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REVIEW

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A global analysis reveals a collective gap in the transparency of offset policies and how biodiversity is measured

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Abstract

Offsetting policies have increased worldwide, utilizing a range of biodiversity metrics to compensate for development impacts. We conducted a global analysis of offset legislation by reviewing policies from 108 countries, which have voluntary offsets, or which require offsets by law. We sought to understand how well biodiversity metrics and offset currencies are documented in current policies. Where biodiversity metrics are documented we aimed to understand how metrics were scored, combined, and multiplied to create offset currencies. We found only 22 jurisdictions (from 14 countries) had guidelines documenting how biodiversity should be assessed during offsetting, representing a significant gap in the guidance available for offsets. Of the 22 guidelines, 14 (63%) documented use of aggregated currencies, eight (23%) did not aggregate biodiversity metrics into a single currency, and three (17%) did not specify either approach. Habitat type and condition, as well as area, were widely recommended across policies (>50%). Where species-level metrics were considered, guidelines generally focused on habitat distributions rather than abundance or population metrics. The lack of consistent and clear guidance about how biodiversity should be measured in offsets reduces our ability to determine the effectiveness of offsets in compensating for development impacts long term.

KEYWORDS
biodiversity, biodiversity metrics, biodiversity offsets, global review, policy

1 | INTRODUCTION

As a conservation tool, offsets aim to achieve a no-net-loss of biodiversity by compensating impacts at a development site with commensurate gains elsewhere (Bull et al., 2013; Maron et al., 2016, 2021). Equating development impacts and offset requirements in these trades can be challenging and the currencies used to trade biodiversity depend largely on the overarching policies under which the offset is required (Maron et al., 2018). These policies should provide guidance on how biodiversity should be measured at the impact and offset site so that equitable trades can be made (Bracy Knight et al., 2020; Bull et al., 2019; Marshall et al., 2020).

Despite the need for clear guidance, the terminology used to describe how biodiversity is valued and traded in offsetting is inconsistent. Hereafter, we use three key terms: biodiversity metric, score, and currency. We use the term metric to describe the aspect of biodiversity being measured, that is, ground cover, species richness etc., whereas we use score to describe how the biodiversity is valued, that is, its contribution to a currency. The term currency is used to describe how the scores for all biodiversity metrics in an offset are combined to get a composite value to be offset.

The biodiversity metrics used in offset design are important as they determine both the type of biodiversity that must be offset, alongside the scale and extent of offset actions required to match losses for gains (Moilanen & Kotiaho, 2021). Measuring offset trades can be based on assessment of biodiversity at a range of levels, from broad habitat types, or vegetation classes, to species-specific requirements (Boykin et al., 2012; Whitehead et al., 2017). Some levels of measurement focus on broad patterns of species occurrence, others on communities (e.g., diversity indices) and some attempt to capture the processes driving population persistence (e.g., metapopulation capacity; Ferrier & Drielsma, 2010). The components of biodiversity, which are measured in offsets, should depend on the overarching legislation and what it is aiming to achieve (Maron et al., 2018; ten Kate et al., 2004), though the expertise, and preferences of key technical people in each jurisdiction are also likely to play a role in what is measured.

In the past, policies have focused predominantly on assessing habitat characteristics and condition to quantify biodiversity (Maron et al., 2012; ten Kate et al., 2004). The rationale for these methods is that by characterizing the habitat affected, outcomes for key species or communities will be adequately represented (Cristescu et al., 2013). Vegetation classes or metrics such as number of large trees or extent of ground litter cover can be relatively easily assessed and may be an effective method for capturing broad habitat patterns for some species (Le Roux et al., 2016; Marshall et al., 2020; Oliver et al., 2014; Travers et al., 2018). These types of metrics are easier to measure than species-specific abundance and demographic data and are therefore often used as surrogates for the species and communities they support (Andréfouët et al., 2012; Gascón et al., 2009; Schmeller et al., 2017).

There is a growing body of scientific literature demonstrating that the habitat-based biodiversity metrics used during offsetting generally fail to capture development impacts, particularly on species and communities (Cristescu et al., 2013; Hanford et al., 2016; Marshall et al., 2022). Over time, reliance on metrics, which do not accurately measure development impacts on species and populations, will ensure offsets fail to deliver their claimed benefits and perpetuate biodiversity declines (Josefsson et al., 2021; Marshall et al., 2021). Increasing awareness of this problem has sparked extensive exploration of metrics, which could improve biodiversity assessment in offsets (Bradford et al., 2016; Marshall et al., 2021; Maseyk et al., 2016; Minns et al., 2011). While there has been significant interest in understanding how biodiversity is quantified, there has been little consensus on how to convert biodiversity metrics into tradable offset currencies (Bracy Knight et al., 2020; Gardner et al., 2013). Approaches for measuring biodiversity and calculating offset requirements can be complex and opaque, with important assumptions often unclear. There is also a high potential for information about biodiversity to be lost or inappropriately transformed in the exchange (Maseyk et al., 2016). Lack of clear guidance on how to score and trade biodiversity has resulted in a plethora of approaches, which are not well scrutinized (Hanford et al., 2016; McCarthy et al., 1999; ten Kate et al., 2004).

Multipliers are used in offsetting to account for uncertainties in offset success, time-lags, and spatial uncertainties, habitat quality concerns, or to account for threatened groups and ecosystems, which may be more difficult to recover through offsetting (Moilanen & Kotiaho, 2018, 2021). Given the limited time and budgets available for offset projects (Apostolopoulou & Adams, 2019; Budiharta et al., 2018), as well as the limited habitat in which offsets can be implemented, improving ecological outcomes, and reducing uncertainties should be a priority (Bull & Brownlie, 2015; Josefsson et al., 2021).

While research is increasingly addressing the ecological efficacy of the multipliers and biodiversity metrics used in offsetting (Bracy Knight et al., 2020; Bull, Lloyd et al., 2016; Josefsson et al., 2021; Laitila et al., 2014; zu Ermgassen et al., 2019), how they are captured in offset policies and guidelines globally has not been explored in detail. Here, we synthesize the biodiversity metrics, multipliers, and offset currencies used to trade development impacts around the world. We seek to determine how well policies from around the world document the biodiversity metrics and currencies required for implementing offsets under those policies. We assess the recommended biodiversity metrics and how they are, scored, and combined into offset currencies, as well as whether multipliers are incorporated. We discuss gaps in the current biodiversity metrics used in offsetting and the potential long-term implications of metric choice for biodiversity.

2 | METHODS

We used the Global Inventory of Biodiversity Offsets Policies (GIBOP) to systematically review policies from around

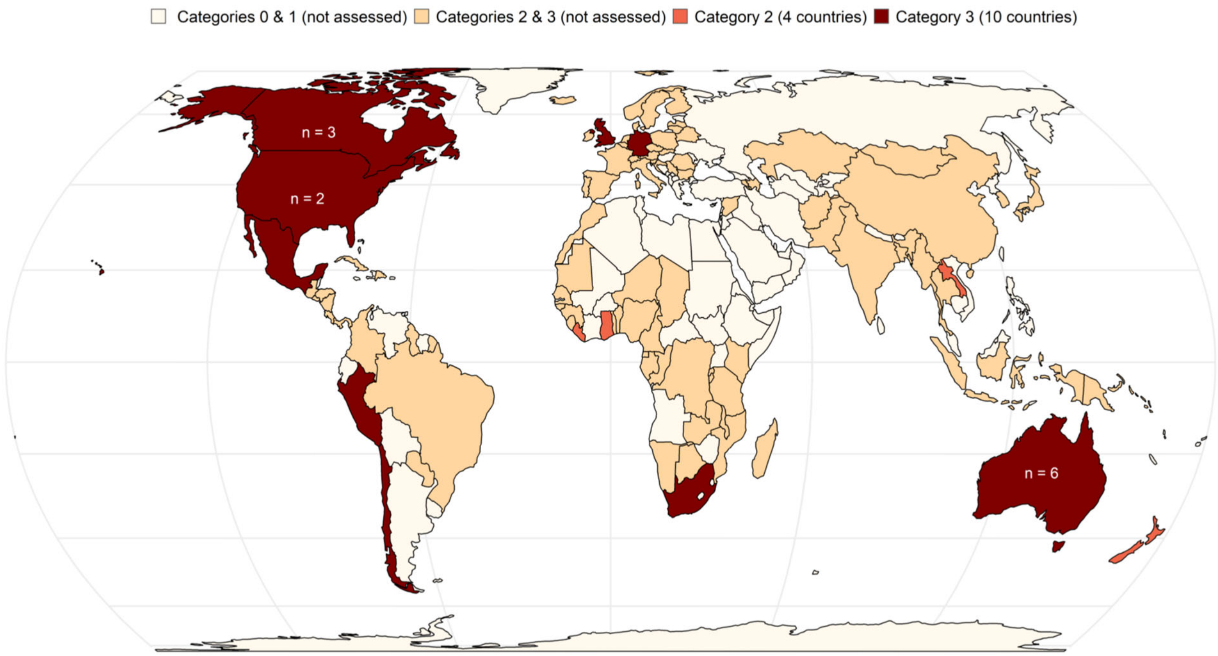

FIGURE 1 Stage of development categories for 198 countries around the world, as shown by the GIBOP database, and countries included in the review. We reviewed a total of 22 policies from four category 2 ($n = 4$) and ten category 3 ($n = 18$) countries. If more than one policy was reviewed for a country, the number of documents is given in white text. For all remaining countries, only one policy or guideline was assessed.

the world (Bull & Strange, 2018; International Union for Conservation of Nature et al., 2019). This is the most extensive collection of offset policies established thus far and contains policies for 198 countries (last updated September 5, 2019). Where policy documents were described in this database (i.e., in the author notes) but not uploaded directly to the database, we sought these out ourselves by following links provided by the authors or using Google to search for the referred document. Countries in this database are categorized according to stage of policy development: category 0 and 1 represents countries for which there is no or little offset supportive legislation; category 2 represents countries where offsets are a voluntary activity, and category 3 represents countries where a legislation requires offsets by law for at least some impacts. We collected all available documents, including the notes written by the database authors for a total of 108 countries from category 2 ($n = 66$) and 3 ($n = 42$; Figure 1).

We assessed the documents available to filter out policies. We were primarily interested in how recording biodiversity is quantified and how metrics are scored and combined into currencies. Therefore, we retained only the policies that specifically described—or referred to guidelines that described—the biodiversity metrics used for calculating offset requirements. Where these policies were not in English, we used the database authors' notes on the policy to determine if adequate guidance on biodiversity metrics were provided and Google translate in one case where these English notes were not available. We collected policy documents or policy notes (hereafter policy) and any guidelines, manuals, or case study reports (hereafter guidelines) that described biodiversity metric choice.

From these policies and guidelines, we recorded (i) the metrics used to measure biodiversity, for example, species richness, large tree counts, ground cover etc. (Table 1); (ii) how the metrics are scored and summarized into an offset currency, if it was described; and (iii) the multipliers used in offset currencies, to account for uncertainty, time-lags, threatened species, expected quality in offsets delivered etc. While there are often commonalities between approaches, different jurisdictions utilize different offset currencies. To simplify the range of possible currencies, we summarize a common structure for determining development impacts and offset requirements based on examples from the policies reviewed. This is not a one size fits all explanation for how these assessments are structured across all offset policies, rather a broad outline of the available information. Specific policies or guidelines often had unique terms for metrics (Table S4), so we classified them into broad categories following the procedures outlined in Marshall et al. (2020). We examined both the count of each metric subcategory assessed (Figure 1) and the proportion of policies, which used each metric at least once in guidelines (Figure 3).

TABLE 1 Final metric categories and the resulting 30 subcategories assessed for each policy.

Metric Category	Subcategory	Example metrics
Area	Area	Patch size (ha)
Habitat	Habitat type	Wetland vs. forested
	Habitat characteristics	Number of logs
	Habitat quantity	Percentage cover
	Habitat condition	Condition scores, e.g., 0 is degraded and 1 is perfect
	Habitat integrity	Intactness of habitat, e.g., soil erosion
Species and habitat suitability	Presence/absence	Occurrence records of a target species
	Habitat suitability	Species distribution maps
	Species abundance	Number of individuals
	Population density	Number of individuals per ha
	Rarity/irreplaceability	Uniqueness of a species in the landscape
	Persistence/viability	Population trajectories
	Species dispersal	Mean dispersal distance
	Demographic variables	Population growth rate
	Biomass	Dry weight of plant species
	Listed or protected attributes	The presence of a threatened species
Community	Genetic diversity	Number of alleles
	Species richness	Number of species
	Diversity indices	Shannon's index
	Taxonomic richness	Number of taxonomic groups
	Taxonomic abundance	Abundance of each taxonomic group
	Functional diversity	Number of functional roles
	Phylogenetic diversity	Number of evolutionarily distinct groups
	Complementarity	Complementarity
Connectivity	Structural connectivity	Landscape metrics
	Functional connectivity	Metapopulation connectivity
Other	Disturbances	Fire frequency
	Threat/risk	Likelihood of development
	Uncertainty	Likelihood of recovery
	Unclear classification/other	Cost of translocation

Note: More detailed descriptions of categories appear in Table S1.

3 | RESULTS

3.1 | Global state of offset policies

From the 108 countries we examined, 94 did not have guidance or documentation on biodiversity metric requirements and were not included in our detailed review. This was the only reason for exclusion. None of the policies were removed exclusively due to a lack of documents or notes available in English. Where there were no documents available in English, we used Google translated versions to determine the availability of guidance on how to measure biodiversity. Only 14 countries had any documentation to determine how biodiversity should be measured in offsets (Figure 1). We conducted a detailed review of a total of 22 documents from these 14 countries (Figure 1).

Policies or guidelines were from 10 countries where offsets are required by law (category 3; Australia, Canada, Chile, Germany, Luxembourg, Mexico, Peru, South Africa, England, and the United States) and four countries with legislation supporting voluntary offsets (category 2; Ghana, Laos, Liberia, and New Zealand; Table S2). The documents reviewed apply to both state and federal jurisdictions with multiple guidelines from Australia ($n = 6$), Canada ($n = 3$), and the United States ($n = 2$; Figure 1). Most policies referred to the protection or conservation of native vegetation, biodiversity, the environment, or habitats of importance as their stated policy goal (Table S3).

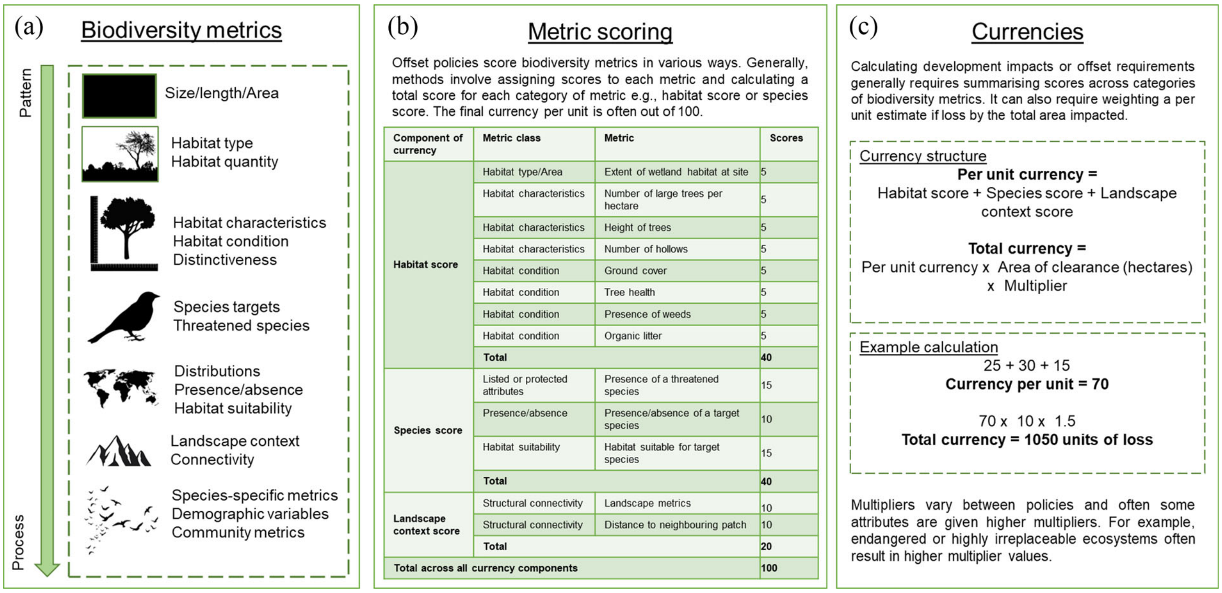

FIGURE 2 An example structure of biodiversity assessment and scoring systems for vegetation and/or habitat-based currency in the policies and guidelines reviewed ($n = 22$). The scoring system shows a hypothetical approach to measuring biodiversity attributes (a), weighting, summarizing (b), and combining these attributes into a single offset currency (c) to trade development losses for equivalent gains. The hypothetical calculation of offset currencies has been informed by the calculation used in the policies assessed.

3.2 | Structure of offset currencies

Policies may require assessment of impacts on habitat or species or both, depending on the type of impact (Gardner et al., 2013; Miller et al., 2015). Generally, policies first define a set of biodiversity metrics that must be assessed as part of the offset (Figure 2a). These metrics sit along an axis of pattern to process (Table 1; Ferrier & Drielsma, 2010; Marshall et al., 2020; Moilanen & Kotiaho, 2018). Sometimes individual metrics may be traded between sites but may not be combined into a currency format. However, often multiple metrics are scored and weighted to achieve a total score across multiple components (Figure 2b). To convert this into a tradable currency, calculations may be used to combine habitat, species, and landscape scores with total area lost, and multipliers (Figure 2c; Bull, Lloyd et al., 2016). For example, England's user guide summarizes several metrics into a single unit of loss using a currency called the 'biodiversity unit' (Natural England, 2019; Box 1).

The majority of the policies we reviewed (14 out of 22, 63%) used multiple biodiversity metrics and combined them into an offset currency (Table S3). These policies also specified a way of calculating an offset currency from the scored metrics. Five policies (23%) did not aggregate their metric scores into a single currency, but instead allowed a variable and context-specific use of metrics (Table S3). For example, the Canadian Fisheries Act, recommended several biodiversity metrics from which to choose, including habitat suitability indices, abundance, biomass, and even demographic variables, which can be incorporated into productivity models (Bradford et al., 2016; Minns, 1997). However, there is not a required approach for combining biodiversity metrics into an aggregated currency under this policy and different metrics may be used for different development impacts.

The remaining three policies (14%) from Mexico, South Africa, and Western Australia did not explicitly specify a currency but did not preclude use of an aggregated currency. The draft South African offset policy states that currencies may be used to assess offset requirements even though an explicit currency or calculation method is not specified (Department of Environmental Affairs, 2017). Similarly, the Western Australia policy refers to case studies using the federal offset calculation tool. In these cases, a habitat quality score was calculated from site condition, site context and species density although the currency selected using this tool depends on the target of the offset and the situation (Australian Government, 2012; Government of Western Australia, 2014).

Example offset currencies from three countries' guidelines: England, Peru, South Australia. See Table S3 for links to the documents describing these calculations

England (the biodiversity metric)

The recently proposed guidance for calculating biodiversity impacts and offset requirements uses four components, which are combined with risk weightings to get a biodiversity unit as follows:

Biodiversity units = Size × Distinctiveness × Condition × Strategic significance × Connectivity ×
Difficulty ×Temporal risk × Off-site risk

Here, size is the total number of hectares impacted. Distinctiveness is a score assigned based on the types of habitats present at the site. Distinctiveness values may be combined for multiple habitat types. Condition is the quality of habitat based on a set of criteria. Strategic significance is a score assigned based on whether the development or offset site has been deemed important for nature, that is, protected area. Finally, the connectivity score is how far away the patch is from similar or related habitat types. Risk weightings are also assigned based on the difficulty of recreating the habitat, how long the habitat will take to establish (Temporal Risk) and whether the offset is undertaken close to the impacted site (Off-site risk).

Peru (total ecological value)

Biodiversity impacts in Peru are calculated by assessing the total ecological value of a site and multiplying this value by the number of compensation units (area in hectares). Ecological value is a measure, which represents the summed conservation value of an ecosystem based on habitat characteristics such as site floristics, soil stability and habitat integrity.

Total Ecological Value = Ecological value × compensation units

South Australia (significant environmental benefit points)

In South Australia, points of loss are calculated using a biodiversity score per unit of area combined with a loss factor:

Unit Biodiversity Score = Landscape context × Vegetation condition × Conservation significance
Total Biodiversity score = Unit biodiversity score × Area of clearance (hectares)
SEB points of loss = Total biodiversity score × loss factor

The approach uses a total of 19 biodiversity metrics to calculate the main components of the unit biodiversity score. For example, the landscape context component considers distance between patches and amount of vegetation within the vicinity. Vegetation condition is assessed by several habitat characteristics, including number of hollows present, species diversity and presence and extent of weeds. The biodiversity score is scaled by area (total biodiversity score) and combined with a multiplier (loss factor) to get the total Significant Environmental Benefit points of loss (SEB points of loss). The loss factor varies depending on the scale of the impact, for example, the degree to which native vegetation will be impacted.

3.3 | Biodiversity metrics

Across the 22 policies, a total of 355 biodiversity metrics were recorded resulting in 439 occurrences across our metric subcategories. Occurrence records exceeded biodiversity metrics since some metrics fit into multiple subcategories. The number of metrics assessed in a single policy varied from two to 90 depending on policies and countries. Policies from Australia, Canada, New Zealand, and the United States listed more metrics overall (average = 29 across all four countries; Table S3). Habitat characteristics and area were counted most frequently (54 and 44 occurrences, respectively), followed by habitat type ($n = 40$), habitat quantity ($n = 37$), and listed or protected attributes ($n = 36$; Figure 1). Area and habitat quantity differed within the policies as area generally referred to size of an impact (in hectares), whereas habitat quantity was often used to measure the amount of a habitat type or feature for example, number of trees or percentage ground cover (Table 1).

Area was used in every policy/guideline (Figure 3) and was often counted as both a metric and used to scale the offset currency into a per hectare value (Figure 2). For example, the Queensland offset guidelines assesses patch size as part of a site context score. This score represents the overall habitat quality, which is then multiplied by a site scaling factor based on the number of hectares impacted (Queensland Government, 2017). Therefore, while area is included in the currency twice, this is an attempt to account for different features, for example, edge effects versus scaling size of impact. Following area, presence of protected or listed attributes (often threatened species), habitat condition, and habitat type were used in most policies (Figure 3). While listed or protected attributes were

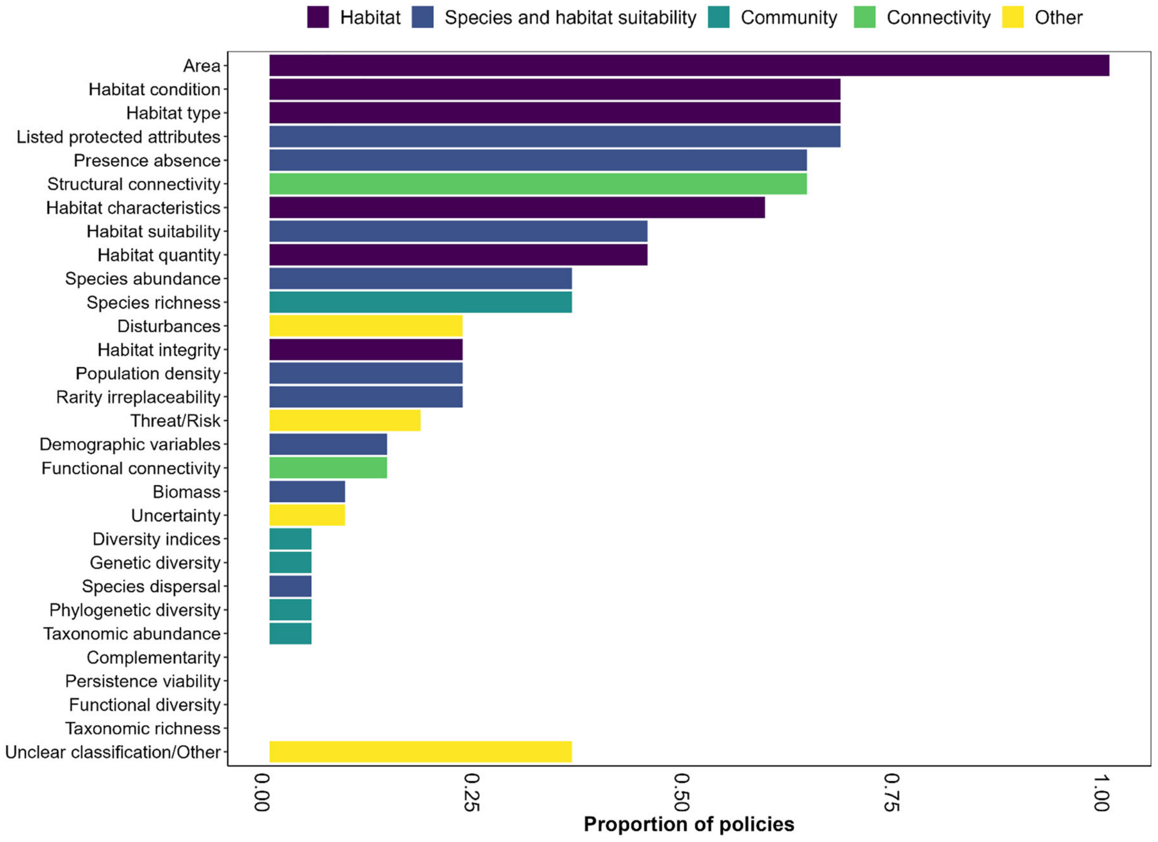

FIGURE 3 Proportion of policies ($n = 22$), which used each metric class ($n = 30$) at least once in their described approach for assessing biodiversity impacts and/or calculating offset requirements.

recorded in 68% and presences/absence of species was used in 64% of the policies respectively, metrics that describe or capture the processes driving species patterns and populations were not frequently used. For example, species abundance, density, demographic variables, species dispersal, and functional connectivity metrics occurred in fewer than half of the reviewed policies and guidelines ($n = 8$, 5 ,3, 1, and 3, respectively; Figure 3).

3.4 | Multipliers

Multipliers were mentioned in 19 of the 22 policies but specific values were only defined in 11 policies. For example, the Chilean "*Guide for Biodiversity Conservation in the Impact Assessment System*" states that multipliers should be applied subjectively depending on the uncertainty and associated risks of compensation (Environment & Services, 2014). Where multiplier values were specified, they varied between zero and 30 depending on the policy. These values were used to either multiply the overall offset requirement after development impacts have been calculated, or as scaling ratios when assessing the scores of individual metrics (Figure 2). For example, South Africa's draft National Biodiversity Offset policy specified the highest offset multipliers, requiring a ratio of 30:1 for areas set to lose irreplaceable biodiversity or critically endangered ecosystems (Department of Environmental Affairs, 2017). Most of the other policies reviewed specified multiplier values between zero and six.

4 | DISCUSSION

This is the first global review that specifically assesses the biodiversity metrics measured in offset policies and how these metrics are scored, combined, and multiplied into offset currencies. Emerging offset policies and guidelines highlight new opportunities to learn and improve best practices for offsetting (Gelcich et al., 2017; Milner-Gulland et al., 2021; Moilanen & Kotiaho, 2021). Of the 108 countries that require offsets by law for some impacts or have options for voluntary offsets, we identified only 14 that included policies with information on the biodiversity metrics relevant to making offset trades (Madsen et al., 2011; McKenney & Kiesecker, 2010). This illustrates a gap in the transparency of offset policies around the world, specifically that these policies are not often accompanied by explicit guidelines describing the biodiversity metrics required (Bracy Knight et al., 2020). However, a cautious interpretation of this finding is required given that policies and guidelines applied in some jurisdictions may not have been publicly available online or were not captured by our search due to language barriers; that is, they did not appear in the database authors' translated notes.

We observed a few notable examples of the disconnect between offset legislation and the presence of accompanying guidelines on biodiversity metrics and currencies. For example, France has a long history of ecological compensation and has established strong no-net-loss policies over the last decade (Madsen et al., 2011). However, under these policies there were no public guidelines on recommended metrics for assessing biodiversity. This has also been documented in reviews of French offset policy in the past (Quétier et al., 2014; Tarabon et al., 2019). Similar reviews for the EU demonstrate that while explicit guidelines are not always available to direct implementation of offsets in some European countries, offsets are still commonly used (Darbi & Tausch, 2010; Rayment et al., 2014). Therefore, it is likely that many offsets occur using undocumented metrics, or that more specific but non-public guidance for conducting offsets is available to proponents on a project-by-project basis within local jurisdictions. Seeking out the biodiversity metrics used in each individual offset project occurring under these policies was not within the scope of this analysis, given the ubiquity of offset projects occurring around the world (Bull & Strange, 2018). However, with offsets rising in popularity as a conservation tool around the globe, ensuring that specific guidelines and procedures are accessible for all offset supportive legalization is a necessary first step (de Witt et al., 2019).

In the reviewed policies and guidelines, area, habitat condition, listed or protected attributes, habitat type and presence/absence of species and habitats were the most recorded metrics (Figure 3). Over half of the policies required listed or threatened species, communities, bioregions, or vegetation types to be recorded (Figure 3). This is generally to ensure development impacts on at-risk populations and species are measured (Bekessy et al., 2010; Bracy Knight et al., 2020; Maron et al., 2012; Miller et al., 2015). However, metrics that describe patterns of occurrence for these listed features, such as habitat suitability, or richness, were required in fewer than half the policies assessed. Even fewer policies required assessment of abundance or population density or the demographic variables and functional connectivity metrics, which may describe the processes affecting persistence on a landscape scale (Figures 3 and S1). A distinct lack of policies, which incorporate or consider genetic and phylogenetic diversity, is also notable as these metrics are increasingly being incorporated into ecological and conservation management (Marshall et al., 2020). Consequently, many policies demonstrate a dichotomy where designing offsets requires that developers consider which species or communities are likely to be affected but not to measure anything, which might help inform conservation actions designed to protect them (Gibbons & Lindenmayer, 2007; Maron et al., 2010). Recent research has demonstrated the risks of ignoring such metrics on species persistence, emphasizing further that inadequate measurement of biodiversity may speed up declines in the populations or ecosystems offsets were originally designed to conserve (Buschke, 2017; Marshall et al., 2021, 2022). This risk is further compounded by a lack of transparency we observed here in terms of how these metrics are scored and combined to get an overall picture of biodiversity impacts (Kujala et al., 2022).

While all the policies we assessed described which biodiversity metrics should be used in some way, only 14 of them explicitly stated how metrics should be scored and aggregated into an offset currency. This may be due to the ad hoc approach with which many offsets are implemented (Brown & Penelope, 2016; Maron et al., 2016). However, in some cases, avoiding aggregate offset currencies is an intentional decision to prevent important biodiversity from getting lost in the exchange (Maseyk et al., 2016). Of the policies that did describe the offsetting currencies explicitly, many followed a similar approach; assessment of biodiversity metric, scoring and weighting these metrics, and calculation of offset requirements. However, the number and type of biodiversity metrics measured varied between policies and are generally dependent on policy goals. Different degrees of flexibility exist in the methods used to summarize biodiversity impacts and calculate offset requirements (Box 1: Bull et al., 2015; Moilanen & Kotiaho, 2018). For example, some policies like the Canadian Fisheries Act are flexible and allow the use of single or multiple metrics under the one approach to determine development impacts or offset requirements depending on the circumstances (Bradford et al., 2016; Poulton, 2014). Conversely, currencies such as the Biodiversity Assessment Method used in New South Wales (NSW) Australia, recommend the assessment, where possible, of over 30 different habitat and species focused metrics to determine impacts and assign offsets (NSW Office of Environment & Heritage, 2018).

Flexibility in offset currencies could potentially improve proponents' capacity to measure biodiversity more accurately and reduce requirements for large multipliers by increasing the likelihood that offset efforts will deliver more equitable outcomes (Bull et al., 2015; Kiesecker et al., 2010; Moilanen & Kotiaho, 2018). However, lack of transparency in many offset policies makes it difficult to estimate the potential benefits provided by the plethora of approaches, which can be used under these policies

(Kujala et al., 2022). Approaches for calculating offset requirements from the measured biodiversity metrics were described in 14 out of 22 (63%) policies. Similarly, multiplier values were only explicitly stated in 11 of the 22 policies we reviewed despite an almost ubiquitous recognition of the importance of accounting for uncertainty in offsets (Bull, Gordon et al., 2016; IUCN, 2014). When multipliers were specified, they varied widely depending on the biodiversity metrics impacted and the size of the development (Table S3). While flexibility in offset currencies may improve biodiversity outcomes (Bull et al., 2015; Moilanen & Kotiaho, 2018), the variation in methods we observed here makes it difficult to determine which approaches for assessing development impacts and assigning offset requirements are appropriate (Birkeland & Knight-lenihan, 2016; Curran et al., 2014). Also, as countries do not systematically collect data on past offsets and their outcomes (Kujala et al., 2022), such information cannot be inferred afterward. It is equally challenging to estimate how the different approaches are likely to function in practice because most policies do not offer transparent information on why specific biodiversity metrics are assessed.

This research has demonstrated that the methods used to quantify biodiversity are not well captured for most countries in which offsets are being used. Where these documents are available, it is not always apparent whether the metric in use aligns with the broader policy goal. Emerging policies and guidelines should explicitly state the end goal of an offset, along with the biodiversity metrics that should be measured, and how to score, weight, and combined them to achieve this target (Sonter et al., 2020). This is necessary to improve understanding of how to account for uncertainty, apply multipliers, and to ensure some biodiversity metrics (e.g., habitat characteristics) are not inadvertently swapped for other non-comparable measures of equal importance (e.g., connectivity). Moreover, increased clarity and accessibility of explicit guidance for offsets will help ensure that offset implementation matches legislation objectives. Improvements in offset legislation and implementation of that legislation are essential to ensure offsets deliver the long-term benefits they aim to achieve.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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