a clear and strong increase of all community characteristics with increasing temperatures of the sampling night (Fig. 1, Table S1.3). An increase of sampling night temperature by 50% of its range (corresponding to a rise of 17.2°C) was related to an increase of abundance by a factor 9.68 (95%-CI: 8.98–10.47), of richness by a factor 6.44

(95%-CI: 6.16–6.74), and of biomass by a factor 5.14 (95%-CI: 4.77–5.55) (Table 1). For an increase of temperature by 5°C, this corresponds to the factors 1.94 (95%-CI: 1.89–1.98); abundance), 1.72 (95%-CI: 1.70–1.74); richness), and 1.61 (95%-CI: 1.57–1.65); biomass). There was also evidence for slight increases in community characteristics with increasing precipitation in the sampling night (factor 1.12 [95%-CI: 1.02–1.24] for abundance, 1.03 [95%-CI: 0.97–1.1] for richness, and 1.19 [95%-CI: 1.07–1.31] for biomass with an increase of 50% of the range, corresponding to 140mm) (Table 1).

For other night- and sampling-specific covariates, which were included to correct for data specificities, we found particularly strong relations of community characteristics to trap type, sampling history (i.e. whether there was sampling in the previous night), and to sampling duration (Fig. S1.7, Table S1.3). While there was no clear difference between the two fixed trap types, samples from manual traps were estimated to have a factor 6.54 (95%-CI: 4.68–9.3) higher abundance compared to fixed traps of type 1, a factor 3.14 (95%-CI: 2.51–3.97) higher richness, and a factor 5.07 (95%-CI: 3.56–7.21) higher biomass. If there was no sampling taking place at a location in the previous night, samples were estimated to have a factor 0.81 (95%-CI: 0.71–0.92) lower abundance, a factor 0.88 (95%-CI: 0.81–0.96) lower richness, and a factor 0.77 (95%-CI: 0.68–0.87) lower biomass. With increasing sampling duration, there were increases in all community characteristics (Fig. S1.7). This increase was not linear, but there was a first peak with a following plateau reached after approx. 7 hours of sampling (flattening of the curve already after approx. 5 hours).

Elevation and landscape composition

All three community metrics increased with elevation, with the increase being close-to linear (Fig. 1, Table S1.3). An increase of elevation by 50% of its range (corresponding to a rise of 1130m) was related to an increase of abundance by a factor 3.33 (95%-CI: 2.49–4.44), of richness by a factor 1.38 (95%-CI: 1.13–1.67), and of biomass by a factor 3.54 (95%-CI: 2.68–4.67) (Table 1). For all three community characteristics and particularly for richness, a peak with a following plateau or decrease was evident after reaching an elevation of around 2000 m asl (Fig. 1).

For the effects of the landscape variables (Fig. 2, Table S1.3), there was strong evidence for community characteristics to be higher if cover of forests in the surrounding was high . If forest cover within a radius of 500m around the plot was higher by 50% of its range (corresponding to an approx. proportion of 0.5) , abundance was higher by a factor 1.93 (95%-CI: 1.45–2.53), richness by a factor 1.49 (95%-CI: 1.22–1.81), and biomass by a factor 1.72 (95%-CI: 1.30–2.29) (Table 1). There was also a tendency for all community characteristics to be higher with increasing proportion of sealed area in the plot surrounding. If sealed area was by 50% of its range higher (corresponding to a proportion of 0.16), abundance was estimated to be higher by a factor 1.26 (95%-CI: 0.97–1.64), richness by a factor 1.16 (95%-CI: 0.98–1.39), and biomass by a factor 1.26 (95%-CI: 0.98–1.61) (Table 1).

DISCUSSION

When relating moth community characteristics to the day of the year (question 1), a clear seasonal pattern was evident, with a peak in early spring and one in summer. The distinct pattern could clearly be related to the life cycles of moth groups distinguished by overwintering stage. The spring peak was related to high activity of species overwintering as adults and pupae, the summer peak to species overwintering as pupae or larvae. In fall, egg-overwintering species were peaking, which was also evident from the seasonal pattern of the overall community. While the observed summer peak matches findings from previous studies (Busse et al., 2022; Jonason et al., 2014; Roth et al., 2021), there is at best some indication for the spring peak in these studies because sampling activity only started around that time. Starting sampling campaigns too late within the year result in systematic under-sampling of species groups that overwinter as pupae or adults. As overwintering stage has regularly been related to species' susceptibility to global change drivers such as climate change or land-use intensification (Forsman et al., 2016; Keret et al., 2020; Mangels et al., 2017; Mattila et al., 2006, 2008), restricted sampling within the season can lead to biased conclusions. Furthermore, the observed spring peak was rather narrow. If species phenologies are shifting within years due to climate change (Duchenne et al., 2020), while sampling schemes are not adapted to these shifts, wrong conclusions about temporal trends might be drawn (Didham et al., 2020).

There was a strong signal of the weather conditions of the sampling night on all moth community characteristics (questions 2). Particularly strong relations were found to the temperature of the sampling night, which is in line with previous findings (Beck et al., 2010; Jonason et al., 2014; Knop et al., 2018) and reflects increases in moth activity with increasing temperature. The effect size was estimated to an increase of community characteristics by 50–100% for a temperature increase of only 5°C (while correcting for elevation and season), which is considerable and needs to be accounted for when analyzing datasets covering nights with fluctuating temperatures.

Unimodal patterns of species richness along elevational gradients with a mid-elevation peak are common for many species groups (Rahbek, 2005). Large-scale analyses are rare for moths, but mid-elevation peaks seem to be common (Beck et al., 2017). For moths in the Alps, one study based on a spatially and temporally restricted dataset reports an unimodal peak, whose position depends on the season but moves as high as 1800 m asl (Beck et al., 2010). Here, we show an increase of all community characteristics – particularly strong for abundance and biomass – along the studied elevational gradient, which levels of at around 2000 m asl (question 3). Because the studied dataset covers few sites above 2000 m asl and none above 2500 m asl, the observed pattern indicates a unimodal pattern in all community characteristics with a peak at around 2000 m asl. Although the peak is comparably high up the elevational gradient, the pattern corresponds well with previous data on moths (Beck et al., 2010) and with data from several other arthropod groups from the Alps (Fontana et al., 2020). The underlying drivers of this pattern might be manifold (Beck et al., 2017; Hodkinson, 2005; McCoy, 1990). For the studied gradient, land-use related pressures as well as light pollution are largely decreasing with elevation, which might be driving at least some of the observed increase with elevation.

With relation to landscape composition (question 4), we found strongest relations of moth community characteristics to the cover of forests. There were more moths present if cover of forests was high, highlighting their importance for sustaining high moth abundance and richness (Fuentes-Montemayor et al., 2012; Kühne et al., 2022). Furthermore, there was indication for a positive effect of a higher cover of sealed area, i.e. of urban areas. As for other pollinator groups, urban areas may present additional floral resources for moth communities (Hall et al., 2017), which might explain this positive relation. Why the potentially negative effect of higher light pollution (van Grunsven et al., 2020) in these urbanized landscapes was not evident needs further investigation, though. Promoting forest elements across the landscape mosaic is imminent to support diverse and abundant moth communities.

Based on a moth community dataset of unseen extent, we could evaluate the relations of different biotic and abiotic factors to moth community characteristics. The bimodal seasonal pattern with two distinct peaks in all community metrics (abundance, richness, biomass) is in this fine resolution new to research and will help to better evaluate and understand results from studies on smaller scales, to plan future sampling campaigns, and to target conservation efforts more effectively. Nightly temperatures are a very important driver of moth numbers, with even small increases having profound effects on all community characteristics. All moth characteristics increased along the investigated elevational gradient, highlighting the importance of high-elevation habitats for conserving moth diversity. At the same time, lower numbers of moth individuals and species at lower elevations might be related to the multitude of anthropogenic pressures such as intensive land use and light pollution, which are more prevalent at lower altitudes. Furthermore, there was a positive relation of moth community characteristics to forest cover. Besides reducing anthropogenic pressures such as light pollution, preserving and promoting woodlands, particularly in low-elevation landscapes, might be key to promote diverse and abundant moth communities in a changing world.

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DATA ACCESSIBILITY STATEMENT

The raw moths records data is hosted by info fauna and protected by a code of conduct, but might be obtained from info fauna upon request when in accordance with this code of conduct. Moths records data at coarser spatial resolution and with unique identifier for the sampling location and sampling details necessary to reproduce the models will be made available through the GBIF database. The weather data are under restricted access but might be directly obtained from MeteoSwiss (https://www.meteoswiss.admin.ch). Other data and codes necessary to reproduce the analyses are available from the GitHub repository located at https://github.com/nefff1/moths-CH-Reser.

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Table 1 Model predictions on the change in moth abundance, richness, and biomass (g), if a variable is increased by 50% of its range of occurring values (indicated in the '50% step' column). Numbers are factors by which the response variable changes. Point estimates (Est.) and 95% credible intervals (CI) are given. Grey shading indicates variables for which the 95%-CI does not include 1.

		Abundance			**Richness**			**Biomass (g)**		
Variable	**50% step**	**Est.**	**Lower 95%-CI**	**Upper 95%-CI**	**Est.**	**Lower 95%-CI**	**Upper 95%-CI**	**Est.**	**Lower 95%-CI**	**Upper 95%-CI**
Elevation[1]	1130 m	3.33	2.49	4.44	1.38	1.13	1.67	3.54	2.68	4.67
Precipitation	140 mm	1.12	1.02	1.24	1.03	0.97	1.10	1.19	1.07	1.31
Temperature	17.2 °C	9.68	8.98	10.47	6.44	6.16	6.74	5.14	4.77	5.55
Prop. forests	0.494	1.93	1.45	2.53	1.49	1.22	1.81	1.72	1.3	2.29
Prop. grasslands	0.488	1.01	0.73	1.39	0.93	0.74	1.14	0.99	0.74	1.36
Prop. croplands	0.443	1.00	0.69	1.43	0.89	0.69	1.15	0.99	0.69	1.42
Prop. sealed area	0.162	1.26	0.97	1.64	1.16	0.98	1.39	1.26	0.98	1.61

[1] Term included as a smoothing term. Because the prediction is close to linear, change factors still harbour useful information. The values are the means across 100 different 50% ranges.

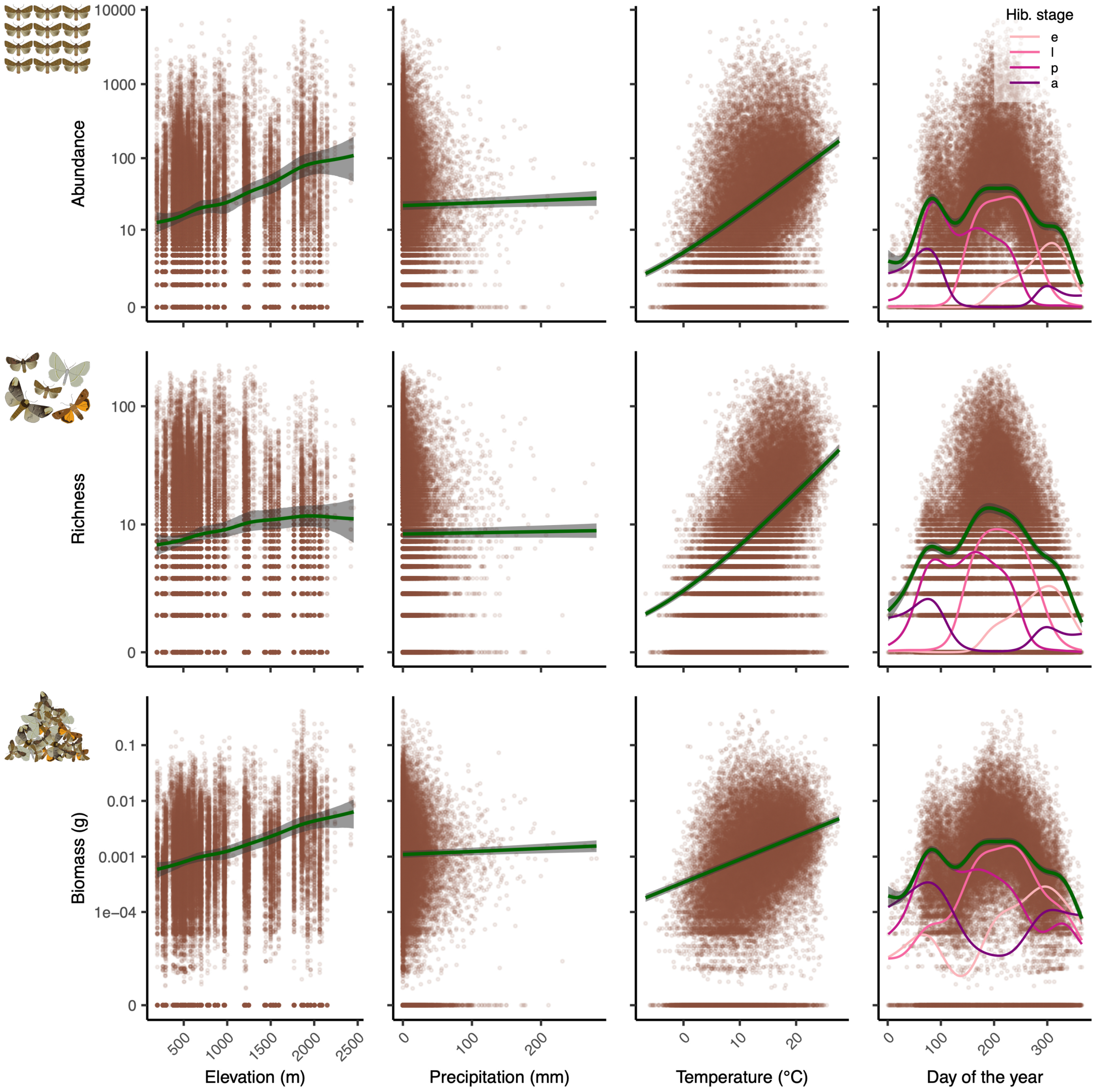

Fig. 1 Conditional effects of different model covariates (elevation, precipitation and temperature of sampling night, day of the year) on moth abundance, richness, and biomass. The *y* axis shows (predicted) abundance, richness, or biomass per sampling night. Point estimates are in green, shaded areas show 95% credible intervals. Underlying points show data per sampling night (*n* = 35,847). For day of the year, conditional effects from models run on subgroups defined by hibernation stage (e: egg; l: larva; p: pupa; a: adult) are shown along the conditional effects from the full model. Note that the *y* axes are on log scale (after adding the minimal non-zero value to all values). Effects of other covariates are shown in Fig. S1.7. Detailed model results in Table S1.3.

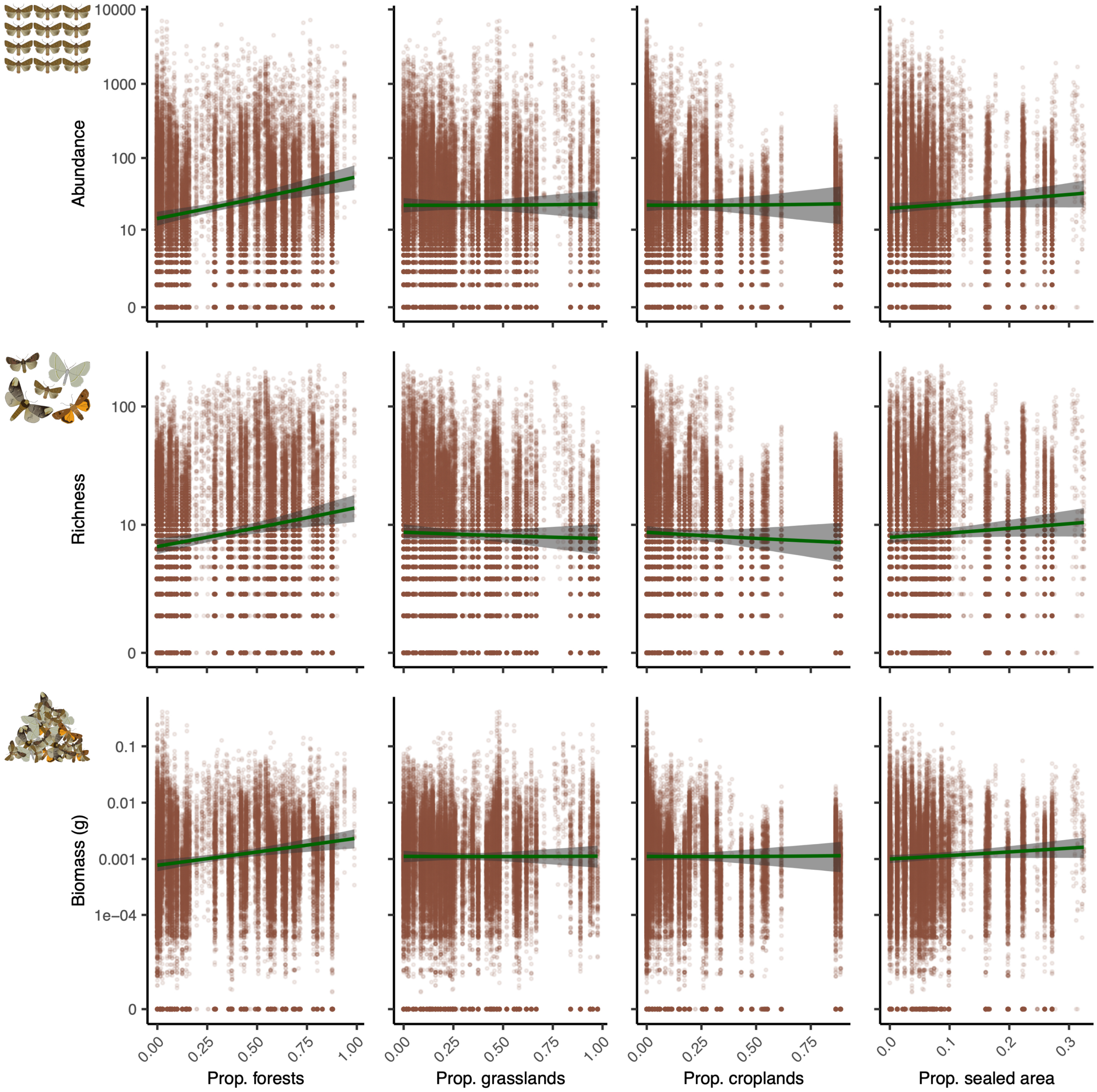

Fig. 2 Conditional effects of different landscape variables on moth abundance, richness, and biomass. Landscape variables are the covers of different land-use types (forests, grasslands, croplands, sealed area) within a radius of 500m around the study site. The *y* axis shows (predicted) abundance, richness, or biomass per sampling night. Point estimates are in green, shaded areas show 95% credible intervals. Underlying points show data per sampling night (*n* = 35,847). Note that the *y* axes are on log scale (after adding the minimal non-zero value to all values). Detailed model results in Table S1.3.

Supporting Information: Appendix S1

Table S1.1 Overview of all moth species recorded with family and superfamily attribution**.**

Superfamily	Family	Species
Bombycoidea	Brahmaeidae	Lemonia taraxaci
	Endromidae	Endromis versicolora
	Saturniidae	Aglia tau, Saturnia pavonia, S. pavoniella, S. pyri
	Sphingidae	Acherontia atropos, Agrius convolvuli, Deilephila elpenor, D. porcellus, Hyles euphorbiae, H. gallii, H. livornica, H. vespertilio, Laothoe populi, Mimas tiliae, Proserpinus proserpina, Smerinthus ocellata, Sphinx ligustri, S. pinastri
Cossoidea	Cossidae	Cossus cossus, Phragmataecia castaneae, Zeuzera pyrina
Drepanoidea	Drepanidae	Achlya flavicornis, Cilix glaucata, Cymatophorina diluta, Drepana curvatula, D. falcataria, Falcaria lacertinaria, Habrosyne pyritoides, Ochropacha duplaris, Polyploca ridens, Sabra harpagula, Tethea ocularis, T. or, Tetheella fluctuosa, Thyatira batis, Watsonalla binaria, W. cultraria, W. uncinula
Geometroidea	Geometridae	Abraxas grossulariata, A. sylvata, Acasis appensata, A. viretata, Adactylotis contaminaria, Aethalura punctulata, Agriopis aurantiaria, A. bajaria, A. leucophaearia, A. marginaria, Alcis deversata, A. jubata, A. repandata, Aleucis distinctata, Alsophila aceraria, A. aescularia, Angerona prunaria, Anticlea derivata, Anticollix sparsata, Apeira syringaria, Aplocera plagiata, A. praeformata, Apocheima hispidaria, Arichanna melanaria, Ascotis selenaria, Aspitates gilvaria, Asthena albulata, A. anseraria, Biston betularia, B. strataria, Bupalus piniaria, Cabera exanthemata, C. pusaria, Campaea margaritaria, Camptogramma bilineata, C. scripturata, Carsia sororiata, Cataclysme riguata, Catarhoe cuculata, C. rubidata, Cepphis advenaria, Charissa ambiguata, C. glaucinaria, C. italohelveticus, C. obscurata, C. pullata, C. variegata, Chesias legatella, C. rufata, Chiasmia clathrata, Chlorissa cloraria, C. viridata, Chloroclysta miata, C. siterata, Chloroclystis v-ata, Cidaria fulvata, Cleora cinctaria, Cleorodes lichenaria, Coenotephria ablutaria, C. salicata, C. tophaceata, Colostygia aptata, C. aqueata, C. kollariaria, C. laetaria, C. olivata, C. pectinataria, C. puengeleri, C. turbata, Colotois pennaria, Comibaena bajularia, Cosmorhoe ocellata, Costaconvexa polygrammata, Crocallis elinguaria, C. tusciaria, Cyclophora albiocellaria, C. albipunctata, C. annularia, C. linearia, C. pendularia, C. porata, C. punctaria, C. puppillaria, C. quercimontaria, C. ruficiliaria, C. suppunctaria, Deileptenia ribeata, Dysstroma citrata, D. truncata, Earophila badiata, Ecliptopera capitata, E. silaceata, Ectropis crepuscularia, Electrophaes corylata, Elophos caelibaria, E. operaria, Ematurga atomaria, Emmiltis pygmaearia, Ennomos alniaria, E. erosaria, E. fuscantaria, E. quercaria, E. quercinaria, Entephria caesiata, E. cyanata, E. flavata, E. flavicinctata, E. infidaria, E. nobiliaria, Epilobophora sabinata, Epione repandaria, E. vespertaria, Epirrhoe alternata, E. galiata, E. molluginata, E. rivata, E. tristata, Epirrita autumnata, E. christyi, E. dilutata, Erannis defoliaria, Euchoeca nebulata, Eulithis mellinata, E. populata, E. prunata, E. testata, Euphyia biangulata, E. frustata, E. unangulata, Eupithecia abbreviata, E. abietaria, E. absinthiata, E. actaeata, E. analoga, E. assimilata, E. carpophagata, E. cauchiata, E. centaureata, E. conterminata, E. cretaceata, E. denotata, E. denticulata, E. distinctaria, E. dodoneata, E. egenaria, E. ericeata, E. exiguata, E. expallidata, E. extraversaria, E. gemellata, E. graphata, E. gueneata, E. haworthiata, E. icterata, E. immundata, E. impurata, E. indigata, E. innotata, E. insigniata, E. intricata, E. inturbata, E. irriguata, E. lanceata, E. laquaearia, E. lariciata, E. linariata, E. nanata, E. ochridata, E. orphnata, E. pernotata, E. pimpinellata, E. plumbeolata, E. pusillata, E. pyreneata, E. satyrata, E. schiefereri, E. selinata, E. semigraphata, E. silenata, E. sinuosaria, E. subfuscata, E. subumbrata, E. succenturiata, E. tantillaria, E. tenuiata, E. tripunctaria, E. trisignaria, E. undata, E. valerianata, E. venosata, E. veratraria, E. virgaureata, E. vulgata, Eustroma reticulata, Fagivorina arenaria, Gagitodes sagittata, Gandaritis pyraliata, Geometra papilionaria, Gnophos furvata, G. obfuscata, Gymnoscelis rufifasciata, Heliomata glarearia, Hemistola chrysoprasaria, Hemithea aestivaria, Horisme aemulata, H. calligraphata, H. radicaria, H. tersata, H. vitalbata, Hydrelia flammeolaria, H. sylvata, Hydria cervinalis, H. montivagata, H. undulata, Hydriomena furcata, H. impluviata, H. ruberata, Hylaea fasciaria, Hypomecis punctinalis, H. roboraria, Idaea aureolaria, I. aversata, I. biselata, I. calunetaria, I. contiguaria, I. degeneraria, I. deversaria, I. dilutaria, I. dimidiata, I. emarginata, I. flaveolaria, I. fuscovenosa, I. humiliata, I. inquinata, I. laevigata, I. macilentaria, I. moniliata, I. muricata, I. nitidata, I. obsoletaria, I. ochrata, I. politaria, I. rubraria, I. rufaria, I. rusticata, I. seriata, I. sericeata, I. serpentata, I. straminata, I. subsericeata, I. sylvestraria, I. trigeminata, I. typicata, Isturgia arenacearia, Jodis lactearia, J. putata, Lampropteryx suffumata, Larentia clavaria, Ligdia adustata, Lobophora halterata, Lomaspilis marginata, Lomographa bimaculata, L. temerata, Lycia alpina, L. hirtaria, L. zonaria, Macaria alternata, M. artesiaria, M. brunneata, M. liturata, M. notata, M. signaria, M. wauaria, Martania taeniata, Melanthia alaudaria, M. procellata, Menophra abruptaria, M. nycthemeraria, Mesoleuca albicillata, Mesotype didymata, M. parallelolineata, M. verberata, Minoa murinata, Nebula achromaria, N. nebulata, Nothocasis sertata, Odontopera bidentata, Operophtera brumata, O. fagata, Opisthograptis luteolata, Orthonama obstipata, O. vittata, Ourapteryx sambucaria, Pachycnemia hippocastanaria, Paradarisa consonaria, Parectropis similaria, Pareulype berberata, Pasiphila chloerata, P. debiliata, P. rectangulata, Pelurga comitata, Pennithera firmata, Perconia strigillaria, Peribatodes perversaria, P. rhomboidaria, P. secundaria, Perizoma affinitata, P. albulata, P. alchemillata, P. bifaciata, P. blandiata, P. flavofasciata, P. hydrata, P. incultaria, P. juracolaria, P. lugdunaria, P. minorata, P. obsoletata, Petrophora chlorosata, Phaiogramma etruscaria, Phigalia pilosaria, Philereme transversata, P. vetulata, Plagodis dolabraria, P. pulveraria, Plemyria rubiginata, Pseudoterpna pruinata, Pterapherapteryx sexalata, Pungeleria capreolaria, Rheumaptera subhastata, Rhodometra sacraria, Rhodostrophia calabra, R. vibicaria, Sciadia zelleraria, Scopula caricaria, S. confinaria, S. decorata, S. floslactata, S. imitaria, S. immorata, S. immutata, S.

		incanata, S. marginepunctata, S. nigropunctata, S. ornata, S. rubiginata, S. submutata, S. subpunctaria, S. ternata, S. umbelaria, S. virgulata, Scotopteryx angularia, S. bipunctaria, S. chenopodiata, S. luridata, S. moeniata, S. mucronata, S. octodurensis, S. vicinaria, Selenia dentaria, S. lunularia, S. tetralunaria, Selidosema brunnearia, S. plumaria, Siona lineata, Spargania luctuata, Stegania cararia, S. trimaculata, Synopsia sociaria, Tephronia sepiaria, Thalera fimbrialis, Thera britannica, T. cembrae, T. cognata, T. cupressata, T. juniperata, T. obeliscata, T. variata, T. vetustata, Theria primaria, T. rupicapraria, Thetidia smaragdaria, Timandra comae, Trichopteryx carpinata, T. polycommata, Triphosa dubitata, T. sabaudiata, T. tauteli, Venusia blomeri, V. cambrica, Xanthorhoe biriviata, X. decoloraria, X. designata, X. ferrugata, X. fluctuata, X. incursata, X. montanata, X. quadrifasiata, X. spadicearia, Yezognophos dilucidaria, Y. serotinaria, Y. vittaria
Hepialoidea	Hepialidae	Gazoryctra ganna, Hepialus humuli, Korscheltellus fusconebulosa, K. lupulina, Phymatopus hecta, Triodia sylvina
Lasiocampoidea	Lasiocampidae	Cosmotriche lobulina, Dendrolimus pini, Eriogaster arbusculae, E. catax, E. lanestris, Euthrix potatoria, Gastropacha quercifolia, Lasiocampa quercus, L. trifolii, Macrothylacia rubi, Malacosoma alpicola, M. castrensis, M. neustria, Odonestis pruni, Phyllodesma tremulifolia, Poecilocampa alpina, P. populi, Trichiura crataegi
Noctuoidea	Erebidae	Arctia caja, A. flavia, A. matronula, A. testudinaria, A. villica, Arctornis l-nigrum, Atolmis rubricollis, Autophila dilucida, Callimorpha dominula, Calliteara pudibunda, Calyptra thalictri, Catephia alchymista, Catocala coniuncta, C. dilecta, C. electa, C. elocata, C. fraxini, C. fulminea, C. nupta, C. nymphaea, C. nymphagoga, C. promissa, C. puerpera, C. sponsa, Chelis simplonica, Colobochyla salicalis, Coscinia cribraria, Cybosia mesomella, Diacrisia purpurata, D. sannio, Diaphora mendica, D. sordida, Dysgonia algira, Eilema caniola, E. cereola, E. complana, E. depressa, E. griseola, E. lurideola, E. lutarella, E. palliatella, E. pseudocomplana, E. pygmaeola, E. sororcula, Epatolmis luctifera, Eublemma ostrina, E. parva, E. polygramma, E. purpurina, Euplagia quadripunctaria, Euproctis chrysorrhoea, Grammodes stolida, Gynaephora fascelina, Herminia grisealis, H. tarsicrinalis, H. tarsipennalis, H. tenuialis, Hypena crassalis, H. lividalis, H. obesalis, H. obsitalis, H. proboscidalis, H. rostralis, Hypenodes humidalis, Hyphantria cunea, Idia calvaria, Laspeyria flexula, Leucoma salicis, Lithosia quadra, Lygephila craccae, L. lusoria, L. pastinum, L. viciae, Lymantria dispar, L. monacha, Macrochilo cribrumalis, Metachrostis dardouini, Miltochrista miniata, Minucia lunaris, Nudaria mundana, Ocneria rubea, Ocnogyna parasita, Orgyia antiqua, O. recens, Paidia rica, Paracolax tristalis, Parascotia fuliginaria, Pechipogo strigilata, Pelosia muscerda, P. obtusa, Phragmatobia fuliginosa, Phytometra viridaria, Polypogon gryphalis, P. plumigeralis, P. tentacularia, Rivula sericealis, Schrankia costaestrigalis, S. taenialis, Scoliopteryx libatrix, Setina irrorella, Sphrageidus similis, Spilarctia lutea, Spilosoma lubricipeda, S. urticae, Thumatha senex, Trisateles emortualis, Tyria jacobaeae, Watsonarctia deserta, Zanclognatha lunalis, Z. zelleralis
	Euteliidae	Eutelia adulatrix
	Noctuidae	Abrostola agnorista, A. asclepiadis, A. tripartita, A. triplasia, Acontia trabealis, Acosmetia caliginosa, Acronicta aceris, A. alni, A. auricoma, A. cuspis, A. euphorbiae, A. leporina, A. megacephala, A. menyanthidis, A. psi, A. rumicis, A. strigosa, A. tridens, Actebia multifida, A. praecox, Actinotia polyodon, Aedia funesta, A. leucomelas, Agrochola helvola, A. laevis, A. litura, A. lota, A. lychnidis, A. macilenta, A. nitida, A. pistacinoides, A. ruticilla, Agrotis bigramma, A. cinerea, A. clavis, A. exclamationis, A. fatidica, A. ipsilon, A. puta, A. segetum, A. simplonia, A. trux, A. vestigialis, Allophyes oxyacanthae, Ammoconia caecimacula, A. senex, Amphipoea fucosa, A. lucens, A. oculea, Amphipyra berbera, A. cinnamomea, A. livida, A. perflua, A. pyramidea, A. tragopoginis, Anaplectoides prasina, Anarta melanopa, A. myrtilli, A. odontites, A. trifolii, Anorthoa munda, Antitype chi, A. suda, Apamea anceps, A. aquila, A. crenata, A. epomidion, A. furva, A. illyria, A. lateritia, A. lithoxylaea, A. maillardi, A. monoglypha, A. platinea, A. remissa, A. rubrirena, A. scolopacina, A. sordens, A. sublustris, A. unanimis, A. zeta, Aporophyla lutulenta, A. nigra, Apterogenum ypsillon, Archanara dissoluta, A. neurica, Asteroscopus sphinx, Atethmia centrago, Athetis gluteosa, A. hospes, A. pallustris, Atypha pulmonaris, Auchmis detersa, Autographa aemula, A. bractea, A. gamma, A. jota, A. pulchrina, Axylia putris, Brachionycha nubeculosa, Brachylomia viminalis, Bryophila domestica, B. ereptricula, B. petricolor, B. raptricula, B. ravula, Bryopsis muralis, Calamia tridens, Calliergis ramosa, Callopistria juventina, C. latreillei, Calophasia lunula, C. platyptera, Caradrina aspersa, C. clavipalpis, C. flavirena, C. gilva, C. kadenii, C. montana, C. morpheus, C. selini, C. terrea, C. wullschlegeli, Ceramica pisi, Cerapteryx graminis, Cerastis leucographa, C. rubricosa, Charanyca trigrammica, Chersotis alpestris, C. andereggii, C. cuprea, C. fimbriola, C. margaritacea, C. multangula, C. ocellina, C. oreina, C. rectangula, Chilodes maritima, Chloantha hyperici, Chrysodeixis chalcites, Cirrhia gilvago, C. icteritia, C. ocellaris, Clemathada calberlai, Colocasia coryli, Conistra erythrocephala, C. ligula, C. rubiginea, C. rubiginosa, C. torrida, C. vaccinii, Cosmia affinis, C. pyralina, C. trapezina, Craniophora ligustri, Cryphia algae, C. ochsi, C. simulatricula, Crypsedra gemmea, Cucullia absinthii, C. artemisiae, C. asteris, C. campanulae, C. gnaphalii, C. lactucae, C. lucifuga, C. lychnitis, C. prenanthis, C. santonici, C. scrophulariae, C. thapsiphaga, C. umbratica, C. verbasci, Dasypolia ferdinandi, D. templi, Deltote bankiana, D. deceptoria, D. pygarga, D. uncula, Denticucullus pygmina, Diachrysia chrysitis aggr., D. chryson, D. nadeja, Diarsia brunnea, D. dahlii, D. mendica, D. rubi, Dichagyris candelisequa, D. flammatra, D. forcipula, D. musiva, D. nigrescens, D. signifera, D. vallesiaca, Dichonia convergens, Dicycla oo, Diloba caeruleocephala, Dryobotodes eremita, Dypterygia scabriuscula, Egira conspicillaris, Elaphria venustula, Enargia paleacea, Enterpia laudeti, Epilecta linogrisea, Epimecia ustula, Epipsilia grisescens, E. latens, Episema glaucina, Eriopygodes imbecilla, Eucarta amethystina, E. virgo, Euchalcia modestoides, E. variabilis, Eugnorisma depuncta, E. glareosa, Eugraphe sigma, Euplexia lucipara, Eupsilia transversa, Eurois occulta, Euxoa aquilina, E. birivia, E. cos, E. culminicola, E. decora, E. distinguenda, E. eruta, E. nigricans, E. obelisca, E. recussa, E. vitta, Gortyna flavago, Graphiphora augur, Griposia aprilina, Hada plebeja, Hadena albimacula, H. bicruris, H. caesia, H. compta, H. confusa, H. filograna, H. irregularis, H. luteocincta, H. magnolii, H. perplexa, H. tephroleuca, Hecatera bicolorata, H. dysodea, Helicoverpa armigera, Heliothis nubigera, H. peltigera, H. viriplaca, Helotropha leucostigma, Hoplodrina ambigua, H. blanda, H. octogenaria, H. respersa, H. superstes, Hydraecia micacea, Hyppa rectilinea, Ipimorpha retusa, I. subtusa, Jodia croceago, Lacanobia aliena, L. contigua, L. oleracea, L. splendens, L. suasa, L. thalassina, L. w-latinum, Lamprotes c-aureum, Lasionhada proxima, Lateroligia ophiogramma, Lenisa geminipuncta, Leucania comma, L. loreyi, L. obsoleta, Lithophane consocia, L.

		furcifera, L. leautieri, L. ornitopus, L. semibrunnea, L. socia, Litoligia literosa, Luperina dumerilii, L. testacea, Luteohadena luteago, Lycophotia porphyrea, Macdunnoughia confusa, Mamestra brassicae, Melanchra persicariae, Mesapamea secalis aggr., Mesogona acetosellae, M. oxalina, Mesoligia furuncula, Mniotype adusta, M. satura, M. solieri, Moma alpium, Mormo maura, Mythimna albipuncta, M. anderreggii, M. congrua, M. conigera, M. ferrago, M. impura, M. l-album, M. pallens, M. pudorina, M. riparia, M. sicula, M. straminea, M. turca, M. unipuncta, M. vitellina, Naenia typica, Noctua comes, N. fimbriata, N. interjecta, N. interposita, N. janthe/janthina aggr., N. orbona, N. pronuba, N. tirrenica, Nonagria typhae, Ochropleura plecta, Oligia dubia, O. latruncula, O. strigilis, O. versicolor, Opigena polygona, Orbona fragariae, Orthosia cerasi, O. cruda, O. gothica, O. gracilis, O. incerta, O. miniosa, O. opima, O. populeti, Pachetra sagittigera, Panchrysia deaurata, P. v-argenteum, Panemeria tenebrata, Panolis flammea, Panthea coenobita, Papestra biren, Paradiarsia punicea, Parastichtis suspecta, Peridroma saucia, Phlogophora meticulosa, P. scita, Photedes captiuncula, P. fluxa, P. minima, P. morrisii, Phragmatiphila nexa, Phyllophila obliterata, Plusia festucae, Polia bombycina, P. hepatica, P. nebulosa, P. serratilinea, Polychrysia moneta, Polymixis rufocincta, P. xanthomista, Polyphaenis sericata, Protolampra sobrina, Pseudeustrotia candidula, Pyrrhia umbra, Rhizedra lutosa, Rhyacia helvetina, R. lucipeta, R. simulans, Rusina ferruginea, Sedina buettneri, Sideridis kitti, S. lampra, S. reticulata, S. rivularis, S. turbida, Spaelotis ravida, S. senna, Spodoptera exigua, Standfussiana lucernea, S. wiskotti, Staurophora celsia, Sunira circellaris, Syngrapha ain, S. hochenwarthi, S. interrogationis, Thalpophila matura, Tholera cespitis, T. decimalis, Tiliacea aurago, T. citrago, Trachea atriplicis, Trichoplusia ni, Trigonophora flammea, Tyta luctuosa, Xanthia togata, Xestia alpicola, X. ashworthii, X. baja, X. c-nigrum, X. castanea, X. collina, X. ditrapezium, X. lorezi, X. ochreago, X. rhaetica, X. sexstrigata, X. speciosa, X. stigmatica, X. triangulum, X. xanthographa, Xylena exsoleta, X. solidaginis, X. vetusta, Xylocampa areola
	Nolidae	Bena bicolorana, Earias biplaga, E. clorana, E. vernana, Meganola albula, M. strigula, M. togatulalis, Nola aerugula, N. confusalis, N. cucullatella, N. subchlamydula, Nycteola asiatica, N. degenerana, N. revayana, N. siculana, Pseudoips prasinana
	Notodontidae	Cerura erminea, C. vinula, Clostera anachoreta, C. anastomosis, C. curtula, C. pigra, Drymonia dodonaea, D. obliterata, D. querna, D. ruficornis, D. velitaris, Furcula bicuspis, F. bifida, F. furcula, Gluphisia crenata, Harpyia milhauseri, Leucodonta bicoloria, Notodonta dromedarius, N. tritophus, N. ziczac, Odontosia carmelita, Peridea anceps, Phalera bucephala, Pheosia gnoma, P. tremula, Pterostoma palpina, Ptilodon capucina, P. cucullina, Ptilophora plumigera, Spatalia argentina, Stauropus fagi, Thaumetopoea pityocampa, T. processionea

Table S1.2 Attribution of land-use and land-cover categories distinguished in the "Arealstatistik" to broad land-use types used in this study. Numbers show codes used in the "Arealstatistik".

Land-use type	**Arealstatistik categories**
Forests	Forests (without agricultural usage) (NOLU300)
Grasslands	Natural meadows (NOLU222), Pastures (NOLU223), Alpine meadows (NOLU241), Alpine and Jura pastures (NOLU242), Alpine sheep pastures (NOLU243)
Croplands	Orchards (NOLU201), Vineyards (NOLU202), Horticulture (NOLU203), Arable land (NOLU221)
Sealed area	Paved areas (NOLC11), Buildings (NOLC12), Greenhouses (NOLC13)

Table S1.3 Detailed model results for the models analysing the relation of elevation, landscape composition, weather, season and other covariates to moth abundance, richness, and biomass. Fixed effects of linear effects and splines and standard deviations of random factors and splines are given. For factors, sum-to-zero contrasts were used. Point estimates and 95% credible intervals (95%-CI) are given. If 95%-CI do not include zero, numbers are bold.

Para-meter	Type	Variable	Abundance			Richness			Biomass		
			Estimate	Lower 95%-CI	Upper 95%-CI	Estimate	Lower 95%-CI	Upper 95%-CI	Estimate	Lower 95%-CI	Upper 95%-CI
Fixed effect	Fixed	Proportion forests	**0.377**	**0.215**	**0.532**	**0.228**	**0.115**	**0.341**	**0.310**	**0.150**	**0.476**
		Proportion grasslands	0.00396	-0.160	0.169	-0.0365	-0.154	0.0692	-0.00262	-0.157	0.159
		Proportion croplands	0.000358	-0.135	0.133	-0.0435	-0.135	0.0512	-0.00280	-0.136	0.130
		Proportion sealed area	0.0971	-0.0149	0.206	0.0627	-0.00646	0.137	0.0970	-0.00918	0.199
		Precipitation	**0.0138**	**0.00202**	**0.0254**	0.00405	-0.00306	0.0115	**0.0206**	**0.00817**	**0.0325**
		Temperature	**0.727**	**0.703**	**0.752**	**0.597**	**0.582**	**0.611**	**0.524**	**0.500**	**0.549**
		Trap type (contr. sum 1)	**-0.426**	**-0.737**	**-0.112**	**-0.325**	**-0.543**	**-0.106**	**-0.320**	**-0.637**	**-0.00668**
		Trap type (contr. sum 2)	**-1.03**	**-1.62**	**-0.454**	**-0.494**	**-0.918**	**-0.0831**	**-0.982**	**-1.56**	**-0.398**
		Lamp type (contr. sum 1)	-0.300	-0.619	0.0186	-0.174	-0.375	0.0277	-0.281	-0.588	0.0435
		Lamp type (contr. sum 2)	-0.0653	-0.721	0.594	-0.125	-0.500	0.269	-0.207	-0.859	0.489
		Lamp type (contr. sum 3)	**-0.378**	**-0.689**	**-0.0532**	-0.189	-0.389	0.0214	**-0.377**	**-0.688**	**-0.0541**
		Nr. of traps (linear)	0.323	-0.677	1.30	0.245	-0.391	0.920	0.263	-0.691	1.18
		Nr. of traps (quadratic)	-0.408	-1.16	0.305	-0.280	-0.762	0.183	-0.513	-1.22	0.196
		Nr. of traps (cubic)	-0.337	-0.701	0.0257	-0.176	-0.408	0.0706	**-0.391**	**-0.767**	**-0.0303**
		Sampl. prev. night (contr. sum 1)	**-0.106**	**-0.169**	**-0.0421**	**-0.0635**	**-0.103**	**-0.0222**	**-0.131**	**-0.190**	**-0.0699**
	Spline	Elevation	1.97	-3.10	5.20	0.246	-3.06	2.44	3.19	-0.838	6.09
		Day of year	**-23.3**	**-28.0**	**-18.7**	**-8.57**	**-12.3**	**-4.76**	**-18.7**	**-23.2**	**-14.4**
		Hrs. active	**6.63**	**1.85**	**11.2**	**3.97**	**0.878**	**7.49**	**5.54**	**0.843**	**10.2**
SD	Random	Spat-temp. cluster	0.267	0.196	0.334	0.133	0.0907	0.173	0.270	0.204	0.337
		Sampling night × Location	0.795	0.774	0.816	0.481	0.472	0.489	0.599	0.579	0.619
		Site ID	0.521	0.453	0.601	0.369	0.321	0.421	0.501	0.434	0.575
		Site ID × Year	0.234	0.196	0.276	0.141	0.120	0.164	0.228	0.190	0.271
	Spline	Elevation	1.60	0.0461	5.87	0.789	0.0489	2.47	1.06	0.0347	3.63
		Day of year	12.6	8.07	20.5	5.88	3.79	9.30	11.0	7.11	17.3
		Hrs. active	1.87	0.938	3.49	1.21	0.528	2.46	1.91	0.890	3.84

Nr. of traps: Number of traps
Sampl. prev. night: Sampling in previous night
Spat.-temp. cluster: Spatio-temporal cluster

Fig. S1.1 Pictures of the three trap types that were used for sampling. **(a)** fixed trap ("type 1"), **(b)** manual trap, **(c)** fixed trap ("type 2"). Pictures from Rezbanyai-Reser (2014, 2018a).

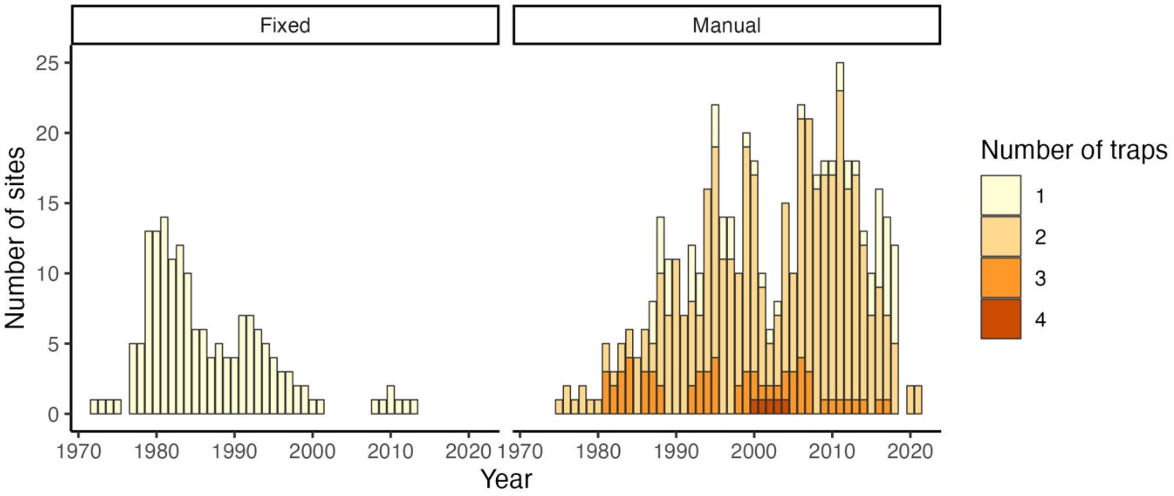

Fig. S1.2 Number of sites per year with respect to the number of traps that were active. Panels on the left show fixed trap samples, panels on the right show manual trap samples.

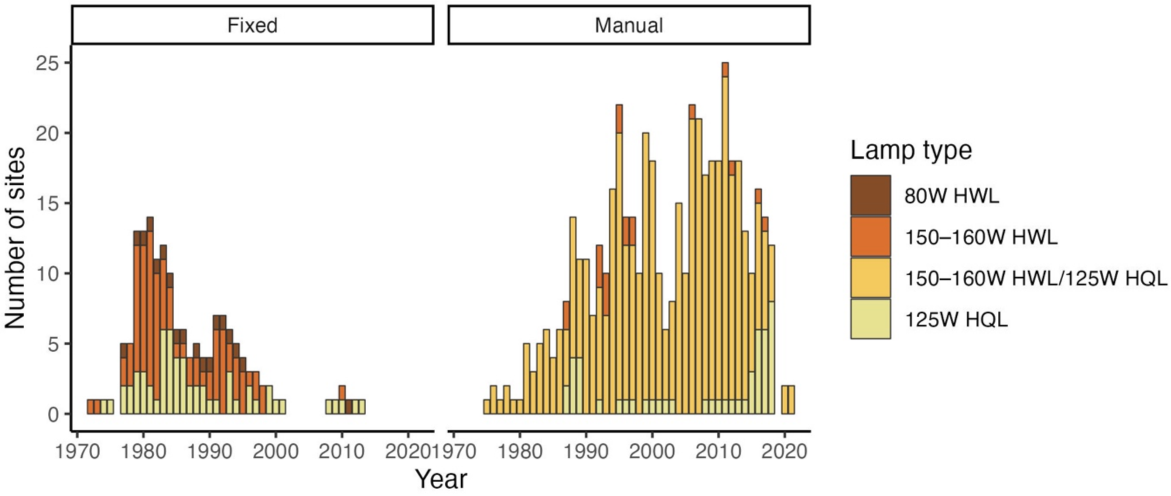

Fig. S1.3 Number of sites per year with respect to the lamp type that was used. Panels on the left show fixed trap samples, panels on the right show manual trap samples.

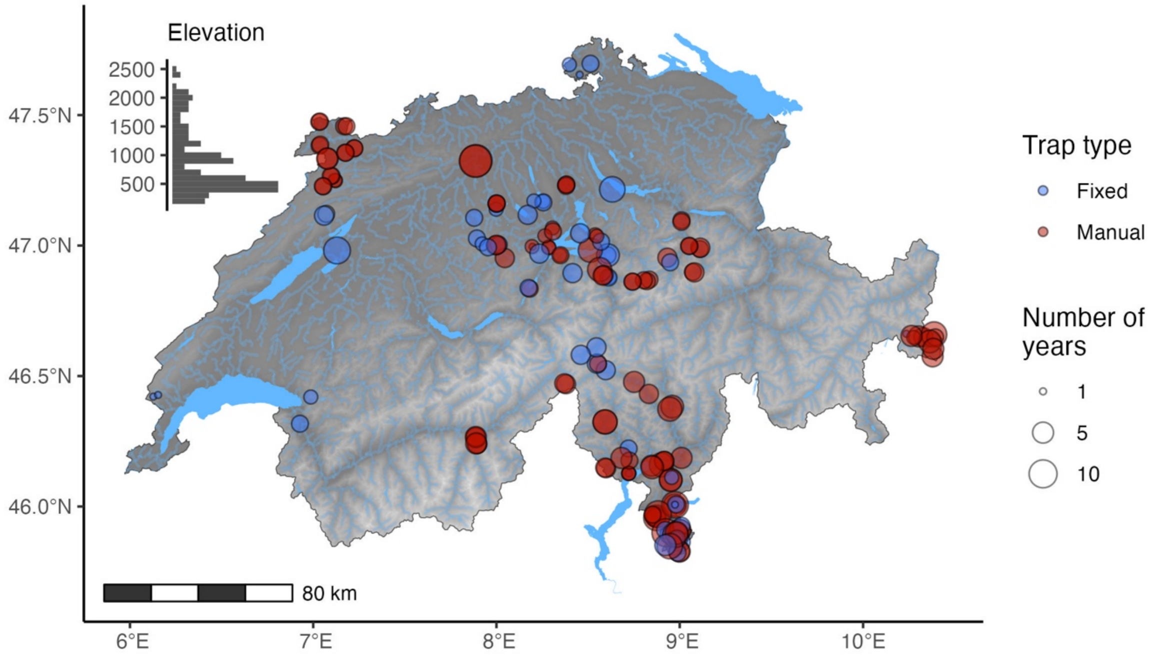

Fig. S1.4 Spatial distribution of sampling sites in Switzerland. Points show sampling sites, colour indicates trap-type and point size indicates the number of years in which the site was sampled. Shading of the map shows elevation (darker shading for lower elevation). The top left inlet shows the distribution of study sites across the elevation gradient (meter above sea level).

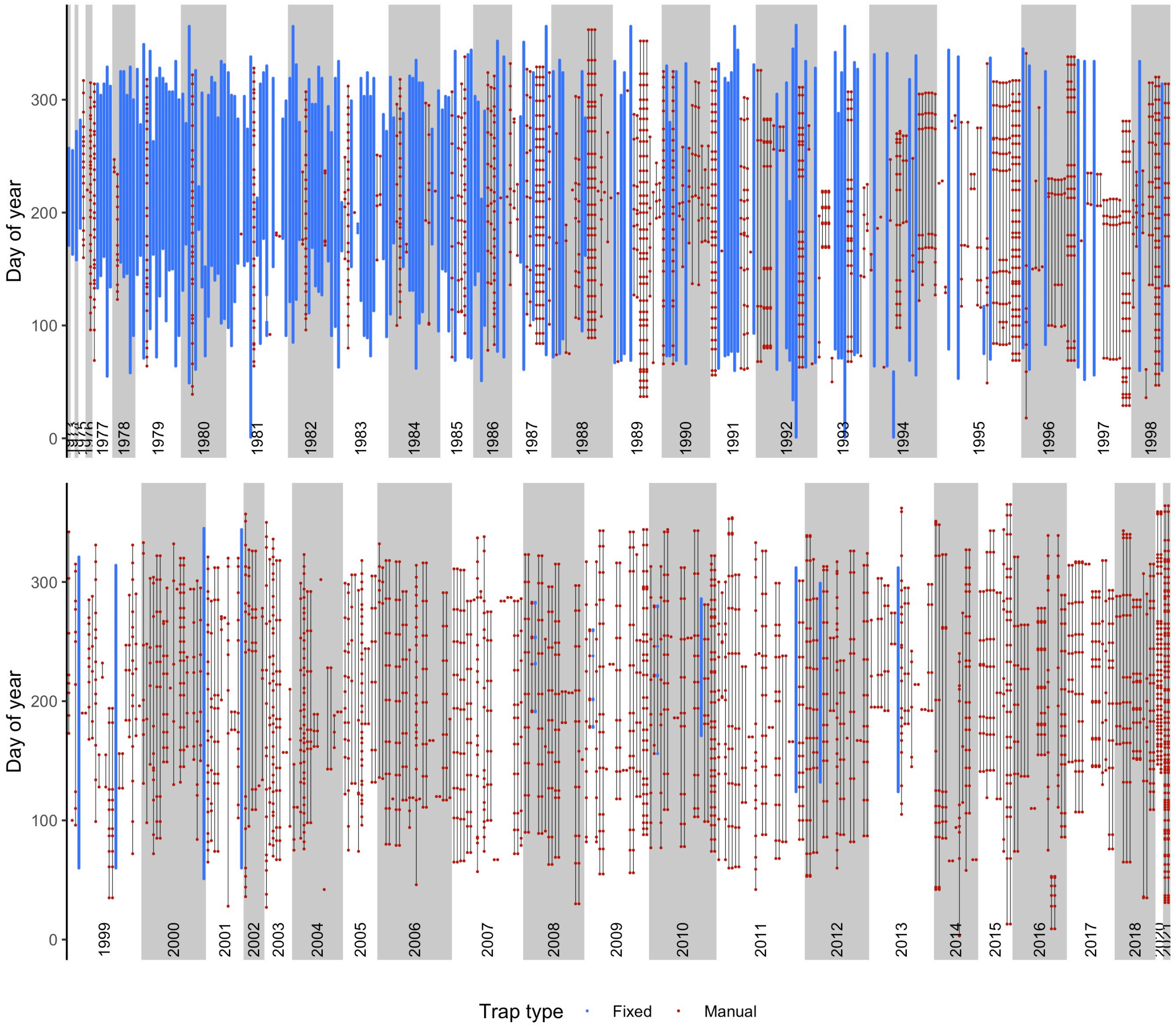

Fig. S1.5 Overview of single sampling nights, arranged chronologically across the whole study period. Each vertical line connects samples from one site and one year. They build blocks of one year, indicates by the shading of the background (starting top left with 1972, ending bottom right with 2021). The *y* axis denotes the day of the year (between 1 and 366) of the sampling night. Single sampling night are shown as points (which might overlay for very dense sampling periods), colors differentiate the fixed samplings (blue) and manual samplings (red).

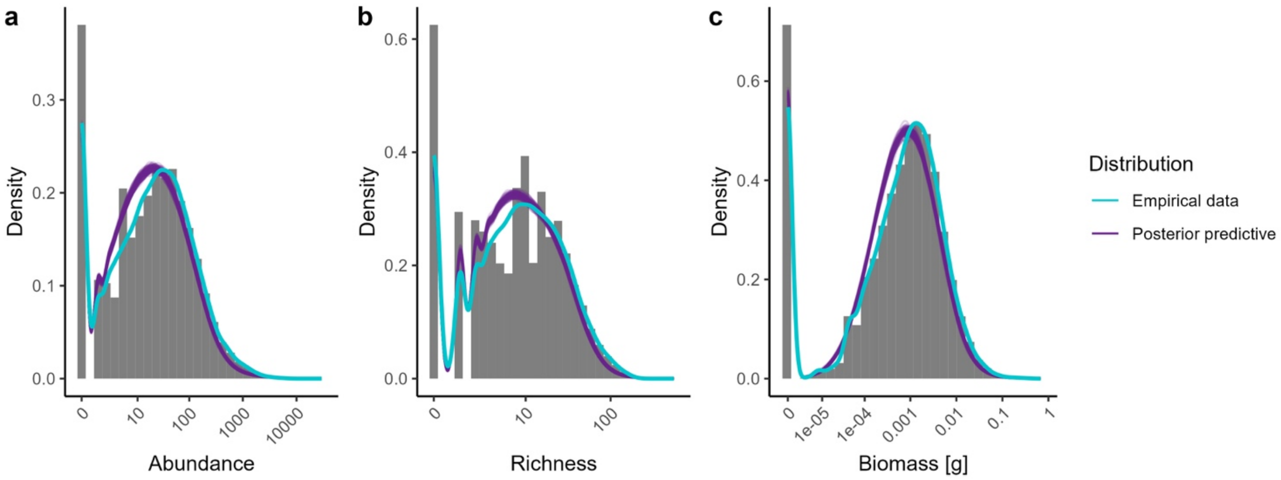

Fig. S1.6 Comparison of empirical data distribution and 100 draws of the posterior predictive distribution from the (**a**) abundance, (**b**) richness and (**c**) biomass models. Lines show kernel density estimates for empirical data (turquoise) and posterior predictive (purple) distributions, bars show histograms of the empirical data distributions. For abundance and richness, a zero-inflated negative binomial distribution was used, whereas for biomass, a hurdle gamma distribution was used. Note that the *x* axes are on log scale (after adding the minimal non-zero value to all values).

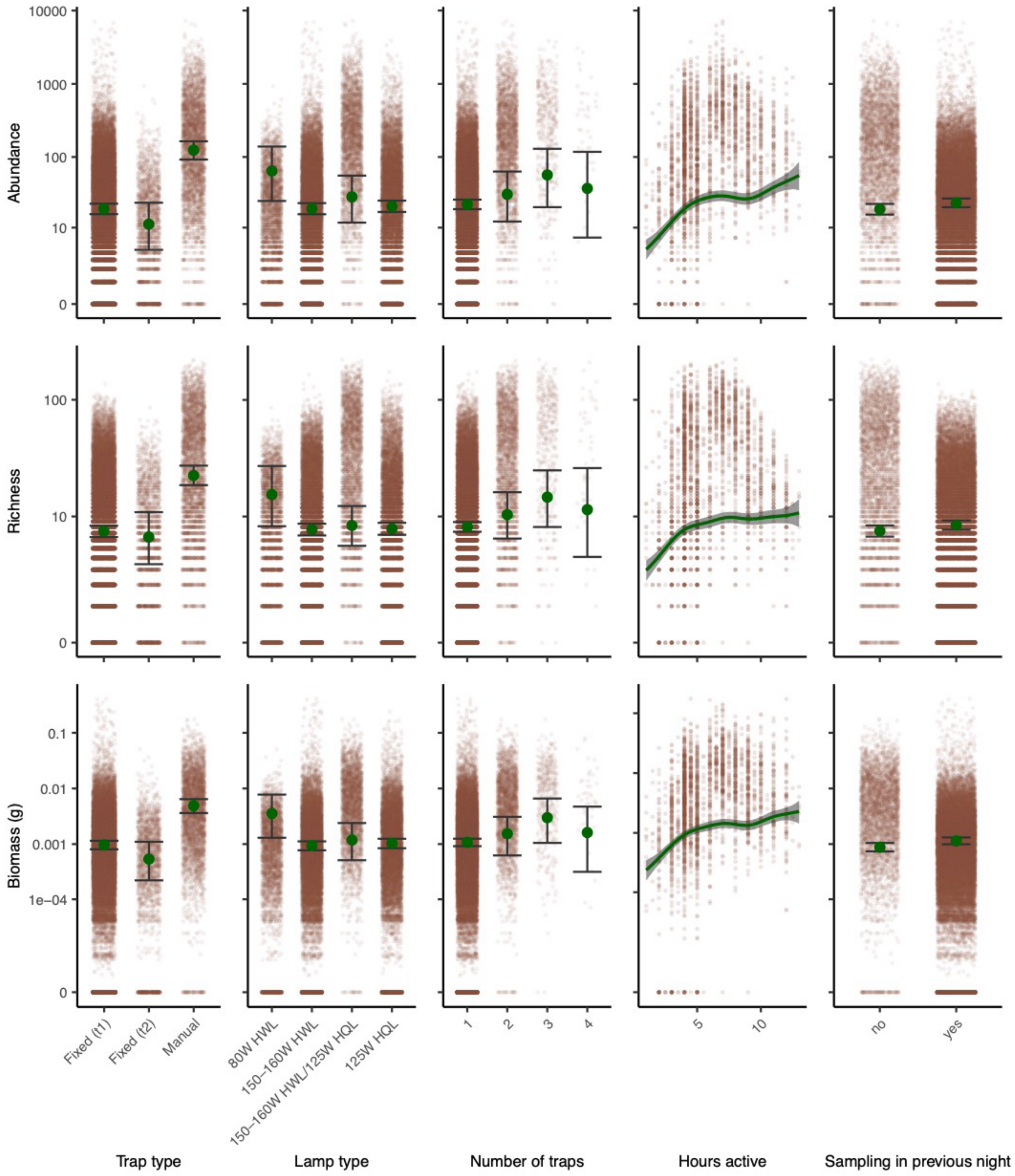

Fig. S1.7 Conditional effects of different model covariates in the abundance, richness, and biomass model. The *y* axis shows predicted abundance, richness, or biomass. Point estimates are in green, shaded areas or error bars show 95% uncertainty intervals. Underlying points show data per sampling night (*n* = 35,847). Detailed model results in Table S1.3.