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Considerable qualitative variability in local-level biodiversity surveys in Finland: A challenge for biodiversity offsetting

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ABSTRACT

High-quality biodiversity monitoring is crucial in the era of rapid global biodiversity loss and for the evaluation of conservation outcomes at different spatial scales. Biodiversity offsets are conservation actions that aim to an outcome of no net loss of biodiversity by compensating for the negative impacts from development projects. Successful use of offsets requires that the biodiversity gains and losses between offset and development areas are adequately and comparably measured. Numerous local-level biodiversity surveys are conducted to estimate the biodiversity values of potential development areas in Finland every year. These surveys are done for local planning purposes, and their results are almost never published. We studied Finnish biodiversity surveys to assess their adequacy with regards to biodiversity offsetting. Our data included all biodiversity surveys (n = 206) documented in the region of Southwest Finland during the time period of 1997–2014. We analysed the surveys based on Finnish nature legislation and biodiversity related criteria gathered from other offset and conservation programs. We found the surveys to be inadequate in their assessment of nature values and spatial considerations for offset purposes. We used cluster analysis to study the differences between surveys based on the inventoried nature values and found surveys were clustered into 3 different groups. The characteristics of surveys also varied between individual surveyors. Our results show that the current execution of biodiversity surveys is not compatible enough with the quality of surveys needed for biodiversity offsets. Surveys must be standardized to ensure their comparability and sufficient measurement of biodiversity with ecologically and geographically important features.

1. Introduction

According to the recent IPBES Report, the rate of global change in nature during the past 50 years is unprecedented in human history, and human actions threaten more species with extinction now than ever before (Diaz et al. 2019). According to the same report, about 25 per cent of species in well studied animal and plant groups are threatened. Habitat transformation, destruction, and degradation are the main reasons for the decline in global biodiversity (Estavillo et al. 2013), and existing development pressures are presumed to continue exacerbating these processes. Addressing the ongoing biodiversity crisis requires active monitoring in the field at multiple levels (Noss 1987, 1990). Both the status of biodiversity and the impacts of conservation measures need to be monitored. Without reliable biodiversity information it would not be possible, for instance, to evaluate the outcomes of ambitious global biodiversity policies, such as the Aichi Biodiversity Targets (CBD 2019).

Finland's Biodiversity Action Plan includes several actions related to biodiversity monitoring (Action Plan 2019). National-level information on threatened species and habitat types is continuously updated by several national organizations. The 5th Red List of Finnish species was published in spring 2019 (Hyvärinen et al. 2019). A preliminary mapping of Finnish species hotspots was completed in 2016, and the joint use of national biodiversity data has proceeded. For instance, the Finnish Biodiversity Information Facility has been established, which currently includes more than 40 million biodiversity observations (FinBIF 2021). Much of nature conservation in Finland is based on the

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EU Birds and Habitats Directives. For instance, the principal aim of the Nature Conservation Act (1996) is to ensure that the favorable conservation statuses of different natural habitat types and native species are maintained or restored (Mehtälä & Vuorisalo 2007).

Such national regulation does not, however, provide a complete view of biodiversity monitoring in Finland. A considerable but unknown number of biodiversity surveys is undertaken in Finland every year for regional and local level land-use planning, to assess the appropriateness of specific areas for development projects, mostly for new housing areas, but also for traffic, power lines, other infrastructure and mining (Söderman 2003). In Finland, such surveys may be required e.g. by the Land Use and Building Act (1999), Environmental Impact Assessment Act (1994, 2017), or Nature Conservation Act (1996; Söderman 2003, 2004). These local surveys are conducted by biodiversity survey specialists with recognized expertise in the field and are usually commissioned by administrative units or companies applying for an environmental permit for their projects (Söderman 2003, 2004). The reports of these surveys are almost never published as scientific publications, although they are usually publicly available. In spite of the potentially great importance of such surveys for conservation at the local level, no studies exist that would have addressed their basic characteristics, objectives or practical impact. It is for instance not known how often the documented nature values have in fact been preserved when development projects have been realized (Söderman 2003).

Biodiversity offsetting (ecological compensation) is a system aiming to compensate for any loss of biodiversity resulting from development projects. There has been a growing interest in biodiversity offsets (Ives & Bekessy 2015), and over 100 countries have established their own offset or compensation programs or are in the process of creating them (Global Inventory of Biodiversity Offset Policies 2019). Biodiversity offsetting is the last phase of the mitigation hierarchy, in which the aim is to first avoid, then minimize, restore on site and, finally, offset any residual impacts on the environment (McKenney & Kiesecker 2010). Offsetting is usually done by restoring, creating, or protecting already existing habitats (Moreno-Mateos et al. 2015). A key principle of offsets is that there will be no net loss (NNL) of biodiversity, and preferably a net gain (Business and Biodiversity Offsets Programme (BBOP) 2012). Despite their popularity, offsets have been criticized for shortcomings including inadequate definition of biodiversity (McKenney & Kiesecker 2010, Maron et al. 2012) and challenges to measure biodiversity values (Quetier & Lavorel 2011, Goncalves et al. 2015, Bezombes et al. 2018, Moilanen & Kotiaho 2018). In addition to comprehensive biodiversity measurement, achieving NNL requires compensating for biodiversity losses with lasting and equivalent gains (Gardner et al. 2013). Hence, the offset mechanism requires extensive biodiversity monitoring to estimate nature values on project sites. Regardless, there has been a lack of transparent offset databases (Bull et al. 2018a, Josefsson et al. 2021).

Biodiversity offsets are currently high on the Finnish environmental policy agenda (Suvantola et al. 2018) and they have been drafted into the Nature Conservation Act under renewal (Ministry of the Environment 2021). Based on currently available information, the overall aim of the obligatory scheme is suggested to focus on conservation statuses of species and habitats, while the voluntary biodiversity offsets should take into account all native species and habitats (Kujala et al. 2021). Consequently, the demand for practical ways to assess nature values is concrete and real.

According to Söderman (2004), there have been considerable quality problems with local biodiversity surveys in Finland. Problems have been mainly related to the methods applied, as well as the poor reporting and monitoring of impacts. Therefore, we will provide the first ever comprehensive analysis of all biodiversity surveys conducted in a single administrative area of Finland until 2014, assuming that they represent the state-of-the-art in the field as no new quality standards have been added since. The aim of this paper is to assess how well these local biodiversity surveys fulfill the quality requirements of both contemporary and future biodiversity monitoring in the era of rapid development of methodologies and policy targets in the context of biodiversity offsets. As a first step, we provide recommendations for the standardization of future biodiversity surveys, focusing particularly on the site characteristics and nature values that need to be surveyed for biodiversity offset purposes.

2. Material and methods

2.1. Region of Southwest Finland

Southwest Finland (Fig. 1) is located on the Baltic Sea coast and consists of a mainland area and more than 22,000 Baltic Sea islands (Nurmela 1994, Region of Southwest Finland, 2018). The region's human population is about 480,000 inhabitants and its land area is 10,663 km^2, marine area 9,628 km^2, and inland water area 247 km^2. The natural terrestrial habitats of Southwest Finland are highly variable, ranging from treeless or forested Baltic Sea islets and islands to deciduous, mixed and coniferous inland forests and mires. Three of Finland's 40 national parks are situated in Southwest Finland (Archipelago Sea, Teijo and Kurjenrahka National Parks).

2.2. Biodiversity surveys in Southwest Finland

We chose Southwest Finland as our case study because of the unique database of nature-related documents gathered from the region during the last three centuries (until 2014). The database was collected by the Southwest Finland Centre for Economic Development, Transport and the Environment, which belongs to the Finnish state regional administration.

The original database included 1519 documents (e.g. biodiversity surveys, journal articles, descriptions, and even narratives by nature enthusiasts), but we chose only genuine biodiversity surveys for our analysis. By "genuine biodiversity survey", we mean a project-based field survey usually based on the inventories of multiple groups of organisms, with clearly specified objectives, temporal limits, and a well-defined target area. None of the surveys had had any biodiversity offsetting considerations. Our purpose was to analyze the state-of-the-art in the survey of nature values comprehensively, i.e. how the survey is able to assess a site's overall biodiversity, and we therefore excluded surveys conducted for only one specific group, for example birds. We chose only the surveys conducted since 1997 to exclude those conducted before the enactment of the present Nature Conservation Act (1996) and the Forest Act (1996) which were updated upon the accession of Finland into the European Union in 1995. After screening, 206 biodiversity surveys remained in our data.

For our analysis, we also collected information on the objectives of surveys as well as the professional profiles of individual biodiversity surveyors to study if personal skills and interests affect the surveyed nature values. The Land Use and Building Act (1999) requires promotion of ecologically, socially and culturally sustainable development. For this purpose, biodiversity surveys are often conducted for zoning at different levels of municipal planning (e.g. master plans, detailed plans, and detailed shore plans). Mostly such surveys are performed for identifying areas suitable for housing or other infrastructure construction.

2.3. Quality assessment and clustering of biodiversity surveys

We first assessed the quality of biodiversity surveys in Southwest Finland from two different perspectives. First, we evaluated the quality of surveys based on *contemporary legislation* that identifies the legally protected nature values. As Maseyk et al. (2016) pointed out, national laws and decrees are important in defining the components of biodiversity of concern (see also Bezombes et al. 2018). Hence, we analysed how well the relevant legislation was taken into consideration in a particular biodiversity survey (Table 1): for habitat preservation, 1) the

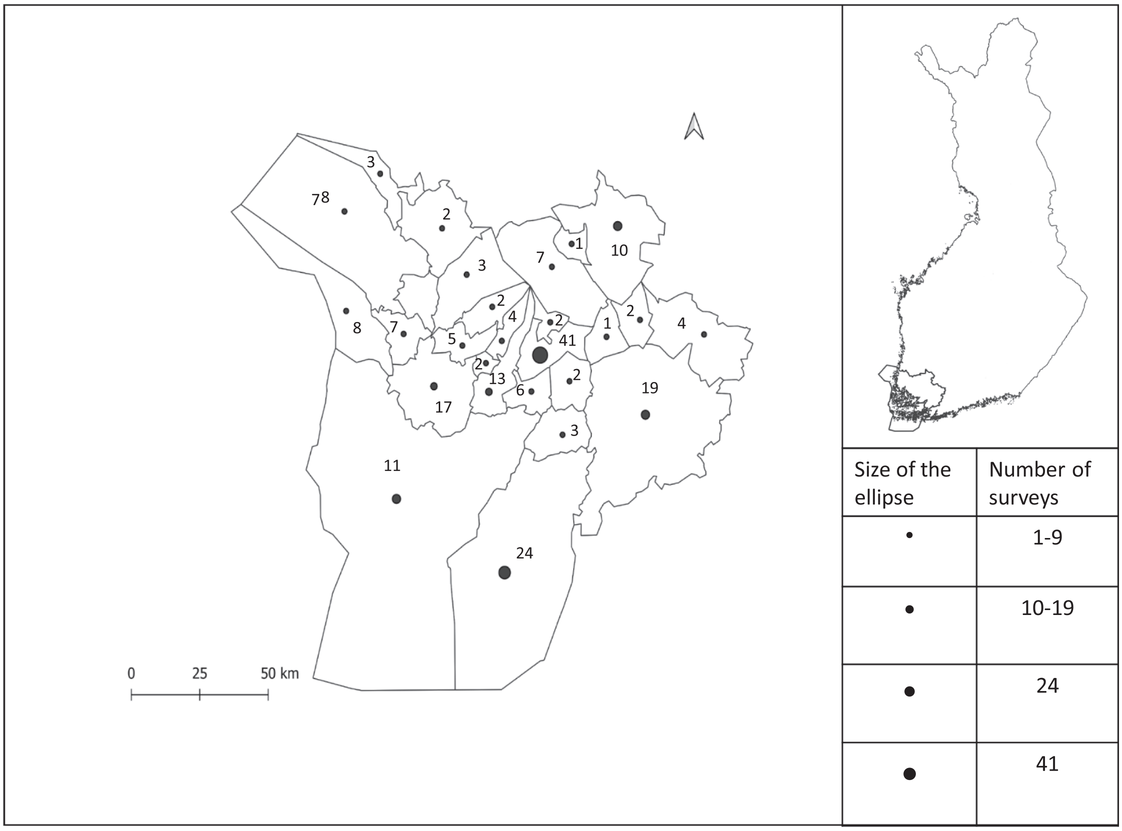

Fig. 1. Map of Finland and the locations of biodiversity surveys (n = 206) in the study area of Southwest Finland. The size of the ellipse represents the number of surveys conducted in a particular area.

Nature Conservation Act (1996), 2) the Forest Act (1996), and 3) the Water Act (2011); and for species preservation 4) the EC Habitats Directive Annex IV (a) (1992), and 5) the Nature Conservation Decree (1997). The Siberian flying squirrel (*Pteromys volans*) and the moor frog (*Rana arvalis*) were included in the survey evaluation criteria separately, because both are well known EC Habitats Directive Annex IV (a) (1992) species and frequently surveyed for land use planning.

Second, we assessed the quality of each biodiversity survey from the perspective of *biodiversity offsetting*. We conducted a comprehensive literature survey of the legal and ecological data requirements for biodiversity offsetting based both on current Finnish conservation legislation and on existing offset practices in the Conservation Banking (U.S. Fish and Wildlife Service (USFWS) 2003, California Department of Fish and Wildlife (CDFW) 2015a, 2015b) of the USA, and the Biodiversity Offsets Scheme of Australia (Office of Environment and Heritage (OEH) 2017; see also Burgin 2008, Koh et al., 2019, Wheeler & Strock 1995). We especially searched for practical guidance in how to develop the prevalent biodiversity survey practices to meet the needs of biodiversity offsetting and to consider especially nature values that are in the risk of disappearance as the Finnish framework currently suggests (USFWS 2003, CDFW, 2015a, 2015b, Kujala et al. 2021, New South Wales Government (NSWG) 2017). Table 2 compares the site characteristics addressed in these schemes with those of two contemporary Finnish forest conservation programs.

We analyzed the 206 biodiversity surveys focusing on the 39 selected criteria (inventories) listed in Table 1. The criteria are based on the inventories found in the surveys that are also relevant to the site characteristics listed in Table 2. Hence, the list includes certain ecological and geographical criteria that were addressed as such in the surveys and are important for biodiversity in Finland while also providing information on the habitat conditions for different species (e.g. soil type).

Although the size and location of the study area should be important parameters for any biodiversity survey, we had considerable difficulties in identifying the locations of some surveyed sites. Sometimes the surveys included maps without a scale. Therefore, we used ArcMap 10.3.1. (ESRI 2015) to measure the areas of each survey location from the maps provided by the surveyors. We then calculated the difference between reported and measured survey area sizes for surveys that included all five legislation related criteria (n = 58), were conducted for smaller areas than entire municipalities and reported both the size of the study area and provided a map of the area (n = 20).

Biodiversity offsetting requires, by definition, a comparison of nature values between the planned development area and the offset area. To determine whether biodiversity surveys in Southwest Finland are sufficiently similar to each other to allow a comparison of their nature values, we made a cluster analysis to study the degree of qualitative homogeneity of the biodiversity surveys (n = 206) based on Table 1. In clustering, surveys that were similar to each other and dissimilar to the surveys belonging to other clusters were grouped together. We clustered (i.e. grouped) the biodiversity surveys using X-means clustering model (Pelleg & Moore 2000), which is an extension to the more traditional k-means clustering algorithm as it does not require determination of the cluster numbers a priori. Instead, X-means algorithm determines cluster numbers by a Bayesian information criterion (BIC), or in other words, it makes local decisions about which subset of the current cluster centroids should split themselves in order to better fit the data. Predictor value combinations that maximized confidences of each cluster were searched using an evolutionary algorithm (Beyer & Schwefel 2002). The general performance of the X-means model was evaluated by using the Davies-Bouldin validity index (Davies & Bouldin 1979). It evaluates both the intra-cluster similarity and the between-cluster differences. The statistical analyses were performed using the RapidMiner software (version Studio Large 9.6.000., https://rapidminer.com /, Mierswa et al. 2006).

Table 1
Quality criteria of biodiversity surveys (n = 206) in relation to the requirements of the contemporary legislation. The five legislation-related criteria (inventories) are shown in *italics*. Other listed inventories were used for clustering of surveys (see text for details). The column % shows the percentage of the 206 surveys that included the specific inventory.

Group	Site characteristic to be inventoried	%
A. Protected habitats and valuable places	*Habitats protected by Nature Conservation Act*	86%
	Habitats protected by Forest Act	84%
	Habitats protected by Water Act	75%
	Habitats protected by Habitats Directive	4%
	Endangered habitats*	8%
	Other places of natural value**	37%
B. Protected species	*Habitats Directive Annex IV (a) species*	39%
	Endangered species (Nature Conservation Decree)	45%
	Endangered polypores	55%
	Endangered epiphytes	56%
	Endangered vascular plants	75%
	Birds Directive Annex I species	59%
	Endangered birds	49%
C. Landscape and vegetation	Vegetation types	76%
	Vegetation inventory	85%
	Landscape value***	34%
	Traditional landscape	22%
	Ecological corridors	15%
D. Other valuable species	Near-threatened species	16%
	Near-threatened vascular plants	22%
	Rare species	12%
	Rare vascular plants	26%
	Specifically protected species	13%
	Demanding vascular plants	31%
	Special responsibility species	1%
E. Geographical criteria and forest age	Area size	24%
	Soil/bedrock	25%
	Topography	17%
	Age of trees and amount of coarse woody debris	69%
	Geographically valuable sites	24%
F. Species observations, Siberian flying squirrel, moor frog presence	Bird observations	75%
	Bat inventory	7%
	Potential bat habitat	30%
	Mammal observations	22%
	Butterfly observations	6%
	Potential Siberian flying squirrel habitat	62%
	Siberian flying squirrel present	21%
	Moor frog present	2%
	Potential moor frog habitat	15%

* Based on Raunio et al. (2008), ** Based on surveyor's own expertise, *** Written as such in the text.

3. Results

3.1. Geographical and temporal distribution of biodiversity surveys and survey area sizes in Southwest Finland

The geographical locations of biodiversity surveys (n = 206) were widely distributed in the study area of Southwest Finland with only one district having no surveys (Fig. 1). The number of surveys taken in different cities and municipalities (n = 27) varied from 0 to 41.

For the 20 surveys that provided maps and met all 5 legislation related criteria, we also conducted a paired *t*-test between the reported area sizes of surveyed sites and those calculated with the ArcMap. The difference was not significant ($t = 0.61$, $df = 19$, $p = 0.548$), but in some individual surveys the areas reported in the text differed considerably from those indicated in associated maps of survey areas.

Table 2
Site characteristics addressed in the US Conservation Banking Scheme (USFWS 2003, CDFW 2015a, 2015b), Australian Biodiversity Offsets Scheme (OEH 2017), and the Finnish Metso (Ministry of the Environment 2016) and Old Growth Forest Conservation (Old Growth Forest Conservation Work Group 1992, 1994) Programmes.

	USA	Australia	Finland
	Conservation Banking	**Biodiversity Offsets Scheme**	**Old Growth Forest Conservation Program, The Metso Program**
Species	Endangered, vulnerable, rare and decreasing species, also species' use value	Endangered and critical species	Endangered, rare, vulnerable, near-threatened, and indicator species
Ecosystems	Numbers of invasive vs. native species, habitats threatened by climate change, habitat of an endangered species, endangered, vulnerable, rare, and decreasing habitats	Vegetation condition, number of native species, maintenance of viable populations	Function and structure, vegetation condition, characteristics of primeval forest, forest cover structure (e.g. amount of coarse woody debris and age of trees), successional stages, important habitats for diversity
Diversity	Species and genetic	Landscape and species	Landscape, species, and genetic
Location	Connections to other conservation areas, topography, ecological corridors, land use in nearby areas, steady water availability	Connections to other conservation areas, regional value, ecological corridors	Surrounding areas, regional value, topography, ecological corridors, habitat islands, drainage basins and coherent water resources, soil nutrient and calcium concentrations
Area	Sufficient for sustaining viable populations	As large as possible	As large as possible

Biodiversity surveys (n = 206) were conducted throughout the study period (Fig. 2). The lowest number of surveys (n = 2) was taken in 2014 and the highest (n = 21) in 2008.

3.2. Clustering of biodiversity surveys

The main feature of the body of surveys is the variability of specific site characteristics inventoried in each survey (Table 1). This means surveys do not provide comparable biodiversity information. In this article, we use the word *inventory* to refer to the different components of the biodiversity surveys that examine a specific site characteristic. Hence, the maximum number of different inventories possibly done for a particular biodiversity survey was 39 (see list in Table 1). None of the surveys, however, included all 39 inventories. On average, the number of different inventories in single surveys was 14.3 (median = 15) with a range from only two (*habitats protected by Nature Conservation Act* and Traditional landscape) in one survey to 31 different characteristics inventoried in another. The most common inventories (carried out in > 80% of the surveys) were the *habitats protected by Nature Conservation Act*, vegetation inventory, and the *habitats protected by Forest Act*. The remaining three inventories that we used as legal criteria, i.e. the *habitats protected by Water Act,* the *endangered species (Nature Conservation Decree)* and the *Habitats Directive Annex IV (a) species*, were included in 75%, 45% and 39% of all the surveys, respectively. Consequently, most of the surveys do not provide sufficiently comprehensive biodiversity information for offset purposes.

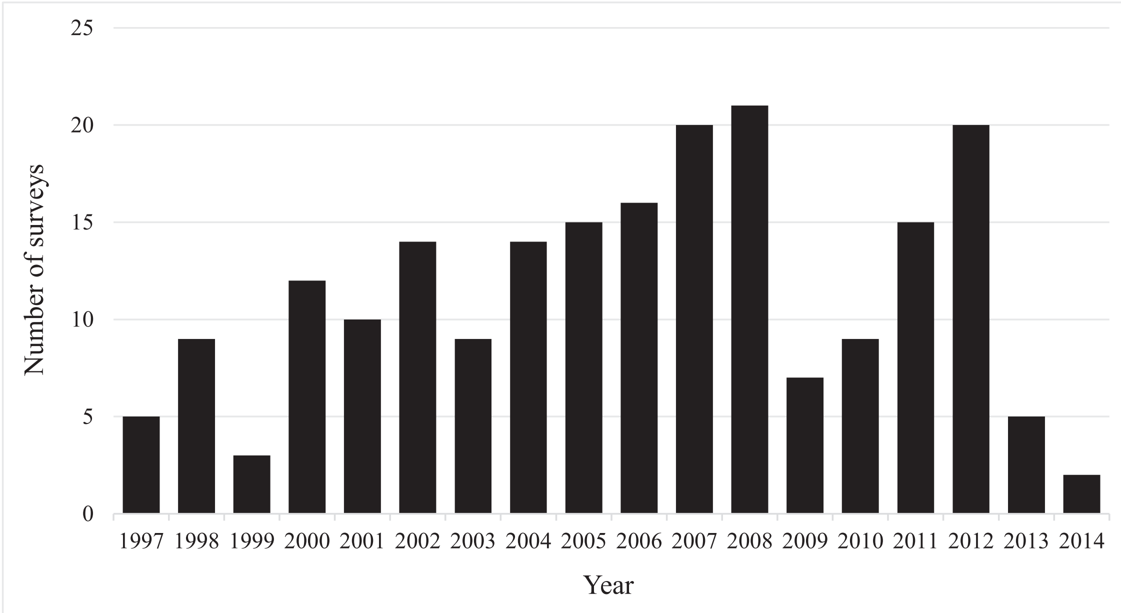

Fig. 2. Number of surveys per year between 1997 and 2014. The list of 2014 surveys was probably not complete as the data were obtained during the year 2014.

In our analysis, we found three distinguishable clusters (groups) of surveys (Fig. 3). The cluster 0 (Landscape) (n = 74) was characterized by a smaller average number of inventories, 9.6 per survey (median = 10) than clusters 1 (Legal-institutional) (n = 78) and 2 (Ad-hoc conservation) (n = 54) which included an average of 17.8 (median = 18) and 15.5 (median = 16) inventories per survey, respectively. A typical survey (mean occurrence > 0.66) in all clusters included a vegetation inventory, and the inventories of vegetation types and the age of trees and amount of coarse woody debris. If the mean occurrence is set to > 0.50, then a typical survey in all clusters also included the *habitats protected by Nature Conservation Act*, bird observations, *habitats protected by Forest Act*, and endangered vascular plants.

The most distinctive (the cluster centroids, i.e. mean occurrence values, differ most positively from the other two clusters) inventories characterizing the cluster 0 (Landscape) are soil, topography and landscape value which are all related to landscape and geographical features (Fig. 3). Also rare vascular plants and butterfly observations are distinctive features for this cluster. None of the most defining inventories for the Cluster 0 (Landscape) are legally required, and this cluster group does not include any of those 58 surveys that have all the five legally required inventories in them. On the contrary, some of the legally most important inventories are those that are the least typically characterizing for the Cluster 0 (Landscape) such as *Habitats Directive Annex IV (a) species* and *endangered species protected by the Nature Conservation Decree*. Surveys belonging to this cluster would not be fit for offset purposes as all necessary legal requirements are not met.

On the contrary, Cluster 1 (Legal-institutional) includes 57 out of the 58 surveys that have all the legal criteria inventoried. The most distinctive inventories for this cluster are the legally required *endangered species protected by the Nature Conservation Decree* and *Habitats Directive Annex IV (a) species* (Fig. 3). The next most distinctive inventories are other places of natural value (based on surveyor's own expertise of valuable places that are not included in any decrees), endangered polypores and near-threatened species. The least characterizing inventories in this cluster are demanding vascular plants with strict ecological requirements, potential moor frog habitat, traditional landscape, and potential bat habitat and vegetation inventory. However, vegetation inventory was included in over 80% of all surveys. Cluster 1 (Legal-institutional) includes surveys that would be the most suitable for offset purposes because they most often fulfill the legal criteria and explicitly consider the endangered species and habitats.

Cluster 2 is named Ad hoc-conservation as the cluster is characterized by very different inventories that do not belong to any particular group like inventories in Cluster 0 (Landscape) and Cluster 1 (Legal-institutional). Cluster 2 includes one survey with all 5 legal criteria inventoried in it. The most characteristic surveys for this cluster are demanding vascular plants with strict ecological requirements, potential moor frog habitat, traditional landscape, potential bat habitat and endangered birds (Fig. 3). Almost all of these inventories, with the exception of endangered birds, are the least characterizing inventories for the Cluster 1 (Legal-institutional). Accordingly, the least characterizing inventories in Cluster 2 (Ad hoc-conservation) are the most characterizing ones in Cluster 1 (Legal-institutional) but in reverse order. Inventory of geographically valuable places is also one of the least characterizing inventories for the Cluster 2 (Ad hoc-conservation). Surveys of this cluster would not be suitable for offsetting because the legally required *endangered species protected by the Nature Conservation Decree* and *Habitats Directive Annex IV (a) species* are rarely inventoried in the surveys.

3.3. Survey objectives and profiles of biodiversity surveyors

In our survey data, biodiversity survey reports invariably began with an introduction articulating the survey's objectives, e.g. by providing information of municipal plans, planned development of wind power plants, power lines, or mineral extraction. This was followed by a description of materials and methods, as well as a review of the previous knowledge of the area.

The presentation of results, however, differed widely between surveys, which is problematic as the information for offsets should be comprehensive and comparable between different areas. The vegetation inventory specificity varied from vegetation being carefully described to the species level to only a few common species listed with a rather superficial description of vegetation in the area. The other taxa included in the surveys also differed widely e.g. from birds and/or mammals to insects. Some surveyors estimated the total number of species or presented census data concerning particular species, whereas other surveyors only listed species observed in the field surveys. The surveys usually had a conclusions section that summarized findings for protected species or habitat types, with some recommendations for the area's future use.

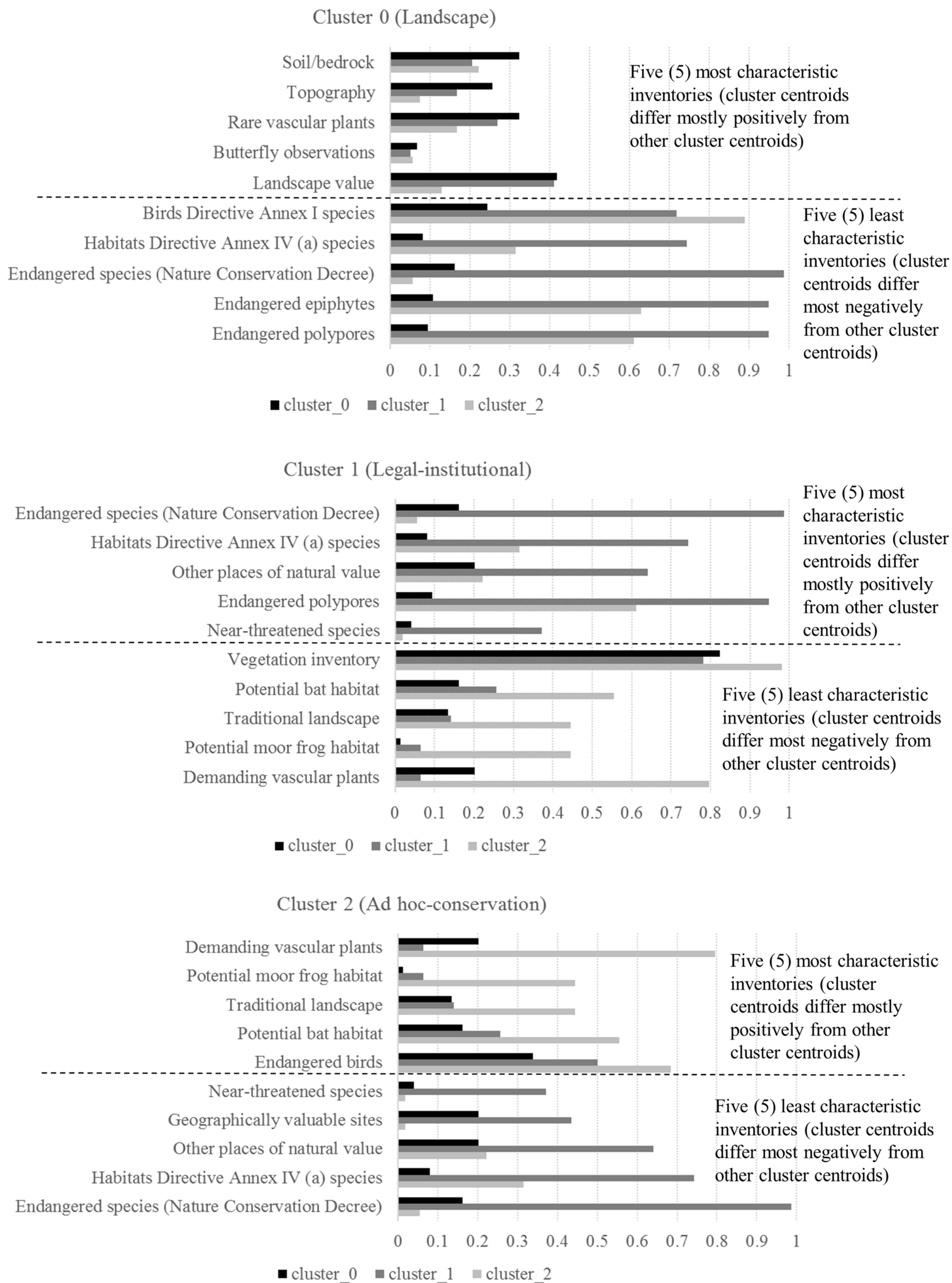

Fig. 3. Characteristics of the three clusters of biodiversity surveys. The bars present the cluster centroids (mean occurrences). The longer the bar the more often the specific inventory was carried out in a survey belonging to a specific cluster. The figure shows the 5 most characteristic (above the dashed line) and uncharacteristic (below the dashed line) inventories per cluster. All cluster centroids are presented in the supplementary materials. The most characteristic inventories for a cluster are those whose cluster centroid differs most positively from the other cluster with the closest cluster centroid. The least characteristic inventories for a cluster differ negatively from the other clusters in a similar way.

Most of the biodiversity surveys (79%, n = 163) were conducted for zoning at different levels of municipal planning (Fig. 4); of these 89 (43%) were made for detailed plans, 47 (23%) for detailed shore plans and 27 (13%) for master plans. Mostly this meant identifying areas suitable for housing or other infrastructure construction. The other biodiversity surveys were performed in projects related to wind power plans (11), different infrastructure projects (8), for projects related to rehabilitation or conservation (8), basic surveys to assess the nature

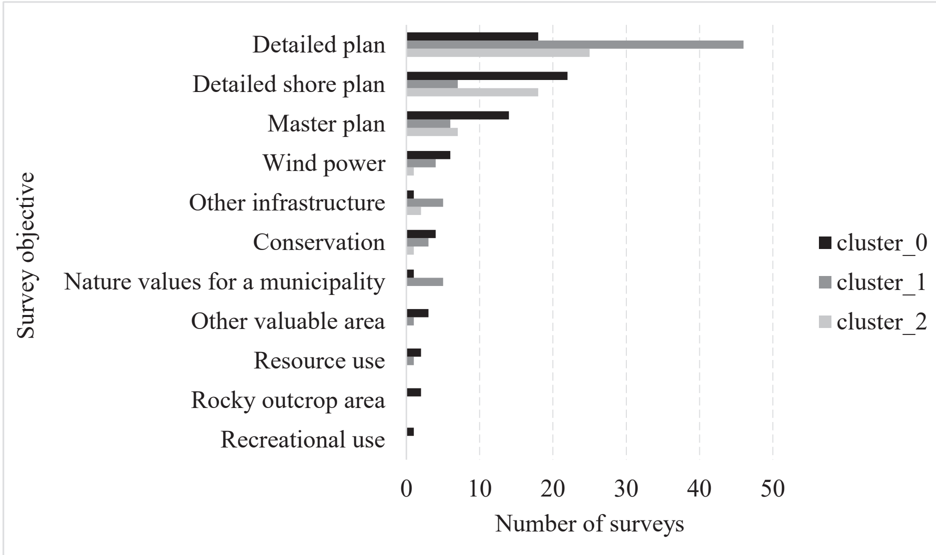

Fig. 4. Survey objectives and the number of surveys belonging to different clusters.

values in given municipalities (6) or other valuable areas (4). Three biodiversity surveys were related to the use of natural resources, and two done to estimate the possibilities for mineral extraction. One survey was conducted in relation to recreational land use.

There were statistically significant differences among survey objectives in relation to clusters ($X^2(6) = 31.6$, p <.001). Surveys falling into Cluster 1 (Legal-institutional) were significantly more common in detailed plans than in detailed shore plans. In surveys conducted for master plans Clusters 0 (Landscape) and 2 (Ad hoc-conservation) dominated over Cluster 1 (Legal-institutional).

There were also significant differences between surveyors in their professional profile, measured as proportions of their studies focusing on particular clusters ($X^2(4) = 134.4$, p <.001). For instance Surveyor 1 clearly focused on surveys in Cluster 2 (Ad hoc-conservation), while Surveyors 3 and 4 had a strong focus on Cluster 1 (Legal-institutional) type surveys (Fig. 5).

4. Discussion

This study examined the currently available body of biodiversity surveys in Southwest Finland with the aim to evaluate the usability of existing survey methods in biodiversity offsetting, compared to the general data requirements of such offsetting schemes (Table 2) and future Finnish offset requirements. It is important to note that the objective was not to find real sites suitable for offsetting from the studied surveys. This would be impossible because construction or other projects, for which the local surveys were originally performed, may in many or most cases have already destroyed or weakened the documented nature values. Our objective was instead to document the adequacy of current biodiversity surveys by assessing how well they cover the site characteristics that are considered essential for offset purposes. Based on our results, biodiversity surveys in Southwest Finland were neither comparable nor comprehensive enough in terms of inventoried site characteristics to be useful for offset purposes as they were highly variable both in their presentation of the results and the information content provided (Figs. 3–5). The surveys were divided into three

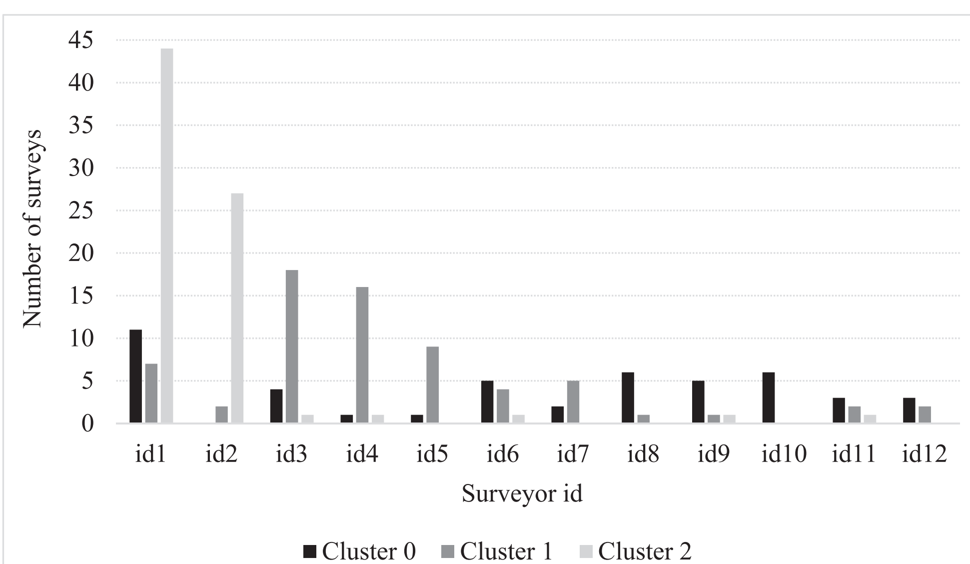

Fig. 5. The division of biodiversity surveys by individual surveyors (n = 12) into different clusters.

clusters that differed in their emphasis of nature-related information provided (Fig. 3). It also seems that the contents of biodiversity surveys depended on the land use planning context (Fig. 4) and the professional profile of the surveyor (Fig. 5). The pessimistic view presented by Söderman (2003, 2004) concerning variable methods and reports thus gained support. Similarly, Mäkeläinen and Lehikoinen (2021) found that also Finnish biodiversity impact assessments could be improved in terms of studied biodiversity attributes.

Despite the variability of surveys, they seemingly served their purpose and fulfilled the assigned requirements as normally surveyors did more than one survey. As there are no official standards and requirements for biodiversity surveys in Finland, it is possible that the surveyor investigates only specific nature values, those listed in the contract with the client or those indicated in the scoping report for the land use plan. It can also be that surveyors' own expertise is reflected in the inventoried site characteristics and hence affects the clustering results. Since 2018 it has been possible for biodiversity surveyors to obtain a certificate primarily for their professional competence in species and habitat type identification (Finnish Environment Institute 2018), but no quality standards for biodiversity surveys are included in the certificate. However, for offset purposes it would be advisable to use only certified biodiversity surveyors to ensure appropriate methods and adequate ecological skills, especially in identifying species and habitats for comparable and comprehensive surveys.

Based on our results, there are three major qualitative problems with the state-of-the-art biodiversity surveys in Finland with regard to offset requirements and achieving NNL of biodiversity. The first problem is their failure to meet the requirements of biodiversity offsetting schemes when it comes to assessing specific nature values. This is true for both mandatory legally-based requirements for biodiversity conservation, and for so-called "non-mandatory good practices encouraged by the offset policies" (as defined by Bezombes et al. 2018).

A key issue in any offset scheme is to assess the defined components or indicators of target biodiversity (Quetier & Lavorel 2011). This, in turn, requires a certain level of agreement on the definition of biodiversity (Bezombes et al. 2018), and on the values of biodiversity that need to be assessed in evaluation of ecological equivalence between development sites and offset sites. The definition based on the Convention of Biological Diversity requires a multilevel approach with biodiversity value identification at both habitat/ecosystem and species levels. Following Noss (1990), Bezombes et al. (2018) identified composition, structure and function as the three primary attributes of biodiversity to be studied at each level of biological organization.

We found that the analysed Finnish surveys did not always consider even the five legislation related mandatory criteria which means that the target biodiversity, i.e. endangered and protected species and habitats, could be lost or damaged without adequate compensation. Furthermore, if the aim is to offset only legally protected species and habitats it is clear that many other nature values, i.e. those recommended as non-mandatory good practices (Bezombes et al. 2018), could be lost in the process. Interestingly, some non-mandatory nature values were included in the studied surveys. In fact, none of the most defining site characteristics addressed for Cluster 0 (Landscape) were legally required.

Kujala et al. (2021) suggested that at least the forthcoming voluntary Finnish offset scheme should indeed consider as many nature values as possible, both mandatory and non-mandatory. This would set the qualitative requirements for biodiversity surveys in biodiversity offsetting to a high level. In addition to the legally required inventories done in the surveys, also endangered habitats and habitats protected by Habitats Directive, near-threatened, rare and regionally rare species as well as EU defined special responsibility species with restricted distributions should be considered in order to reach or maintain the favorable conservation statuses of species and habitats required under the Nature Conservation Act (1996) and the EC Habitats Directive (1992). Moreover, genetically distinct local populations should be assessed if possible, both because genetic-level biodiversity is emphasized by the Convention on Biological Diversity, and because their loss can affect the long-term survival of species in the rapidly changing environment (Moreno-Mateos et al. 2015). Also, the amount of decaying wood is an important indicator of Finnish forest quality in terms of species diversity (Kotiaho et al. 2016), and should thus be included in surveys. Kangas et al. (2021) for instance suggest an offset calculation method that considers the amount of decaying wood, broad-leaved trees and large trees to be used for assessing the habitat quality of boreal forests.

The second problem considers the lack of adequate spatial data (Table 2, see also e.g. Bezombes et al. 2017). An important aspect of offsets is their size and how they are located in the landscape, especially in relation to the development site. The required size of the offset site is advised to be calculated with multipliers which can result in considerably larger offset areas than the associated development areas (Moilanen et al. 2009, Laitila et al. 2014). Zu Ermgassen et al. (2019) found that using a high multiplier was the most common positive factor in achieving NNL. Offsets are also usually advised to be located in the close proximity of the development area to ensure similar nature values between sites, because biotic and abiotic conditions are most likely shared between areas located in the same biogeographical area (Huston 1994). Allowing a greater distance between sites might bring more options and reduce costs (Moilanen & Kotiaho 2018), but problems could easily appear due to reduced ecological equivalence between offset and development sites. Standardizing the surveys to include appropriate maps of the areas would advance accurate sizing of the offsets and locating them near the development sites.

Precise spatial data will also be needed for the consideration of the area's entire landscape context (Quetier & Lavorel 2011, BBOP 2012). Berges et al. (2020) emphasize the importance of landscape connectivity and well-connected habitat patches in reaching NNL. Strategically located offset sites can contribute to conservation area networks that enable the movement of species, individuals and genes between different areas and habitat patches. Different tools and methods for the inclusion of landscape connectivity should be part of offset planning process (Kujala et al. 2015, Berges et al. 2020). Furthermore, considering the impact of the planned project on habitat fragmentation can provide information about how the planned development may affect ecosystems (e.g. rivers and streams) in a wider perspective or increase disturbance around the development area through increased accessibility, noise, and light (Moreno-Mateos et al. 2015). Including offsets into landscape planning can also advance cost-effective conservation (Underwood 2011, Kujala et al. 2015, Kennedy et al. 2016).

Accurate mapping is also important as biodiversity contributes to ecosystem services from flood regulation to recreational use (MEA 2005) and these services should remain available for people in the same local community where the development takes place (Moilanen & Kotiaho 2018). The maintenance of social equity and recreational values, for instance, strongly supports relative proximity of development and offset areas (Kalliolevo et al. 2021). Griffiths et al. (2019) suggest that project-affected people should perceive the component of their wellbeing associated with biodiversity losses and gains to be after offsets at least at the same level as before project implementation. Useful practical principles for ensuring the NNL for people are available (Bull et al. 2018b).

The third major problem with the documented biodiversity surveys is their considerable heterogeneity in contents, clearly demonstrated by the division of surveys into three rather distinct clusters. Some biodiversity surveys even failed to unequivocally report which nature values were considered, or whether some values were omitted simply because they did not exist in the area. This is problematic for reaching ecological equivalency between sites, because the surveyed nature values should be the same in all surveys of the project. The current practice of having variable different inventories in different biodiversity surveys makes their comparison very difficult if not impossible. It is possible that the ongoing certification process of nature surveyors will standardize their expertise and help reaching the requirements needed for offset surveys.

Standardization of the survey methods is crucial, because biodiversity losses and gains should be assessed identically on both development and offset sites if the ultimate aim is to achieve ecological equivalence for NNL (Quetier & Lavorel 2011). In the Finnish case this means that if the target biodiversity will be defined solely based on mandatory legislation related requirements that focus on endangered species and habitats, a set of indicators and metrics for quantifying those particular values should also be explicitly decided upon and then surveyed by using identical methods (see e.g. Maseyk et al. 2016, Bezombes et al. 2017, Bezombes et al. 2018). It is yet unclear how the target biodiversity will be measured in Finland, but the metrics for biodiversity evaluation should obviously include, in addition to mandatory requirements, criteria related to composition, structure and function at both species and habitat levels (Bezombes et al. 2018).

Specific indices have also been proposed for use in offsetting to ensure NNL and to account for ecological equivalence such as the net present biodiversity value (Overton et al. 2013) or "habitat hectares" (Parkes et al. 2003), but their usability is limited by the great amount of biological and landscape information required for meaningful habitat comparisons. By using simplified calculation metrics for biodiversity, some important components may be overlooked and NNL is not achieved (Overton et al. 2013). Marshall et al. (2020) found that current offset metrics are indeed unlikely to capture all important biodiversity values. Instead of using only habitat and vegetation-based metrics, offsets should account for species-level information more precisely (Kujala et al. 2015, Marshall et al. 2021).

5. Conclusions

Although our biodiversity survey data were entirely Finnish, our results hold general relevance, particularly with respect to the content, comparability and presentation of the surveys. Also, as Finland is a member of the EU, and important nature related EU directives guide nature conservation in all member states, our study can provide beneficial information about biodiversity measurements required in offsetting in all member states. We found remarkable shortcomings in the quality of most local level biodiversity surveys. We do not criticize the surveyors, however, because the content of the surveys most likely responds to the terms of reference of their assignments and remuneration (Punttila et al. 2018), and hence the client should also be required to order adequate surveys. In current situation, the result is that the surveys differ greatly in their contents and clearly fail to meet the qualitative requirements of biodiversity offsetting schemes. Overall, surveyors, their expertise and the terms of reference should be better aligned.

We suggest that data collection for biodiversity offsetting in Finland and elsewhere should in all cases be standardized to consider the inclusion of valuable species and habitat types listed in national legislation as well as those nature values under the risk of not having favorable conservation status, and to confine biodiversity offsetting within particular biogeographical areas, and at all phases of projects apply the best available geoinformatics systems to consider the whole landscape context with habitat networks. This standardization of the surveys considers the principal aspects of offsets and what kind of initial ecological and geographical data are needed to achieve NNL. However, calculating equivalent losses and gains requires even more comprehensive surveying of the areas to estimate the ecological quality or functioning of the sites. Accordingly, the next steps in the planning process for offset surveys requires specific decisions on the indicators used to measure the target biodiversity, whether this is concentrating on species or on ecosystem condition. Nevertheless, comprehensive and high-quality biodiversity surveys are required for documenting and monitoring the actualization of anticipated gains or to demonstrate where the offsets fall short. Without adequate and compatible surveys the nature values of different sites cannot be compared and achieving NNL will be highly unlikely.

Although remote sensing and other novel methodologies (for example, airborne lidar) may provide a considerable amount of useful background information for biodiversity surveys, surveyor *on-site* visits to study areas will always be required to confirm species identification and microhabitat issues.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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