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

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ABSTRACT

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

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

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

1. Introduction

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

Post-implementation evaluation of NNL policies is uncommon, including for the most controversial component of the mitigation hierarchy, biodiversity offsetting (Bull et al., 2013; ten Kate et al., 2014). Biodiversity offsets ('offsets') involve compensating for unavoidable residual impacts through conservation or restoration activities elsewhere. Some published analyses of offset implementation exist, assessing data on the implementation of offset projects at sub-national to

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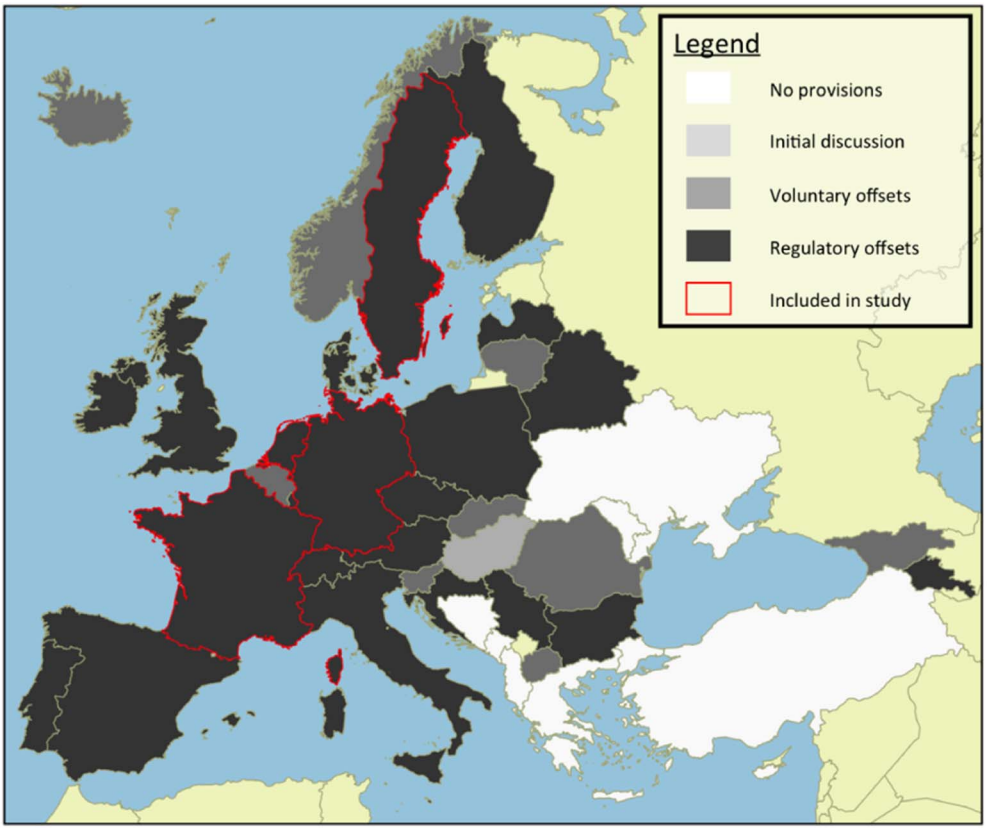

Fig. 1. Map of Europe, showing current biodiversity offset policy status for all countries contained within the GIBOP dataset (available at: https://testportals.iucn.org/offsetpolicy), and according to the classification scheme from the same dataset. The boundaries of the four countries included within this study are highlighted in red. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

national scales. They find that a minority of offsets are implemented as per technical requirements, yet conclude that the approach is improving and has some potential for conservation (Matthews and Endress, 2008; Brown et al., 2014; Olszynski, 2015; May et al., 2016).

Transparency (e.g. ensuring that "clear, up to date, and easily accessible information is provided to stakeholders and the public on the offset design and implementation, including outcomes"; BBOP, 2012) is considered good practice for offsetting. Further, the availability of comprehensive and reliable datasets on offset implementation would be essential for understanding the scope of offset activity, and is a prerequisite for eventually assessing the effectiveness and suitability of offsetting for conservation in different regional and national contexts. Yet to date there has been no explicit assessment of data transparency in the implementation of offset projects, or indeed in NNL policy outcomes more generally; let alone a comparative analysis that would enable lessons to be shared across jurisdictions. The lack of readily available data on the implementation of NNL policy hampers any effort to make clear, empirical statements in relation to key controversies surrounding NNL, and ultimately, evaluation of the contribution made by NNL policy to biodiversity conservation. The need to ascertain the validity of NNL has become increasingly pressing with the introduction of far-reaching policies supporting their use (Maron et al., 2016a). It is thus critical to better understand the degree to which data on offsetting efforts, and NNL-related measures more generally, are available. We note that the desire to obtain transparent and reliable data is a topical concern for conservation science more broadly. The availability and accessibility of data with relevance to topics in conservation has improved notably in recent decades — for instance, with resources such as the Global Biodiversity Information Facility (Gaiji et al., 2013), remotely sensed imagery (Turner et al., 2003), the World Database on Protected Areas (UNEP-WCMC, 2017), and the PREDICTS database (Hudson et al., 2014). This is consistent both with the movement towards evidence-based conservation (Sutherland et al., 2004), and with profound changes in the way scientific data are created and disseminated (Kitchin, 2014).

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

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

towards more general provisions for biodiversity offsets. An exploration of the level of data transparency for NNL implementation in Europe is therefore highly conservation policy-relevant.

2. Materials and methods

2.1. Methodology

We compiled all publicly available data on offset projects through a process of intensive data extraction, alongside expert verification, for four countries: France, Germany, the Netherlands and Sweden. Our intention was to explore offset implementation for a significant (in terms of implementation) subset of European countries, and these four countries are documented as being key countries actually implementing NNL projects in Europe (Tucker et al., 2014). It should be noted that policies that make provision for offsets are in place or in discussion throughout Europe, as a result of both national legislation and EU Directives (Fig. 1; Maron et al., 2016a). However, given that the four countries included within our study are considered to be leading proponents of offsetting, and contain a significant proportion of the terrestrial surface of Europe (> 10%), we consider the selection justified. To obtain relevant data, we began by contacting at least three established national NNL experts in each country, where 'experts' were considered to be those either publishing academic research on offsets in that country in peer-reviewed journals, or those working directly on offset projects (listed in Table A.1). We sought to ensure that for each country, our experts included those representing academia, the public sector, and the private sector. These individuals were asked to indicate all known data sources on offset implementation for that country, and notify us of any other potentially useful individual or organisational contacts. Consequently, those further individual and organisational contacts were approached until contacts confirmed that no further data were readily accessible. Since all data were provided to us through the recommendation of multiple experts, we did not independently verify the data.

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

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

1. What is the implementation status of each offset project (e.g. in progress/complete)?
2. What component of biodiversity is targeted (e.g. species, habitat types)?
3. What conservation management actions are involved (e.g. designation as protected area, habitat restoration)?
4. Where are they approximately located (latitude/longitude)?
5. How much area does each offset project occupy?
6. Which sector is causing the impacts for which offsets are required (e.g. transport infrastructure, extractive)?
7. For what specific development project does each offset project provide ecological compensation?
8. Where is that development project located (latitude/longitude)?
9. What components of biodiversity are impacted by that development project?

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

To meet the secondary objective of the manuscript, to provide a preliminary estimate of offsetting effort across Europe, we generated maps in QGIS Geographic Information System v.2.8.1[1] of all offset locations (base data: Natural Earth v.3.1.0[2]). For interest, we analysed the overlap with protected areas registered for each country in the World Database on Protected Areas (WDPA; UNEP-WCMC, 2015). The 'points in polygons' analysis tool was implemented for these overlapping layers, and attributes table from the resulting shapefiles exported (.csv format). Note again that in this study we sought to understand implementation status, and not the *effectiveness* of offsets — as such, we did not include a question on effectiveness. Judging offset effectiveness can be extremely subjective, varying depending upon the stakeholder in question. As a result, the question of offset effectiveness is worthy of multiple studies in its own right.

2.2. Methodological challenges

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

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

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

[1] http://qgis.osgeo.org.
[2] http://www.naturalearthdata.com.

distribution and data transparency we considered this an acceptable margin of error.

3. Results

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

3.1. France

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

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

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

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

3.2. Germany

Since the enactment of the Federal Nature Conservation Act (*Bundesnaturschutzgesetz*) in 1976, ecological compensation requirements have existed. Amendments to the Act (2002, 2009) facilitating

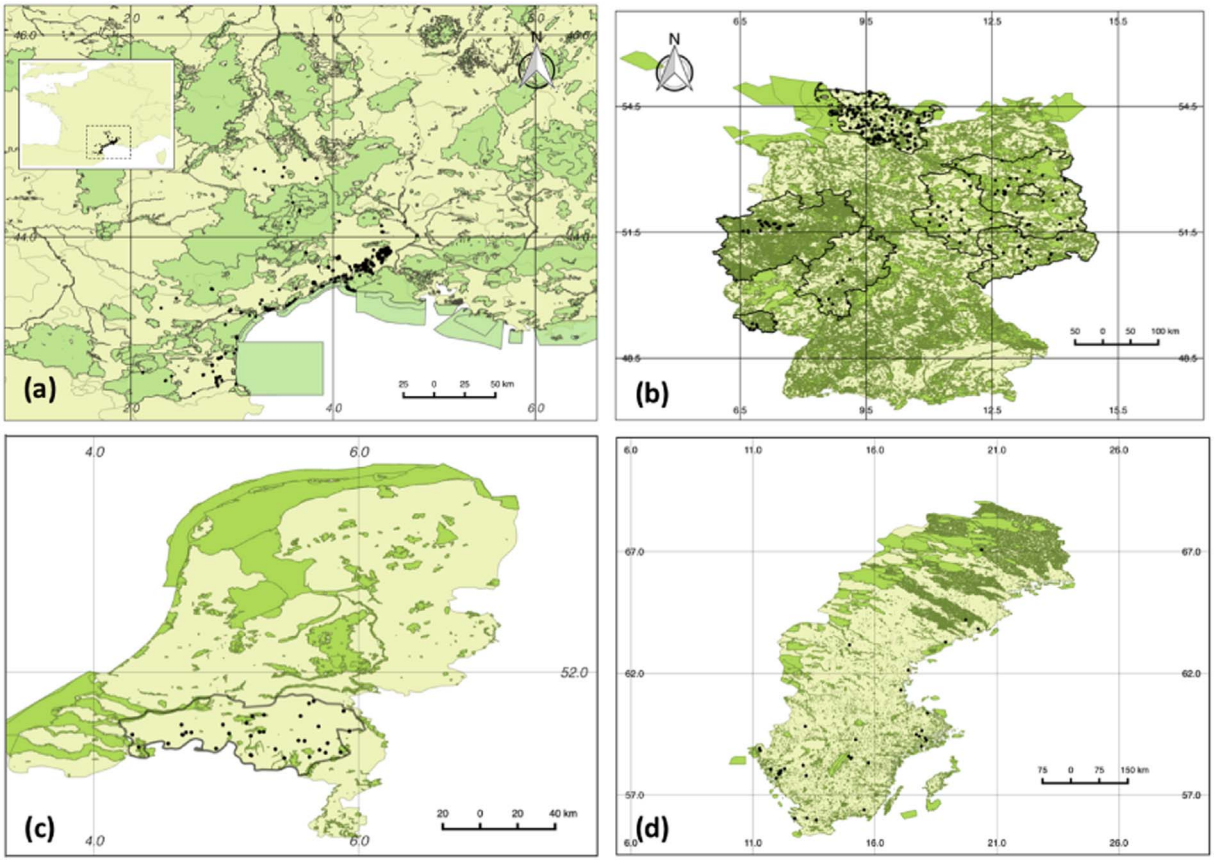

Fig. 2. Maps of offset projects (black points) and protected areas contained in the WDPA (shaded green), for the four countries. (a) Languedoc-Roussillon province, France. Inset map of France, showing location of the province. (b) Germany. (c) The Netherlands. Location data available for Noord-Brabant province only, the border for which is marked in black. (d) Sweden. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

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

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)

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

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

habitat banking allowed "loosening of the spatial and functional connection between impact and compensation" (Wende et al., 2005; Darbi, 2010). Under the Act, state governments are responsible for maintaining an offset registry, to avoid double counting and allow verification of implementation. While all German states do so (BFAD, 2011), individual registries differ in completeness, data accuracy, and type of data recorded (Wübbe et al., 2006). Data availability for German offset projects varies dramatically between states (Fig. 3). Offsets are most obviously found in 'compensation pools' or 'eco-accounts' (*Flächenpools* and *Ökokonten*) i.e. habitat banks, rather than tied to specific developments, although the proportion of each is unknown. The German system includes *Ausgleichsmaßnahmen* ('compensation measures') and *Ersatzmaßnahmen* ('substitution measures'). The former involve restoring "impaired functions of the ecosystem" ensuring that "natural scenery has been restored or re-landscaped" (Darbi et al., 2010) — they are 'restoration compensation', 'on-site' (Tucker et al., 2014). Since *Ausgleichsmaßnahmen* involve reversing the impacts caused by a specific development, they most closely match the remediation category of the mitigation hierarchy. Conversely, *Ersatzmaßnahmen* are offsets, in that they involve achieving biodiversity gains in habitats unaffected by the specific development for which they provide compensation (Albrecht et al., 2014; Tucker et al., 2014). All offsets in Germany are restoration-based, involving active management e.g. habitat restoration, pond creation. Protection-based ('averted loss') offsets are not permissible according to the relevant legislation, and requirements exist for "measures to restore lost functionality" (Herbert, 2015; Darbi et al., 2016).

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

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

In summary, data transparency in Germany was highly variable by state, with no offset data available for some yet sufficient data for answering questions 1–6 (see Materials and methods) in others. Data were

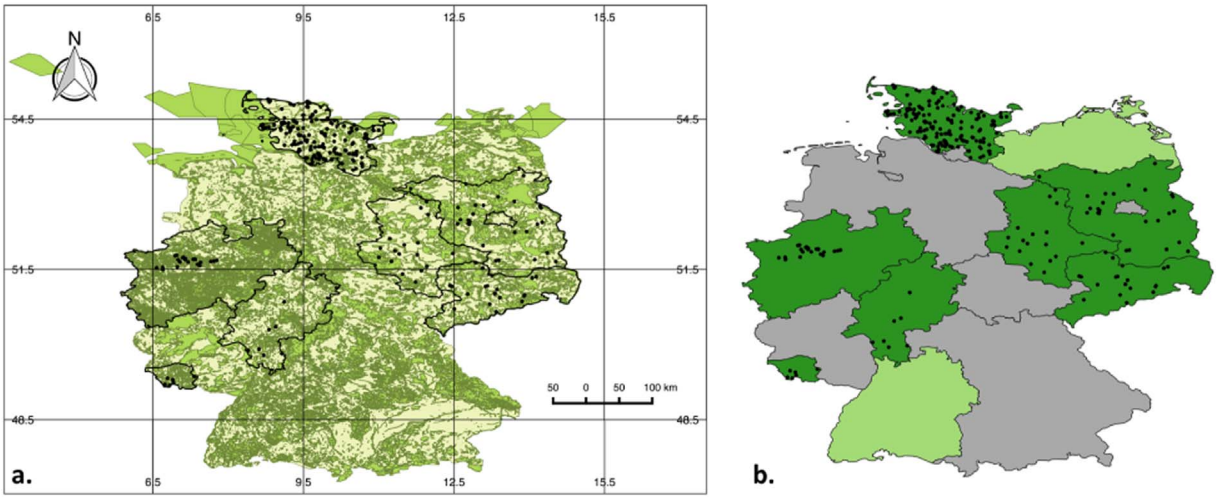

Fig. 3. Variability of data transparency by state, for offsets in Germany. (a) Map of identified compensation pools, and protected areas (shaded green), as per Fig. 2. (b) Dark green = states with location data, light green = data on area occupied by compensation pools only, grey = no data. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

only transparent for offsets delivered in compensation pools in Germany, so we could not answer questions 7–9 (associated developments) for any state. Up to half of the states in Germany could be considered transparent regarding offset data (Table 1).

3.3. The Netherlands

Forest offsets have existed since the Forest Act came into force in 1961, which have been complemented by offsets for species and habitats of conservation concern in 1998 with the enactment of the Flora and Fauna Act and the Nature Conservancy Act (Van Teeffelen, in press). These three laws have been merged in 2017 into a new Nature Conservation Act and applied to Natura 2000 sites, other sites of the National Nature Network and species of conservation concern. For habitats the provisions have stayed the same, for species they have been aligned more closely to the EU Birds and Habitats Directives (Van Teeffelen, in press). Since 2007, responsibility for keeping an offset registry has rested with the 12 provinces, to which municipalities are obliged to report on offset project status. No national database of Dutch offset projects exists. The Netherlands Court of Audit recently concluded that offsetting practice had improved since 2007, thanks to clarifications of roles and responsibilities and reduced complexity, but: "Provinces do not have good insight/overview of the offsetting that has been required through permits. There are no guidelines for registration leading to gross variations in the process and an inability to compare information across provinces" (Algemene Rekenkamer, 2014). Information on all offsets in the Netherlands is ostensibly available online through individual planning permits.[3] Extracting that information, however, requires going through the documentation on a plan-by-plan basis. This is hindered by the web portal containing all spatial plans of which only a fraction involve offsetting, and, because no project list can be generated. Provinces are required to compile overviews of offsets projects on an annual basis and monitor offsets, but these overviews are not commonly publicly available.

For two provinces, Noord-Brabant and Limburg, a list of offset projects could be accessed containing offset project names, municipality involved, and dates and phases of implementation and monitoring thereof. The Noord-Brabant list also mentions area of offsets. The Noord-Brabant dataset lists 74 projects (2005–2014), occupying 551 ha (Provincie Noord-Brabant, 2014). By sector, infrastructure development generated the most offsets (33.8%), but recreation and urbanisation were also well represented (Table A.2). Location data were obtainable for 35 projects (Fig. 2c). The Limburg dataset lists 38 projects (2005–2011), totalling approximately 300 ha of offsets (Provincie Limburg, 2012). Progress is being made in Noord-Brabant with the launch of a webviewer,[4] where impact locations and offset locations will be projected on a map, further increasing transparency. Offset project details still have to be looked up in the individual planning permits. Following the research of the Southern Court of Audit regarding offset implementation, registration and monitoring in Noord-Brabant and Limburg (Zuidelijke Rekenkamer, 2013, 2014), the Court of Audit of the provinces Noord-Holland, Zuid-Holland, Utrecht and Flevoland ("Randstedelijke Rekenkamer") announced similar studies during 2016/2017, suggesting progress regarding registration and monitoring of Dutch offsets.

All offsets in the Netherlands are restoration-based. In line with national guidelines, several provinces allocate offsets within the National Nature Network, where the government planned to create additional habitat but has not yet done so due to budget constraints. This should be accompanied by an extension of the total size of the National Nature Network, to avoid that offsets are used as a source of funding for protected areas — which could be considered 'misuse' of offsets (Maron et al., 2015, 2016b). Not every province ensured this extension, a point raised by a regional Court of Audit (Randstedelijke Rekenkamer, 2017). An important consideration regarding the Netherlands is that space is constrained for offsets, due to high land-use demand and a strict requirement for equivalence and spatial proximity between a specific development and the associated offset (Broekmeyer et al., 2012) — an emerging challenge for offsets more generally (Vanderduys et al., 2016). This has resulted in payments of in-lieu fees instead of physical compensation, managed by the Dutch National Fund for Rural Areas (*Groenfonds*), amounting to €145 m (2015) (Nationaal Groenfonds, 2015).

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

3.4. Sweden

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

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

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

4. Discussion

4.1. Data transparency

For all four countries we studied, comprehensive information on

[3] http://www.ruimtelijkeplannen.nl.

[4] http://kaartbank.brabant.nl/viewer/app/natuurbeheerplan.

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

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

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

4.2. Tackling barriers to data transparency

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

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

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

When there is no consistent national framework for offset data reporting and collation, it becomes problematic to combine available offset data collated at sub-national level. Transparent implementation databases are necessary to evaluate whether offsets have likely enabled delivery of NNL of biodiversity on development projects. For this purpose, the data should include answers to the questions 1–9 asked here (Methods) as a bare minimum, including extent and type of impacts (BenDor et al., 2009). Preferably, the data should provide more extensive information on offsets as per categories outlined by Bull et al. (2013); e.g. equivalence rules, counterfactuals used for evaluation, time lag between development losses and offset gains, magnitude of multipliers incorporated, etc.). It is insufficient to consider the outcomes of NNL policies at any one scale, and so databases must be designed to allow analysis from project up to a landscape (e.g. national) scale, where the latter would include assessments of spatial and temporal redistribution of ecological components (BenDor et al., 2007; Robertson and Hayden, 2008; BenDor et al., 2009). Due to differences between country NNL policies and approach to offset implementation, a standard international reporting framework on offsetting is currently likely unfeasible — but there is a need for countries to develop coherent national standards for offset data.

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

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

4.3. Informing controversies around offsetting

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

The potential misuse of offsets in existing protected areas is a key theoretical controversy for NNL (Pilgrim and Bennun, 2014), but it has not previously been shown whether this is widespread practice in

countries implementing offsets. Comprehensive versions of the datasets we collate here would enable such analyses. From our data, we can say that: in Germany, approximately a quarter of recorded 'offsets' involved activities within protected areas, in France it was closer to half, whereas in the Netherlands and Sweden the proportion was zero and < 3% (1 of 44) of projects respectively (Fig. 2). If similar findings were borne out across a more comprehensive dataset, it would suggest that the proportion of offsets *implemented* in protected areas is low. In turn, this would imply that concern about regulatory offsets being misused to support protected areas could in practice be a moot point for certain countries.

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

4.4. Limitations

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

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

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

5. Conclusion

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

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Appendix A. Supplementary data

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