Appendix S1 – Supporting Information

Article in Ecosphere

Landscape composition and orchard management effects on bat assemblages and bat foraging activity in apple crops

Marcos Miñarro & Daniel García

Corresponding author: danielgarcia@uniovi.es

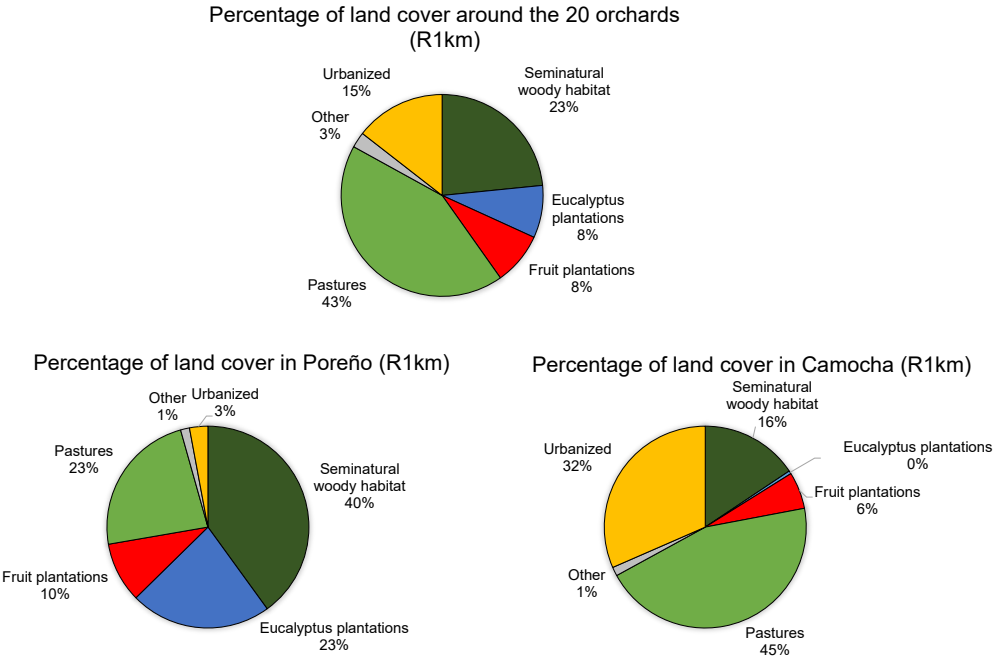

Figure S1. (A) Average percentage of land cover types around the 20 apple orchards (1000-m radius plot) and (B) examples of one orchard (Poreño) with a predominance of seminatural woody habitats and (C) another (Camocha) with high presence of urbanized habitats (C).

Table S1. Results of Principal Components Analysis (PCA) accounting for the variability in the six general land-cover types in 1000-m radius plots across apple orchards. PCAs were calculated from the area proportion of area of different land-cover types in 1 km radius plot around each orchard (quantified by GIS, QGIS 3.28). PCA factor scores were obtained from the three first Varimax-rotated eigenvectors of each analysis. The percentage of variance accounted for by each eigenvector, as well as the loadings of rotated factors (correlations, coefficients ≥ |0.750| highlighted in bold) are shown.

Factors	PC1	PC2	PC3
% Variance explained	41.94	24.64	16.36
Seminatural woody habitats	-0.002	**0.956**	-0.154
Eucalyptus plantations	**-0.979**	0.101	-0.048
Fruit plantations	-0.168	0.076	**0.778**
Pastures	**0.876**	-0.18	-0.254
Other habitats	0.012	-0.116	**0.825**
Urbanized ground	0.449	**-0.801**	-0.164

Table S2. Trait values of the bats occurring in apple orchards, obtained from the database EuroBaTrait_v1.0. For species complexes, the average value across species was calculated (*Myotis* spp. included *M. alcathoe*, *M. crypticus*, *M. daubentonii*, *M. emarginatus*, *M. escalerai* and *M. mystacinus*).

Species	Body mass (g)	Wing loading index (g/dm^2)	Call band width (kHz)	Call peak frequency (kHz)	Seasonal activity pattern skewness	Home range (ha)
Barbastella barbastellus	8.92	7.87	11.73	36.47	-0.17	464.71
Eptesicus serotinus/Nyctalus leisleri	19.44	13.03	15.14	29.19	-0.07	4026.20
Hypsugo savii	7.31	8.94	11.70	34.96	0.36	200.00
Miniopterus schreibersii	12.51	8.97	20.33	53.50	-0.38	11721.21
Myotis myotis	27.03	9.79	37.04	36.56	0.00	36.20
Myotis spp.	7.28	7.42	55.83	50.74	-0.47	346.39
Plecotus auritus/P. austriacus	8.52	7.18	22.24	33.96	0.33	239.63
Pipistrellus pipistrellus	4.85	7.61	13.30	47.07	-0.03	116.13
Pipistrellus nathusii/P. kuhlii	7.23	8.96	13.05	40.19	-0.42	622.00
Rhinolophus ferrumequinum	21.27	10.40	7.64	80.87	-0.92	622.04
Rhinolophus hipposideros	5.50	5.99	10.11	109.14	-0.48	138.36
Tadarida teniotis	29.18	12.73	5.89	12.61	-0.16	102.00

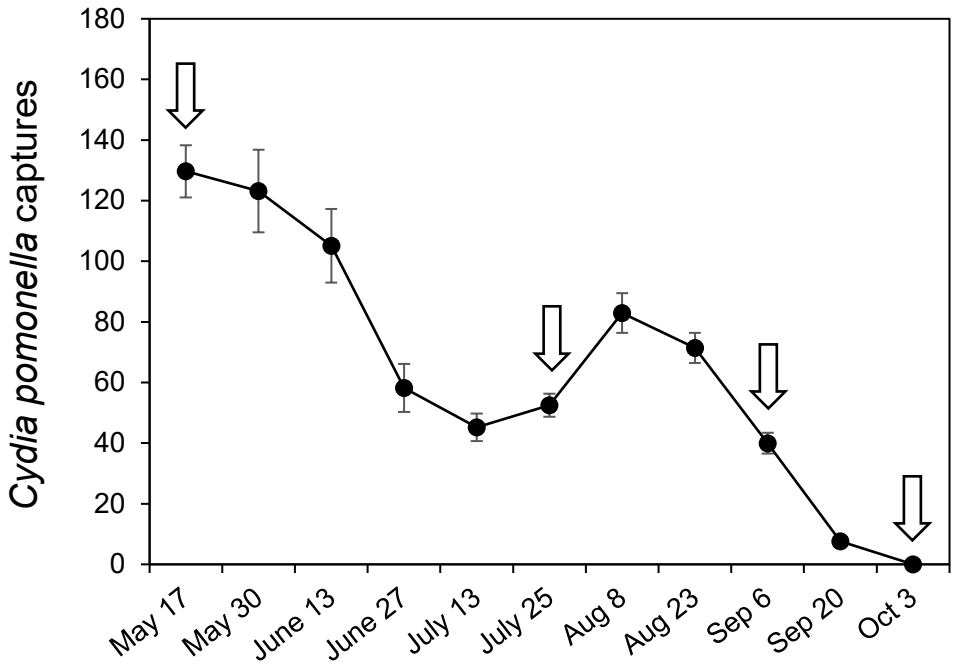

Figure S2. Fortnightly captures of codling moth *Cydia pomonella* per orchard (mean ± standard errors) in 20 orchards (1 trap per orchard) throughout the season. Arrows indicate the four nights on which bats were sampled.

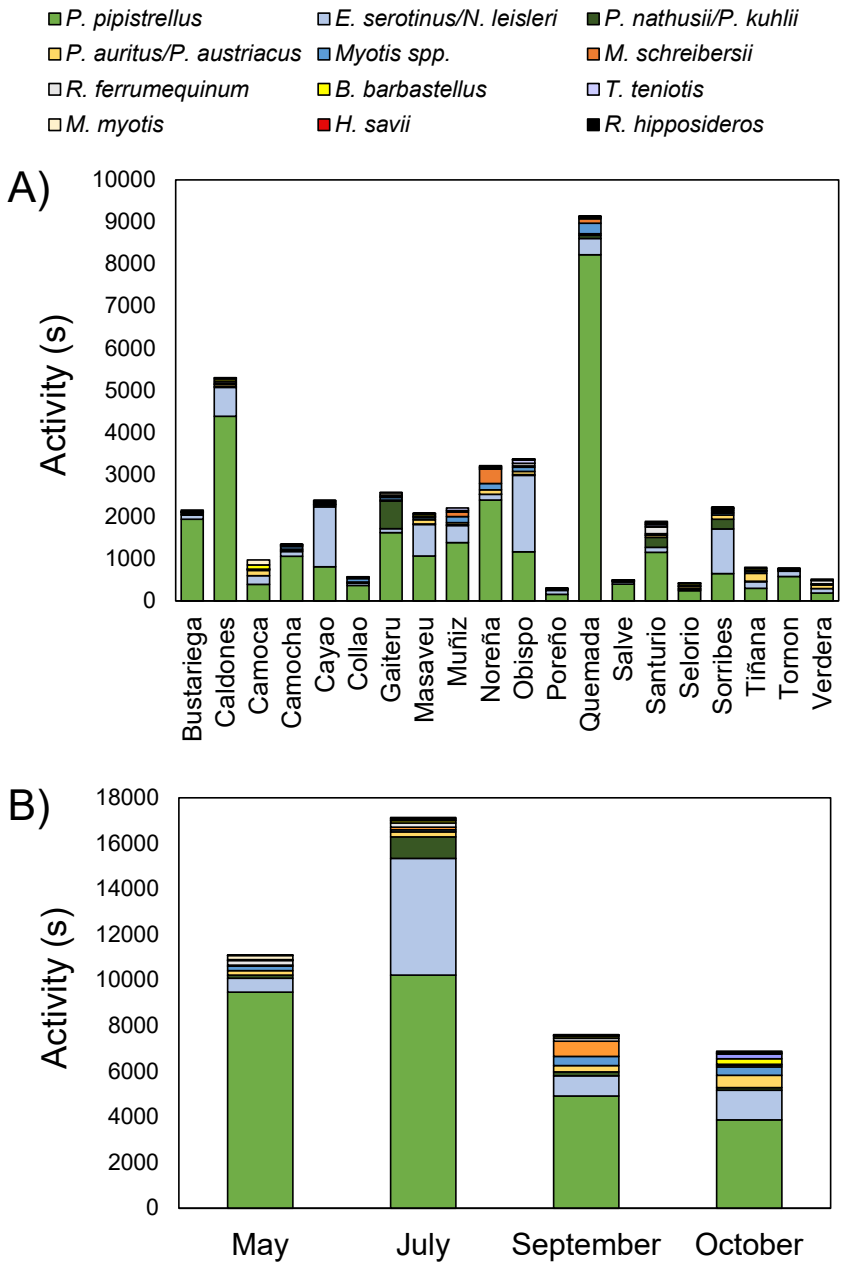

Figure S3. Activity per bat species/species complex in (A) the 20 orchards (all months pooled) and (B) the four sampled months (all orchards pooled).

Table S3. Results of Generalized Linear Mixed Models evaluating the effects of landscape structure (PC1, PC2; see Table S1), landscape heterogeneity, the cover of apple plantations in a 125-m radius plot and the cover of apple tree canopy on the NMDS dimensions. Details of the family of distribution and link function used (in parentheses), values of marginal and conditional (in parentheses) R^2, as well as variance (SD) estimates for orchard identity and month, considered as random factors, are also shown.

NMDS2 (Gaussian, identity) R^2 = 0.050 (0.257)				
Predictors	Estimate	SE/SD	t	P
Intercept	0.000	0.078	0.00	1.000
PC1	-0.037	0.061	-0.61	0.549
PC2	-0.048	0.054	-0.89	0.390
Landscape heterogeneity	-0.067	0.056	-1.21	0.246
Apple cover R125	0.015	0.057	0.26	0.796
Apple canopy cover	0.001	0.058	0.01	0.991
Orchard (random factor)	0.023	0.151		
Month (random factor)	0.013	0.114		

Table S4. Model selection procedure applied to Generalized Linear Mixed Models evaluating the effects of landscape structure (PC1, PC2; see Table S1), landscape heterogeneity, the cover of apple plantations in a 125-m radius plot, the cover of apple tree canopy, the abundance of codling moth and the interaction of the last two variables on the number of feeding buzzes (see Table S7). For illustration, the five models with lowest Δ*AIC*c values (from 80 potential models including null model) are shown. Effect estimates for each parameter/predictor, as well as model parsimony parameters, are shown for each model.

Model no.	1	2	3	4	5
Intercept	2.132	2.181	2.141	1.992	2.143
PC1	1.015	1.182	1.059	1.375	1.012
PC2	-0.727	-0.781	-0.725	-	-0.725
Landscape heterogeneity	0.761	0.716	0.713	0.859	0.749
Apple cover R125	-	-	0.227	-	-
Apple canopy cover	-	-0.368	-	-	-
Codling moth abundance	-	-	-	-	0.041
Apple canopy cover * Codling moth abundance	-	-	-	-	-
df	7	8	8	6	8
logLik	-208.3	-207.6	-208.1	-210.7	-208.3
*AIC*c	432.8	434.2	435.1	435.2	435.4
Δ*AIC*c	0	1.373	2.233	2.281	2.640
*AIC*c weight	0.204	0.103	0.067	0.065	0.055

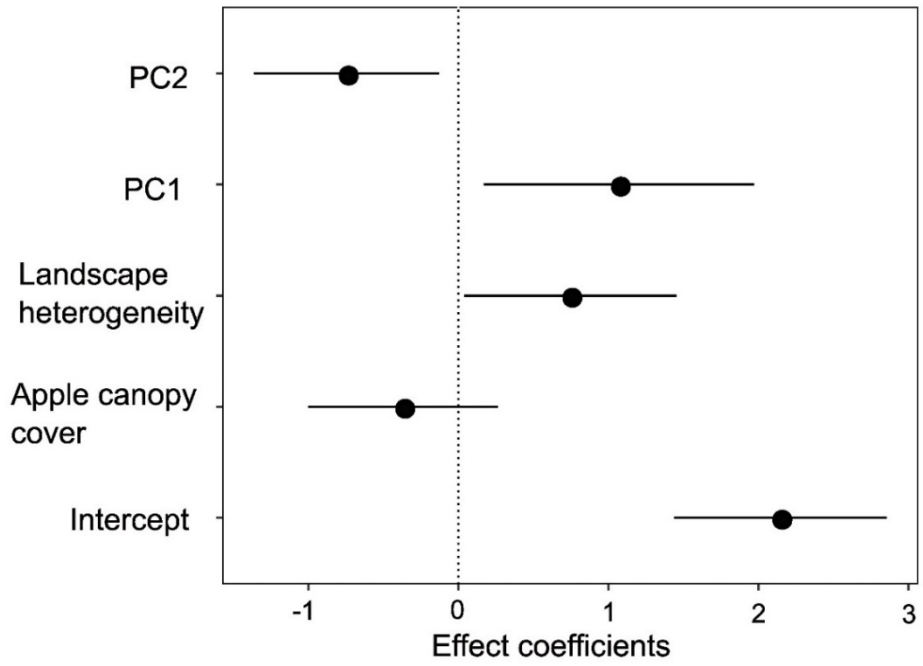

Figure S4. Average estimates for different parameters/predictors from the most parsimonious models selected (Table S8) from the Generalized Linear Mixed Models evaluating the effects of landscape composition (PC1, PC2), landscape heterogeneity, the cover of apple plantations in a 125-m radius plot, the cover of apple tree canopy, the abundance of codling moth and the interaction of the last two variables on the number of bat feeding buzzes (Table S7). Confidence intervals (2.5 and 97.5%) from averaging procedure are shown for each parameter/predictor.

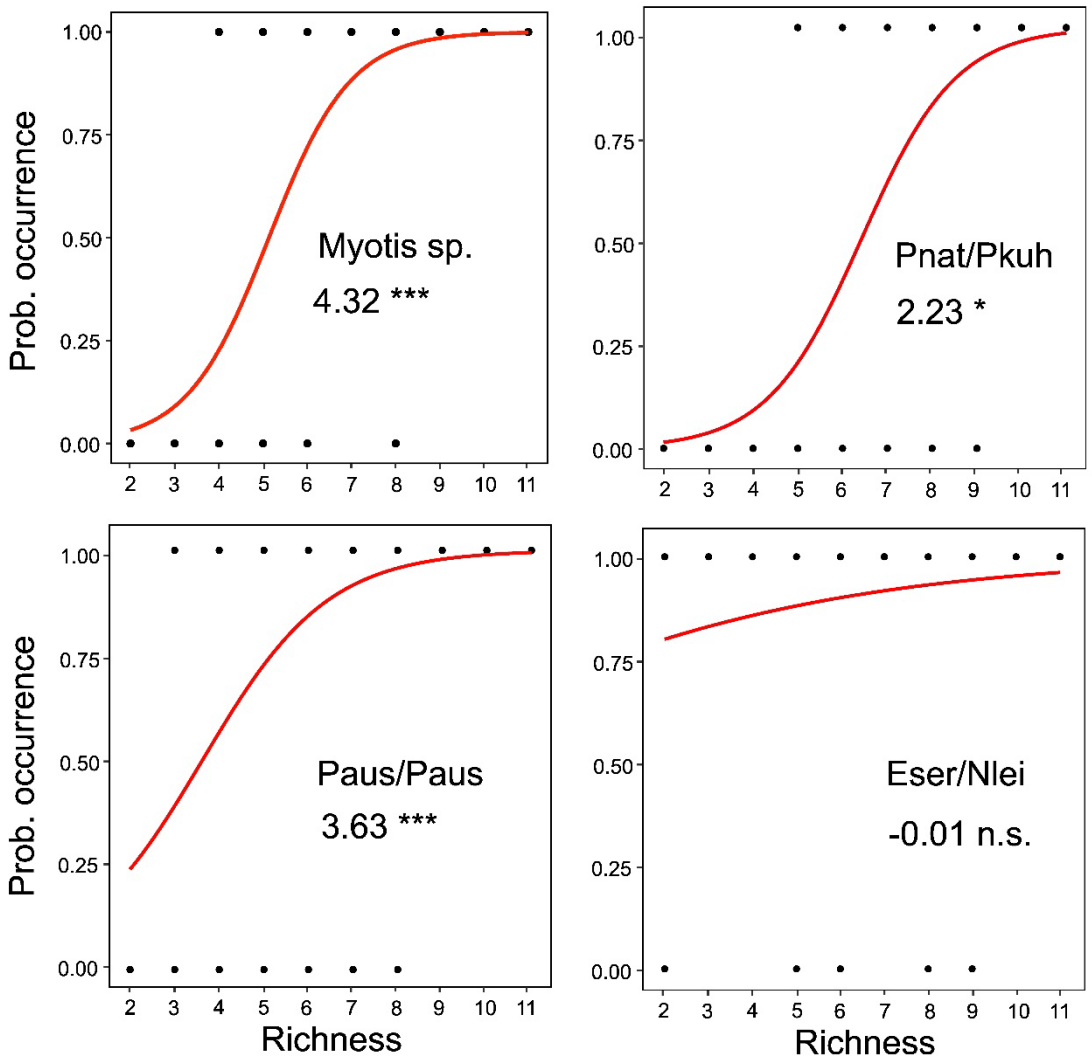

Figure S5. Plots of probability of occurrence of different bat species complexes predicted by the number of bat species/species complexes in different orchards and nights in a generalized linear mixed model (binomial distribution family, logit link) considering orchard and month as intercept random factors. The values of z statistics corresponding to the effect size of the number of bat species/species numbers are shown for each model (***: $P \leq 0.001$; *: $P \leq 0.05$; n.s.: $P > 0.05$). Plots indicate that *Myotis* sp., Pnat/Pkuh and Paur/Paus complexes mostly occur in orchards and nights with high numbers of species/species complexes.

Table S5. Results of Generalized Linear Mixed Models evaluating the effects of landscape structure (PC1, PC2; see Table S1), landscape heterogeneity, the cover of apple plantations in a 125-m radius plot, and the cover of apple tree canopy, on the proportion of bat activity by *Pipistrellus pipistrellus*, the most abundant bat (*P. pipistrellus* activity/total bat activity). Details of the family of distribution and link function used (in parentheses), values of marginal and conditional (in parentheses) R^2, as well as variance (SD) estimates for orchard identity and month, considered as random factors, are also shown.

Activity of *Pipistrellus pipistrellus* (Binomial, logit)				
R^2 = 0.359 (0.993)				
Predictors	Estimate	SE/SD	z	P
Intercept	0.551	0.320	1.72	0.086
PC1	0.235	0.170	1.38	0.166
PC2	-0.453	0.150	-3.02	0.003
Landscape heterogeneity	-0.203	0.155	-1.31	0.190
Apple cover R125	0.396	0.158	2.51	0.012
Apple canopy cover	0.143	0.163	0.87	0.382
Orchard (random factor)	0.424	0.651		
Month (random factor)	0.324	0.569		

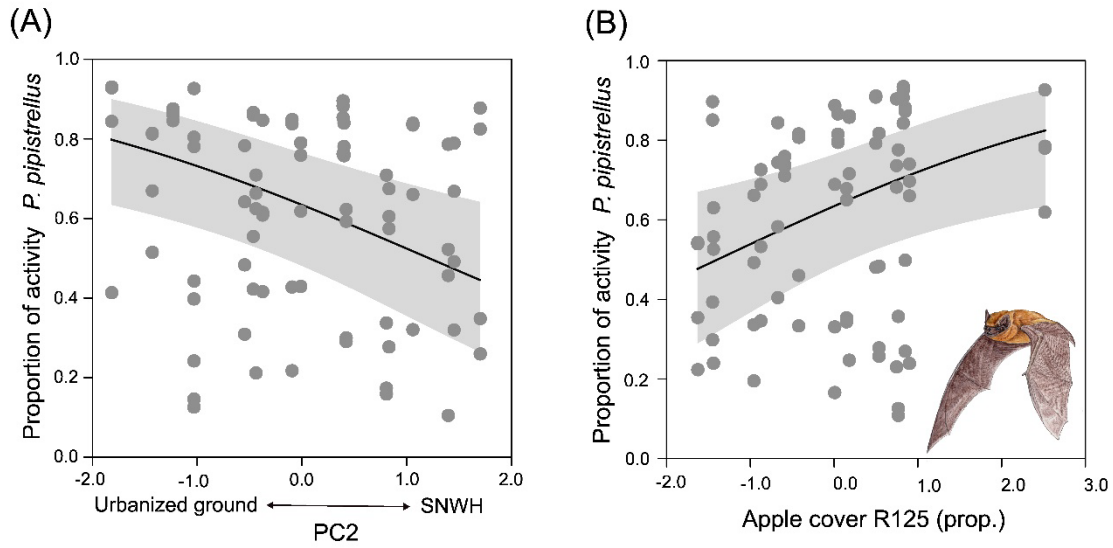

Figure S6. Significant effects predicted by Generalized Linear Mixed Models of landscape features (PC2 and the cover of apple orchards in a 125-m radius plot from the sampling point) on the proportion of total bat activity accounted for by *Pipistrellus pipistrellus*. Landscape gradients represented by PCA axes are shown. Confidence bounds and fitted values of partial effects predicted by models are shown (artwork by Daniel García).

Table S6. Results of Generalized Linear Mixed Model evaluating the effects of landscape structure (PC1, PC2; see Table S1), landscape heterogeneity, the cover of apple plantations in a 125-m radius plot, and the cover of apple tree canopy, on the number of bat species (i.e. excluding species complexes) and on the maximum number of bat species (number considering all potential species included in a species complex) per orchard and night. Details of the family of distribution and link function used (in parentheses), values of marginal and conditional (in parentheses) R^2, as well as variance (SD) estimates for orchard identity and month, considered as random factors, are also shown.

Number of species (Gaussian, Identity)				
R^2 = 0.314 (0.329)				
Predictors	Estimate	SE/SD	t	P
Intercept	1.644	0.077	21.34	<0.001
PC1	0.079	0.074	1.07	0.285
PC2	-0.278	0.066	-4.24	<0.001
Landscape heterogeneity	0.157	0.067	2.32	0.023
Apple cover R125	-0.178	0.068	-2.58	0.012
Apple canopy cover	-0.262	0.071	-3.67	<0.001
Orchard (random factor)	0.000	0.000		
Month (random factor)	0.007	0.085		
Maximum number of species (Gaussian, identity)				
R2 = 0.226 (0.278)				
Predictors	Estimate	SE/SD	t	P
Intercept	11.970	0.506	23.67	<0.001
PC1	0.650	0.584	1.11	0.284
PC2	-1.690	0.518	-3.27	0.006
Landscape heterogeneity	1.110	0.536	2.08	0.056
Apple cover R125	-0.799	0.545	-1.47	0.164
Apple canopy cover	-0.909	0.563	-1.61	0.128
Orchard (random factor)	1.150	1.070		
Month (random factor)	0.000	0.000		

Table S7. Correlations between the values of community weighted mean (CWM) values of the bat traits of body mass (BM, log), wing load index (WLI), call band width (CBW), call peak frequency (CPF), pattern of seasonal activity (SAPS), home range (HR, log), and the scores of landscape composition PC2 axis (gradient from urbanized ground to semi-natural woody habitat) across different orchards and nights. CWMs are estimated as the sum of the products of each bat taxa relative abundances multiplied by the taxa trait average value, for the taxa present in each orchard x night combination. Pearson's correlation coefficients (r) and P values are shown (N = 80).

Trait	r	P
BM	0.326	0.0031
WLI	0.359	0.0011
CBW	-0.025	0.8242
CPF	-0.322	0.0036
SAPS	0.187	0.0956
HR	0.245	0.0282