Supplementary Material 1: Radiometric and Photometric Quantities

It is of major importance to distinguish radiometric quantities (energetic) which describe the energy transport and its spatial distribution from Electromagnetic Radiation (EM) and photometric quantities (visual) which express energy transport and it's the spatial distribution of light only as perceived by the human eye (visible part of EM spectrum ranging from 360nm to 780 nm)

An electric light source that receives an Input Electrical Power, Pin (measured in W), will transform a part of that power in radiation emission distributed among all wavelengths, λ, EM spectrum, this is called Radiant Spectral Distribution, Φ(λ) (measured in $W.nm^{-1}$). The integral of this quantity among all EM spectrum wavelengths is called the Radiant Flux (or Radiant Power), Φ_e (measured in W); $\Phi_e = \int \Phi(\lambda)d\lambda$. The ratio between the Radiant Flux over the Input Electrical Power in the lamp, is known as the Radiant Efficiency of the light source, ε, and is expressed in percentage (%).

When the Radiant Spectral Distribution is perceived by the human eye it is "selectively filtered" following the spectral response *of the eye*. This spectral response, depends also on the surrounding quantity of light. We can speak in terms of Photopic Luminosity Function, V(λ), when enough light is available (daylight or standard indoor lighting conditions), on the opposite, when very few light is available (eg. starlight only) we speak about Scotopic Luminosity Function, V'(λ). All intermediate situations (eg. twilight) are known as mesopic conditions and described by a series of $V_m(\lambda)$ functions depending, among others, on the surrounding quantity of light. All the Luminosity Functions above are standardized by the International Commission on Illumination (CIE); all of them are strictly equal to zero beyond the visible radiation limits. The Luminosity Function is used to switch from Radiometric to Photometric quantities. Thus, we define:

The Luminous Flux, Φ_v, measured in lumens (lm) is defined as a proportion of the integral of the product of the Radiant Spectral Distribution by the luminosity function: $\Phi_v = K_{cd} \int \Phi(\lambda)V(\lambda)d\lambda$, where the proportionality constant, K_{cd}, is one of the 7 fundamental constants of SI-unit system (redefined in 2019) and it is equal to 683 $lm.W^{-1}$ (it can be seen, as the luminous flux induced by 1 W of monochromatic radiant power at 555 nm). The ratio between the Luminous Flux over the Input Electrical Power in the lamp, is known as the Luminous Efficacy of the light source, η, and is expressed in lumens per watt ($lm.W^{-1}$).

When a part of the flux (radiant or luminous), $d\Phi_{(e\text{ or }v)}$, is directed towards a specific direction within a beam defined by a sold angle dΩ (expressed in steradians, sr), the ratio $d\Phi_{(e\text{ or }v)}/d\Omega$ is called either Radiant Intensity, I_e (expressed in $W.sr^{-1}$) in radiometry, or luminous Intensity, I_v (expressed in $lm.sr^{-1}$, or, in candelas -cd- which is the official unit) in photometry.

When a part of the flux (radiant or luminous), $d\Phi_{(e\text{ or }v)}$, irradiates/illuminates a surface element dS, the ratio $d\Phi_{(e\text{ or }v)}/dS$ is called either Irradiance, E_e (expressed in $W.m^{-1}$) in radiometry, or Illuminance, E_v (expressed in $lm.m^{-1}$, or, in lux -lx- which is the official unit) in photometry.

When a part of the flux (radiant or luminous), $d\Phi_{(e\text{ or }v)}$, originating from a single direction defined by a sold angle dΩ, hits a surface element dS the quantity $dI_{(e\text{ or }v)}/dS$ is called either Radiance, Le (expressed in $W.sr^{-1}.m^{-1}$) in radiometry, or, Luminance, L_v (expressed in $lm.sr^{-1}.m^{-}1$, or, in $cd.m^{-2}$ which is the official unit) in photometry. In some case, in photometry, the term Brightness or Luminosity are also used to define that quantity, but the second is obsolete and must be avoided. Luminance is a very important quantity for photometry because it is the attribute of a visual sensation according to which an area appears to emit more or less light.

All the defined quantities above, radiometric or photometric, are integrated among wavelength, but, in some cases, we may need to use them for specific wavelengths, in that cases the qualificative "spectral" has to be added to the quantity name to differentiate it from integral quantities. For our study, the integral quantities are more relevant.

Photometric quantities are relevant to define indoor/outdoor artificial lighting systems performance and design the system. However, there are fully meaning less for animals for whose visual response could be different from that of human beings.

In most cases basic photometric instruments (lux-meters and luminance-meters) are designed and calibrated to measure photometric quantities (respectively, illuminance and luminance) under Photopic conditions. Hence, when light level is not sufficient (mesopic or even scotopic conditions) the values obtained are not representative of the reality even for the human eye. This can be the case in outdoor lighting especially in remote areas. Further, all lighting standards for indoor and outdoor lighting assume photopic conditions only.

All the above description is based on IEC (International Electrotechnical Commission) vocabulary (IEC 60050) as can be found in: http://www.electropedia.org/iev/iev.nsf/index?openform&part=845.

Supplementary Material 2: Composition of landscape variables and streetlight column characteristics among sites.

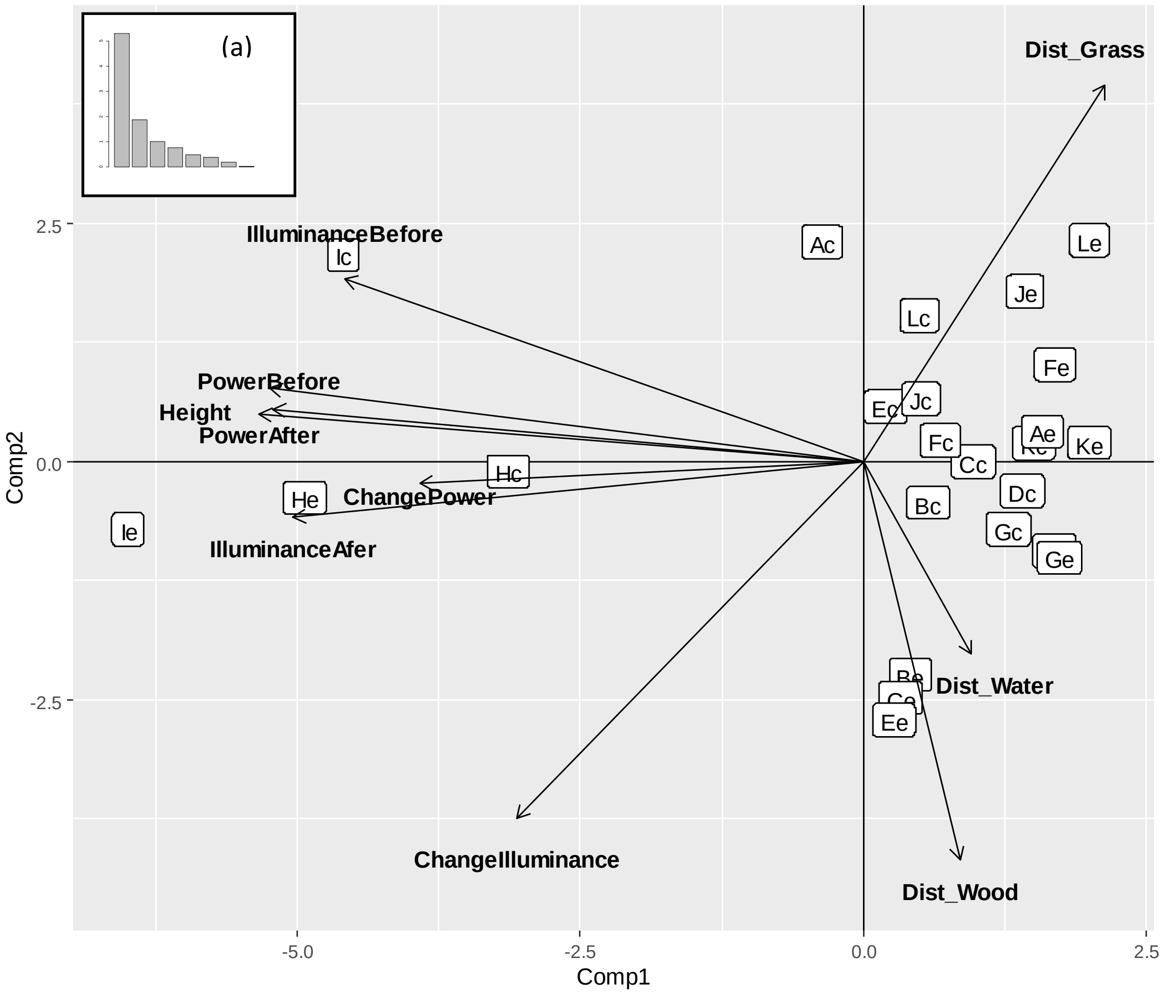

Figure S1. Principal Component Analysis (R Pacakge *ade4*, function *dudi.pca*, Chessel D. & Dufour AB) performed on landscape variables and streetlight column characteristics among sites (Ac: control lighting column of the pair A, Ae: experimental lighting column of the pair A). The streetlight characteristics included characteristics that did not change such as the lighting height (*Height*) and characteristics that changed during the switch such as power and illuminance: *PowerBefore* is the power (Watts) in site before the switch, *PowerAfter*, power after the switch (same typology for illuminance), *ChangePower* is the difference between the power of LPS in experimental site before the switch and the power of LED after the switch (same definition for the *Changeilluminance*). Landscape variables included the distance to a wooded area (m), *Dist_Wood*, the distance to freshwater (m) *Dist_Water* and the distance to grassland (m), *Dist_Grass*. (a) eigenvalues of the PCA.

Supplementary Material 3: Comparison of the results of parametric and non-parametric approaches when changes in light intensity are not taken into account

Statistical analysis

We ran Generalized Linear Mixed-effects Models (GLMMs R package glmmTMB) focused on the changes in bat activity between before and after switch-over periods for control and experimental lighting columns, without considering changes in light intensity (power or illuminance). According to the response variable: the number of bat passes or buzz ratio, we used respectively a negative binomial and binomial distribution. As fixed explanatory variables we included in our model the type of lighting column (*i.e.* control or experimental), the period (*i.e.* before or after the switch-over) and the interaction between the type of site and period. We used a nested random effect (site) to account for the structure of the BACIP data (*i.e.* a control and experimental pair sampled inside a site). The statistical models were thus structured as follows:

*Bat activity ~ Type of column * Period + (1|site)*

Where *Bat activity* was the total number of bat passes, or the number of bat passes for a given species or the feeding buzz ratio, *Type of column* was either the control or the experimental lighting column and *Period* either the period before or after the switch from LPS to LED lamps. Since a total bat activity could be strongly driven by species identity (some species can have more weight than other due to their local abundance or their distance of detection), instead of summing the activity of the different species, we thus added a nested random effect on the species to all models with *total number of bat passes* as response variable.

Results concerning BACIP-based analyses, like in Rowse et al. (2016), i.e. when light intensity was not accounted for

We did not find any significant effect of the switch from LPS to LED on the number of bat passes when. However, we found significant effects of the switch-over on the buzz ratio (Table 3). Specifically, we found that at experimental sites the switch from LPS to LED lamps strongly decreased the buzz ratio, while for control site which stayed lit using LPS throughout the study the buzz ratio tended to increase between these periods (Table 3; Fig. 4).

Table S1. Estimates, standard errors (SE) and P-value of the bat activity at control (*i.e.* without change of LPS lights) and experimental sites (*i.e.* with LPS lights switched to LED lights) before and after LPS lights were switched to LED lights. Here, the 'reference' category (i.e. the intercept) is 'control' and is identified as a category of comparison for the other categories (here 'experimental').

	Estimate ± SE	**P-value**
Total bat activity		
Intercept	3.815 ± 0.840	<0.001
Experimental *vs* Control	0.173 ± 0.316	0.584
Before *vs* after	0.161 ± 0.308	0.600
Experimental vs. Control : before vs. After period	-0.340 ± 0.425	0.425
Pipistrellus pipistrellus		
Intercept	5.977 ± 0.429	<0.001
Experimental *vs* Control	0.432 ± 0.481	0.369
Before *vs* after	0.042 ± 0.490	0.932
Experimental vs. Control : before vs. After period	-0.398 ± 0.645	0.537
Pipistrellus pygmaeus		
Intercept	3.674 ± 0.631	<0.001
Experimental *vs* Control	0.568 ± 0.658	0.388
Before *vs* after	-1.121 ± 0.643	0.081
Experimental vs. Control : before vs. After period	-0.815 ± 0.832	0.327

Nyctalus spp.		
Intercept	2.490 ± 0.658	<0.001
Experimental *vs* Control	-0.139 ± 0.553	0.801
Before *vs* after	0.299 ± 0.587	0.611
Experimental vs. Control : before vs. After period	-0.088 ± 0.757	0.907
Feeding buzz ratio		
Intercept	-1.735 ± 0.141	<0.001
Experimental *vs* Control	-1.183 ± 0.062	<0.001
Before *vs* after	-0.487 ± 0.070	<0.001
Experimental vs. Control : before vs. After period	1.601 ± 0.091	<0.001

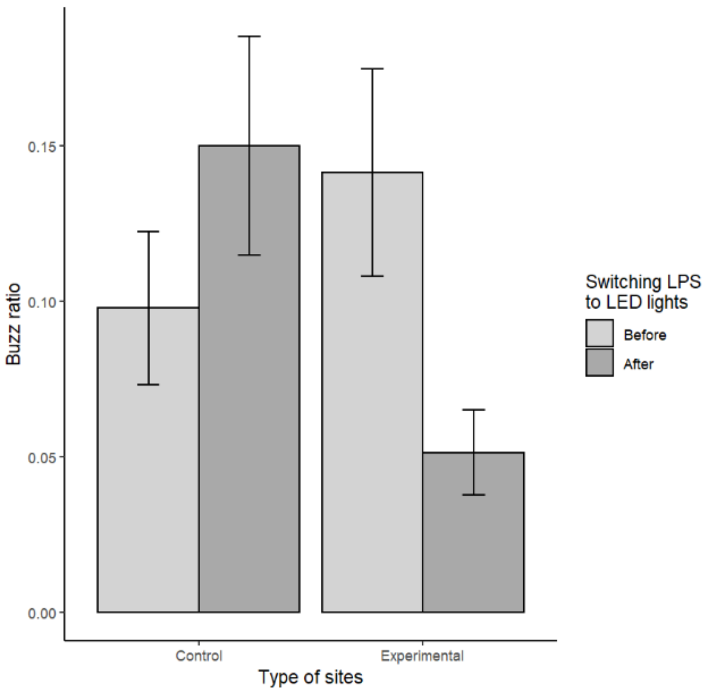

Figure S2. Predicted buzz ratios of *P. pipistrellus* at control (*i.e.* lit using LED lamps throughout both years of the experiment) and experimental sites (*i.e.* lit using LED lamps only the first year and LPS lamps only the second year) before and after the switch from LPS to LED lamps under experimental sites. Results come from the BACIP modelling.

Supplementary Material 4: assessment of the relative importance of environmental variables on bat activity before the experiment of shift from LPS to LED, thus only under LPS streetlight

We assessed the relative importance of environmental variables on bat activities using a Generalized Linear Model (GLM, function glm, R package 'stat'). According to the nature of the response and potential over dispersion of data we performed modeling with a negative binomial (link = log) (Zuur *et al.* 2009), except for the feeding buzz ratio, for which we used a quasi-binomial distribution (link = logit). As some variables were too correlated (i.e. Power and Illuminance) we ran separate regressions to avoid multi-collinearity problem. Thus, our statistical models were structured in the following way:

Bat activity ~Environmental variable

Where *Bat activity* is either the total activity (*Activity*), the number of buzz (*Buzz*) or the activity of a single species, for *P. pipistrellus*, *P. pygmaeus* or *Nyctalus ssp*; and *Environmental variable* is either the height of the streetlamp (*Height*), the power in watts (*Powe*r), the illuminance (lux), the distance to a wooded area expressed in meter *(Dist. Wood)*, the distance to freshwater expressed in meter (*Dist. Water)* and the distance to grassland expressed in meter (*Dist. Grass*) (the three distance variables being log-transformed).

Table S2. Effect of environmental variables on bat activities (β is the estimate of GLM), P- values were calculated using an ANOVA with a *F*-test for expressed. According to the need to adjust P-values for multiple comparisons, Bonferroni correction indicates that a α=0.05 threshold level should be considered here as α=0.008, thus significant P-values in regard to Bonferroni correction are indicated in bold, * indicated that error distribution used was a quasi-poisson instead of a negative binomial due to problem of model convergence.

Power	**Illuminance**	**Height**	**Dist. Wood**	**Dist. Water**	**Dist. Grass**
			Total Activity		
0.016±0.008	***β*=0.019±0.006**	*β*=0.224±0.098	*B*=-0.012±0.006	*β* =8.2e-05±1.1e-03	*β*=-0.002±0.002
P=0.045	***P*= 0.003**	*P*=0.028	*P*=0.040	*P*=0.932	*P*=0.297
			P. pipistrellus		
β=-0.002±0.009	*β*=0.005±0.007	*β*=-0.011±0.116	*β*=-0.009±0.006	*β*=0.001±0.001	*β*=0.001±0.002
P=0.812	*P*=0.567	*P*=0.922	*P*= 0.065	*P*=0.144	*P*=0.746
			P. pygmaeus		
β=0.032±0.011	*β*=0.032±0.009	***β*= 0.431±0.127**	*β*= -0.020±0.009	*β*= 0.0004±0.002	*β*= -0.005±0.003
P= 0.010	*P*= 0.011	***P*= 0.004**	*P*= 0.031	*P*= 0.863	*P*= 0.132
			Nyctalus ssp.		
***β*=0.061±0.015**	***β*=0.047±0.010**	***β*=0.745±0.1791**	*β*=-0.020±0.014	**β*=-1.313±0.486	**β*=-0.881±0.413
***P*<0.0001**	***P*<0.0001**	***P*<0.0001**	*P*=0.358	*P*=0.008	*P*=0.046
			Feeding buzz ratio		
***β*=0.012±0.005**	***β*=0.008±0.003**	***β*=0.1355±0.061**	*β*=-0.007±0.004	*β*=-0.001±0.001	*β*=-0.001±0.001
***P*=0.035**	***P*=0.048**	***P*=0.044**	*P*=0.113	*P*=0.244	*P*=0.585

In addition to the regression modelling that informed on the significance of each effect one by one, we used the Hierarchical Partition of the variance (R package hier.part) to identify the most likely causal factors while alleviating multicollinearity problems (Mac Nally, 2000).

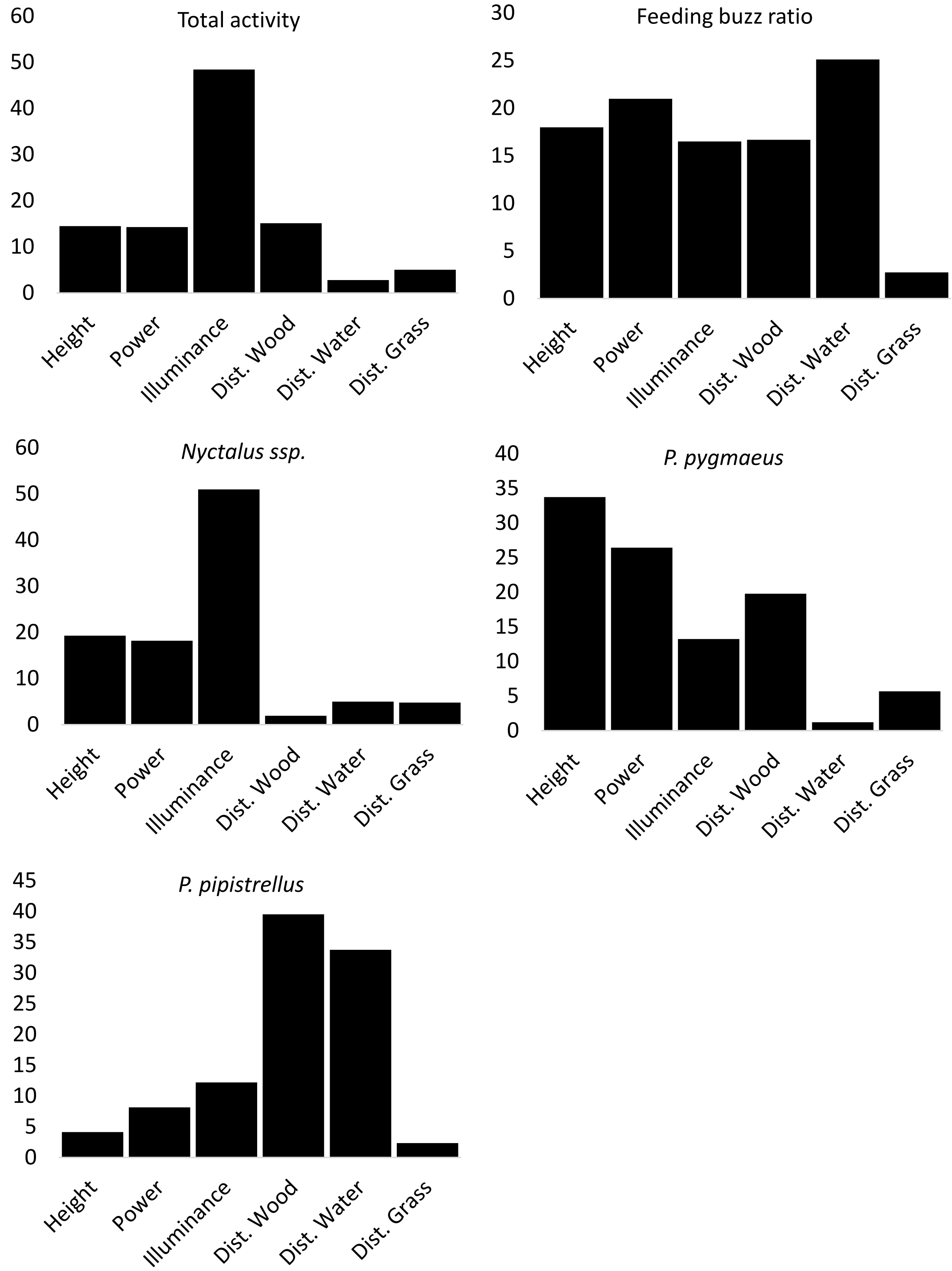

Figure S3. Percentage of total explained variance.

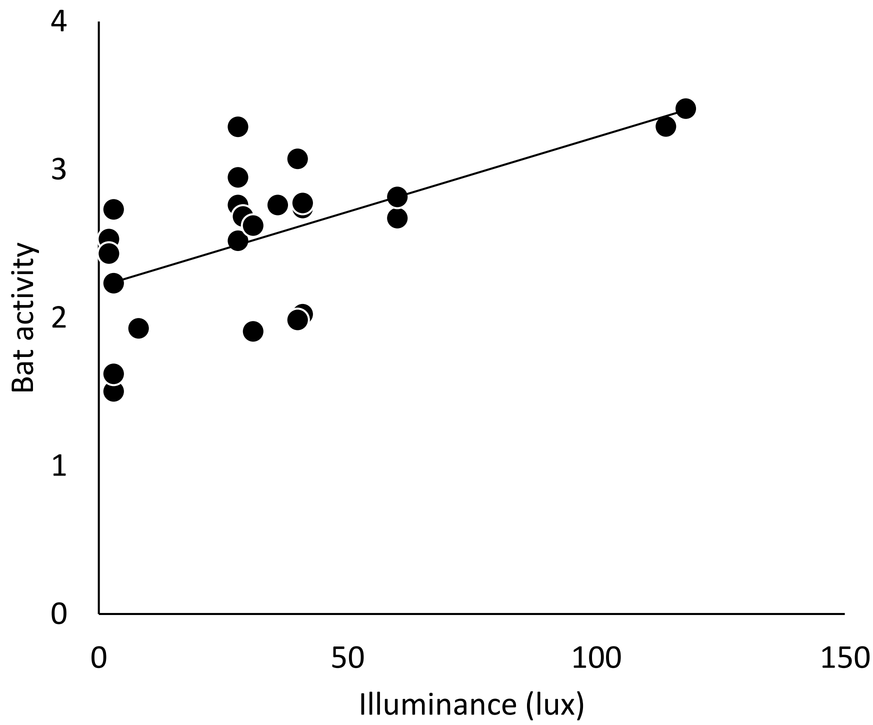

Figure S4. Relationship between bat activity (log-transformed of the number of bat passes) and illuminance (lux) at the 24 LPS streetlights in control and experimental sites before the switch.

References

Mac Nally, R., 2000. Regression and model building in conservation biology: biogeography and ecology: the distinction between and reconciliation of 'predictive' and 'explanatory' models. *Biodiversity and Conservation* 9, 655–671.

Zuur A, Ieno EN, Walker N, Saveliev AA, Smith GM (2009) Mixed Effects Models and Extensions in Ecology with R. Springer-Verlag, New York, pp. 322–342.