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1 **Biodiversity offsetting: certainty of the net loss but uncertainty of the net gain**

2  
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8  
9 **Abstract (250 words)**

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

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

30

31 **Highlights:**

32 - In 24 infrastructure projects, the descriptions of gains and impacts, habitats of offset sites and offset  
33 measures showed a clear imbalance between unequivocal biodiversity losses and uncertain potential  
34 gains.

35 - The pre-offset state of sites is rarely evaluated on an ecological basis, and richer sites are preferred  
36 to guarantee a rich final state of offset sites with eventually no gain of biodiversity.

37 - Restoration ecology can offer an appropriate framework to assess equivalence between biodiversity  
38 gains and losses.

39

39

## 40 **Introduction**

41 Biodiversity offsetting is a landscape planning tool which aims to compensate for the impacts  
42 of projects on biodiversity, with the broader goal of coupling development and biodiversity  
43 conservation. It is usually part of a mitigation hierarchy in which multiple steps (2 or 3) are  
44 considered before resorting to offsetting, including avoidance and reduction of impacts (Quétier et al.,  
45 2014; Gardner et al., 2013; Bull et al., 2016). Biodiversity offsetting, therefore, concerns the residual  
46 unavoidable predictable impacts of a project. Since the 1970s, biodiversity offsetting has attracted  
47 growing interest and formalization (Gelcich et al., 2017); it is now widely incorporated in much  
48 environmental legislation and in the charters of businesses (BBOP, 2013). This tool has broad  
49 applicability in delivering the key environmental objective of “no net loss” (NNL) or even of “net  
50 gain” (NG) of biodiversity.

51 As soon as biodiversity offsetting spread more widely and became the focus of academic  
52 research, reservations were expressed about its value in biodiversity conservation (Calvet et al., 2015)  
53 in terms of its fundamental principles, methods and effectiveness. More recently, some authors have  
54 stated more directly that it is not an appropriate tool with which to conserve biodiversity (Bull et al.,  
55 2016; Moilanen and Kotiaho, 2018). The central point of the malaise surrounding biodiversity  
56 offsetting is the principle of NNL. There is a huge gap between the scientific definitions of  
57 biodiversity in ecology, which include multiple levels (genetic, specific and ecosystem) and  
58 interactions (between biotic entities and with abiotic components), and what is intended when  
59 implementing NNL policies (Bull et al., 2016). It has been suggested, therefore, that NNL policies  
60 should always clearly outline the “frame of reference against which NNL is to be achieved” (Bull et  
61 al., 2016). Further, the ecological relevance of the tool depends on which qualitative and quantitative  
62 losses are considered in environmental assessments and how gains are generated to ensure  
63 equivalence (Bezombes et al., 2019).

64 Assessment of losses depends on the administrative procedures that define obligations. As  
65 noted by Bull et al. (2016), official guidelines generally refer to a comprehensive approach to

66 biodiversity, before translating it into a reductive approach during implementation. There is, therefore,  
67 a need for empirical analysis of how losses and gains are evaluated.

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

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

82 Following Moreno-Mateos et al. (2015), we assume that biodiversity offsetting and ecological  
83 restoration (sensu SER, 2004) should intrinsically be linked in a context of the NNL goal, because  
84 restoration operations can precisely compensate for degradation. Interestingly, restoration ecology  
85 provides a conceptual framework applicable to the analysis of biodiversity offsetting. In this  
86 framework, the only means to guarantee that gains equal losses is to ensure equivalence between the  
87 restored and the reference state. In the context of biodiversity offsetting, the balance between gains  
88 and losses is sought through the equivalence between the pre-impacted state of the development site  
89 and the final state of the offset site, completely ignoring a fourth state that should be introduced,  
90 namely the initial state of the offset site. Indeed, gains of biodiversity that are expected to meet losses  
91 states in the difference between the pre-offset site and the offset site enriched by offsetting measures.  
92 Our hypothesis is that including a pre-offset site that exhibits the same level of degradation as the site

93 impacted by the infrastructure will have post-development, is theoretically the only means to achieve  
94 equivalence and balance between losses and gains, especially for projects causing irreversible  
95 artificialization of semi-natural or natural areas. Ignoring the pre-offset state could encourage  
96 developers to look for sites already having the final expected state.

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

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

111

## 112 **Material and methods**

### 113 **Sources of information on biodiversity offsetting**

114         In most countries applying the mitigation hierarchy, EIA and supplementary documents  
115 provide the most complete picture of projects, with respect to ecological impacts and mitigation  
116 measures. Developers generally mandate environmental consultants to draft the documents. In France,  
117 these documents constitute the material on which administrative authorities evaluate projects and  
118 decide whether they should be approved. Our principal sources of information, therefore, were the  
119 administrative documents used for validation and the specific procedure documents in which  
120 biodiversity offsetting plans are detailed. Offsetting measures described in the documents are

121 presented as a combination of offset sites and offsetting actions. We used this material to analyze both  
 122 the proposed offsetting measures and the nature of information underpinning the decision about each  
 123 project.

124 We focused on offsetting that concerned protected species and wetlands and water bodies;  
 125 these procedures are the main ones involving the implementation of the mitigation hierarchy<sup>1</sup>. Since  
 126 2016 they have been combined, and are referred to as the “joint procedure”. Contacts were established  
 127 with administrative authorities in charge of project management in two French administrative regions  
 128 (Occitanie and Hauts-de-France) to obtain the relevant documents. We selected the dossiers as  
 129 follows: (i) we first focused on the protected species procedures and restricted the research to the  
 130 period 2012-2017, roughly corresponding to a stable regulatory context; (ii) we focused on linear  
 131 infrastructures that constitute the type of projects for which the mitigation hierarchy is implemented  
 132 most often; (iii) from this group of projects, we considered only complete dossiers, i.e. those  
 133 containing the three steps of the hierarchy and already authorized; and (iv) we searched for the water  
 134 and wetlands procedures for the same project. In total, we collated 25 procedures (Table 1). Most of  
 135 these came from Occitanie (17) where the administration was able to gather the required documents  
 136 easily. For this region, the sample constitutes 25% of authorized projects during the period 2012-  
 137 2017. The 24 projects include 16 roads and highways (10 new constructions and six widening), one  
 138 railway, two power lines, two underground aqueducts and three gas pipelines.

139 **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

140

141 **Analyses of potential biodiversity gains**

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<sup>1</sup>The French legislation also covers procedures concerning woodland and Natura 2000 areas.

142 **1. Information available about offsetting and gains**

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

149  
150 **2. Area ratios between impacted sites and offset sites**

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

159  
160 **3. Type of land on which offsetting was conducted**

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



170

171 **4. Ecological quality of pre-offset sites**

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

182

183 **5. Actions carried out at those sites**

184 In order to determine the types of actions that were intended to be performed at offset sites, we  
185 classified all the actions (n=118, from 1 to 15 per project) into 28 categories based on their description  
186 in the documents. We looked at the proportion of procedures associated with each of the 28 types of  
187 actions. Then, the action types were analyzed and classified according to the ecosystem attribute they  
188 concerned. The attributes were defined using the SER "recovery wheel". The wheel was developed to  
189 track the recovery over time of various properties of ecosystems during restoration (McDonald et al.,  
190 2016). It comprises six parts or attributes: absence of threats, ecosystem function, external exchange,  
191 species composition, physical conditions and structural diversity, which we used to determine the  
192 main expected effects of the actions at the offset site. We looked at the number of ecosystem  
193 attributes associated with actions at each offset site.

194

195 **Results**

196 **1. Great imbalance in the information available**

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

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

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

216

## 217           **2. Areas of offset are smaller than areas impacted**

218           Impacted **site** areas ranged from 5.6 ha to 1081 ha, showing a diversity of project sizes. Total  
219 offset site areas ranged from 0.16 ha to 130 ha. The total area of impacted sites amounts to 2451 ha  
220 while the total area of offset amounts to 577 ha. Overall, in 17 out of 24 projects, the total area of  
221 offset sites was smaller than the area of the impacted sites (Figure 2). This means that biodiversity  
222 losses per unit area are smaller than diversity gained per area unit. This is not necessarily  
223 unacceptable, but implies highly effective restoration. However, 18 procedures use ratios and in all of  
224 them the mean of ratios is greater 1, which implies that biodiversity losses per unit area are greater

225 than biodiversity gains per area unit. This can be explained by the entire impacted area not being  
226 taken into account for offsetting, but only areas supporting certain elements of biodiversity. Thus,  
227 priorities are given to those components of biodiversity considered worthy of offsetting over those  
228 considered to have a lower value.

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

235

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

237 Over 25 procedures, we managed to identify habitat descriptions of offset sites matching  
238 categories of the Corine biotopes typology for 467.85 ha out of 577.42 ha (Figure 3). This means that  
239 109.57 ha were not described in enough detail for us to identify them with certainty. The offset sites  
240 were distributed over 19 biotope categories (Figure 3).

241 Three of these categories (ruderal communities, old industrial sites, and reservoirs and canals)  
242 were artificialized land, covering 15.8 ha. Four categories (crops, improved grassland, plantations,  
243 and vineyards) were habitats resulting from intensive agricultural activities, covering 93.2 ha. The 12  
244 other categories were semi-natural and natural land, totaling 358.4 ha. Most of the offset sites were  
245 thus focused on semi-natural habitats, which can introduce strong biases in conservation toward just a  
246 few dimensions of biodiversity. For instance, the main type of land chosen for offsetting was  
247 “sclerophyllous scrub”, amounting to 124.80 ha, which mainly corresponded to shrubby formations,  
248 more or less tall, also commonly known as *garrigue* in French. Such semi-natural habitats are  
249 abundant in Occitanie where 17 out of 24 of the infrastructure projects were located, as in the whole  
250 Mediterranean area. They are human-created habitats, derived from different levels of shrub  
251 encroachment following the abandonment of agriculture during the last 150 years. Although shrub  
252 clearing can increase biodiversity richness, especially bird species dependent on open areas (Barbaro

253 et al., 2001, Fonderflick et al., 2010), the ability of these types of site to provide gains equivalent to  
254 losses can be challenged, since such offset sites are definitely not as degraded as the impacted site will  
255 be.

256

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

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

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

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

275

#### 276 **5. Actions undertaken are overall diverse but concern few attributes of the ecosystem on** 277 **site**

278 We found 28 different action types across all 25 procedures (Table 2), nevertheless some  
279 descriptions were too vague to be categorized. Over the 92 offset sites present in the documents, 90  
280 contained sufficient information to be categorized. The description of the actions on the two sites that

281 we excluded only specified that “restoration followed by the management of natural habitat will be  
282 performed. Both will be favorable to target biota” for one and that “actions will favor the  
283 development of protected fauna and flora populations on the site” for the other. Some other actions  
284 however contained several pages of explanation, for instance the tree species to plant, why and where.  
285 In three projects one action presented as offsetting was not, in fact, offsetting according to its broader  
286 definition (e.g. creation of a wildlife crossing), we did not consider them in the analysis.

287         The most commonly planned actions were maintenance of open habitat through reinstatement  
288 of appropriate disturbance regimes (mulching, shredding, grazing), pond creation, habitat protection,  
289 transplanting desirable plant species, opening up habitats (tree cutting, mulching, shredding) and  
290 reinstatement of tree layers (structure). Twenty-six of these 28 actions could be associated with the  
291 ecosystem attribute of the SER recovery wheel they concerned, and two were unidentified. In general,  
292 the entire set of offsetting actions carried out on a site concerned only one attribute of the ecosystem  
293 (48 out of 90 sites, i.e. 53%) (Figure 5). In this case, the attribute “structural diversity” is over-  
294 represented (28 out of 48). When two or three attributes were concerned, no attribute or combination  
295 of attributes appeared to be favored. Actions concerning four or more ecosystem attributes were found  
296 for three sites only. Finally, on seven sites, actions did not concern any attribute or could not be  
297 associated with one (habitat protection, ecologically sound management). Intervention on sites  
298 appears to have a very specific target and be mainly focused on one element of biodiversity.  
299 Therefore, plans do not treat the offset site ecosystems as a whole and are partly disconnected from  
300 the ecosystem’s overall functioning.

301

## 302 **Discussion**

303

### 304 **Offsetting certain impacts against uncertain gains**

305         This study shows that projects are written, reviewed and even approved with no information  
306 that makes it possible to foresee the equivalence between losses and gains. Information might not be  
307 present in documents, but known by those involved in the project, as Persson et al. (2015) concluded  
308 in a study of offsetting in Sweden. In most reports, future offset sites were designated through

309 location and land use: most of the areas were either semi-natural or natural land. However, ecological  
310 assessments of the pre-offset state were very rare; their ecological quality, therefore, remained mostly  
311 unknown. When described, indicators of good site quality were used as an argument to justify the  
312 selection of the offset site. In a few cases (15 ha), sites in a good state of conservation had been  
313 deliberately sought. Thus, biodiversity gains were expected on sites that were relatively undegraded.  
314 For developers, this ensures that high biodiversity levels are obvious at the end of offsetting, as  
315 expected in administrative procedures, but it doesn't mean that actual gains will be delivered. Land  
316 pressure and associated prices may also encourage developers to target natural areas.

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

326 Surely gains should be related to losses, i.e. to impact intensity, and small gains should match  
327 small impacts. However, a complete loss of biodiversity – either temporarily at a construction site or  
328 permanently in an area that becomes completely artificial – will always occur due to infrastructure  
329 development. When a complete loss of biodiversity is offset on a site which already supports  
330 considerable biodiversity, NNL cannot be delivered, either because the losses of biodiversity are too  
331 large (Moreno-Mateos 2015) or because no gains are actually generated (Gibbons and Lindenmayer,  
332 2007; Bezombes et al., 2019).

333 This clearly raises questions about conducting ecological restoration on appropriate offset  
334 sites, which would suggest the need to search for degraded sites instead and paying attention to  
335 potential biodiversity gains. Indeed, our research reveals that the large majority of measures fall into  
336 the “averted loss offset” category at the expense of “restoration offset”. In that case, it would be better

337 to assume the “averted loss offset” approach in the NNL policy to ensure important requirements are  
338 delivered and gains generated (Moilanen and Kotiaho, 2018).

339

### 340 **Substituting local biodiversity for the champions of “offset biodiversity”**

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

354 This restrictive view of biodiversity creates a hierarchy of biodiversity, so that that some  
355 components of biodiversity are worth offsetting while others are not. This also leads to some  
356 components being offset, i.e. the champions of “offset biodiversity”, to the detriment of others that are  
357 abandoned by the wayside. In the projects we studied, opening up habitat and keeping it open are easy  
358 aims to deliver and provide quick rewards (e.g. Barbaro et al., 2001), and so these were widely used  
359 offsetting actions; consequently, many offset sites are sclerophyllous scrub or *garrigue*. In such a  
360 situation, *creating* open scrub is performed to the detriment of maintaining woody scrub. The same  
361 goes for ponds, which replace whatever ecosystem was there before. Some offset frameworks do take  
362 into account the fact that conducting offsetting on a site may harm some components of biodiversity  
363 already present (Bezombes, 2017). When examining ecological restoration and ecosystem recovery,  
364 Elliott et al. (2007) distinguished four types of recovery, among them habitat “enhancement or

365 creation” which “implies a quality judgment (which itself implies subjectivity and operator bias) that  
366 the science and engineering are sufficient to improve habitats and also that one type of habitat is  
367 preferable to another” (Elliott et al., 2007). In the same way this explains why vegetation change is  
368 considered a source of degradation. Sources of ecosystem degradation are complex (Andrade et al.,  
369 2015) as is the definition of a degraded ecosystem (Veldman, 2016). It requires a reference state,  
370 missing from most of the procedures we analyzed in this study. A more precise definition of biota  
371 degradation may be needed to prevent biodiversity offsetting from replacing some “less valuable”  
372 with “more valuable” biodiversity.

373

#### 374 **Restoration ecology to reinforce offsetting**

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

382 There is, therefore, a challenge to demonstrate gains based on the data currently available:  
383 when examined in depth, gains obtained to deliver outstanding biodiversity appear small and  
384 insufficient to deliver NNL. The framework of restoration ecology that guides action and evaluation  
385 could be a convenient solution to this problem. Indeed, it has been expanded to assess the ecological  
386 status of an ecosystem in a degraded state, determine what the reference state is – the original, a  
387 healthy or a historical ecosystem – and scientifically design and deliver actions that would repair the  
388 ecosystem to match the reference one (Higgs, 1997). The standards for the practice of ecological  
389 restoration (McDonald et al., 2016) propose a framework to track the progress towards restoration for  
390 various components of the ecosystems which allows the evaluation of ecosystem components before  
391 and after the restoration operations. Improvements on sites showed through the wheel can illustrate  
392 the success or the limit of restoration operations and consequently the difficulty to create gains



393 equivalent to losses. Moreover, the framework provided by restoration includes the uncertainties of  
394 restoration operations. First using a restoration framework in offsetting context put forward the need  
395 to look not only at the post-offset state but at the positive changes that occurred from the pre-offset  
396 state. Second, restoration ecology shows that those positive changes needing to balance impacts are  
397 uncertain and likely to fail, thus challenging impacts authorization. However, it would imply that EIA  
398 integrates these various components, since as it is, the delivered information might not be sufficient to  
399 evaluate all the components of biodiversity. From the documents we examined describing the  
400 offsetting procedures in France, the original state, or pre-impacted state of the site to be developed, is  
401 precisely described in most of the projects. The same is true for the degraded state once development  
402 has been completed, since impacts of the infrastructure on ecosystems are relatively well evaluated. In  
403 contrast, the choice of offset sites does not seem optimal in the material studied. Strictly speaking, for  
404 achieving NNL, the pre-offset state should be as close as possible to the state of the development site  
405 once work has been completed, and restoration action should tend to restore the offset site to a state as  
406 close as possible to the pre-impacted state of the development site. While being cautious with the high  
407 uncertainty regarding restoration operations (Crouzeilles et al., 2016, Jones et al., 2018), this is a more  
408 relevant method to guarantee gains being equivalent to losses within a NNL perspective than  
409 managing an already good-quality site for protected species.

410

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418

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## 505 506 **Figures and table caption**

507  
 508 **Graphical abstract:** A. The three states required to predict and evaluate the results of  
 509 ecological restoration. In this context, the restored state should equal the reference state, i.e.  
 510 restoration should remedy degradation. B. The four states required to predict and evaluate the  
 511 results of offsetting by adding the before offset state into the multiple comparison. In this  
 512 context the offset state should equal the pre-impacted state, and the pre-offset state should  
 513 equal the impacted state, i.e. gains should offset the impact.

514  
 515 **Figure 1.** Presence (in dark grey) or absence (in light grey) of information in the documents  
 516 related to the ability to evaluate gains (n = 25).

517  
 518 **Figure 2.** Surfaces (ha) of offsite sites (Y axis) compared to impacted sites (X axis) for the  
 519 24 projects. Each point represents a different/single project. The line  $y = x$  shows the limit  
 520 between >1 and <1 offset ratios.

521  
 522 **Figure 3.** Surfaces (in ha) of different types of ecosystem selected to conduct offsetting in the  
 523 24 projects analyzed. Black bars represent artificialized or close to artificialized land; grey  
 524 bars represent intensive agricultural activity land; white bars represent semi-natural and  
 525 natural land.

526

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

529

530 **Figure 5.** Number of ecosystem attributes affected by offsetting actions on each offset site (n  
531 = 90 sites).

532

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

535