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1 **Data transparency regarding the implementation of European**
2 **'no net loss' biodiversity policies**

3

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30 **Abstract**

31 'No net loss' (NNL) conservation policies seek to address development impacts on
32 biodiversity. There have been no peer-reviewed multinational assessments concerning the
33 actual implementation of NNL policies to date. Such assessments would facilitate more
34 informed debates on the validity of NNL for conservation, but assessing implementation
35 requires data. Here, we explore data transparency concerning NNL implementation, with four
36 European countries providing a case study.

37 Biodiversity offsets (offsets) are the most tangible outcome of NNL policy. Using an
38 expert network to locate all offset datasets available within the public domain, we collated
39 information on offset projects implemented in France, Germany, the Netherlands and
40 Sweden. Implementation data for offsets were found to be non-transparent, but the degree of
41 transparency varies widely by country. We discuss barriers preventing data transparency –
42 including a perceived lack of necessity, lack of common protocols for collecting data, and a
43 lack of resources to do so. For the data we collected we find that most offsets in Europe: are
44 not within protected areas; involve active restoration; and, compensate for infrastructure
45 development. The area occupied by European offsets is at least of the order $\sim 10^2$ km².

46 Transparent national NNL databases are essential for meeting good practice NNL
47 principles, but are not currently available in Europe. We discuss what such databases might
48 require to support evaluation of NNL policy effectiveness by researchers, the conservation
49 community and policymakers.

50

51 Keywords: Biodiversity offset; compensation; Europe; mitigation hierarchy; no net loss;
52 policy evaluation; data transparency.

53 1.1 Introduction

54 The conservation policy principle of 'no net loss' (NNL) of biodiversity, originating in US and
55 European environmental legislation in the 1970s, has attracted considerable attention from
56 researchers and decision-makers. NNL policies are those through which any negative
57 biodiversity impacts associated with economic development are quantified, mitigated and fully
58 compensated for (Gardner et al., 2013). Those seeking to achieve the NNL objective
59 commonly do so through implementing actions categorised into a mitigation hierarchy (e.g.
60 predicted development impacts are sequentially Avoided, Minimised, Remediated, and finally
61 Offset; Gardner et al., 2013; Bull et al., 2016). Theoretical barriers to achieving NNL are well
62 documented (Bull et al., 2013). While the concept of NNL appeals to many policymakers,
63 academics and NGOs, it is deemed unethical and open to misapplication by some (Gordon et
64 al., 2015). Nonetheless, NNL-type policies are widespread (being applicable to certain
65 projects in almost every country on the planet) and increasingly adopted by the private sector
66 (Maron et al., 2016a).

67

68 Post-implementation evaluation of NNL policies is uncommon, including for the most
69 controversial component of the mitigation hierarchy, biodiversity offsetting (Bull et al., 2013;
70 ten Kate et al., 2014). Biodiversity offsets ('offsets') involve compensating for unavoidable
71 residual impacts through conservation or restoration activities elsewhere. Some published
72 analyses of offset implementation exist, assessing data on the implementation of offset
73 projects at sub-national to national scales. They find that a minority of offsets are
74 implemented as per technical requirements, yet conclude that the approach is improving and
75 has some potential for conservation (Matthews & Endress, 2008; Brown et al., 2014;
76 Olszynski, 2015; May et al., 2016).

77

78 Transparency (e.g. ensuring that "clear, up to date, and easily accessible information is
79 provided to stakeholders and the public on the offset design and implementation, including
80 outcomes"; BBOP, 2012) is considered good practice for offsetting. Further, the availability of
81 comprehensive and reliable datasets on offset implementation would be essential for
82 understanding the scope of offset activity, and is a prerequisite for eventually assessing the

83 effectiveness and suitability of offsetting for conservation in different regional and national
84 contexts. Yet to date there has been no explicit assessment of data transparency in the
85 implementation of offset projects, or indeed in NNL policy outcomes more generally; let alone
86 a comparative analysis that would enable lessons to be shared across jurisdictions. The lack
87 of readily available data on the implementation of NNL policy hampers any effort to make
88 clear, empirical statements in relation to key controversies surrounding NNL, and ultimately,
89 evaluation of the contribution made by NNL policy to biodiversity conservation. The need to
90 ascertain the validity of NNL has become increasingly pressing with the introduction of far-
91 reaching policies supporting their use (Maron et al., 2016a). It is thus critical to better
92 understand the degree to which data on offsetting efforts, and NNL-related measures more
93 generally, are available. We note that the desire to obtain transparent and reliable data is a
94 topical concern for conservation science more broadly. The availability and accessibility of
95 data with relevance to topics in conservation has improved notably in recent decades – for
96 instance, with resources such as the Global Biodiversity Information Facility (Gaiji et al.,
97 2013), remotely sensed imagery (Turner et al., 2003), the World Database on Protected
98 Areas (UNEP-WCMC, 2017), and the PREDICTS database (Hudson et al., 2014). This is
99 consistent both with the movement towards evidence-based conservation (Sutherland et al.,
100 2004), and with profound changes in the way scientific data are created and disseminated
101 (Kitchin, 2014).

102

103 Our main objective was to assess the availability and transparency of data on offset projects
104 implemented under a NNL objective, for multiple countries. We collated all accessible data on
105 offsets implemented by key countries within Europe that are actively implementing NNL
106 policies. We assess the state of data on offset implementation, to understand whether such
107 information is unavailable, available, or transparent (by which we mean both available and
108 readily accessible). As a secondary objective, we sought to analyse data on known offset
109 projects, to provide a first quantitative measure of European offsetting effort. It should be
110 noted that, whilst such data go beyond policy analysis and capture implementation, they do
111 not allow an assessment of the ecological effectiveness of offsets in achieving NNL – the
112 latter would require widespread empirical assessment.

113

114 Europe is an active region for multinational NNL policy, and simulations suggest that such
115 policies could result in good outcomes for nature against business-as-usual scenarios (Schulp
116 et al., 2016). Yet, there has been no assessment to date concerning the physical
117 implementation of NNL (Tucker et al., 2014; Schulp et al., 2016). For context: the current EU
118 Biodiversity Strategy aims “to halt the loss of biodiversity and the degradation of ecosystem
119 services in the EU by 2020, and to restore them in so far as feasible”. This includes to “ensure
120 no net loss of biodiversity and ecosystem services” (Target 2, Action 7), including through
121 offsetting schemes (Tucker et al. 2014). Since then, potential NNL approaches have been
122 discussed extensively by the EU Commission and by member states. Whilst legislative NNL
123 requirements, which make provisions for offsetting, already exist in certain protected areas
124 (Natura 2000 sites) as a result of the EU Habitats Directive, the Strategy and associated
125 discussions imply that NNL of biodiversity could be sought more widely (Wende et al., in
126 press). Consequently, whilst biodiversity impact mitigation is already required in EU member
127 states through the Directive on Environmental Impact Assessment, and offsetting is similarly
128 enabled for Natura 2000 sites protected under the Birds and Habitats Directives, there is a
129 movement towards more general provisions for biodiversity offsets. An exploration of the level
130 of data transparency for NNL implementation in Europe is therefore highly conservation
131 policy-relevant.

132

133 **2.1 Materials and methods**

134 2.1.1 Methodology

135 We compiled all publicly available data on offset projects through a process of intensive data
136 extraction, alongside expert verification, for four countries: France, Germany, the Netherlands
137 and Sweden. Our intention was to explore offset implementation for a significant (in terms of
138 implementation) subset of European countries, and these four countries are documented as
139 being key countries actually implementing NNL projects in Europe (Tucker et al., 2014). It
140 should be noted that policies that make provision for offsets are in place or in discussion
141 throughout Europe, as a result of both national legislation and EU Directives (Fig. 1; Maron et
142 al., 2016a). However, given that the four countries included within our study are considered to

143 be leading proponents of offsetting, and contain a significant proportion of the terrestrial
144 surface of Europe (>10%), we consider the selection justified. To obtain relevant data, we
145 began by contacting at least three established national NNL experts in each country, where
146 'experts' were considered to be those either publishing academic research on offsets in that
147 country in peer-reviewed journals, or those working directly on offset projects (listed in Table
148 A.1). We sought to ensure that for each country, our experts included those representing
149 academia, the public sector, and the private sector. These individuals were asked to indicate
150 all known data sources on offset implementation for that country, and notify us of any other
151 potentially useful individual or organisational contacts. Consequently, those further individual
152 and organisational contacts were approached until contacts confirmed that no further data
153 were readily accessible. Since all data were provided to us through the recommendation of
154 multiple experts, we did not independently verify the data.

155

156 To be included within our study, offset projects had to be associated with a NNL objective, i.e.
157 offsets with the underlying intention as captured by Bull et al. (2013): "(1) they provide
158 additional substitution or replacement for unavoidable negative impacts of human activity on
159 biodiversity, (2) they involve measurable, comparable biodiversity losses and gains, and (3)
160 they demonstrably achieve, as a minimum, no net loss of biodiversity". To operationalize
161 these criteria for each country, we collated information on any offset projects that were
162 presented as an offset and appeared to have been implemented, or were in the process of
163 being implemented. We ignored offset projects that were at the proposal stage.

164

165 For each country, we determined first whether offset data were unavailable or available. In the
166 latter case, we then comprehensively reviewed online data sources (from single projects to
167 offset databases) to extract information relevant to the following questions:

- 168 1. What is the implementation status of each offset project (e.g. in progress/complete)?
- 169 2. What component of biodiversity is targeted (e.g. species, habitat types)?
- 170 3. What conservation management actions are involved (e.g. designation as protected
171 area, habitat restoration)?
- 172 4. Where are they approximately located (latitude/longitude)?

- 173 5. How much area does each offset project occupy?
- 174 6. Which sector is causing the impacts for which offsets are required (e.g. transport
175 infrastructure, extractive)?
- 176 7. For what specific development project does each offset project provide ecological
177 compensation?
- 178 8. Where is that development project located (latitude/longitude)?
- 179 9. What components of biodiversity are impacted by that development project?

180

181 A condition for including offsets within our analyses was that sufficient information existed to
182 allow us to answer questions 1 – 3 above, and either question 4 or 5. Based on the amount
183 and type of data that we could collate, we determined whether offset data could be
184 considered available or transparent. ‘Availability’ is defined as data being publicly available
185 (however difficult to obtain), and ‘transparent’ is defined as data being readily accessible in
186 e.g. existing databases online. In addition, we requested all key expert contacts (Table A.1) to
187 provide a qualitative explanation of the primary barriers obstructing the collation and
188 dissemination of offset data in their country. Having collated the data, we assessed the total
189 number of individual offset projects, the approximate area occupied by those offsets, and the
190 proportion of offset types by development activity and compensation type (e.g. active
191 restoration, or averted loss), in each country and in sub-national regions.

192

193 To meet the secondary objective of the manuscript, to provide a preliminary estimate of
194 offsetting effort across Europe, we generated maps in QGIS Geographic Information System
195 v.2.8.1¹ of all offset locations (base data: Natural Earth v.3.1.0²). For interest, we analysed the
196 overlap with protected areas registered for each country in the World Database on Protected
197 Areas (WDPA; UNEP-WCMC, 2015). The ‘points in polygons’ analysis tool was implemented
198 for these overlapping layers, and attributes table from the resulting shapefiles exported (.csv
199 format). Note again that in this study we sought to understand implementation status, and not
200 the effectiveness of offsets – as such, we did not include a question on effectiveness. Judging
201 offset effectiveness can be extremely subjective, varying depending upon the stakeholder in

¹ <http://qgis.osgeo.org>

² <http://www.naturalearthdata.com>

202 question. As a result, the question of offset effectiveness is worthy of multiple studies in its
203 own right.

204

205 2.1.2 Methodological challenges

206 Given that information was mainly available in the relevant national language for each
207 country, the research team included native speakers of Dutch, French and German. However,
208 the lack of a Swedish co-author necessitated the use of Google Translate. A number of
209 Sweden-based experts were consulted (Table A.1), to avoid misinterpretation. Further, the
210 term used for 'biodiversity offset' can have subtly different meanings in different languages,
211 and there is often no specific term for offsets as distinct from 'compensation' more generally
212 (Bull et al., 2016). Again, offsets were here defined as per Bull et al. (2013).

213

214 Due to international variation, it was necessary to clarify what we considered a single 'offset
215 project'. In some instances, a single restoration project offsets a single development, whereas
216 in others, multiple restoration projects can be combined to compensate for a single
217 development. Similarly, in some countries, developers turn to 'habitat banks' (i.e. a collection
218 of previously implemented offset actions from which developers can buy credits) as an
219 aggregated offset potentially associated with multiple development projects. To allow
220 evaluation across countries with different approaches, we considered a single 'offset project'
221 to be one contiguous area of land upon which ecological compensation activities of some kind
222 are undertaken as a result of a NNL policy. Consequently, we treated habitat banks as single
223 offset projects even they provided compensation for multiple developments.

224

225 Precise location data were only accessible online for offsets in France. In all other cases, the
226 project location was described or displayed visually on online maps, and we extracted
227 approximate latitude/longitude coordinates using Google Maps. Doing so introduced spatial
228 uncertainty to offset coordinates, which we conservatively estimate to be ± 3 km of the true
229 location. Improved data would be required to accurately map sites. However, for the purposes
230 of assessing their broad distribution and data transparency we considered this an acceptable
231 margin of error.

232

233 3.1 Results

234 For each country, we present results as follows: (i) NNL policy context; (ii) description of offset
235 data obtained; and, (iii) degree to which data can be considered transparent.

236

237 3.1.1 France

238 National legislation enabling offsets goes back to the 1970s, although since 2007 (following
239 the transposition of the EU Birds and Habitats Directives) offsets have begun to be
240 implemented more widely (Quétier et al., 2014). State agencies are required to give access to
241 documentation for developments and associated offsets if requested, but do not
242 systematically place them online. Rather, they meet requests for information by proposing
243 appointments to consult hardcopy documents (A-C. Vaissière, pers. comm.). There is no
244 existing national offset database in the public domain, but a new Biodiversity Law (August
245 2016) requires the government to develop one that will be publicly accessible online. The
246 public institution CEREMA has been commissioned to develop a single nationwide GIS
247 database of French offsets, and has so far limited the corresponding data search to protected
248 species derogations and water law (2012 – 2015).

249

250 At a subnational level, a publicly available offset database exists for the Languedoc-
251 Roussillon province, containing 87 offset projects (Fig. 2a; DREAL, 2015). Languedoc-
252 Roussillon has experienced relatively intense offset activity because several large
253 infrastructure projects received permits after the 2012 publication of official offsetting
254 guidance, such as the Nîmes-Montpellier railway bypass (construction of 80 kilometres of
255 high-speed railway line between Nîmes and Montpellier; Quétier et al., 2015). Another
256 database exists for Provence-Alpes-Côte d'Azur, containing 91 offset projects (2002 – 2014),
257 but is not publicly available. Local authorities in the Rhône-Alpes province are developing a
258 database (A-C. Vaissière, pers. comm.). Most provinces have not collated a database of
259 offset projects, in spite of some offsets actually being implemented. Some provinces have
260 non-digitized spatial plots of compensatory measures, but these are in the minority and do not

261 use a uniform data entry format, complicating compilation at a national level (S. Hubert, pers.
262 comm.).

263

264 The 87 offsets in the Languedoc-Roussillon database include compensation for impacts on
265 234 species and 37 wetland areas, constituting 254 separate conservation actions on
266 compensatory land (occupying 28.41 km²), and 202 accompanying monitoring measures
267 (DREAL, 2015). The majority of offsets are associated with infrastructure, particularly the
268 Nîmes-Montpellier railway and A9 motorway, accounting for 59% and 9% of all measures
269 respectively (Table A.2). Approximately half of all offsets are located within existing protected
270 areas (Fig. 2a).

271

272 In summary, we could answer questions 1 – 9 (see Methods) for offsets in France, but only
273 for one province. Offset data in this one province can thus be considered transparent, with
274 non-transparent reporting in all other provinces (Table 1).

275

276 3.1.2 Germany

277 Since the enactment of the Federal Nature Conservation Act (Bundesnaturschutzgesetz) in
278 1976, ecological compensation requirements have existed. Amendments to the Act (2002,
279 2009) facilitating habitat banking allowed “loosening of the spatial and functional connection
280 between impact and compensation” (Wende et al., 2005; Darbi, 2010). Under the Act, state
281 governments are responsible for maintaining an offset registry, to avoid double counting and
282 allow verification of implementation. While all German states do so (BFAD, 2011), individual
283 registries differ in completeness, data accuracy, and type of data recorded (Wübbe et al.,
284 2006). Data availability for German offset projects varies dramatically between states (Fig. 3).
285 Offsets are most obviously found in ‘compensation pools’ or ‘eco-accounts’ (Flächenpools
286 and Ökokonten) i.e. habitat banks, rather than tied to specific developments, although the
287 proportion of each is unknown. The German system includes *Ausgleichsmaßnahmen*
288 (‘compensation measures’) and *Ersatzmaßnahmen* (‘substitution measures’). The former
289 involve restoring “impaired functions of the ecosystem” ensuring that “natural scenery has
290 been restored or re-landscaped ” (Darbi et al., 2010) – they are ‘restoration compensation’,

291 'on-site' (Tucker et al., 2014). Since *Ausgleichsmaßnahmen* involve reversing the impacts
292 caused by a specific development, they most closely match the remediation category of the
293 mitigation hierarchy. Conversely, *Ersatzmaßnahmen* are offsets, in that they involve achieving
294 biodiversity gains in habitats unaffected by the specific development for which they provide
295 compensation (Albrecht et al., 2014; Tucker et al., 2014). All offsets in Germany are
296 restoration-based, involving active management e.g. habitat restoration, pond creation.
297 Protection-based ('averted loss') offsets are not permissible according to the relevant
298 legislation, and requirements exist for "measures to restore lost functionality" (Herbert, 2015;
299 Darbi et al., 2016).

300

301 Provincial registries were available online for eight federal states. The remaining state
302 administrations did not respond or provided no data. Data accessibility is variable, with data
303 sometimes available for viewing only, or available only upon request (Table A.3). Additional
304 offset data were also displayed online by compensation agencies (Flächenagenturen), service
305 providers that support offset implementation. Data made available through these agencies
306 represent a subset of all offset sites, but likely a substantial one. Online spatial data from
307 agencies exist for nine provinces (Tables 1, A.2).

308

309 We mapped 288 compensation pools in nine of 16 federal states (Fig. 2b). 74 are located in
310 protected areas, including 29 within Natura 2000 sites. For Baden-Württemberg, data
311 licensing restrictions stated by the relevant compensation agency meant we were able to view
312 offset locations, but not analyse the data for reproduction elsewhere. We therefore include the
313 estimated area occupied by offsets in Baden-Württemberg only (Table 2). Another state
314 (Mecklenburg-Vorpommern) was noted to contain 179 compensation pools, but no location
315 data were available. The **minimum** area occupied by the 467 (288 + 179) compensation
316 pools considered here (spatial information was only available for 38% of projects), plus the
317 area reported by Baden-Württemberg, was 23.7 km². This is less than some estimates: e.g.
318 according to Battefeld (2012), in Hessen alone, 191.5 km² are recorded in the compensation
319 registry (see Wende et al., 2015). The majority of habitats in compensation pools were
320 grasslands or wetlands. Data on German offsets do not generally link compensation pool to

321 specific development projects, so we were unable to determine the proportion of offsets
322 implemented by sector.

323

324 In summary, data transparency in Germany was highly variable by state, with no offset data
325 available for some yet sufficient data for answering questions 1 – 6 (see Methods) in others.
326 Data were only transparent for offsets delivered in compensation pools in Germany, so we
327 could not answer questions 7 – 9 (associated developments) for any state. Up to half of the
328 states in Germany could be considered transparent regarding offset data (Table 1).

329

330 3.1.3 The Netherlands

331 Forest offsets have existed since the Forest Act came into force in 1961, which have been
332 complemented by offsets for species and habitats of conservation concern in 1998 with the
333 enactment of the Flora and Fauna Act and the Nature Conservancy Act (van Teeffelen, in
334 press). These three laws have been merged in 2017 into a new Nature Conservation Act and
335 applies to Natura 2000 sites, other sites of the National Nature Network and species of
336 conservation concern. For habitats the provisions have stayed the same, for species they
337 have been aligned more closely to the EU Birds and Habitats Directives (van Teeffelen, in
338 press). Since 2007, responsibility for keeping an offset registry has rested with the 12
339 provinces, to which municipalities are obliged to report on offset project status. No national
340 database of Dutch offset projects exists. The Netherlands Court of Audit recently concluded
341 that offsetting practice had improved since 2007, thanks to clarifications of roles and
342 responsibilities and reduced complexity, but: “Provinces do not have good insight/overview of
343 the offsetting that has been required through permits. There are no guidelines for registration
344 leading to gross variations in the process and an inability to compare information across
345 provinces” (Algemene Rekenkamer, 2014). Information on all offsets in the Netherlands is
346 ostensibly available online through individual planning permits³. Extracting that information,
347 however, requires going through the documentation on a plan-by-plan basis. This is hindered
348 by the webportal containing all spatial plans of which only a fraction involve offsetting, and,
349 because no project list can be generated. Provinces are required to compile overviews of

³ <http://www.ruimtelijkeplannen.nl>

350 offsets projects on an annual basis and monitor offsets, but these overviews are not
351 commonly publicly available.

352

353 For two provinces, Noord-Brabant and Limburg, a list of offset projects could be accessed
354 containing offset project names, municipality involved, and dates and phases of
355 implementation and monitoring thereof. The Noord-Brabant list also mentions area of offsets.
356 The Noord-Brabant dataset lists 74 projects (2005 – 2014), occupying 551 ha (Provincie
357 Noord-Brabant, 2014). By sector, infrastructure development generated the most offsets
358 (33.8%), but recreation and urbanisation were also well represented (Table A.2). Location
359 data were obtainable for 35 projects (Fig. 2c). The Limburg dataset lists 38 projects (2005 –
360 2011), totalling approximately 300 ha of offsets (Provincie Limburg, 2012). Progress is being
361 made in Noord-Brabant with the launch of a webviewer⁴, where impact locations and offset
362 locations will be projected on a map, further increasing transparency. Offset project details
363 still have to be looked up in the individual planning permits. Following the research of the
364 Southern Court of Audit regarding offset implementation, registration and monitoring in Noord-
365 Brabant and Limburg (Zuidelijke Rekenkamer, 2013; 2014), the Court of Audit of the
366 provinces Noord-Holland, Zuid-Holland, Utrecht and Flevoland (“Randstedelijke
367 Rekenkamer”) announced similar studies during 2016/2017, suggesting progress regarding
368 registration and monitoring of Dutch offsets.

369

370 All offsets in the Netherlands are restoration-based. In line with national guidelines, several
371 provinces allocate offsets within the National Nature Network, where the government planned
372 to create additional habitat but has not yet done so due to budget constraints. This should be
373 accompanied by an extension of the total size of the National Nature Network, to avoid that
374 offsets are used as a source of funding for protected areas – which could be considered
375 ‘misuse’ of offsets (Maron et al., 2015; 2016b). Not every province ensured this extension, a
376 point raised by a regional Court of Audit (Randstedelijke Rekenkamer, 2017). An important
377 consideration regarding the Netherlands is that space is constrained for offsets, due to high
378 land-use demand and a strict requirement for equivalence and spatial proximity between a

⁴ <http://kaartbank.brabant.nl/viewer/app/natuurbeheerplan>

379 specific development and the associated offset (Broekmeyer et al., 2012) – an emerging
380 challenge for offsets more generally (Vanderduys et al., 2016). This has resulted in payments
381 of in-lieu fees instead of physical compensation, managed by the Dutch National Fund for
382 Rural Areas (Groenfonds), amounting to €145m (2015) (Nationaal Groenfonds, 2015).

383

384 In summary, information on existing offset projects in the Netherlands could be considered
385 transparent for one province (Noord-Brabant), although information is still scattered. The data
386 enable us to readily answer questions 1 – 6 for this province. Otherwise, offset data sufficient
387 to answer all questions in the Netherlands are available in principle, but not transparent
388 (Table 1).

389

390 3.1.4 Sweden

391 Unlike the other countries in this study, aside from mandatory requirements resulting from the
392 EU Birds and Habitats Directives, there is no specific national NNL requirement in Sweden.
393 However, the Environmental Code enables regional authorities to demand full compensation
394 for significant residual impacts through the planning process (Tucker et al., 2014). As a result,
395 there are numerous examples of individual development projects that have been required by
396 regional authorities to quantitatively deliver full ecological compensation for impacts, meeting
397 our definition of offsetting. The nature of this legislative structure means there is no regulatory
398 requirement for offset databases to be maintained. So, unlike the other three countries we
399 studied, national experts directed us to online reports containing lists of developments for
400 which offsets had been required, and we collected information regarding the type of
401 compensation through planning permissions and environmental impact assessments. Our
402 findings on offset implementation were compared to findings in an article published by
403 Persson et al. (2015), who identified Swedish offset projects by surveying 141 officials
404 “handling nature-conservation cases” for regional authorities. In both the Persson report and
405 our own dataset, habitats targeted in Sweden are primarily wetlands and stonewalls (i.e. old
406 dry stone walls constructed to demarcate field boundaries, which now provide important
407 invertebrate habitat).

408

409 We obtained data on 44 offsets. For all but two, locations of the associated developments
410 were established, and as associated offsets were required to be in close proximity, these
411 were used as approximate offset locations (Fig. 2d). One was located in a protected area.
412 Sectors implementing offsets are overwhelmingly infrastructure or energy (Tables 2, A.1). The
413 majority of projects implemented involve some proactive management action i.e. habitat
414 restoration, mainly on public land. Most projects involve active management (68.1%), financial
415 payment to new or existing conservation activities (13.7%), or the protection of existing
416 habitat against likely drivers of decline (6.8%). For comparison, Persson et al. (2015)
417 identified 37 compensation projects (primarily infrastructure development).

418

419 In summary, offset data in Sweden can be considered transparent for the whole country, and
420 sufficient to enable us to answer questions 1 – 9 (see Methods). But it should be considered
421 that no one official database exists of offsets in Sweden, so it is only the fact that a relatively
422 small number of offset projects exist in Sweden that makes these data effectively accessible.

423

424 **4.1 Discussion**

425 4.1.1 Data transparency

426 For all four countries we studied, comprehensive information on offset projects is not yet
427 systematically collated, digitised and disseminated on a national scale; and cannot be
428 accessed remotely. There would likely be resource costs associated with improving offset
429 data transparency. However, a conceptual pre-requisite for offsets is quantitative
430 demonstration to stakeholders that biodiversity losses and gains associated with a
431 development are balanced (BBOP, 2012; Bull et al., 2013). Consequently, the cost burden of
432 monitoring is no argument for non-transparency. While other European countries have
433 implemented some offsets (e.g. Spain, UK), these four countries are considered leading
434 practitioners in Europe for offset implementation (Tucker et al., 2014). Comprehensive
435 assessment of these four nations alone thus likely captures a substantial proportion of all
436 implemented offsets in Europe.

437

438 For context, consider Australia and the US, which are leading countries on the
439 implementation of NNL policies worldwide (Bull et al., 2013). Australia collates transparent
440 online regional datasets on offsetting for most states, including associated developments (e.g.
441 May et al., 2016). The US is the only country in the world that, to our knowledge, collates a
442 transparent national dataset on offsetting: the Regional In-Lieu Fee and Bank Information
443 Tracking System (RIBITS) (Table 1; US ACE, 2015). However, the quality and completeness
444 of these data are questionable (Robertson & Hayden, 2008; BenDor et al., 2009), and
445 information on associated developments is not easily extracted from the database (see
446 Introduction). In general, offset data appear to be more comprehensively transparent for
447 countries with more mature NNL policies (Australia, Germany, the US; Table 1), and so
448 availability will perhaps also improve over time for countries with emerging offset policies such
449 as Denmark, Belgium or the UK (Maron et al., 2016a).

450

451 More broadly, no country in the world records implementation of all stages of the mitigation
452 hierarchy under NNL policy. Whilst understanding the scale and distribution of implementation
453 does not automatically enable an assessment of how and where NNL is being used
454 effectively in practice, the lack of accessible data almost certainly hampers efforts to
455 determine this. Constructing a global picture of NNL implementation, or even offset
456 implementation, would be an important step towards assessing efficacy for nature
457 conservation. Nations implementing NNL should ensure that offsets and other NNL measures
458 are tracked, carefully monitored, and records maintained. The availability of geo-referenced
459 data would also allow NNL to be linked to landscape-level planning, and strengthen broader
460 conservation policies – particularly where some degree of flexibility is permitted in NNL
461 policies (Bull et al., 2015).

462

463 4.1.2 Tackling barriers to data transparency

464 Potential barriers to data transparency that we noted include: lack of regulatory requirement;
465 lack of political will; lack of clarity on requirements or the capacity to meet them; no protocols
466 for combining sub-national datasets; and, heterogeneity in data formats.

467

468 Concerning a lack of regulatory requirements to compile databases (Sweden), or if there is a
469 perceived lack of necessity or capacity to fulfil such requirements on the part of authorities
470 (the Netherlands). Sufficient institutional capacity (e.g. financial and human resources) is
471 needed to systematically collect, verify, display and maintain offset data (BenDor et al., 2009;
472 Brown et al., 2014; Maron et al., 2016a; Bull et al., 2017). Placing and enforcing a
473 requirement upon the original developer to adequately fund monitoring and reporting for any
474 offsets associated with their developments could overcome this barrier (Maron et al., 2016a).
475 It is possible that regulatory requirements to monitor and report on offsets could be developed
476 around existing EU policy, such as the Habitats or EIA Directives, thereby obviating the need
477 to construct entirely new regulatory obligations (Tucker et al., 2014).

478

479 Other authors have noted that transparency in NNL could be politically unpalatable (Maron et
480 al., 2016a). In spite of this, the recent introduction of a legal requirement to report offset
481 implementation appears to be driving more transparent reporting in France, where the on-
482 going creation of a national offsets database represents a response to concerns about offsets
483 being a 'license to trash'. Likewise, in the Netherlands, the clarification of offset registration
484 and monitoring responsibilities (and raised awareness thereof by the Court of Audit) also
485 appears to be driving transparency at the regional level. We therefore consider it likely that
486 transparent reporting on offsets, and NNL in general, will only become standard where
487 reporting is explicitly required and encouraged through policy or legislation.

488

489 When there is no consistent national framework for offset data reporting and collation, it
490 becomes problematic to combine available offset data collated at sub-national level.

491 Transparent implementation databases are necessary to evaluate whether offsets have likely
492 enabled delivery of NNL of biodiversity on development projects. For this purpose, the data
493 should include answers to the questions 1 – 9 asked here (Methods) as a bare minimum,
494 including extent and type of impacts (BenDor et al., 2009). Preferably, the data should provide
495 more extensive information on offsets as per categories outlined by Bull et al., (2013; e.g.
496 equivalence rules, counterfactuals used for evaluation, time lag between development losses
497 and offset gains, magnitude of multipliers incorporated, etc.). It is insufficient to consider the

498 outcomes of NNL policies at any one scale, and so databases must be designed to allow
499 analysis from project up to a landscape (e.g. national) scale, where the latter would include
500 assessments of spatial and temporal redistribution of ecological components (BenDor et al.,
501 2007; Robertson & Hayden, 2008; BenDor et al., 2009). Due to differences between country
502 NNL policies and approach to offset implementation, a standard international reporting
503 framework on offsetting is currently likely unfeasible – but there is a need for countries to
504 develop coherent national standards for offset data.

505

506 Extracting and analysing information in different formats is problematic. The approach of
507 listing offset projects online alongside a map of locations (Germany, the Netherlands) was
508 particularly time-consuming in terms of extraction and analysis, and liable to cause
509 researchers to introduce uncertainties e.g. in spatial location. Vastly preferable was the
510 availability of offset data for immediate download in a combination of spreadsheet (.csv, .xcl)
511 and spatial (.shp, .tif) data formats (France). Consequently, it would be insufficient to consider
512 only the format in which offset data are to be captured, but not also the format in which they
513 are displayed and disseminated.

514

515 In seeking to achieve improved offset data transparency, policymakers may already have
516 specific methods in place for capturing and disseminating the relevant information. Where this
517 is not the case, however, there are numerous extant databases – designed to capture
518 information of direct relevance to conservation science and practice – which could serve as
519 technical models. For instance: in terms of a database designed to collate information from
520 multiple different sources and of variable types, including automatic data validation and
521 maintaining traceability to sources, the PREDICTS database provides an excellent example
522 (Hudson et al., 2014). Equally, in terms of a protocol for updating and maintaining a live
523 database over a period of decades, as well as disseminating outcomes to the conservation
524 community, the WDPA is a potential model (UNEP-WCMC, 2017). The largest national offset
525 database in the world is currently RIBITS, but as mentioned above, the accuracy of this
526 database has been questioned.

527

528 4.1.3 Informing controversies around offsetting

529 Controversies arise around offsets in part due to concerns about the actual conservation
530 outcomes of NNL policy, and whether these are positive or negative (e.g. Schoukens &
531 Cliquet, 2016). Again, this highlights the utility of transparent data on implementation, to
532 inform such concerns.

533

534 The potential misuse of offsets in existing protected areas is a key theoretical controversy for
535 NNL (Pilgrim & Bennun, 2014), but it has not previously been shown whether this is
536 widespread practice in countries implementing offsets. Comprehensive versions of the
537 datasets we collate here would enable such analyses. From our data, we can say that: in
538 Germany, approximately a quarter of recorded 'offsets' involved activities within protected
539 areas, in France it was closer to half, whereas in the Netherlands and Sweden the proportion
540 was zero and < 3% (1 of 44) of projects respectively (Fig. 2). If similar findings were borne out
541 across a more comprehensive dataset, it would suggest that the proportion of offsets
542 implemented in protected areas is low. In turn, this would imply that concern about regulatory
543 offsets being misused to support protected areas could in practice be a moot point for certain
544 countries.

545

546 Similarly, concerns have been raised that offsets too often resort to averted loss measures
547 that, despite being valid against appropriate counterfactuals (Bull et al., 2014), are considered
548 open to abuse (Gordon et al., 2015) and poor accounting (Maron et al., 2015). But our data
549 suggest that most offsets involve active management e.g. habitat restoration. Again, if
550 developers rarely resort to averted loss, the associated controversy is of little relevance. The
551 debate around both issues is of course more nuanced – for instance, a greater proportion of
552 offsets outside of Europe might, and perhaps should, involve existing protected area
553 commitments if they would otherwise be insufficiently financed (e.g. Hardner et al., 2015). But
554 our point is that improving transparent reporting of offset implementation would allow more
555 empirical exploration of such topics, and the opportunity to draw more robust and
556 generalizable conclusions about offsetting.

557

558 4.1.4 Limitations

559 All data were collected remotely, and we did not visit the offset projects themselves for
560 verification. Nonetheless, since information was generated by public authorities and by
561 commercial enterprises, it was considered sufficiently reliable for the purposes of our study.
562 We primarily relied upon experts to confirm the absence of any additional accessible relevant
563 datasets for each country, and supported this by consulting existing literature reviews (Bull et
564 al., 2013; Calvet et al., 2015). We accept that it is difficult to prove no additional datasets
565 exist, however, any available data not uncovered using the process described here would
566 arguably fail to meet our criteria of 'accessibility', and we can therefore assume they are non-
567 transparent.

568

569 By seeking at least three contacts in each country, representing a range of interests, we
570 sought to reduce knowledge and information bias in the responses of experts consulted.
571 Since we were asking for the existence and location of datasets rather than for any opinion on
572 NNL or offsetting per se, our questions required primarily objective responses. However, our
573 sample of experts was small, and consequently there may be some bias towards
574 classification of projects into offsets, or a lack of knowledge about the existence of additional
575 data. Whilst we acknowledge knowledge bias, other studies corroborate that our approach
576 resulted in essentially comprehensive data capture for Sweden (Persson et al., 2015), and
577 greater data capture than studies for other countries (Bennett et al., 2017).

578

579 We have focused here upon biodiversity offsetting, although noting that offsets should always
580 be seen as part of the broader mitigation hierarchy. Quantitative assessment of the
581 implementation of other stages of the hierarchy (e.g. avoidance measures) is more
582 problematic than for offsets, as such measures can be less physically tangible, though
583 absolutely necessary (Phalan et al., 2017). Ultimately, assuming that avoidance is more
584 desirable from a biodiversity conservation perspective than offsetting, the implementation of
585 avoidance measures would be a stronger indicator of NNL effectiveness.

586

587 5.1 Conclusion

588 To conclude, there is a lack of data transparency obstructing comprehensive assessment of
589 the actual use of biodiversity offsetting, and the broader implementation of NNL policy. In turn,
590 this limits progress on important conservation questions related to offsetting, such as what
591 type of compensation interventions work, and under which circumstances. In Europe and
592 elsewhere offset datasets are being built at regional and national levels, however, much work
593 is still to be done, including overcoming technical and political barriers. If and when
594 comprehensive offset databases are made available, analysts will be able to provide
595 quantitative insights into NNL practice. Such insights will prove highly informative with regards
596 to offset implementation globally. Centralised data repositories that enable authorities,
597 financiers, shareholders and the public to scrutinise the state of implemented offsets will be
598 an essential step towards ensuring effective NNL.

599

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610

611 **References**

612 Albrecht J, Schumacher J, Wende W (2014) The German impact-mitigation regulation – a
613 model for the EU's no-net-loss strategy and biodiversity offsets? *Environ Policy Law*,
614 **44**(3):317-325.

615 Algemene Rekenkamer (2014) *Compensatie van schade aan natuurgebieden:*
616 *vervolgonderzoek naar de bescherming van natuur-gebieden.* Den Haag, Netherlands.

617 Battefeld KU (2012) Hintergründe zum Kompensationsflächenmanagement. Aktuelle
618 Probleme und Entwicklungen in Hessen. NAH-Tagung, 30.01.2012, Wetzlar [available
619 at: [http://www.na-hessen.de/dokumentation/veranstaltungen/veranstaltungen-](http://www.na-hessen.de/dokumentation/veranstaltungen/veranstaltungen-2013/index.php)
620 [2013/index.php](http://www.na-hessen.de/dokumentation/veranstaltungen/veranstaltungen-2013/index.php)].

621 BBOP (Business and Biodiversity Offsets Programme) (2012) Standard on Biodiversity
622 Offsets. BBOP; Washington D.C., USA.

623 BenDor T, Brozovic N, Pallathucheril VG. (2007) Assessing the Socioeconomic Impacts of
624 Wetland Mitigation in the Chicago Region. J Amer Planning Ass, **73**(3):263-282.

625 BenDor T, Sholtes J, Doyle MW. (2009) Landscape Characteristics of a Stream and Wetland
626 Mitigation Banking Program. Ecol Appl, **19**(8):2078-2092.

627 Bennett G, Chavarria A, Ruef F (2017) State of European markets 2017: biodiversity offsets
628 and compensation, Forest Trends; Washington, D.C., USA.

629 BFAD (Bundesverband der Flächenagenturen in Deutschland) (2011)
630 Kompensationsverzeichnisse in den Bundesländern. Newsletter Ausgabe Nr.4, **S.3**.

631 Broekmeyer MEA, Bugter RJF, Van Teeffelen AJA (2012) Natuurcompensatie: slim beleid
632 begint op tijd. Landschap, **29**(2):57–67.

633 Brown MA, Clarkson BD, Stephens RTT, Barton BJ (2014) Compensating for ecological harm
634 – the state of play in New Zealand. New Zeal J Ecol, **38**(1).

635 Bull JW, Suttle KB, Gordon A, Singh NJ, Milner-Gulland EJ (2013) Biodiversity offsets in
636 theory and practice. Oryx, **47**(3):369-380.

637 Bull JW, Gordon A, Law E, Suttle KB, Milner-Gulland EJ (2014) The importance of baseline
638 specification in evaluating conservation interventions and achieving no net loss of
639 biodiversity. Conserv Biol, **28**(3):799–809.

640 Bull JW, Hardy MJ, Moilanen A, Gordon A (2015) Categories of flexibility in biodiversity
641 offsetting, and their implications for conservation. Biol Conserv, **192**:522-532.

642 Bull JW, Gordon A, Watson JEM, Maron M (2016) Seeking convergence on key concepts in
643 No Net Loss. J Appl Ecol, DOI: 10.1111/1365-2664.12726.

644 Bull JW, Lloyd SP, Strange N (2017) Implementation gap between the theory and practice of
645 biodiversity offset multipliers. Conserv Lett, DOI: 10.1111/conl.12335.

646 Calvet C, Guillaume O, Claude N. (2015) Tracking the origins and development of biodiversity
647 offsetting in academic research and its implications for conservation: a review. *Biol*
648 *Conserv*, **192**:492-503.

649 Darbi M (2010) Compensation agencies in Germany - a tool to facilitate development and to
650 safeguard environmental protection and restoration. In: Davy, B. et al. (Eds.): Program
651 and Abstracts of the Fourth International Academic Conference on Planning, Law, and
652 Property Rights. Dortmund: Technische Universität, **S.86-87**.

653 Darbi M, Albrecht J, Schumacher J (2016) Die europäische No Net Loss initiative und
654 biodiversity offsets. Einblicke in die aktuelle Diskussion zur Kompensation von
655 Eingriffen in die Biodiversität aus deutscher Perspektive. *Jahrbuch des Umwelt- und*
656 *Technikrechts*.

657 Darbi M, Ohlenburg H, Herberg A, Wende W (2010) Impact mitigation and biodiversity offsets
658 - Compensation approaches from around the world. A Study on the application of
659 Article 14 of the CBD (Convention on Biological Diversity). Bundesamt für Naturschutz,
660 **S.249**; Bonn, Germany.

661 DREAL Languedoc-Roussillon (2015) Données générales. [Available at:
662 [http://carmen.application.developpement-
664 durable.gouv.fr/19/dreal_lr_general.map&layer=Mesures%20compensatoires](http://carmen.application.developpement-
663 durable.gouv.fr/19/dreal_lr_general.map&layer=Mesures%20compensatoires)].

664 Gaiji S, et al. (2013) Content assessment of the primary biodiversity data published through
665 GBIF network: status, challenges and potentials. *Biodiv Inform*, **8**:94-172.

666 Gardner TA, et al. (2013) Biodiversity offsets and the challenge of achieving No Net Loss.
667 *Conserv Biol*, **27**:1254-1264.

668 Gordon A, Bull JW, Wilcox C, Maron M (2015) Perverse incentives risk undermining
669 biodiversity offset policies. *J Appl Ecol*, **52**:532–537.

670 Hardner JJ, Gullison RE, Lowry III PP (2015) Offsets: Conservation served by flexibility.
671 *Nature*, **524**:doi: 10.1038/524415e.

672 Herbert M (2015) German Impact Mitigation Regulation – National, European, International. A
673 Comparison from the Viewpoint of the Federal Agency for Nature Conservation. In:
674 UVP-report, **29**(3):149-151. Eingriffsregelung; Umweltverträglichkeitsprüfung;
675 Strategische Umweltprüfung; Biologische Vielfalt.

676 Hudson LN, et al. (2014) The PREDICTS database: a global database of how local terrestrial
677 biodiversity responds to human impacts. *Ecol Evol*, **4**(24):4701-4735.

678 IUCN, UNEP-WCMC (2015) The World Database on Protected Areas (WDPA) [On-line],
679 [downloaded August 2015], Cambridge, UK: UNEP-WCMC. [Available at:
680 www.protectedplanet.net].

681 Kitchin R (2014) Big Data, new epistemologies and paradigm shifts. *Big Data Soc*, 1-12.

682 Maron M, Bull JW, Evans MC, Gordon A (2015) Locking in loss: baselines of decline in
683 Australian biodiversity offset policies. *Biol Conserv*, doi: 10.1016/j.biocon.2015.05.017.

684 Maron M, et al. (2016a) Taming a wicked problem: resolving controversies in biodiversity
685 offsetting. *BioScience*, doi: 10.1093/biosci/biw038.

686 Maron M, Gordon A, Mackey BG, Possingham HP, Watson JEM (2016b) Interactions
687 between biodiversity offsets and protected area commitments: avoiding perverse
688 outcomes. *Conserv Lett*, doi: 10.1111/conl.12222.

689 Matthews JW, Endress AG (2008) Performance criteria, compliance success, and vegetation
690 development in compensatory mitigation wetlands. *Environ Manage*, **41**(1):130-141.

691 May J, Hobbs RJ, Valentine LE (2016) Are offsets effective? An evaluation of recent
692 environmental offsets in Western Australia. *Biol Conserv*, doi:
693 0.1016/j.biocon.2016.11.038.

694 Nationaal Groenfonds (2015) Jaarverslag (Annual Report) 2015. [available at:
695 <https://www.nationaalgroenfonds.nl/over-groenfonds/jaarverslagen>].

696 Olszynski, MZP (2015) From 'badly wrong' to worse: an empirical analysis of Canada's new
697 approach to fish habitat protection laws. *J Environ Law Practice*, **28**(1).

698 Persson J, Larsson A, Villarroya A (2015) Compensation in Swedish infrastructure projects
699 and suggestions on policy improvements. *Nature Conserv*, **11**:113-127.

700 Phalan B, et al. (2017) Avoiding impacts on biodiversity through strengthening the first stage
701 of the mitigation hierarchy. *Oryx*, DOI: 10.1017/S0030605316001034.

702 Pilgrim JD, Bennun L (2014) Will biodiversity offsets save or sink protected areas? *Conserv*
703 *Lett*, **7**(5):423-424.

704 Provincie Limburg (2012) Monitor Limburgs kwaliteitsinstrumentarium 2003 – 2011.
705 Maastricht, Netherlands. [Available at: <http://www.limburg.nl>].

706 Provincie Noord-Brabant (2014) Memo, Natuurcompensatieprojecten: Stand van zaken 1 juli
707 2014, 's Hertogenbosch, Netherlands. [Available at: www.brabant.nl].

708 Quétier F, Moura C, Menut T, Boulnois R, Rufay X (2015) La compensation écologique
709 fonctionnelle : innover pour mieux traiter les impacts résiduels des projets
710 d'aménagements sur la biodiversité. *Sciences, Eaux et Territoires*, **17**:24-29.

711 Quétier F, Regnery B, Levrel H (2014) No net loss of biodiversity or paper offsets? A critical
712 review of the French no net loss policy. *Environ Sci Pol*, **38**:120-131.

713 Randstedelijke Rekenkamer (2017) Natuurlijk bevoegd: onderzoek naar de invulling van de
714 provinciale rol bij natuurcompensatie. Provincie Noord Holland. [Available at:
715 <http://www.randstedelijke-rekenkamer.nl/onderzoek/natuurcompensatie/>].

716 Robertson MM, Hayden N (2008) Evaluation of a Market in Wetland Credits: Entrepreneurial
717 Wetland Banking in Chicago. *Conserv Bio*, **22**(3):636-646.

718 Schoukens H, Cliquet A (2016) Biodiversity offsetting and restoration under the European
719 Union Habitats Directive: balancing between no net loss and deathbed conservation?
720 *Ecol Society*, **21**(4):572-585.

721 Schulp, CJE, Van Teeffelen AJA, Tucker, G, Verburg PH (2016) A quantitative assessment of
722 policy options for no net loss of biodiversity and ecosystem services in the European
723 Union. *Land Use Policy*, **57**:151-163.

724 Sutherland WJ, Pullin AS, Dolma PM, Knight TM (2004) The need for evidence-based
725 conservation. *Trends Ecol Evol*, **19**(6):305-308.

726 ten Kate K, et al. (2014) Biodiversity offsets technical study paper. International Union for the
727 Conservation of Nature (IUCN) Gland, Switzerland. ISBN: 978-2-8317-1695-4.

728 Tucker G, et al. (2014) Policy Options for an EU No Net Loss Initiative. Report to the
729 European Commission. Institute for European Environmental Policy; London, UK.

730 Turner W, et al. (2003) Remote sensing for biodiversity science and conservation. *Trends*
731 *Ecol Evol*, **18**(6):306-314.

732 UNEP-WCMC (2017) World Database on Protected Areas User Manual 1.5. UNEP-WCMC:
733 Cambridge, UK. [Available at: http://wcmc.io/WDPA_Manual].

734 US ACE (US Army Corps of Engineers) (2015) Regulatory In-Lieu Fee and Bank Information
735 Tracking System. [Available at: https://ribits.usace.army.mil/ribits_apex/f?p=107:2].

736 Vanderduys EP, Reside AE, Grice A, Rechetelo J (2016) Addressing potential cumulative
737 impacts of development on threatened species: the case of the endangered Black-
738 throated Finch. PLoS 1, doi: 10.1371/journal.pone.0148485.

739 Van Teeffelen, A.J.A. (in press) In: Wende, W., Tucker, G., Quétier, F., Rayment, M., Darbi,
740 M. (Eds) Biodiversity Offsets - European Perspectives on No Net Loss of Biodiversity
741 and Ecosystem Services. Springer, USA. DOI: 10.1007/978-3-319-72581-9.
742

743 Wende W, Darbi M, Stein C (2015) Annex 4 Evidence Of The Costs Of Offsetting In
744 Germany. In: The Institute for European Environmental Policy (IEEP), Biotope, eftec
745 and ICF (ed. 2015): Supporting the Elaboration of the Impact Assessment for a Future
746 EU Initiative on No Net Loss of Biodiversity and Ecosystem Services. 2nd Draft Interim
747 / Task 2 Report. Unpublished draft (2015).

748 Wende W, Herberg A, Herzberg A (2005) Mitigation banking and compensation pools:
749 improving the effectiveness of impact mitigation regulation in project planning
750 procedures. J Impact Assess Project Appraisal, **23**(2):101-111.

751 Wende, W., Tucker, G., Quétier, F., Rayment, M., Darbi, M. (Eds) Biodiversity Offsets -
752 European Perspectives on No Net Loss of Biodiversity and Ecosystem Services.
753 Springer, USA. DOI: 10.1007/978-3-319-72581-9.

754 Wübbe I, Szaramowicz M, Rößling H (2006) Digitale Eingriffs- und Kompensationskataster.
755 Entwicklungsstand und Potenziale. Natur und Landschaft, **81**(2):88-95.

756 Zuidelijke Rekenkamer (2013). Kwaliteit natuurcompensatie provincie Limburg. Eindhoven,
757 available from www.zuidelijkerekenkamer.nl

758 Zuidelijke Rekenkamer (2014) Kwaliteit natuurcompensatie provincie Noord-Brabant.
759 Eindhoven, available from www.zuidelijkerekenkamer.nl.

760 **Table 1:** Headline summary of data transparency for the four countries studied, with Australia
 761 and US for comparison (Bull & Strange, unpublished data)
 762

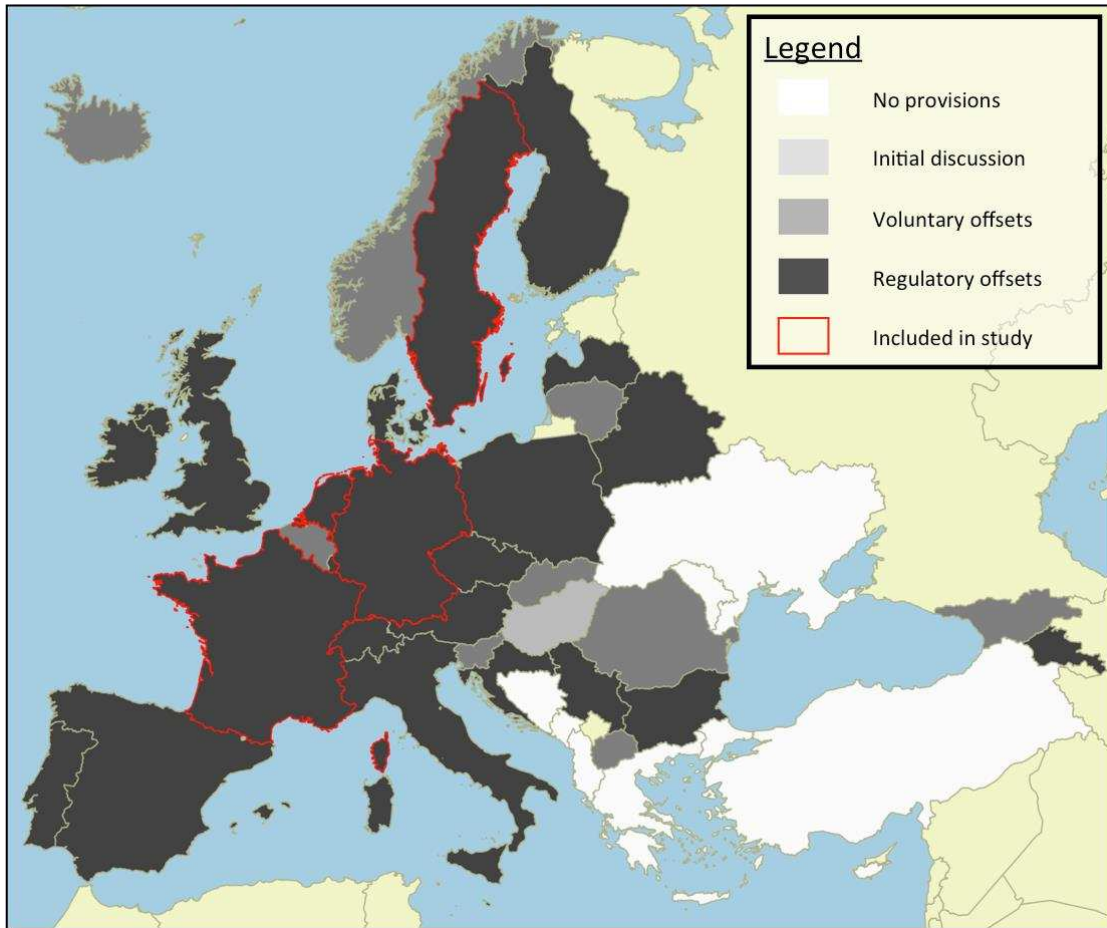
Country	Data available	Data accessible	Regionally collated	Nationally collated	Number of regions covered (of total)
France	Yes	Limited	In progress	In progress	1 (27)
Germany	Yes	Yes	Partial	In progress	9 (16)
Netherlands	Yes	Limited	In progress	No	2 (12)
Sweden	Yes	Yes	No	No	24 (24)
Australia	Yes	Yes	Yes	No	4 (6)
US	Yes	Yes	Yes	Yes	50 (50)

763

764 **Table 2:** Data summary for the countries studied, including known offset locations, area
 765 occupied by offsets, number in protected areas, and main sector implementing offsets
 766

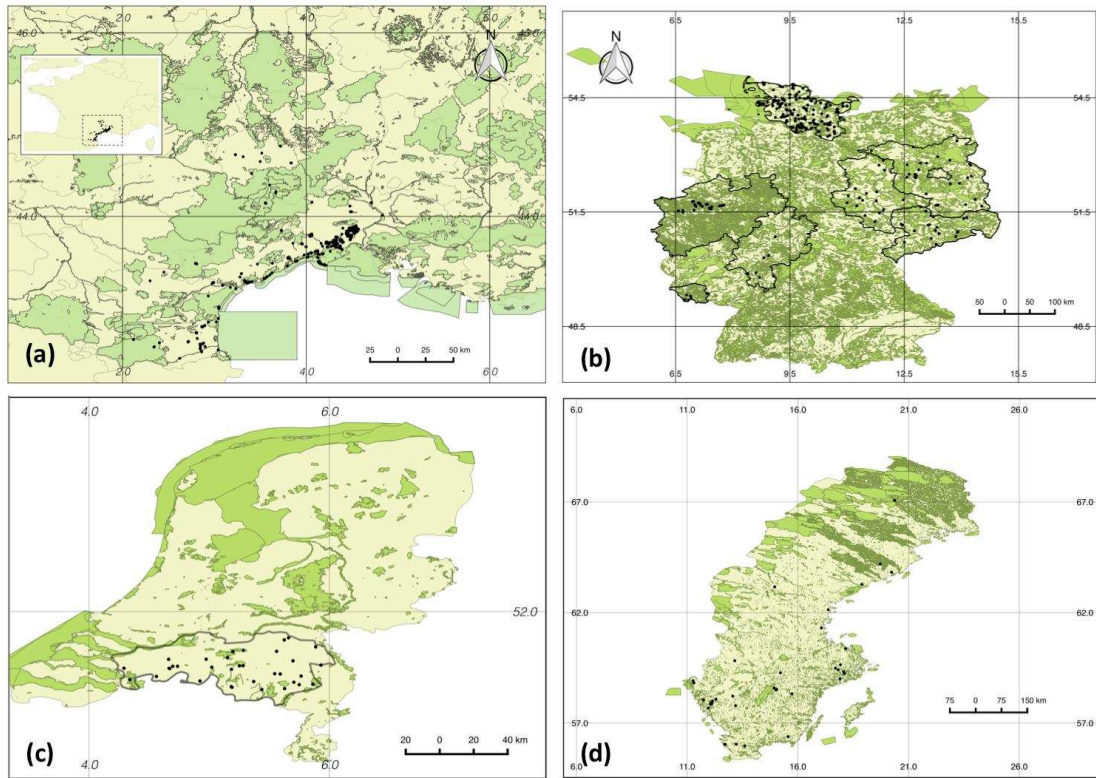
Country	Biodiversity offset locations	Corresponding area (km ²)	# in Protected Areas	Main sector (%)
France	87 mapped	28.41	~ 40	Infrastructure (>68)
Germany	288 mapped 467 known	23.70 -	74 -	-
Netherlands	35 mapped 112 known	5.51 ~ 8.51	0 -	Infrastructure (33.8)
Sweden	42 mapped 44 known	- -	1 -	Infrastructure (68.2)

767
 768



769

770 **Figure 1:** Map of Europe, showing current biodiversity offset policy status for all countries
 771 contained within the GIBOP dataset (available at: <https://testportals.iucn.org/offsetpolicy>), and
 772 according to the classification scheme from the same dataset. The boundaries of the four
 773 countries included within this study are highlighted in red.



774

775

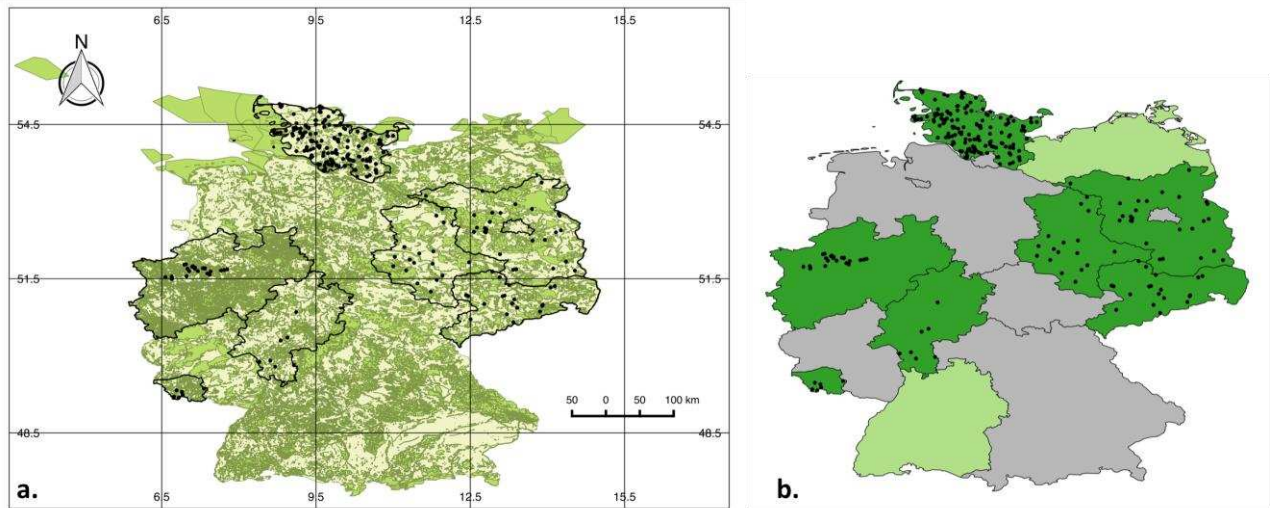
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Figure 2: Maps of offset projects (black points) and protected areas contained in the WDPA (shaded green), for the four countries. (a) Languedoc-Roussillon province, France. Inset map of France, showing location of the province. (b) Germany. (c) The Netherlands. Location data available for Noord-Brabant province only, the border for which is marked in black. (d) Sweden.



780

781 **Figure 3:** Variability of data transparency by state, for offsets in Germany. (a) Map of

782 identified compensation pools, and protected areas (shaded green), as per Figure 2. (b) Dark

783 green = states with location data, light green = data on area occupied by compensation pools

784 only, grey = no data.