Which factors contribute to uncertain outcomes of biodiversity offsets?

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Do biodiversity offsets achieve No Net Loss? An evaluation of offsets in a French department

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Key words

Biodiversity offsets, no net loss, monitoring, mitigation hierarchy, offset efficiency

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Abstract

Biodiversity offsetting is a policy approach that compensates for the ecological losses from development projects affecting biodiversity with equivalent gains through offsets, aiming at "No Net Loss" (NNL). Although offsets seem appealing in theory, several concerns have been raised about the difficulties reaching NNL in practice. While most of the discussion about offsets improvement is based on principles and strategies, we evaluated empirical evidence of offsets implemented, both from the procedure files (protected species and wetlands) and field surveys. Our objective was to evaluate whether offsets achieve NNL based on 91 procedure files in the Isère department in France. We identified that necessary data for assessing offsets gains, such as the location and offset sites' initial state, were not available in part (location) or all (initial state) procedure files investigated. We evaluated 59 offsets implemented for 22 development projects and where minimum data for monitoring offsets were available; we surveyed the presence or absence of target species and habitat from the offset site. The type of offsets (restoration, creation or maintenance of target habitat) was one of the characteristics that helped to explain both species and habitat absence, implying offset failure. Based on our analysis, we suggest three principal angles for progressing in NNL achievement: (i) collecting and publishing a set of essential information on offsets, (ii) requiring a management plan for each offset, and (iii) accumulating empirical evidence of offsets failure and success.

1. Introduction

Biodiversity offsets have become a widespread conservation policy tool (McKenney & Kiesecker 2010) in response to the massive biodiversity loss caused by human activities (Naeem *et al.* 2012). Offsets aim to compensate for unavoidable negative impacts from development projects on biodiversity. The overall result should be a “No Net Loss” (NNL) of biodiversity (BBOP 2012), or even a net gain (but see Bull & Brownlie 2015). This NNL objective is set to stop biodiversity erosion. To reach this goal, offsets must be actions (such as ecosystem restoration) that provide gains of biodiversity equivalent to related losses due to impacts (Quétier & Lavorel 2011).

Although offsets seem appealing in theory, several concerns have been raised about the difficulties implementing offsets and achieving NNL (Bull *et al.* 2013; Gibbons & Lindenmayer 2007; Quetier *et al.* 2014). Firstly, the term “NNL” has various meanings depending on the national policy and is applied only on a few biodiversity features (Maron *et al.* 2018). In the European offset policy, NNL is applied for protected species and habitats (Regnery et al. 2013). In addition, in France legislation requires that losses of wetlands be compensated according to a specific procedure (Bezombes *et al.* 2018). Secondly, offset implementation and monitoring by developers and authorities face many uncertainties regarding (i) the measurement of losses and gains of the targeted biodiversity features (Moreno-Mateos *et al.* 2015) (ii) the time until the expected gains are provided by offsets (Curran *et al.* 2013) and (ii) the risk that offsets fail to provide the expected gains (Maron *et al.* 2012).

Most of the discussion about offsets improvement is based on the principles and strategies of offsetting (Bull *et al.* 2013; Gibbons & Lindenmayer 2007; Quetier *et al.* 2014). Only little empirical evidence of whether offsets actually succeed in achieving NNL exists (Quigley & Harper 2006b; May *et al.* 2017) and even less is validated by field monitoring (Pickett *et al.* 2013; Lindenmayer *et al.* 2017). In this paper we provide an evaluation of offsets implemented in the Isère department in France, with empirical evidence from the procedures files and field surveys.

According to the French law on biodiversity no. 2016-1087, developers must demonstrate that their offsets result in NNL of the targeted biodiversity features (protected species and habitats including wetlands). This implies measuring that gains (i) are equivalent in quality and quantity compared to losses (Bezombes *et al.* 2017), (ii) are only attributable to the offset actions (Bull *et al.* 2014) and (iii) would not have happened otherwise (Maron *et al.* 2013). For all the above, and in particular for (i), monitoring is necessary, but offset monitoring is still very heterogeneous in France (Quetier *et al.* 2014).

To evaluate the efficiency of offsets in achieving NNL, we first analysed the availability of data necessary to measure biodiversity gains in the procedure files of the Isère department of France. Based on available data, we surveyed for each offset whether the target biodiversity features were present or absent from the offset site after offset implementation. Although the presence of the target biodiversity features alone is not sufficient to measure gains, their absence is considered as an indicator of failure to achieve NNL. Finally, we analysed the characteristic of the offsets where target biodiversity features were absent and provide perspectives for better monitoring and NNL achievement.

2. Material and methods

2.1. Minimum information, study area and time span covered

Prior to the field survey and characterisation of offsets, we elaborated a list of minimum information necessary to include the offsets in our analysis: the targeted biodiversity features, offset location, type of offsets and contact details of the manager in charge of monitoring. We also identified that the information necessary to determine whether offsets provided gains was the offset site's initial state (before offset implementation) in quality (presence or absence of target habitat and/or species) and quantity (surface for habitats and number of individuals for species).

We reviewed all procedure files available in the archives of the Isère department administration in charge of the procedure directive. Only the files fulfilling the requirements for the minimum information were selected. In these files, all projects required offsets for protected species, wetlands or both following the designated procedures (Bezombes *et al.* 2018), and all were approved by the Isère department's prefect. Offsets were implemented between 2001 and 2015 on sites that were all located in the Isère department in South-East France (Figure 1). The projects were mainly situated around urban areas and along motorways, in areas dominated by agriculture and small natural patches.

Each offset site was surveyed between spring and summer 2016 during a 1-day visit. Managers in charge of monitoring were always present to allow access to the sites and provided complementary information on offsets that were not available in the files. During the survey, we visited all offsets implemented and assessed the presence or absence of the protected species and their habitat (protected species procedure), or wetland vegetation and the related fauna (wetland procedure). The target habitat was considered present when the necessary hydrologic conditions (for wetlands) and vegetation structure (for wetlands and species habitat) were observed. When the vegetation was not mature, the habitat was considered absent. The target species was considered present when individuals or tracks of individuals (nest, egg-laying) were observed.

2.2. Offset characteristics influencing the presence or absence of the target species and habitats

To analyse whether certain offset characteristics influence the presence or absence of the target species and habitats, we described in Table 1 the offsets with eights characteristics: (1) the offset procedure, (2) the type of offsets, (3) the type of developer, (4) the distance between the impacted and the offset site, (5) the distance between the offset site the nearest landscape ecological corridor, (6) the time since offset implementation, (7) the number of offsets implemented on the site and (8) five variables for the target species group (birds, reptiles, amphibians, mammals, and "others" including bats, insects and flora (see Table 1 for the reasons for these choices).

We classified offsets into five types, from the least to the most intensive actions and uncertainties about the outcomes (Tischew *et al.* 2010): maintenance of a favourable habitat; management of a terrestrial ecosystem; restoration of a wetland or river; and creation of linear plantation, micro-habitat or pond (see Appendix 1 for details). The distance between offset sites and either impacted sites or the nearest ecological corridor was calculated as the shortest distance from one perimeter to another.

2.3. Data analysis

We assessed the influence of the offset characteristics on the presence or absence of (i) the target habitat and (ii) the target species at the offset site using a generalised linear mixed model (GLMM; R package MASS, Ripley *et al.* 2013). Due to the nature of our response variables (i.e. the presence/absence of the target species or the habitat) we used a binomial error distribution. The hierarchical structure of our sampling design (59 offsets allocated on 30 offset sites), imposed that we treated the variable "offset site" as a random effect, while considering the other explanatory variables as fixed effects (Zuur *et al.* 2009).

Following a multi model inference (Burnham *et al.* 2011; Grueber *et al.* 2011) we generated a set of candidate models containing all possible variable combinations and ranked them by corrected Akaike information criterion (AICc) using the dredge function (R package MuMIn; Barton 2015). We only integrated the models complying with the following conditions: (i) models do not include simultaneously correlated covariates ($R^2>0.7$) and (ii) models do not include more than three variables to avoid over-parameterisation due to the limited data set. This resulted in a total model set of 251 models for both targeted habitat and targeted species (see Appendix 2 and 3). We restricted this set of models using a cut-off of 3.8 AICc for targeted habitat and 7 AICc for targeted species corresponding to the AICc values of a model with no predictor variables. We finally obtained a total of 45 and 31 top models, respectively (see Appendix 2 and 3).

3. Results

3.1. Missing data necessary to monitor offsets

Out of the 91 offset procedure files reviewed, only 33% contained the minimum information necessary to include the offsets in our analysis. Among the 30 projects selected, eight had to be excluded because the offset site manager did not respond to our inquiry. Finally, 22 procedures files were included in the analysis (see Table 2 for details on the projects). Since between one and five offsets were implemented on one or two sites per project (Table 2), a total of 59 offsets were surveyed.

Nonetheless, information on the offset sites' initial state (both in quality and quantity) was absent from all 22 projects selected. Therefore, we were not able to verify whether actual gains were provided by the offsets. Only offset failure (absence of the target species and habitat on the offset site after offsets were implemented) could be analysed.

In addition, some data expected to be found due to regulatory requirements were absent. Indeed, for seven out of 22 projects (33.9% of the offsets surveyed) the impacted site area was not found in the files. For six out 22 projects (23.7% of the offsets surveyed), no mention of a management plan was found in the files (even though an offset manager was in charge of the offsets).

3.2. Offset characteristics influencing the presence or absence of the target species and habitats

The target habitats were found absent for 27.1% of the offsets and target species absence represented for 39% of the 59 offsets surveyed in 2016 (i.e. 1–15 years after offset implementation depending on the project; Table 2).

In the set of the top models for the target habitat (Table 3), only the type of offset exhibited notable relative importance (0.73, see Appendix 2) as it appeared in every top models. The type of offset influenced the occurrence of target habitats, which was greater when offsets consisted in creation of a micro-habitat and maintenance of the already favourable habitat (Figure 2a).

In the set of the top models for the target species (Table 3), the type of offset and the number of offsets were both variables with the greatest sum of the Akaike weights (respectively, 0.96 and 0.73, see Appendix 3). Note, however, that the confidence interval for the estimate of the number of offsets on the offset site (conditional average β =7.22 ± 13.45 SE) includes zero, so there is little evidence in the data set that this affects the occurrence of target species. However, the type of offset influenced the occurrence of the target species, which was lowest when offsets consisted in management of a terrestrial ecosystem (Figure 2b).

4. Discussion

4.1. Information gaps when evaluating NNL

By evaluating offset implementation in the Isère department in France, we showed that the implementation of offsets lags behind the regulatory requirements of NNL policy (Gibbons & Lindenmayer 2007; Quetier *et al.* 2014; Lindenmayer *et al.* 2017). We established two levels of information gaps in current practices: i) access to procedures files and ii) missing data in the procedures files.

First, because of organization difficulties within the regional authorities' services, we could only obtain information on offset implementation at the department level (even though this information should be publicly available). Once access was granted by the Isère departmental authorities, 66% of the projects could not be selected for the survey due to the absence of the minimum necessary data, mostly the offset site location. Lack of human and financial resources provided for public environmental authorities (Quétier *et al.* 2014), which impacts the archiving of procedure files, may contribute to these difficulties to access the files.

We observed further that 25% of the procedure files did not contain a management plan, which we interpreted as an indication that no monitoring (and therefore no control) was foreseen by the developer. However, to reach NNL, international recommendations (BBOP 2012) and the national legislation (law on biodiversity no. 2016-1087) stipulate that offset sites have to be maintained and managed by the developer until the gains are effective

Second, the data found in the procedure files was of heterogeneous quality (i.e. missing data, confusion between minimisation and offsets), also noted for another department in France (Bigard *et al.* 2017). This restrained our analysis to potentially 33% of all offsets (assuming 100% were accessible). Moreover, given that we depended on the managers for access to the offset sites, our data set did not necessarily reflect the reality of the offset practices as there is a higher probability that managers did only grant access to the sites if they were confident in the success of their offset. Consequently, our results presented here might underestimate offset failure.

Even for projects that had been surveyed, available information was not sufficient to verify if the offsets provided the expected gains. The initial state of the offset site is the essential data missing, even in its simplest form: presence or absence of the target habitats and species. This information could be used in future analysis to measure gains of the target biodiversity features. These gains would be provided if the biodiversity features were absent at the offset site at the start of implementation but were present during the survey. To achieve NNL, quantitative criteria related to the dynamics of populations and counterfactual scenarios should also be measured (Bull et al. 2014). Other combinations such as no changes of the biodiversity features on the offset site, or even losses if they disappear from the site (e.g. meadow succession towards forest) could be considered as failures to achieve NNL.

4.2. Characteristics of offsets that fail in providing gains

Characteristics of offsets that fail to provide gains can be discussed based on the absence of the target habitats or species from the offset site during the survey. However, their presence alone does not provide enough information to discuss the characteristics of offsets that succeed in providing gains (Bull *et al.* 2014). There could still be a bias in the measurement of the absence of species (we could have missed individuals or tracks during the 1-day survey), but we consider our measurement as valid since (i) we were assisted by the site manager (with deeper knowledge of the offset site) and (ii) we were specifically searching for the target species.

Our analysis should be seen as preliminary results since the data set is relatively small from a statistical point of view. That being said, we showed that among the eight identified offset characteristics (Table 1), only the type of offsets influenced the absence of the protected species and their habitat or wetland and the related fauna community.

Two out of six types of offset contributed to a high occurrence of the target habitat (creation of micro-habitats and maintenance of an already favourable habitats; Figure 2a). These actions, often implemented by developers (Regnery et al. 2013) are indeed simple to realize. In most cases, rocks or wood piles are placed in a relevant spot for micro-habitats and human disturbances are prevented from the area. Reasons for unsuccessful establishment of the target habitat are manifold: absence of a persistent management effort over time leading to recolonization of grasslands by shrubs (Gibbons & Lindenmayer 2007), or non-adapted techniques that do not achieve the estimated effect when setting up the offset, as demonstrated for invasive plant removal (Early *et al.* 2016).

Similarly, management of terrestrial ecosystem never contributed to any occurrence of the target species (Figure 2b). In most cases, the target species required a particular vertical habitat structure (e.g. no shrub for birds of open areas), but as observed for the target habitat, the management was often inappropriate (e.g. too much shrubs), resulting in the absence of the target species.

4.3. Perspectives for better monitoring and NNL achievement

Even despite the small sample size of the offsets surveyed, the principal lesson learnt from our study is that an analysis of offsets can be conducted in order to verify NNL achievement (equivalence between losses and gains, effectiveness of gains in time, etc.; BBOP 2012). Based on the above-mentioned limitations concerning accessibility and availability of data of offset and the high failure rates for some types of offsets, we suggest three principal angles for progress: (i) collecting and publishing minimum information on offsets, (ii) requiring a management plan for each offset, and (iii) accumulating empirical evidence of offsets failure and success.

First, systematically collecting the minimum necessary information, most particularly a comprehensive initial state of the offset site, allows evaluating the gains provided by offsets and is essential to assess NNL accurately (Pickett *et al.* 2013). Better organisation of offset data would substantially improve offset monitoring at the regional and national scale (Quigley & Harper 2006a; May *et al.* 2017). In France, since the law on biodiversity (2016), a national database is being developed with the aim of centralising information on biodiversity offsets, including the localisation of offset sites. Making such a database publicly available should allow more transparency in offset implementation and facilitate standardised monitoring.

Second, according to international recommendations, a management plan should be required to (i) monitor offset effectiveness and (ii) adapt management practices if necessary to reach the expected gains. The management plan must last long enough to record the succession of all biodiversity features, mostly those with slow vegetation succession (such as forest; Maron *et al.* 2012).

Third, accumulating empirical evidence following the principles of evidence-based conservation (Sutherland 2003) is suggested as a final axis of improvement. The offset characteristics leading to failure (Lindenmayer *et al.* 2017) or success (Tischew *et al.* 2010) in providing gains can be identified and either avoided or developed. Furthermore, offset implementation could include an efficiency rate with more attention given to risky offsets. We encourage that feedback from analyses of offsets such as provided herein is transferred from scientists to stakeholders (developers, authorities, etc.) to make offsets efficient in actually achieving NNL.

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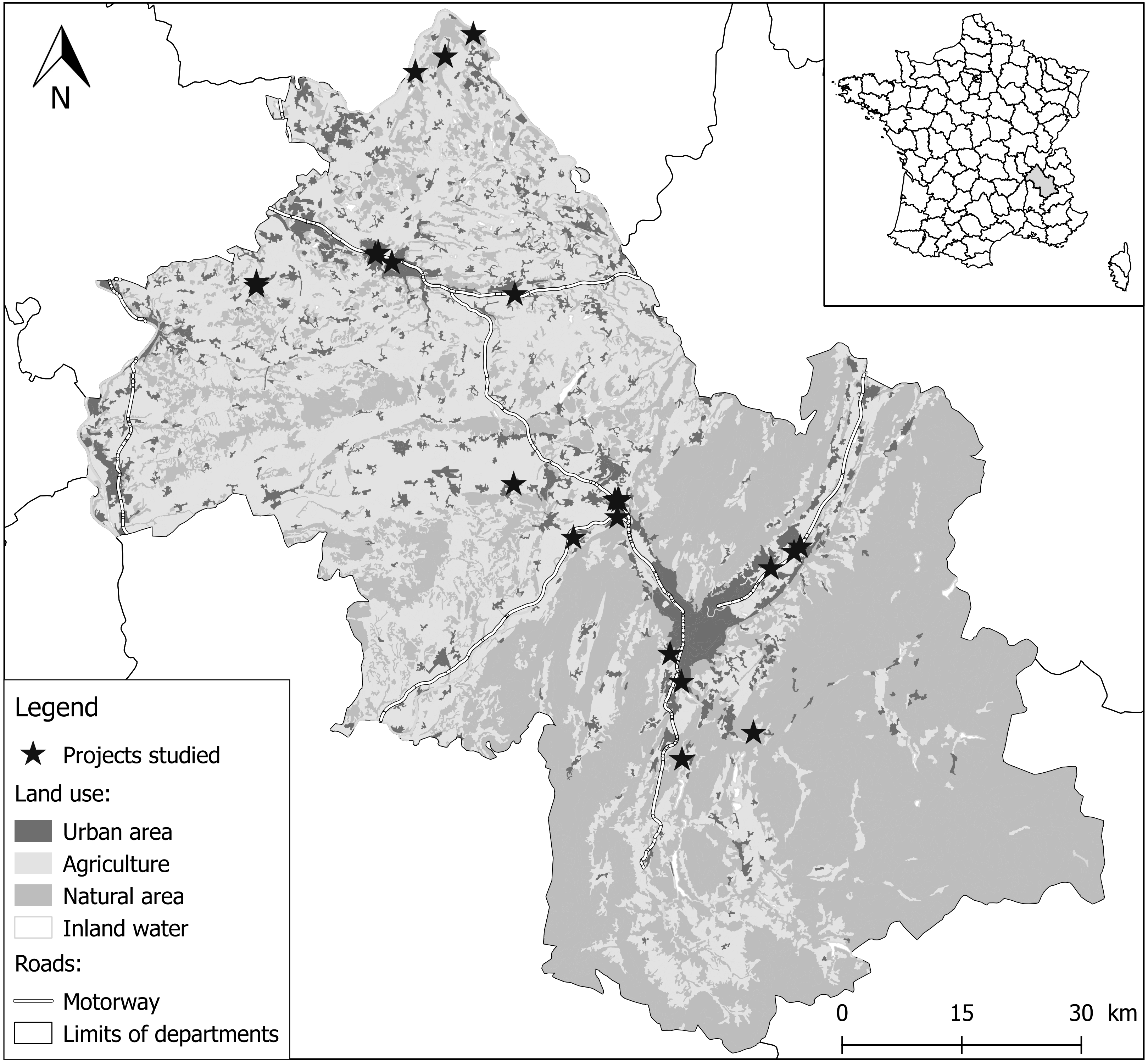
N
Legend
Projects studied
Land use:
Urban area
Agriculture
Natural area
Inland water
Roads:
Motorway
Limits of departments
0
15
30
km

Figure 1 caption: Location of the 22 projects surveyed in the Isère department in France

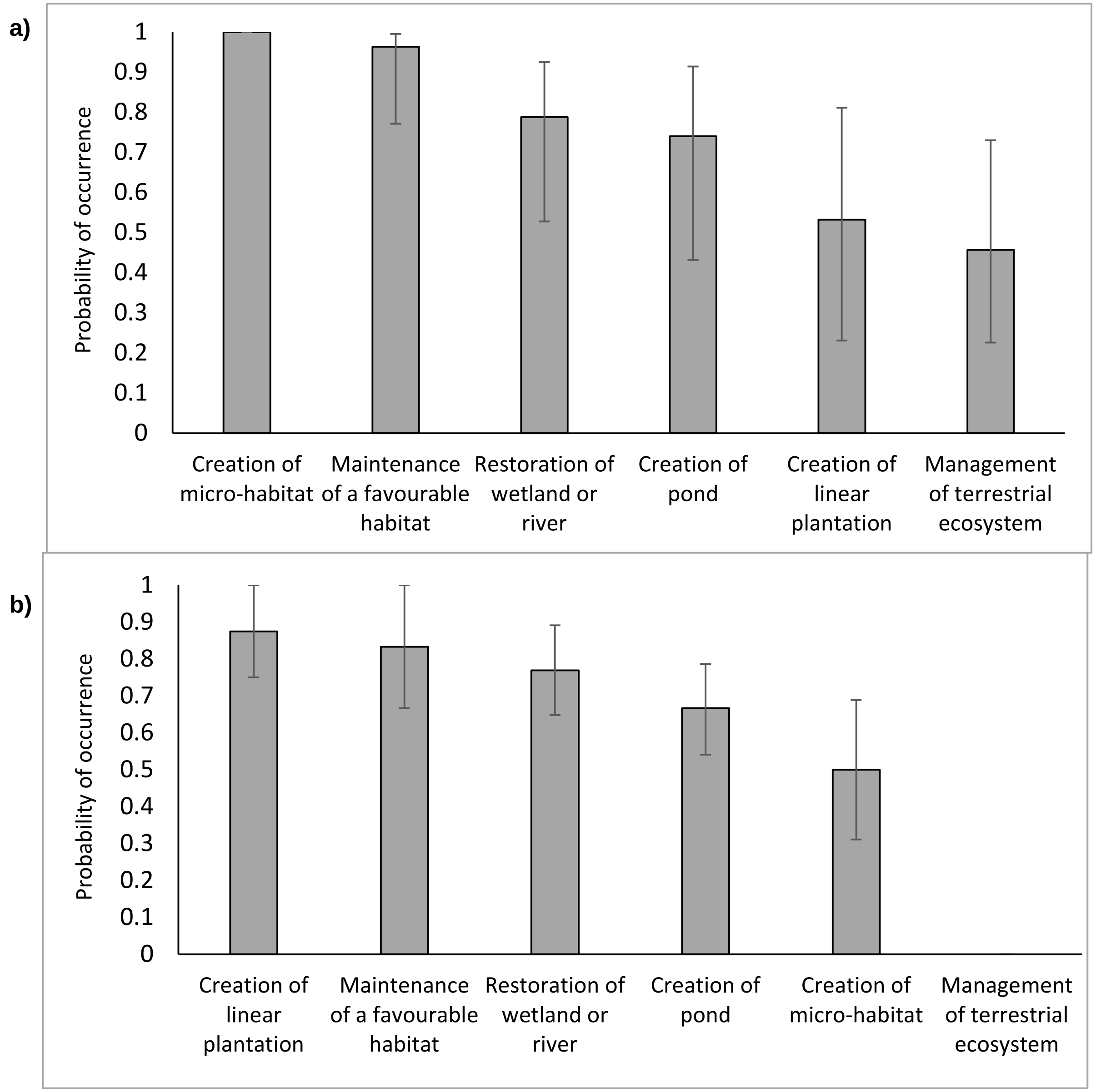

Figure 2: Probability of occurrence, i.e. backtransform estimate from the selected set of model, of a) the target habitats and b) the target species on offset site depending on the type of offset implemented.

Table 1: Offset characteristics that could influence the presence or absence of the target habitat or species.

Offsets characteristics	Variable description	Reasons for variable choice
Offsets procedure **(Procedure)**	Categorical: Protected Species (n=18), Wetland (n=24), Both (n=17)	There may be different expectations from the administration towards offsets implementation and monitoring depending on the procedure
Type of offsets **(Type offsets)**	Categorical: Management of terrestrial ecosystem (*n*=5), Restoration of wetland or river (*n*=13), Creation of pond (*n*=16), Creation of micro-habitat (*n*=10), Creation of linear plantation (*n*=9), Maintenance (*n*=6).	Using different ecological engineering techniques can lead to various outcomes of offset actions (Maron *et al.* 2012)
Type of developer (**Type dev)**	Categorical: Private (*n*=31), Public (*n*=28)	There may be different expectations from the administration towards offsets implementation and monitoring depending on the status of the developer.
Distance between impacted and offsets site **(Dist. Imp. offset)**	Quantitative continuous (km)	There is a greater chance that the environment on offset site is similar to impacted site when they are nearby (Kiesecker *et al.* 2009)
Distance between offsets site and nearest landscape ecological corridor **(Dist. offset. Corr)**.	Quantitative continuous (km)	Landscape ecological corridors are important areas for biodiversity (Taylor *et al.* 1993)
Time since offsets implementation (**Time**)	Quantitative continuous (years)	The outcomes of offset actions can be visible after a certain number of years (Maron *et al.* 2012)
Number of offsets on the site (**Nb. offsets**)	Quantitative continuous (number of offset measures)	The combination of several offsets on a compensatory site could be more favourable for the target biodiversity features (Tischew *et al.* 2010)
Group of species targeted by offsets: birds, mammals, reptiles, amphibians, “others” (bats, insects and flora) (**Target species**)	Categorical: Yes /No	Groups of species have different requirements (home range, dispersal ability) and life cycles: some might be easier to maintain, restore or create.

Table 2: Details on projects studied (impacted and offset sites)

Project	Procedure W=wetland PS=protected species	Impacted site area (ha)	Type of developer	Type of impacts	Target taxonomic groups	Year of offsets	Number of offset sites	Number of offsets on each site
Project A	W	0,95	Public	Urbanization	Wetland fauna	2012	1	1
Project B	W	0,45	Private	Transport infrastructure	Birds, bats, reptiles, odonates, amphibians	2013	2	3 - 3
Project C	W	0,3	Private	Hydraulic construction	Birds, bats, reptiles, odonates, amphibians	2013	1	1
Project D	W PS	0,005	Public	Transport infrastructure	Odonates, amphibians	2014	1	1
Project E	PS	NA	Private	Quarry	Amphibians, reptiles, birds, mammals	2012	2	1 - 1
Project F	PS	5,58	Private	Quarry	Amphibians, reptiles, birds	2013	2	2 - 1
Project G	PS	NA	Private	Quarry	Amphibians, reptiles, birds	2013	1	5
Project H	W	7	Public	Urbanization	Wetland fauna	2001	1	1
Project I	W	NA	Private	Transport infrastructure	Amphibians, reptiles, birds	2012	1	2
Project J	W PS	0,55	Private	Transport infrastructure	Birds, reptiles, odonates, amphibians	2013	1	4
Project K	W	0,4	Public	Hydraulic construction	Wetland fauna	2011	1	6
Project L	W	0,21	Public	Urbanization	Wetland fauna	2009	1	1
Project M	PS	13,37	Private	Hydraulic construction	Amphibians, reptiles, birds, mammals, bats, insects, flora			
Project N	W	0,974	Public	Urbanization	Wetland fauna	2014	1	2
Project O	W	1,8	Public	Transport infrastructure	Wetland fauna	2012	1	1
Project P	W PS	NA	Public	Urbanization	Amphibians, reptiles, birds, mammals	2011	2	3 - 1
Project Q	PS	NA	Private	Electricity network	Reptiles, flora	2013	2	1 - 1
Project R	W PS	NA	Public	Hydraulic construction	Birds, bats, reptiles, amphibians, fishes	2013	1	2
Project S	W PS	27,5	Private	Hydraulic construction	Amphibians, reptiles, birds, mammals, bats, flora	2012	2	2 - 1
Project T	W	0,2	Public	Water treatment	Wetland fauna	2013	2	1 - 5
Project U	W	0,5	Public	Urbanization	Wetland fauna	2015	2	1 - 2
Project V	W PS	NA	Public	Urbanization	Amphibian	2007	1	3

Table 3: Models set for target habitat and species

Models set with df, log-likelihood, AICc, ΔAICc and Akaike weights for target habitat and species. Only the first models (cut-off ΔAICc < 3.8 for target habitat and 7.0 for target species) are provided. Abbreviations: the type of offsets (Type offset), the number of offsets implemented on the site (Nb. Site), the distance between the offset site the nearest landscape ecological corridor (Dist. Cor.), the time since offsets implementation (Year), and variables for the target species group "others" including bats, insects and flora (Others).

Models	df	log-likelihood	AICc	delta	weight
Target Habitat					
Others+Proced.+Type offset	10	-24.28	68.57	0	0.04
Proced.+Type offset	9	-25.93	69.87	1.30	0.02
Type offset	7	-28.14	70.27	1.71	0.02
Others+Type offset	8	-27.20	70.41	1.84	0.02
Amph.+Proced.+Type offset	10	-25.29	70.59	2.02	0.02
Target Species					
Dist. Cor.+Nb. site+Type offset	9	-18.89	59.87	0.00	0.13
Nb. site+Type offset	8	-20.54	60.28	0.42	0.11
Others+Type offset	8	-20.83	60.87	1.00	0.08
Nb. site+Type offset+Year	9	-19.39	60.87	1.00	0.08
Nb. site+Others+Type offset	9	-19.81	61.70	1.84	0.05