Biodiversity offsetting: Certainty of the net loss but uncertainty of the net gain

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Abstract (250 words)

Biodiversity offsetting is usually the last step in the mitigation hierarchy and aims to compensate for impacts of development projects on biodiversity. It is supposed to contribute to the key environmental objective of "no net loss" of biodiversity by delivering gains equivalent to losses. We hypothesize that such gains can only be attained through ecological restoration of degraded sites: the restored ecosystem should not only equal the original or reference ecosystem as usually assumed, but rather the original state of degradation of the ecosystem used for offsetting should be of the same level as the impacted ecosystem after development. We built on this starting assumption to determine whether impacts and gains were considered equally in the offsetting measures of 24 infrastructure projects, and to infer the potential gains in offset sites, based on an analysis of procedure and administrative documents. The analysis showed that impacts were presented in much more detail than the offsetting measures. In addition, out of 577 ha that was intended to offset areas being artificialized, only 3% of the area was artificial prior to offsetting work, i.e. delivering high potential gains, whilst 81% could be considered semi-natural habitats, thus with lower potential gains. Little information on the ecological quality of offset sites was available. When described, their good quality was used as an argument to justify their selection, resulting in relatively uncertain gains in comparison to certain impacts. Our results suggest that including multiple comparisons of multiple ecosystem states is a way forward to better evaluate the equivalence between gains and losses, and thus would ensure no net loss of biodiversity.

Keywords: Conservation science, Mitigation hierarchy, Biodiversity gain, No net loss, Offset

Highlights:

- In 24 infrastructure projects, the descriptions of gains and impacts, habitats of offset sites and offset measures showed a clear imbalance between unequivocal biodiversity losses and uncertain potential gains.
- The pre-offset state of sites is rarely evaluated on an ecological basis, and richer sites are preferred to guarantee a rich final state of offset sites with eventually no gain of biodiversity.
- Restoration ecology can offer an appropriate framework to assess equivalence between biodiversity gains and losses.

Introduction

Biodiversity offsetting is a landscape planning tool which aims to compensate for the impacts of projects on biodiversity, with the broader goal of coupling development and biodiversity conservation. It is usually part of a mitigation hierarchy in which multiple steps (2 or 3) are considered before resorting to offsetting, including avoidance and reduction of impacts (Quétier et al., 2014; Gardner et al., 2013; Bull et al., 2016). Biodiversity offsetting, therefore, concerns the residual unavoidable predictable impacts of a project. Since the 1970s, biodiversity offsetting has attracted growing interest and formalization (Gelcich et al., 2017); it is now widely incorporated in much environmental legislation and in the charters of businesses (BBOP, 2013). This tool has broad applicability in delivering the key environmental objective of "no net loss" (NNL) or even of "net gain" (NG) of biodiversity.

As soon as biodiversity offsetting spread more widely and became the focus of academic research, reservations were expressed about its value in biodiversity conservation (Calvet et al., 2015) in terms of its fundamental principles, methods and effectiveness. More recently, some authors have stated more directly that it is not an appropriate tool with which to conserve biodiversity (Bull et al., 2016; Moilanen and Kotiaho, 2018). The central point of the malaise surrounding biodiversity offsetting is the principle of NNL. There is a huge gap between the scientific definitions of biodiversity in ecology, which include multiple levels (genetic, specific and ecosystem) and interactions (between biotic entities and with abiotic components), and what is intended when implementing NNL policies (Bull et al., 2016). It has been suggested, therefore, that NNL policies should always clearly outline the "frame of reference against which NNL is to be achieved" (Bull et al., 2016). Further, the ecological relevance of the tool depends on which qualitative and quantitative losses are considered in environmental assessments and how gains are generated to ensure equivalence (Bezombes et al., 2019).

Assessment of losses depends on the administrative procedures that define obligations. As noted by Bull et al. (2016), official guidelines generally refer to a comprehensive approach to biodiversity, before translating it into a reductive approach during implementation. There is, therefore, a need for empirical analysis of how losses and gains are evaluated.

In addition, there is a need to develop a robust methodology to anticipate potential biodiversity gains through offsetting actions. The spectrum of possible actions ranges from those that generate quantifiable benefits for target biota (Bull et al., 2016) to wider actions including habitat improvement, maintenance, rehabilitation, enhancement, preservation, re-creation, re-generation, restoration, removal of threats, management and protection (Maron et al., 2012, McKenney and Kiesecker, 2010).

However, resulting gains may vary greatly in terms of biodiversity, from species-rich habitats to be protected to degraded habitats to be restored. Indeed, “management offsets” or “averted loss offsets” often considered to be synonymous, whilst “restoration offsets” differ in terms of the means and space needed to implement them and with respect to their outcome for biodiversity and ecosystem functioning (Kujala et al., 2015). Averted loss offsets may be effective for specific biota (Moilanen and Kotiaho, 2018), and thus be acceptable if we accept a restricted vision of biodiversity. However, restoration offsetting may benefit more components of biodiversity than initially expected when only specific target biota is considered and may, therefore, provide wider ecological benefits.

Following Moreno-Mateos et al. (2015), we assume that biodiversity offsetting and ecological restoration (sensu SER, 2004) should intrinsically be linked in a context of the NNL goal, because restoration operations can precisely compensate for degradation. Interestingly, restoration ecology provides a conceptual framework applicable to the analysis of biodiversity offsetting. In this framework, the only means to guarantee that gains equal losses is to ensure equivalence between the restored and the reference state. In the context of biodiversity offsetting, the balance between gains and losses is sought through the equivalence between the pre-impacted state of the development site and the final state of the offset site, completely ignoring a fourth state that should be introduced, namely the initial state of the offset site. Indeed, gains of biodiversity that are expected to meet losses states in the difference between the pre-offset site and the offset site enriched by offsetting measures. Our hypothesis is that including a pre-offset site that exhibits the same level of degradation as the site impacted by the infrastructure will have post-development, is theoretically the only means to achieve equivalence and balance between losses and gains, especially for projects causing irreversible artificialization of semi-natural or natural areas. Ignoring the pre-offset state could encourage developers to look for sites already having the final expected state.

Such a requirement highlights the need to study the way losses and gains are planned and evaluated by infrastructure planners and authorities in biodiversity offsetting. We therefore conducted a study of 24 infrastructure projects requiring a mitigation hierarchy to reach NNL of biodiversity, to examine how losses and gains are evaluated before project achievement, and to evaluate potential gains generated by offsetting actions. To ensure a homogeneous legislative context, the projects were all located in France, where biodiversity offsetting has increased in prominence and importance since the environmental reforms in 2010 (*Loi Grenelle II*, 2010).

Based on a document analysis, we specifically examined: (i) the quality and quantity of information available on impacts, offsetting and expected gains to draw up an empirical framework for the French NNL policy, i.e. on what basis decisions are made; (ii) how gains are supposed to be generated by considering all the different ecological states of impacted sites, offset sites and by including the pre-offset state in our framework, along with actions being carried out; and (iii) how by multiple comparisons of different ecosystem states, restoration ecology could provide a framework to evaluate the equivalence of gains and losses.

Material and methods

Sources of information on biodiversity offsetting

In most countries applying the mitigation hierarchy, EIA and supplementary documents provide the most complete picture of projects, with respect to ecological impacts and mitigation measures. Developers generally mandate environmental consultants to draft the documents. In France, these documents constitute the material on which administrative authorities evaluate projects and decide whether they should be approved. Our principal sources of information, therefore, were the administrative documents used for validation and the specific procedure documents in which biodiversity offsetting plans are detailed. Offsetting measures described in the documents are presented as a combination of offset sites and offsetting actions. We used this material to analyze both the proposed offsetting measures and the nature of information underpinning the decision about each project.

We focused on offsetting that concerned protected species and wetlands and water bodies; these procedures are the main ones involving the implementation of the mitigation hierarchy[1]. Since 2016 they have been combined, and are referred to as the "joint procedure". Contacts were established with administrative authorities in charge of project management in two French administrative regions (Occitanie and Hauts-de-France) to obtain the relevant documents. We selected the dossiers as follows: (i) we first focused on the protected species procedures and restricted the research to the period 2012-2017, roughly corresponding to a stable regulatory context; (ii) we focused on linear infrastructures that constitute the type of projects for which the mitigation hierarchy is implemented most often; (iii) from this group of projects, we considered only complete dossiers, i.e. those containing the three steps of the hierarchy and already authorized; and (iv) we searched for the water and wetlands procedures for the same project. In total, we collated 25 procedures (Table 1). Most of these came from Occitanie (17) where the administration was able to gather the required documents easily. For this region, the sample constitutes 25% of authorized projects during the period 2012-2017. The 24 projects include 16 roads and highways (10 new constructions and six widening), one railway, two power lines, two underground aqueducts and three gas pipelines.

Table 1. Number of regulatory procedures and projects by region and biodiversity subset.

	Protected species only	Wetlands and water bodies only	Both protected species and wetlands and water bodies	Joint procedure	Total
Occitanie	13	1	1	2	17
Hauts-de-France	6	1	0	0	7
Number of projects	19	2	1	2	24
Number of regulatory procedures	19	2	2	2	25

Analyses of potential biodiversity gains

[1]The French legislation also **covers** procedures concerning woodland and Natura 2000 areas.

1. Information available about offsetting and gains

The role of procedure documents is to allow the National Council for Nature and public authorities to evaluate the quality of mitigation and NNL. We examined the documents to determine whether they contained several types of information: future infrastructure site (area, habitats), project impacts, offsetting ratios, offset sites (area, habitats), offsetting actions, gain evaluation and surveys (see Annex 1). It should be noted that all information on biodiversity gains was, therefore, declaratory and not performative. Thus, they represent what could, at best, be achieved in the field.

2. Area ratios between impacted sites and offset sites

We checked the relationship between the areas altered by undertaking the projects (impacted site) and the areas covered by offsetting actions (offset sites). The impacted site area is given in some projects and we calculated it for the others. Moreover, it includes either the area of the infrastructure only or the area of the infrastructure plus the construction site. We always present the given area where possible, regardless of what it includes. In our calculations, we favored areas including the construction site. As a consequence, over the 24 projects: 11 impacted areas were given (5 infrastructure only, 6 infrastructure and construction) and 13 were estimated (6 infrastructure only, 7 infrastructure and construction).

3. Type of land on which offsetting was conducted

To determine the type of land on which offsetting was conducted, we analyzed how the sites selected for offsetting were described in the documents. Based on these descriptions, sites were classified using the Corine biotopes typology because many descriptions explicitly referred to these categories. This typology is the European reference classification of the natural and semi-natural habitats present on the European soil. When this classification was not used, the descriptions of flora and land use allowed us to classify sites according to the Corine biotopes categories, at least to the second level of classification. In total, the 92 offset sites described were split into 19 different categories of the Corine biotopes typology (see Appendix 2 for a detailed description of the habitats). Finally, we calculated the total area of offset falling under those categories, across all projects.

4. Ecological quality of pre-offset sites

In order to determine the ecological quality of pre-offset sites, we examined how and the extent to which the conservation state and the habitat quality of pre-offset sites was evaluated in the 25 procedures. When mentioned, the conservation state of pre-offset sites was classified by the documents' authors as "good" or "bad", sometimes with the support of a standard assessment, e.g. according to the document of objectives (DOCOB) of a Natura 2000 area or by other methodologies (Carnino, 2009, Lenglet, 2011), and sometimes without clear or standardized methodology. The evaluation of habitat quality of pre-offset sites was analyzed based on the information given in the assessments. When evaluated, the habitat quality referred to three criteria: habitat degradation through vegetation change, presence/absence of the target biota, and inclusion of the pre-offset site in a protected area.

5. Actions carried out at those sites

In order to determine the types of actions that were intended to be performed at offset sites, we classified all the actions (n=118, from 1 to 15 per project) into 28 categories based on their description in the documents. We looked at the proportion of procedures associated with each of the 28 types of actions. Then, the action types were analyzed and classified according to the ecosystem attribute they concerned. The attributes were defined using the SER "recovery wheel". The wheel was developed to track the recovery over time of various properties of ecosystems during restoration (McDonald et al., 2016). It comprises six parts or attributes: absence of threats, ecosystem function, external exchange, species composition, physical conditions and structural diversity, which we used to determine the main expected effects of the actions at the offset site. We looked at the number of ecosystem attributes associated with actions at each offset site.

Results

1. Great imbalance in the information available

Considering the presence / absence of information reveals that most steps of the offsetting calibration appear in the documents; however, there is a great imbalance between them (Figure 1). In all projects, impacts of infrastructure on the concerned areas are described in detail with inventories supported by references in ecology. These descriptions mostly include areas of habitats affected; counts of affected specimens are found in half of the projects. Impacts on ecosystem functioning are tackled in all projects but they only discuss ecological corridors and fragmentation for a few species. Three projects discuss hydrological functioning and one ecosystem services.

Offsetting measures were well presented at first glance: offset sites were located and described and corresponding offsetting actions are detailed for all projects. Nevertheless, these descriptions were superficial, consequently the ecological state of offset sites was not determined, and actions supposed to fit a site and upgrade its biodiversity appear hypothetical. Moreover, if ratios are generally used to convert impacts foreseen to gain needed, they may consist of multiple ratios stemming from a complex system of scores (36%), or multiple ratios with a basic explanation of their origin (40%), or as a unique ratio for the whole project without explanation of its origin (24%). Finally, concerning outputs expected from offsetting, almost none of the projects provide an explicit objective of gains and consequently no method to evaluate any gain.

There is a clear imbalance between the biodiversity losses part and the biodiversity gains part of the process. Thus, the location, nature and extent of impacts are documented and certain. On the other hand, the generation and evaluation of gains are vague and uncertain.

2. Areas of offset are smaller than areas impacted

Impacted **site** areas ranged from 5.6 ha to 1081 ha, showing a diversity of project sizes. Total offset site areas ranged from 0.16 ha to 130 ha. The total area of impacted sites amounts to 2451 ha while the total area of offset amounts to 577 ha. Overall, in 17 out of 24 projects, the total area of offset sites was smaller than the area of the impacted sites (Figure 2). This means that biodiversity losses per unit area are smaller than diversity gained per area unit. This is not necessarily unacceptable, but implies highly effective restoration. However, 18 procedures use ratios and in all of them the mean of ratios is greater 1, which implies that biodiversity losses per unit area are greater than biodiversity gains per area unit. This can be explained by the entire impacted area not being taken into account for offsetting, but only areas supporting certain elements of biodiversity. Thus, priorities are given to those components of biodiversity considered worthy of offsetting over those considered to have a lower value.

Moreover, it should be noted that total area of offset sites is the sum of many sites, while impacted sites tend to be a single tract of land. We counted 92 offset sites over 24 projects with an average of 3.83 sites per project. Over 92 offset sites there was a mean area of 12.4 ha and a median of 2.4 ha. Offsetting is supposed to encourage conditions for biodiversity to thrive, so should target large sites. However, it is actually performed on a myriad of small sites, making it even more challenging to deliver biodiversity gains.

3. Offsetting is conducted mainly on semi-natural and natural land

Over 25 procedures, we managed to identify habitat descriptions of offset sites matching categories of the Corine biotopes typology for 467.85 ha out of 577.42 ha (Figure 3). This means that 109.57 ha were not described in enough detail for us to identify them with certainty. The offset sites were distributed over 19 biotope categories (Figure 3).

Three of these categories (ruderal communities, old industrial sites, and reservoirs and canals) were artificialized land, covering 15.8 ha. Four categories (crops, improved grassland, plantations, and vineyards) were habitats resulting from intensive agricultural activities, covering 93.2 ha. The 12 other categories were semi-natural and natural land, totaling 358.4 ha. Most of the offset sites were thus focused on semi-natural habitats, which can introduce strong biases in conservation toward just a few dimensions of biodiversity. For instance, the main type of land chosen for offsetting was "sclerophyllous scrub", amounting to 124.80 ha, which mainly corresponded to shrubby formations, more or less tall, also commonly known as *garrigue* in French. Such semi-natural habitats are abundant in Occitanie where 17 out of 24 of the infrastructure projects were located, as in the whole Mediterranean area. They are human-created habitats, derived from different levels of shrub encroachment following the abandonment of agriculture during the last 150 years. Although shrub clearing can increase biodiversity richness, especially bird species dependent on open areas (Barbaro et al., 2001, Fonderflick et al., 2010), the ability of these types of site to provide gains equivalent to losses can be challenged, since such offset sites are definitely not as degraded as the impacted site will be.

4. The quality of sites: rare information and a heterogenous situation

The conservation state of sites is rather rarely included in the procedures – only 34.18 ha out of the 577.42 ha of offset site descriptions – leaving 543.24 ha unclassified in this respect. The conservation state of 20.5 ha is described as poor and 13.6 ha as good. However, this assessment is supported for only 8.3 ha (1.1 ha of good and 7.1 ha of poor), using Natura 2000 DOCOB methods or other standard methods (Carnino, 2009; Lenglet, 2011). Conservation state is an important piece of information, complementary to land type, making it possible to evaluate potential gains. However, it is most often determined by environmental experts without clear and standardized methodology. The limitations of such unsupported assessments are clear.

The description of 338.29 ha contained some elements that provided information about the ecological quality of sites. These elements constitute arguments for site selection. Target biota on offset sites was specified for 231.2 ha: present on 104.3 ha, probable on 100.2 ha and absent on 26.7 ha (Figure 4). On 145.6 ha, the ongoing vegetation dynamic was considered as indicating a degraded site. Finally, the motive for choosing an offset site is the opposite of the intended purpose for 41.7 ha, which are situated in an outstanding area (e.g. ZNIEFF) or a protected area (e.g. Natura 2000).

The ecological quality of sites is, therefore, mostly unevaluated in the assessments. Nevertheless, the presence of target biota appears to be favored, which is a sign of good quality, as is the placement of the site in an outstanding area (e.g. ZNIEFF) or a protected area (e.g. Natura 2000).

5. Actions undertaken are overall diverse but concern few attributes of the ecosystem on site

We found 28 different action types across all 25 procedures (Table 2), nevertheless some descriptions were too vague to be categorized. Over the 92 offset sites present in the documents, 90 contained sufficient information to be categorized. The description of the actions on the two sites that we excluded only specified that “restoration followed by the management of natural habitat will be performed. Both will be favorable to target biota” for one and that “actions will favor the development of protected fauna and flora populations on the site” for the other. Some other actions however contained several pages of explanation, for instance the tree species to plant, why and where. In three projects one action presented as offsetting was not, in fact, offsetting according to its broader definition (e.g. creation of a wildlife crossing), we did not consider them in the analysis.

The most commonly planned actions were maintenance of open habitat through reinstatement of appropriate disturbance regimes (mulching, shredding, grazing), pond creation, habitat protection, transplanting desirable plant species, opening up habitats (tree cutting, mulching, shredding) and reinstatement of tree layers (structure). Twenty-six of these 28 actions could be associated with the ecosystem attribute of the SER recovery wheel they concerned, and two were unidentified. In general, the entire set of offsetting actions carried out on a site concerned only one attribute of the ecosystem (48 out of 90 sites, i.e. 53%) (Figure 5). In this case, the attribute “structural diversity” is over-represented (28 out of 48). When two or three attributes were concerned, no attribute or combination of attributes appeared to be favored. Actions concerning four or more ecosystem attributes were found for three sites only. Finally, on seven sites, actions did not concern any attribute or could not be associated with one (habitat protection, ecologically sound management). Intervention on sites appears to have a very specific target and be mainly focused on one element of biodiversity. Therefore, plans do not treat the offset site ecosystems as a whole and are partly disconnected from the ecosystem’s overall functioning.

Discussion

Offsetting certain impacts against uncertain gains

This study shows that projects are written, reviewed and even approved with no information that makes it possible to foresee the equivalence between losses and gains. Information might not be present in documents, but known by those involved in the project, as Persson et al. (2015) concluded in a study of offsetting in Sweden. In most reports, future offset sites were designated through location and land use: most of the areas were either semi-natural or natural land. However, ecological assessments of the pre-offset state were very rare; their ecological quality, therefore, remained mostly unknown. When described, indicators of good site quality were used as an argument to justify the selection of the offset site. In a few cases (15 ha), sites in a good state of conservation had been deliberately sought. Thus, biodiversity gains were expected on sites that were relatively undegraded. For developers, this ensures that high biodiversity levels are obvious at the end of offsetting, as expected in administrative procedures, but it doesn't mean that actual gains will be delivered. Land pressure and associated prices may also encourage developers to target natural areas.

Gains can also be considered through the cumulative effects of various actions carried out on one single offset site. Combined, they could improve a site (Carey, 2006), however, we found that on each offset site only a few ecosystem attributes were targeted by actions. This low level of intervention may also indicate that sites were not greatly degraded (Chazdon, 2008). Furthermore, some actions were aimed at maintaining a habitat (e.g. maintenance of open habitat through reinstatement of an appropriate disturbance regime - mulching, shredding, grazing), suggesting management rather than restoration. Expected gains thus appear to be low, since they are achieved by undertaking small-scale, low investment actions on semi-natural or natural sites of presumably good ecological status.

Surely gains should be related to losses, i.e. to impact intensity, and small gains should match small impacts. However, a complete loss of biodiversity – either temporarily at a construction site or permanently in an area that becomes completely artificial – will always occur due to infrastructure development. When a complete loss of biodiversity is offset on a site which already supports considerable biodiversity, NNL cannot be delivered, either because the losses of biodiversity are too large (Moreno-Mateos 2015) or because no gains are actually generated (Gibbons and Lindenmayer, 2007; Bezombes et al., 2019).

This clearly raises questions about conducting ecological restoration on appropriate offset sites, which would suggest the need to search for degraded sites instead and paying attention to potential biodiversity gains. Indeed, our research reveals that the large majority of measures fall into the "averted loss offset" category at the expense of "restoration offset". In that case, it would be better to assume the "averted loss offset" approach in the NNL policy to ensure important requirements are delivered and gains generated (Moilanen and Kotiaho, 2018).

Substituting local biodiversity for the champions of "offset biodiversity"

In France, administrative procedures are organized in a way that splits up biodiversity into different components, including one – representing the majority of the 24 we studied – that focuses solely on protected or endangered flora and fauna. This highlights the point already stressed: a mismatch between a broader functional definition of biodiversity and its definition in an offset context (Bull et al., 2016). This focus on protected and endangered biota would be valuable if it drove offsetting actions to the entire biotic community and ecosystem functioning. In the 24 projects studied, we observed that most of the conservation measures were very specific to the single or few targeted species and only certain measures were aimed at delivering benefit to the whole habitat of the targeted species – if well implemented. Although this was often argued in reports, our results confirmed that offsetting actions are mainly driven by a restrictive vision of biodiversity. On an impacted site, it is common not to consider all the area altered when calibrating the offsetting, but only the area containing the targeted, often threaten, species, and even some protected species do not benefit from any measures (Regnery et al., 2013).

This restrictive view of biodiversity creates a hierarchy of biodiversity, so that that some components of biodiversity are worth offsetting while others are not. This also leads to some components being offset, i.e. the champions of "offset biodiversity", to the detriment of others that are abandoned by the wayside. In the projects we studied, opening up habitat and keeping it open are easy aims to deliver and provide quick rewards (e.g. Barbaro et al., 2001), and so these were widely used offsetting actions; consequently, many offset sites are sclerophyllous scrub or *garrigue*. In such a situation, *creating* open scrub is performed to the detriment of maintaining woody scrub. The same goes for ponds, which replace whatever ecosystem was there before. Some offset frameworks do take into account the fact that conducting offsetting on a site may harm some components of biodiversity already present (Bezombes, 2017). When examining ecological restoration and ecosystem recovery, Elliott et al. (2007) distinguished four types of recovery, among them habitat "enhancement or creation" which "implies a quality judgment (which itself implies subjectivity and operator bias) that the science and engineering are sufficient to improve habitats and also that one type of habitat is preferable to another" (Elliott et al., 2007). In the same way this explains why vegetation change is considered a source of degradation. Sources of ecosystem degradation are complex (Andrade et al., 2015) as is the definition of a degraded ecosystem (Veldman, 2016). It requires a reference state, missing from most of the procedures we analyzed in this study. A more precise definition of biota degradation may be needed to prevent biodiversity offsetting from replacing some "less valuable" with "more valuable" biodiversity.

Restoration ecology to reinforce offsetting

In the current context, biodiversity offsetting focused mainly on outstanding biodiversity and targeted natural areas. By doing so, it is clearly rooted in a conservation biology approach, that applies well to the two first steps of the mitigation hierarchy: avoidance and reduction. However, we believe that the last step, offsetting, instead requires an approach rooted in restoration ecology. This implies a conceptual change since, although conservation biology and restoration ecology are deeply linked, they are also very different, notably in their dominant focal taxa, mode of inquiry and conceptual bases (Young, 2000).

There is, therefore, a challenge to demonstrate gains based on the data currently available: when examined in depth, gains obtained to deliver outstanding biodiversity appear small and insufficient to deliver NNL. The framework of restoration ecology that guides action and evaluation could be a convenient solution to this problem. Indeed, it has been expanded to assess the ecological status of an ecosystem in a degraded state, determine what the reference state is – the original, a healthy or a historical ecosystem – and scientifically design and deliver actions that would repair the ecosystem to match the reference one (Higgs, 1997). The standards for the practice of ecological restoration (McDonald et al., 2016) propose a framework to track the progress towards restoration for various components of the ecosystems which allows the evaluation of ecosystem components before and after the restoration operations. Improvements on sites showed through the wheel can illustrate the success or the limit of restoration operations and consequently the difficulty to create gains equivalent to losses. Moreover, the framework provided by restoration includes the uncertainties of restoration operations. First using a restoration framework in offsetting context put forward the need to look not only at the post-offset state but at the positive changes that occurred from the pre-offset state. Second, restoration ecology shows that those positive changes needing to balance impacts are uncertain and likely to fail, thus challenging impacts authorization. However, it would imply that EIA integrates these various components, since as it is, the delivered information might not be sufficient to evaluate all the components of biodiversity. From the documents we examined describing the offsetting procedures in France, the original state, or pre-impacted state of the site to be developed, is precisely described in most of the projects. The same is true for the degraded state once development has been completed, since impacts of the infrastructure on ecosystems are relatively well evaluated. In contrast, the choice of offset sites does not seem optimal in the material studied. Strictly speaking, for achieving NNL, the pre-offset state should be as close as possible to the state of the development site once work has been completed, and restoration action should tend to restore the offset site to a state as close as possible to the pre-impacted state of the development site. While being cautious with the high uncertainty regarding restoration operations (Crouzeilles et al., 2016, Jones et al., 2018), this is a more relevant method to guarantee gains being equivalent to losses within a NNL perspective than managing an already good-quality site for protected species.

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References

Andrade, B.O., Koch, C., Boldrini, I.I., Vélez-Martin, E., Hasenack, H., Hermann, J.-M., Kollmann, J., Pillar, V.D., Overbeck, G.E., 2015. Grassland degradation and restoration: a conceptual framework of stages and thresholds illustrated by southern Brazilian grasslands. Nat. Conserv. 13, 95–104. https://doi.org/10.1016/j.ncon.2015.08.002

Barbaro, L., Dutoit, T., Cozic, P., 2001. A six-year experimental restoration of biodiversity by shrub-clearing and grazing in calcareous grasslands of the French Prealps.

BBOP, 2013. To No Net Loss and Beyond: An Overview of the Business and Biodiversity Offsets Programme.

Bezombes, L., 2017. Développement d'un cadre méthodologique pour l'évaluation de l'équivalence écologique: Application dans le contexte de la séquence" Éviter, Réduire, Compenser" en France (PhD Thesis). Université Grenoble Alpes.

Bezombes, L., Kerbiriou, C., Spiegelberger, T., 2019. Do biodiversity offsets achieve No Net Loss? An evaluation of offsets in a French department. Biol. Conserv. 231, 24–29. https://doi.org/10.1016/j.biocon.2019.01.004

Bull, J.W., Gordon, A., Watson, J.E.M., Maron, M., 2016. Seeking convergence on the key concepts in 'no net loss' policy. J. Appl. Ecol. 53, 1686–1693. https://doi.org/10.1111/1365-2664.12726

Calvet, C., Napoléone, C., Salles, J.-M., 2015. The Biodiversity Offsetting Dilemma: Between Economic Rationales and Ecological Dynamics. Sustainability 7, 7357–7378. https://doi.org/10.3390/su7067357

Carey, A.B., 2006. Aiming to Restore Forests: Evaluation with SER Criteria. Northwest. Nat. 87, 31–42.

Carnino, N., 2009. État de conservation des habitats d'intérêt communautaire à l'échelle du site – Méthode d'évaluation des habitats forestiers.

Chazdon, R.L., 2008. Beyond deforestation: restoring forests and ecosystem services on degraded lands. science 320, 1458–1460.

Crouzeilles, R., Curran, M., Ferreira, M.S., Lindenmayer, D.B., Grelle, C.E.V., Benayas, J.M.R., 2016. A global meta-analysis on the ecological drivers of forest restoration success. Nat. Commun. 7, 11666. https://doi.org/10.1038/ncomms11666

Elliott, M., Burdon, D., Hemingway, K.L., Apitz, S.E., 2007. Estuarine, coastal and marine ecosystem restoration: Confusing management and science – A revision of concepts. Estuar. Coast. Shelf Sci. 74, 349–366. https://doi.org/10.1016/j.ecss.2007.05.034

Gardner, T.A., Von Hase, A., Brownlie, S., Ekstrom, J.M.M., Pilgrim, J.D., Savy, C.E., Stephens, R.T.T., Treweek, J., Ussher, G.T., Ward, G., Ten Kate, K., 2013. Biodiversity Offsets and the Challenge of Achieving No Net Loss. Conserv. Biol. 27, 1254–1264. https://doi.org/10.1111/cobi.12118

Gelcich, S., Vargas, C., Carreras, M.J., Castilla, J.C., Donlan, C.J., 2017. Achieving biodiversity benefits with offsets: Research gaps, challenges, and needs. Ambio 46, 184–189. https://doi.org/10.1007/s13280-016-0810-9

Gibbons, P., Lindenmayer, D.B., 2007. Offsets for land clearing: No net loss or the tail wagging the dog? Ecol. Manag. Restor. 8, 26–31. https://doi.org/10.1111/j.1442-8903.2007.00328.x

Higgs, E.S., 1997. What is Good Ecological Restoration? Conserv. Biol. 11, 338–348. https://doi.org/10.1046/j.1523-1739.1997.95311.x

Ibanez, M., 2012. Garrigue et garrigues : un milieu « naturel », des paysages, un territoire. For. Méditerranéenne XXXIII, 249–254.

Jones, H.P., Jones, P.C., Barbier, E.B., Blackburn, R.C., Rey Benayas, J.M., Holl, K.D., McCrackin, M., Meli, P., Montoya, D., Mateos, D.M., 2018. Restoration and repair of Earth's damaged ecosystems. Proc. R. Soc. B Biol. Sci. 285, 20172577. https://doi.org/10.1098/rspb.2017.2577

Kujala, H., Whitehead, A.L., Morris, W.K., Wintle, B.A., 2015. Towards strategic offsetting of biodiversity loss using spatial prioritization concepts and tools: A case study on mining impacts in Australia. Biol. Conserv. 192, 513–521. https://doi.org/10.1016/j.biocon.2015.08.017

Lenglet, E., 2011. Evaluation de l'état de conservation des ripisylves méditerranéennes du Site d'Importance Communautaire de «Petite Camargue».

Loi Grenelle II, 2010.

Maron, M., Hobbs, R.J., Moilanen, A., Matthews, J.W., Christie, K., Gardner, T.A., Keith, D.A., Lindenmayer, D.B., McAlpine, C.A., 2012. Faustian bargains? Restoration realities in the context of biodiversity offset policies. Biol. Conserv. 155, 141–148. https://doi.org/10.1016/j.biocon.2012.06.003

McDonald, T., Gann, G., Jonson, J., Dixon, K., 2016. International standards for the practice of ecological restoration–including principles and key concepts.(Society for Ecological Restoration: Washington, DC, USA.). Soil-Tec Inccopyright Marcel Huijser Bethanie Walder.

McKenney, B.A., Kiesecker, J.M., 2010. Policy Development for Biodiversity Offsets: A Review of Offset Frameworks. Environ. Manage. 45, 165–176. https://doi.org/10.1007/s00267-009-9396-3

Moilanen, A., Kotiaho, J.S., 2018. Fifteen operationally important decisions in the planning of biodiversity offsets. Biol. Conserv. 227, 112–120. https://doi.org/10.1016/j.biocon.2018.09.002

Moreno-Mateos, D., Maris, V., Béchet, A., Curran, M., 2015. The true loss caused by biodiversity offsets. Biol. Conserv. 192, 552–559. https://doi.org/10.1016/j.biocon.2015.08.016

Persson, J., Larsson, A., Villarroya, A., 2015. Compensation in Swedish infrastructure projects and suggestions on policy improvements. Nat. Conserv. 11, 113–127. https://doi.org/10.3897/natureconservation.11.4367

Quétier, F., Regnery, B., Levrel, H., 2014. No net loss of biodiversity or paper offsets? A critical review of the French no net loss policy. Environ. Sci. Policy 38, 120–131. https://doi.org/10.1016/j.envsci.2013.11.009

Regnery, B., Couvet, D., Kerbiriou, C., 2013. Offsets and Conservation of the Species of the EU Habitats and Birds Directives: Offsets and Conservation of the Species. Conserv. Biol. 27, 1335–1343. https://doi.org/10.1111/cobi.12123

SER, 2004. The SER International Primer on Ecological Restoration.

Veldman, J.W., 2016. Clarifying the confusion: old-growth savannahs and tropical ecosystem degradation. Philos. Trans. R. Soc. B Biol. Sci. 371, 20150306. https://doi.org/10.1098/rstb.2015.0306

Young, T.P., 2000. Restoration ecology and conservation biology. Biol. Conserv. 92, 73–83.

Figures and table caption

Graphical abstract: A. The three states required to predict and evaluate the results of ecological restoration. In this context, the restored state should equal the reference state, i.e. restoration should remedy degradation. B. The four states required to predict and evaluate the results of offsetting by adding the before offset state into the multiple comparison. In this context the offset state should equal the pre-impacted state, and the pre-offset state should equal the impacted state, i.e. gains should offset the impact.

Figure 1. Presence (in dark grey) or absence (in light grey) of information in the documents related to the ability to evaluate gains (n = 25).

Figure 2. Surfaces (ha) of offsite sites (Y axis) compared to impacted sites (X axis) for the 24 projects. Each point represents a different/single project. The line $y = x$ shows the limit between >1 and <1 offset ratios.

Figure 3. Surfaces (in ha) of different types of ecosystem selected to conduct offsetting in the 24 projects analyzed. Black bars represent artificialized or close to artificialized land; grey bars represent intensive agricultural activity land; white bars represent semi-natural and natural land.

Figure 4. Information given to justify the choice of offset site with regard to the ecological quality and areas covered by different classifications.

Figure 5. Number of ecosystem attributes affected by offsetting actions on each offset site (n = 90 sites).

Table 2. Actions conducted on offset sites (n = 89 sites), rate of use (in percent of procedures resorting to/using the action), and attributes of ecosystems targeted by the action.