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Achieving biodiversity net gain by addressing governance gaps underpinning ecological compensation policies

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Abstract

Biodiversity compensation policies have emerged around the world to address the ecological harms of infrastructure expansion, but historically compliance is weak. The Westminster government is introducing a requirement that new infrastructure developments in England demonstrate they achieve a biodiversity net gain (BNG). We sought to determine the magnitude of the effects of governance gaps and regulator capacity constraints on the policy's potential biodiversity impacts. We collated BNG information from all new major developments across six early-adopter councils from 2020 to 2022. We quantified the proportion of the biodiversity outcomes promised under BNG at risk of noncompliance, explored the variation in strategies used to meet developers' biodiversity liabilities, and quantified the occurrence of simple errors in the biodiversity metric calculations. For large developments and energy infrastructure, biodiversity liabilities frequently met within the projects' development footprint. For small developments, the purchase of offsets was most common. We estimated that 27% of all biodiversity units fell into governance gaps that exposed them to a high risk of noncompliance because they were associated with better-condition habitats delivered on-site that were unlikely to be monitored or enforced. More robust governance mechanisms (e.g., practical mechanisms for monitoring and enforcement) would help ensure the delivery of this biodiversity on-site. Alternatively, more biodiversity gains could be delivered through off-site biodiversity offsetting. For the latter case, we estimated that the demand for offsets could rise by a factor of 4; this would substantially increase the financial contributions from developers for conservation activities on private land. Twenty-one percent of development applications contained a simple recurring error in their BNG calculations. One-half of these applications were approved by councils, which may indicate under-resourcing in council development assessments. Our findings demonstrate that resourcing and governance shortfalls risk undermining the policy's effectiveness.

KEYWORDS
biodiversity net gain, biodiversity offsetting, Environment Act, environmental policy, infrastructure sustainability, nature conservation

sObtención de la ganancia neta de biodiversidad mediante el abordaje de las lagunas en la gobernanza que apuntalan las políticas de compensación ecológica

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Resumen: Las políticas de compensación por biodiversidad han surgido en todo el mundo para abordar los daños ecológicos de la expansión infraestructural, aunque su cumplimiento histórico es deficiente. El gobierno de Westminster está introduciendo un requerimiento para que las nuevas infraestructuras en Inglaterra demuestren que obtienen una ganancia neta de biodiversidad (GNB). Buscamos determinar la magnitud que tienen los efectos de las lagunas de gobernanza y las restricciones de la capacidad regulatoria sobre los impactos potenciales de la política en la biodiversidad. Recopilamos la información de GNB de todos los desarrollos principales en seis consejos pioneros entre 2020 y 2022. Cuantificamos la proporción de los resultados de biodiversidad prometidos bajo la GNB en riesgo de no ser cumplidos, exploramos la variación de estrategias usadas para cumplir las responsabilidades de biodiversidad de los desarrolladores y cuantificamos la incidencia de errores simples en el cálculo de las medidas de biodiversidad. En los grandes desarrollos y en la infraestructura energética, las responsabilidades de biodiversidad fueron cumplidas con frecuencia dentro de la huella de desarrollo del proyecto. En los pequeños desarrollos, la compra de compensaciones fue más común. Estimamos que el 27% de todas las unidades de biodiversidad caen dentro de las lagunas de gobernanza que las exponen a un riesgo elevado de no ser cumplidas porque se asociaban con hábitats en mejores condiciones entregados en sitios con mayor probabilidad de no ser monitoreados o implementados. Tener mecanismos de gobernanza más robustos (mecanismos prácticos para el monitoreo y la implementación) ayudaría a asegurar la entrega de esta biodiversidad en sitio. Como alternativa, una mayor ganancia de biodiversidad podría entregarse a través de las compensaciones de biodiversidad fuera de sitio. Para el último caso, estimamos que la demanda de compensaciones podría aumentar en un factor de 4; esto incrementaría sustancialmente las contribuciones económicas de los desarrolladores para las actividades de conservación en suelo privado. El 21% de las aplicaciones de desarrollo incluyeron un error simple recurrente en los cálculos de su GNB. La mitad de estas aplicaciones fueron aprobadas por consejos, lo que podría indicar una escasez de evaluaciones en los consejos. Nuestros resultados demuestran que la insuficiencia en la dotación de recursos y la de gobernanza arriesga la efectividad de las políticas.

PALABRAS CLAVE
compensación por biodiversidad, conservación de la naturaleza, ganancia neta de biodiversidad, Ley Ambiental, política ambiental, sostenibilidad de la infraestructura

INTRODUCTION

The physical mass of all the world's anthropogenic built infrastructure now outweighs the world's living biomass (Elhacham et al., 2020). Yet, the expansion of infrastructure development is at a historic high (Krausmann et al., 2018). Built infrastructure is a key driver of carbon emissions and biodiversity loss (Laurance et al., 2015; zu Ermgassen et al., 2022). Therefore, a range of policies have emerged to help societies navigate trade-offs between infrastructure and ecological objectives.

One of the most influential and increasingly widely adopted set of policies is ecological compensation, typically operationalized through legislation requiring mitigation of ecological damage from new development (zu Ermgassen et al., 2019a). These policies aim to avoid and minimize biodiversity losses from new development and offset residual impacts and have an overall goal of no net loss or a net gain of biodiversity (Bull et al., 2013). The outcomes of such compensation systems are mixed. There are problems with policy design and compliance (Bezombes et al., 2019; Samuel, 2021; Theis et al., 2020; zu Ermgassen et al., 2019b) and a large literature criticizing biodiversity offsetting on theoretical grounds. Criticisms include concerns that offsetting risks operationalizing an anthropocentric and instrumental view of nature that may undermine people's intrinsic motivations to protect nature in the long-term and contribute to further disconnection between people and nature (Apostolopoulou & Adams, 2019); offsetting reinforces the narrative of humans being separate from biodiversity, incentivizing creation of human spaces where biodiversity is increasingly absent (Hannis & Sullivan, 2012); and offsetting being used as a tool to legitimize biodiversity loss rather than conserving it (Apostolopoulou & Adams, 2019).

It is a major governance challenge to ensure that compensatory ecological gains materialize, last long enough to effectively compensate for the harm caused, and are ecologically matched to losses (Damiens et al., 2021). Regulators rely heavily on assessments and reporting conducted by consultants paid by project proponents. Perverse incentives occur in offset implementation (Gordon et al., 2015). For example, project proponents minimize costs by underestimating the project's biodiversity impacts or seeking the least costly forms of compensation. Regulators, whose responsibility it is to represent the public interest and ensure compensation is compliant with regulatory requirements, are entrusted to counter these perverse incentives. However, the interests of project proponents are typically better resourced than regulators or statutory agencies (Walker et al., 2009). Examples of under-resourcing include regulators not being unable to send staff to assess offset sites or conduct basic compliance checks (Carver & Sullivan, 2017; Samuel, 2021). Overstretched regulators in Australia sometimes defer the most complex aspects of offset decisions until after developments are approved, when opportunities for public accountability and engagement are severely restricted (Evans, 2023). This is in part because of a lack of capacity to deal with reconciling different values expressed by stakeholders at the public consultation stage. These factors combined mean that regulators are highly dependent on project proponents to deliver and accurately report on promised biodiversity gains. However, empirical work on compensation outcomes demonstrates that offsetting systems are subject to systemic compliance shortfalls (Bezombes et al., 2019; Theis et al., 2020; zu Ermgassen et al., 2019b)

Learning from weaknesses in compensation policies can inform new policies to achieve better ecological outcomes. England is on track to adopt (currently scheduled for early 2024) the most wide-ranging jurisdictional policy to date, mandating that new developments that require permission under the Town and Country Planning Act and Nationally Significant Infrastructure Projects (NSIPs) (from 2025 onward) achieve a biodiversity net gain (BNG) to be granted planning permission. Small exceptions are made, including development affecting areas of <25 m^2 or of 5 linear m; householder applications; and small-scale, self-build, and custom house building (Defra, 2023). According to Natural England, mandatory BNG aims to "leave the natural environment in a measurably better state than it was beforehand" (Natural England, 2021a). The BNG policy seeks to reinforce the mitigation hierarchy and incorporate biodiversity gains in development projects through habitat retention, enhancement, and creation. In practice, BNG is implemented as part of the planning process. Every new development affecting unbuilt areas will have to submit a BNG assessment when seeking planning permission. The BNG assessment explicates the baseline biodiversity level before development and the predicted biodiversity level after development, both expressed with a simple composite indicator, the "biodiversity metric" (Panks et al., 2022). Under the planned policy, all developments must deliver a minimum 10% increase in biodiversity units (a unit of biodiversity as measured using the biodiversity metric) after development. Current policy recognizes that some NSIPs may be able to deliver net gain, but at a lower percentage target than 10% (Defra, 2022).

The biodiversity metric is used to assess the biodiversity value of each distinct patch of habitat (as defined using the UK habitats classification) within the development footprint (on-site) or of associated developer-led compensation sites (off-site). Natural England has developed several BNG metrics; metric 3.1 was released in 2022 (Panks et al., 2022). All metrics require the same basic inputs, although newer versions, for example, no longer require measurement of connectivity and differ slightly in habitat categories. Using the most recent version of the metric at the time, the developer's consultant records for the baseline assessment the following for all areas affected by the development: habitat type (selected from a list of options), area, condition (from very poor to very good or N/A for urban and cropland areas), distinctiveness (from very low to very high), and strategic significance (based on location relative to areas identified as ecologically valuable in local nature strategies). The biodiversity unit value for each habitat type is given by a simple multiple of these numerical scores. Additional information is required for the postdevelopment assessment of the area. For example, multipliers increase the number of biodiversity units required where ecological uncertainty is high or if units are to be delivered in the future. Ecological uncertainty reflects the degree of difficulty in creating and restoring the habitat type. For example, land-cover types requiring high levels of management, such as lowland calcareous grassland, are given a high score for ecological uncertainty and receive a multiplier of 0.33, whereas land-cover types with low uncertainty scores receive a multiplier of 1. Hence, three times as many units are required when creating high-uncertainty habitats than when creating low-uncertainty habitats, all else being equal.

Biodiversity units are derived from retaining or enhancing existing habitat or by creating new habitat, with the number of biodiversity units derived through each process calculated differently. Information on retention or enhancement is collated for on-site areas (i.e., within the development footprint of the proposed infrastructure projects) and off-site areas (i.e., land next to or near on-site areas owned or managed by the project proponent). The metric is used to calculate an overall loss or gain of biodiversity units and highlights outstanding errors, such as mismatching total site areas between the baseline and postdevelopment. If the BNG postdevelopment score is ≥10% more than the baseline, the development can be approved; if not, the project plan must be altered to achieve the mandatory target or the developer must purchase the shortfall in biodiversity units from the council or a third-party as a biodiversity offset. If no appropriate units are available, developers can purchase statutory biodiversity credits from the national government. For off-site gains to be counted toward a development's BNG, they must be registered on a public register. Information on the off-site gain register is used to determine whether sites provide genuine gains for biodiversity, and information on the location of off-site gains will in theory help mitigate the double-counting of biodiversity gains (Defra, 2022).

With BNG expected to become mandatory in early 2024, and little data available on its implementation to date, the practical outcomes of the policy are yet to be seen. The policy's stated aims are to improve biodiversity, enhance people's access to greenspace, and streamline the planning system while increasing certainty for developers (Defra, 2019a; Natural England, 2021b). It is hoped that BNG will provide a commercial incentive for private landowners to generate biodiversity units to sell. This would fund conservation activities on private land and initiate a new market for biodiversity units equivalent to the compensatory wetland mitigation markets in the United States (Defra, 2019b). It has been suggested that once BNG becomes mandatory, up to 50% of all biodiversity units delivered by the policy would be off-site (EFTEC, 2021). Thus, the BNG policy could be an important revenue stream for funding the implementation of England's proposed new Local Nature Recovery Strategies (Smith et al., 2022). However, biodiversity compensation is a defensive expenditure (i.e., making up for an equal and opposite loss elsewhere), so these investments are not made to improve the state of nature, but to prevent ongoing biodiversity declines and compensate for biodiversity losses resulting from development. At most, only the residual 10% increase in biodiversity units can be considered to enhance nature (Hawkins et al., 2023).

To date, there has been only one empirical evaluation of BNG in England (zu Ermgassen et al., 2021). That study identified four main threats to achieving the stated ecological outcomes of the policy. First, the magnitude of the offset market was smaller than foreseen in government reports. Second, subjective decisions in the classification of habitats and their condition could undermine policy effectiveness; many classification judgments differed even among experts. This is concerning because local planning authorities (LPAs) rarely have the expertise to critique the reports of consultants representing project proponents. Third, developments in the study's database delivered a 20% net gain in biodiversity units, but this corresponded to a 34% loss of greenspace within the total development area covered by the database. This was because the design of the metric allowed developers to offset immediate losses with promises to deliver smaller but high-quality gains in the future, predominantly in the built environment. The possibility that policies such as BNG could trade biodiversity losses today for uncertain gains in the future is a common concern and criticism of offsetting policies (Bekessy et al., 2010; Maron et al., 2012). Given that BNG policy trades negative outcomes in one biodiversity measure (the area of available greenspace) for positive outcomes in another (the metric), it is essential that the promised biodiversity gains be delivered. However, one of zu Ermgassen et al.'s (2021) major findings was that biodiversity units delivered on-site fall within a governance gap; that is, there is no guarantee they will be monitored or legally enforced. Central government guidance advises LPAs to take planning enforcement action only in the case of "serious harm to a local public amenity"—failure to deliver compensatory actions promised in a planning application is unlikely to meet such a threshold (zu Ermgassen et al., 2021).

Empirical evaluations of other biodiversity compensation policies demonstrate that England's BNG policy addresses some of the shortcomings identified in existing offset policies, but not others. For example, one of the key reasons behind poor outcomes in Australian offset policies has been a reliance on avoided-loss offsets, which are based on simple and often incorrect assumptions about land clearance that would have occurred in the absence of offsets, leading to the systematic nonadditionality of offsets (Gibbons et al., 2018; zu Ermgassen et al., 2023). The English system implements biodiversity improvements relative to a static baseline, therefore, increasing the probability that the biodiversity gains are additional, a method that successfully delivers additionality in the US wetland compensation system (Inkinen et al., 2022). In contrast, systematic under-resourcing of the key implementing agencies (local authorities) risks replicating shortcomings, such as compliance failures identified in Australia, France, and North American wetland compensation schemes (Bezombes et al., 2019; Samuel, 2021; Theis et al., 2020;).

We empirically explored the potential outcomes and associated risks from implementing mandatory BNG in England. We quantified the variation in the strategies used by developers to achieve BNG to understand the range of strategies used in projects of different types and sizes. We then quantified the associated ecological risks of these different approaches and explored trends among infrastructure types. Finally, we quantified the occurrence of errors in completed BNG metrics to provide an insight into how the BNG policy will be implemented. Our overall aim was to identify problems with BNG policy and its metric that could jeopardize its potential to mitigate biodiversity loss and help inform the creation of a more robust and effective BNG policy.

METHODS

Data collection

We expanded the database initiated in zu Ermgassen et al. (2021) by sampling for an additional 1.5 years. We collected all BNG assessments associated with major developments (defined as ≥10 dwellings, sites with area ≥1 ha, or building provision with floor space ≥1000 m^2; DLUHC, 2012) submitted from January 2020 to July 2022 to six LPAs in England that have begun implementing policies equivalent to BNG in advance of it becoming mandatory nationally (Appendix S1). The BNG assessments are publicly available on the LPAs' online planning portals and are often found in preliminary ecological appraisal reports, ecological impact assessments, or in separate documents, all of which are submitted as part of the planning process for a proposed development. Using the advanced search tools on the LPA planning portals, we searched for all major developments submitted within the study time frame. We then extracted developments that included BNG calculations as part of the proposal. For some developments, the information provided in the BNG assessments was incomplete. In these cases, we contacted the biodiversity officers in the relevant LPAs to obtain the full metric spreadsheets or used the available information to estimate the unknown information by iteratively running alternative scenarios through the metric until the values matched the public information (Panks et al., 2022; zu Ermgassen et al., 2021).

We identified 242 projects referencing BNG assessments. Of these, 152 contained sufficient BNG assessment information to include in our database and had been accepted or were in review by the LPA as determined on 30 September 2022. We defined development projects as one of the following infrastructure types: commercial (including retail parks and supermarkets), dwellings (<500 dwellings on-site), education (schools, universities), energy (solar farms, battery storage), health or social care (hospitals, residential homes), industry (warehouses,

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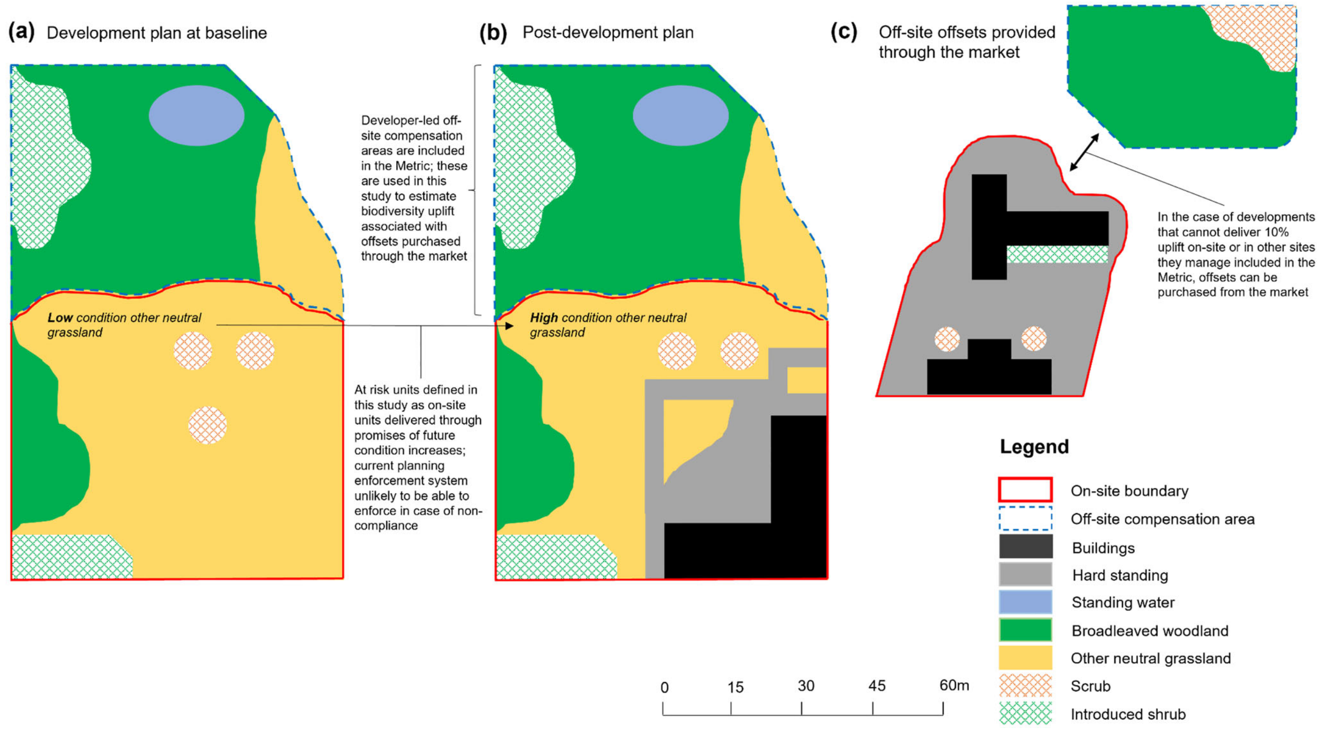

FIGURE 1 Strategies for achieving biodiversity net gain (BNG) when a developer submits a planning application: hypothetical example of a: (a) baseline BNG assessment in which the developer achieves BNG through on-site enhancements and enhancements to an adjacent compensation area, (b) postdevelopment plan (data from off-site compensation areas used to estimate biodiversity increase derived from offsets), showing how we estimate the number of biodiversity units that fall within governance gaps based on the difference between the number of units promised in the postdevelopment plan and number of units delivered if these habitats were not enhanced as planned, and (c) development purchasing an offset from the BNG market.

car parks, agricultural landscaping), recreational (holiday homes, hotels, camping sites), settlement (≥500 dwellings), or transport (airports, rail, roads, cycleways). For each development project, we collected BNG baseline and postdevelopment information for on-site and off-site areas (Figure 1). We used the database to explore variation in the ecological performance of alternative infrastructure types and identify best practice within infrastructure types.

Evaluating exposure of BNG outcomes to governance risks

We estimated the proportion of biodiversity units delivered under BNG exposed to severe governance risks and estimated the degree of off-site offsetting required if the policy were to replace these at-risk units with units delivered off-site (associated with more robust governance).

To evaluate this risk, we assumed that project proponents attempt to deliver the specific habitat types promised in their BNG assessments. However, we classified as being highly exposed to governance risks all biodiversity units that were associated with on-site compensation that were in excess of the condition they were in before the project was initiated (or for newly created habitat patches, those in excess of poor condition). We justify these categories based on four observations. First, on-site habitat creation or enhancement falls within a crucial governance gap. They are not recorded on the national BNG site register and there are no currently established mechanisms for systematically monitoring outcomes in on-site habitats. Failing to deliver biodiversity units to the condition promised in the planning application falls below the threshold of what is conventionally enforced by LPAs, so enforcement is very unlikely. Second, biodiversity units delivered on-site are likely to be under intense human and pet pressure, especially as one of the key aims of the BNG is to improve public access to green space (Natural England, 2021b). Third, there are potential conflicts between residential preferences and BNG commitments that may lower the habitat quality of green spaces. Public perceptions may prevent the delivery of high-quality habitats under BNG should the overall aesthetic not appeal to local communities. Finally, it is expected that there will be skill shortages in property management companies, which tend to maintain properties and manage the built environment intensively, not for the benefit of biodiversity.

To estimate the number of units exposed to governance risk, we calculated the number of units delivered by creating or enhancing habitats on-site at a condition level exceeding the baseline or minimum (poor) condition level. The logic here is that existing governance mechanisms for habitats delivered on-site are likely to be insufficient to ensure they exceed the minimum condition level because outcomes will be largely unmonitored and unenforceable. In calculating this number of units exposed to governance risk, we used different methodologies for units delivered through habitat enhancement and through habitat creation because these are calculated differently in the metric. From the total number of biodiversity units delivered by habitat enhancement or creation, we subtracted our estimates for the number of units that would be delivered if these habitats did not exceed their lowest possible condition levels. For newly created habitats, this was the condition level poor, and for existing habitats, this was the baseline condition of the habitat (i.e., we assume it was retained only, not enhanced). When these units were subtracted from the total reported units, the differential represented our estimate for the number of units exposed to the risk of not being delivered under the policy.

To estimate the total number of units delivered if newly created on-site habitats achieved poor condition, as opposed to their promised condition, we summed the areas of each habitat type created on-site at a given condition level and ran these through metric 3.1. Then, for each habitat type, we repeated this under the assumption that the final condition was poor. We then calculated the difference between the total number of units delivered under BNG commitments for each habitat and the number of units delivered if these on-site habitats were considered in poor condition.

The units generated by habitat enhancement were calculated differently because they enhanced the habitat that already exists. To calculate the potential units delivered in excess of the baseline habitat simply being retained, for every on-site habitat patch in the database, we calculated the biodiversity units that would have been delivered had the habitat been retained instead of enhanced. We used the following formula to calculate the value of retention in the metric: area * distinctiveness * condition * strategic significance * connectivity. We subtracted this value from the total number of biodiversity units projected to be delivered from the enhancement of each habitat patch.

To evaluate exposure to governance risks in an alternative way, we explored how far in the future units would be delivered. Because the planning system is poorly equipped to enforce violations of planning conditions associated with old applications, we assumed that the further into the future the delivery of biodiversity units is realized, the less likely they are to be enforced. In the metric, "time to target condition" is "the length of time (in years) between the intervention and the point in time when the habitat reaches the pre-agreed target quality (i.e., distinctiveness, condition)" (Panks et al., 2022). This time scale is from 0 to over 32 years. For all biodiversity units delivered on- and off-site, we assessed habitat improvement type (retention, creation, or enhancement), condition type, and habitat type along this timeline to quantify the predicted time scales for biodiversity units to be realized.

Estimating area of offsetting

Currently, there is limited public reporting on habitat banking or third-party-provided off-site biodiversity offsetting in England. Most offsetting activities are held as intellectual property by private offsetting brokers and providers. However, 24 of the developments in our database delivered offsets directly adjacent or close to their developments, and the land-cover changes associated with these offsetting activities were captured in the metric. Therefore, in the absence of publicly available offset data, we used these off-site compensation areas as proxies for the activities and outcomes that might be expected of offset sites selling units into the offset market. We used the areas and increase in biodiversity units generated at these offset sites to estimate the mean biodiversity unit increase expected per hectare of offsetting. To estimate the total area of offsetting that would be required if the biodiversity units with high governance risk were instead to be delivered through off-site offsetting, we divided the total number of at-risk units by the mean increase in biodiversity units per hectare of offsets. To estimate the area required to meet the residual offsetting liabilities in the data set (i.e., for developments not expected to reach a 10% increase in biodiversity units), we divided the number of biodiversity units required through offsets by the mean increase in biodiversity units per hectare for offsets. In these offsets, the majority of land under the baseline was modified grassland in poor and fairly poor condition. In offsets, these areas were mostly transformed into relatively high-quality other neutral grassland ("grass and herb dominated vegetation on neutral soils" [UKHab, 2018]), scrub, or woodland.

Metric suitability and associated error rates

Within the metric, a difference of >0.01 ha between the area of the site before and after development is an error (Panks et al., 2022). In theory, no metrics should be approved that do not satisfy this basic criterion. To test the rate at which erroneous metrics were submitted to or accepted by LPAs, we quantified the number of projects that had a ≥10% or a ≤−10% difference in the total area before development and after development and then calculated their overall proportion. We determined that a ≥10% and ≤−10% threshold was appropriate to highlight larger differences in area that could not be accounted for by rounding. From this, we summed the total area difference before and after development to identify the amount of area unaccounted for in the BNG database.

RESULTS

Of the 152 projects we examined, 24 were expected to achieve the 10% BNG through off-site compensation. Seventy-five should meet their full biodiversity liability with only on-site compensation, and 53 were required to purchase offsets. Our sample covered 1637 ha of development footprint (16,052 dwellings, 72 other infrastructure).

Quantifying habitat and biodiversity changes under BNG

Projects in the database ranged from 0.12 to 246 ha (mean 10.7 ha, $n = 152$). Developments across the database as a whole plan to deliver a 23.5% increase in biodiversity as measured by the metric. Most new developments were constructed on croplands and modified grasslands (Appendix S2). The natural areas expected to deliver the largest number of biodiversity units under the policy was moderate condition other neutral grassland at 23% of total delivered units (Appendix S2).

Off-site biodiversity offsets purchased from third parties or LPAs were 7.4% of all biodiversity units predicted to be delivered. Of the 24 offsets delivered via off-site compensation areas where metric information was available, the mean biodiversity increase was 3.7 units/ha. Using this mean number of biodiversity units per hectare, the total area of offsets required to meet the offsetting liability in the database would be 127 ha.

Developer heterogeneity to achieve BNG liability

There was substantial heterogeneity in BNG delivery between and within infrastructure types in the database. A key result was a clear association between development size and the degree to which developments could meet their BNG liability on-site (Figure 2). Thirty-nine percent of all projects planned to deliver an increase in urban cover and an overall loss of biodiversity units, which means they must purchase units from offsets delivered via the market. These projects were mainly small, indicating that small developments are the main procurers of biodiversity units from the market in our sample. In contrast, 46% of all developments (top-right quadrant) were committed to delivering an increase in biodiversity units, despite increasing the extent of urban area. These projects, which were associated with urban land take and an increase in biodiversity according to the metric, were predominantly large developments, such as settlements and energy projects. Overall, 12.5% of all projects reduced urban cover (i.e., converted urban to nonurban land uses) while increasing biodiversity unit delivery (bottom-right quadrant). Forty-eight percent of all projects would be required to purchase offsets to reach the 10% biodiversity unit uplift threshold.

Another key finding was that some infrastructure types consistently outperformed others. Solar farms were a particular outlier; plans showed large increases in biodiversity units despite no increase in greenspace area (Figure 2, purple bubbles). Solar farms in the data set committed to converting land cover of low quality and distinctiveness into better quality habitats, and the solar projects in our sample counted all the land under the panels as a habitat that contributes to meeting or exceeding their BNG liability.

Exposure of BNG outcomes to governance risks

The total number of biodiversity units expected to be delivered via the creation and enhancement of habitats on-site was 2985 and 1661, respectively. The number of biodiversity units that would be delivered if on-site newly created natural habitats did not exceed a condition score of poor and on-site enhanced habitats did not exceed the condition they were before the project was initiated was 1837 and 1095 units, respectively (Figure 3a). Therefore, the total number of units developers committed to deliver on-site but that were subject to high levels of governance risk was 1714 units (27% of all the biodiversity units delivered in our sample) (Figure 3b).

All predicted on-site units that risked being unenforceable and susceptible to high levels of governance risk could be delivered instead via the relatively more robust governance pathways associated with off-site biodiversity offsets. Assuming that offsets deliver a mean increase of 3.7 units/ha as in our database's off-site areas, this would equate to an additional 441 ha of biodiversity offsets, an approximate four-fold increase in the total area of biodiversity offsets delivered under BNG in our sample.

Temporal risks for BNG outcomes

Fifty-one percent of biodiversity units in the data set would be delivered via creation followed by 34% enhancement and 15% retention. Around one-half of all biodiversity units were due to reach maturity 0–5 years after implementation and just under one-third 10 years after implementation (Appendix S3a). Biodiversity units committed to being delivered at 15, 20, and 32 years were to be achieved primarily through enhancement. Around one-quarter of all projects were expected to take 20 years or longer to achieve the desired condition, of which 54% would enhance current woodlands, and 74% would create new woodlands.

In BNG assessments, 88% of all biodiversity units (via retention, creation, and enhancement) would be achieved by delivering habitats at a condition level higher than the poor (Appendix S3b). We found that 22% of all biodiversity units would be achieved by providing land cover in moderate condition that would reach maturity 10 years after implementation. Three-quarters of the moderate condition land cover delivered in 10 years' time would be other neutral grassland, of which 69% would be delivered through creation.

Metric suitability and associated error rates

Basic aggregation errors were identified in the biodiversity metric calculations in one-fifth of all projects (defined as there being differences in the area between the baseline and post-development scenarios that falls within our ≥10% to ≤−10% threshold). Over 40% of these had a 10–20% difference in area between baseline and postdevelopment scenarios (Figure 4). Overall, just over one-half of all projects that contained errors had been accepted by LPAs and the remainder were in review. Of all accepted projects in our data set, 24% contained errors. There was no evidence that the occurrence of errors declined over time. Seventeen percent of projects that used metric 2.0 contained errors, and 39% of projects that used metric 3.1 contained errors. For projects with errors of ≥10%, the total baseline area was 43 ha and total postdevelopment area was 57.9 ha, respectively, leaving 14.9 ha of baseline habitat unaccounted for in the database. For projects with errors of ≤−10%, the total baseline area was 34 ha and total

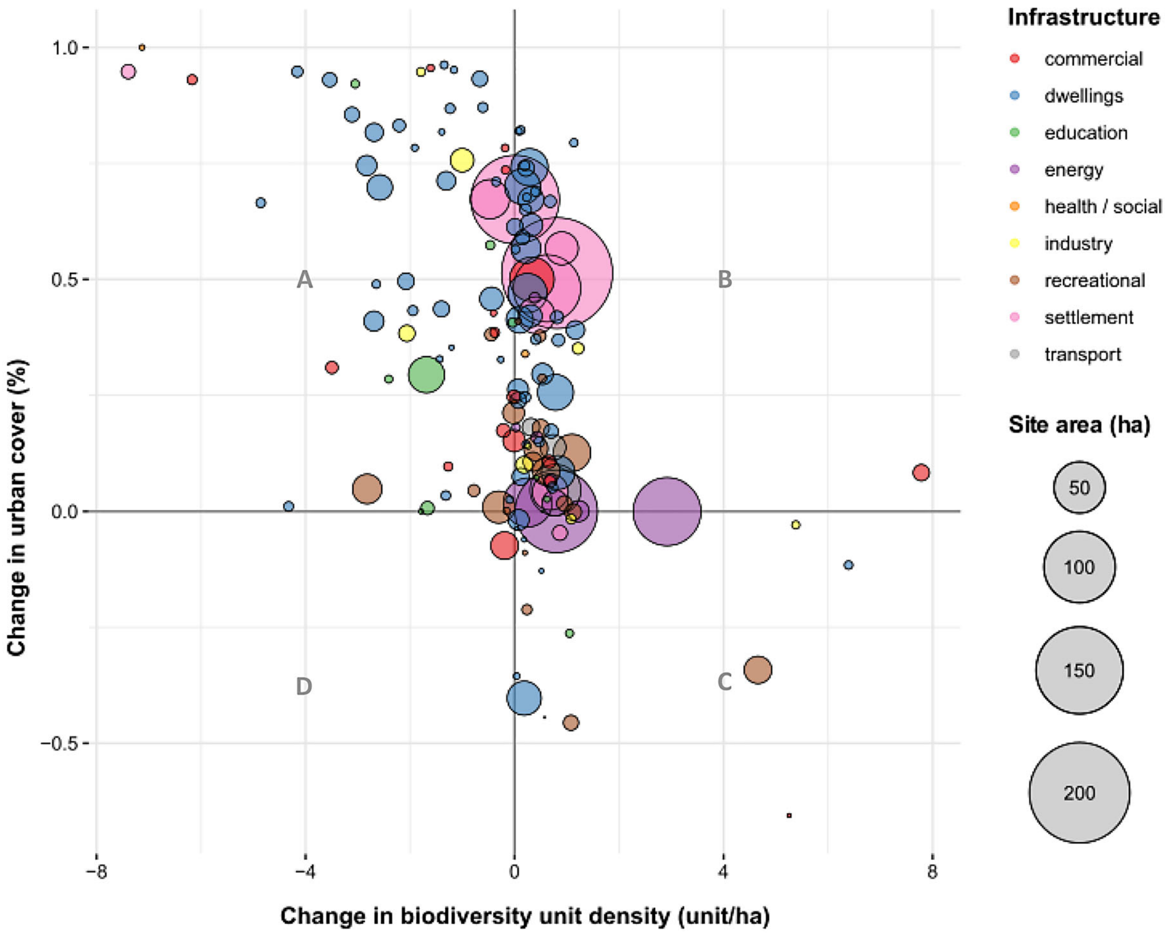

FIGURE 2 Expected percentage change in urban cover (built urban surface and other urban habitats in the metric) and the change in biodiversity unit density between the baseline and postdevelopment sites for 152 major infrastructure developments examined (left half, developments required to purchase biodiversity offsets to meet required gain in biodiversity units; right half, development meets all or nearly all biodiversity gains through habitat enhancement; top half, development associated with increases in urban land cover; bottom half, developments associated with reductions in urban land cover according to the metric; a, development increases urban land cover and reduces density of biodiversity units delivered [developers required to purchase biodiversity offsets]; b, developments associated with an increase in urban land cover and an increase in biodiversity unit density that are expected to meet all or nearly all their BNG liability within their own development footprint; c, developments associated with a decrease in urban land cover and an increase in biodiversity unit density that are expected to deliver an increase in greenspace and biodiversity units; d, developments associated with a decrease in urban land cover and a decrease in biodiversity unit density that are required to purchase biodiversity offsets).

postdevelopment area was 19.1 ha, leaving 14.9 ha of postdevelopment habitat unaccounted for. Omitting baseline habitats is a critical error, as these will likely increase the baseline value of the habitat and, therefore, require additional compensation to meet the 10% increase threshold.

DISCUSSION

As with other wealthy nations, England must reconcile infrastructure expansion with environmental commitments (zu Ermgassen et al., 2022). Although the UK government has committed to adding 300,000 housing units per year by the mid-2020s (DCLG, 2017) and investing £96 billion and £24 billion in rail and road expansion (HM Government, 2022), respectively, it recognizes the country's biodiversity is in steady decline (Betts et al., 2022; UKNEA, 2014). The BNG policy was designed to address these interconnected challenges. With the upcoming implementation of mandatory BNG, it is important to evaluate the available evidence to better understand how well its policy mechanisms work for reconciling such trade-offs. Our results demonstrate there is wide variation in how developers meet their BNG obligations. Moreover, there are differences in the quality of governance overseeing the alternative strategies, meaning that numerous strategies are associated with varying degrees of risk of nondelivery. These results have significant implications for policy.

BNG policy exposure to governance risks

A fundamental principle within the habitat delivery hierarchy of the BNG approach is to deliver habitats on-site or locally first, followed by off-site interventions (Defra, 2018). This is

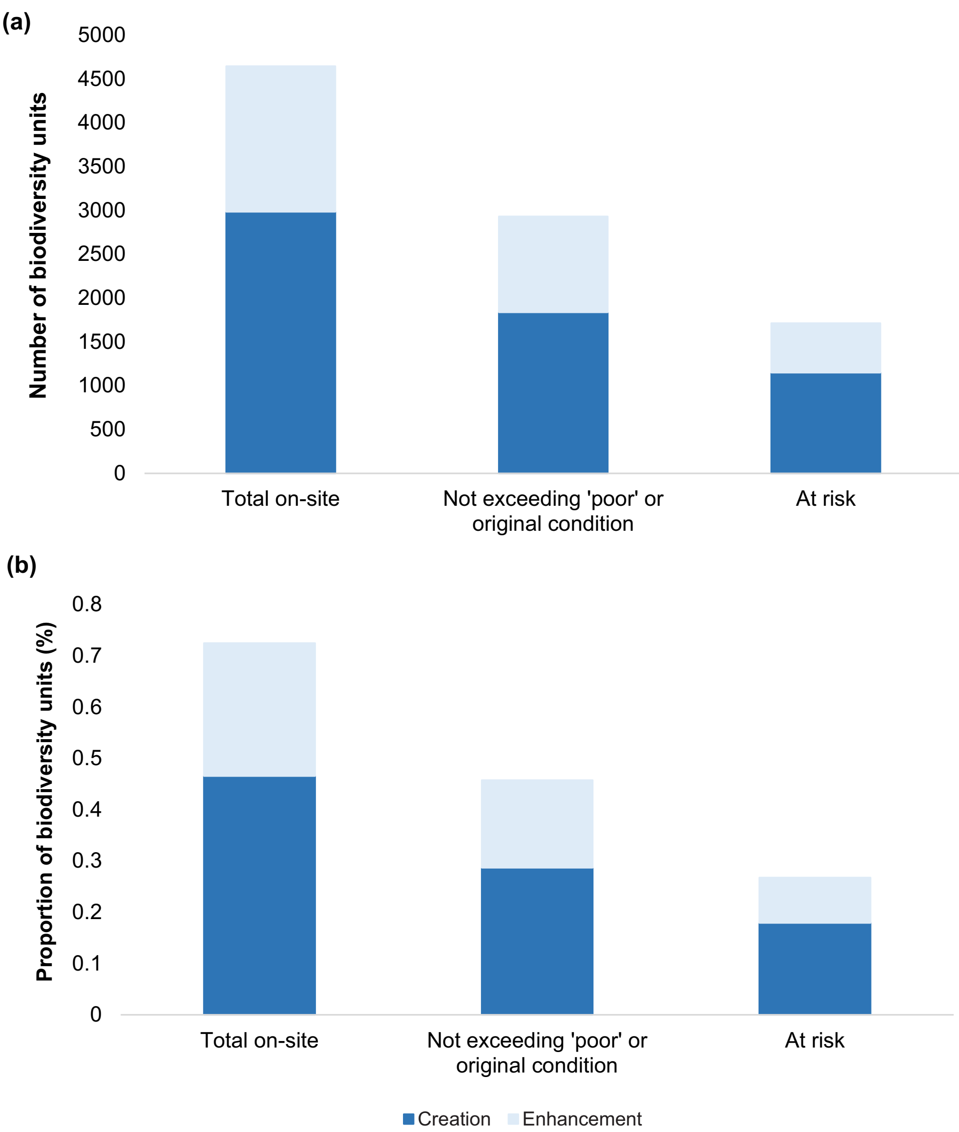

FIGURE 3 The (a) number and (b) proportion of on-site biodiversity units in the data set delivered through the creation and enhancement categories (middle graph, units that would be delivered if these habitats were not to exceed their minimum condition level [i.e., poor for created habitats, the baseline condition level for enhanced habitats]; right graph, number of units exposed to high levels of governance risk because of insufficient monitoring and enforcement mechanisms).

supported by a UK government consultation with BNG stakeholders, which showed there was overall support for delivering the majority of biodiversity units on-site (Defra, 2018). The government estimates that 50% of units under BNG may be delivered through on-site actions (EFTEC, 2021), whereas we found in our sample of developments from early-adopter jurisdictions that over 90% of biodiversity units would be delivered on-site. Although the drive to deliver on-site compensation is likely a product of one of the key policy goals to improve public access to green spaces (Natural England, 2021b), our results demonstrate that this goal is likely to conflict with the goal to enhance wildlife and ecosystems.

Delivering such a high proportion of biodiversity units on-site exposes the policy to substantial risk of noncompliance. Urban areas are often exposed to significant human pressure and conflicting management objectives, such as recreation, aesthetics, and biodiversity, that will likely affect on-site habitat establishment, quality, and longevity. In addition, biodiversity units delivered on-site within the BNG policy fall within a major governance gap. The government is planning to launch a register of biodiversity offsets when the policy becomes mandatory in early 2024. However, as it currently stands, this database will not contain on-site habitat enhancements, which is a major potential barrier to evaluating the long-term outcomes of the policy (Kujala et al., 2022). This means that habitat enhancements delivered on-site are at high risk of being unmonitored.

Furthermore, gains promised on-site risk being legally unenforceable because of a significant lack of resourcing and the majority of LPAs having no in-house ecological expertise

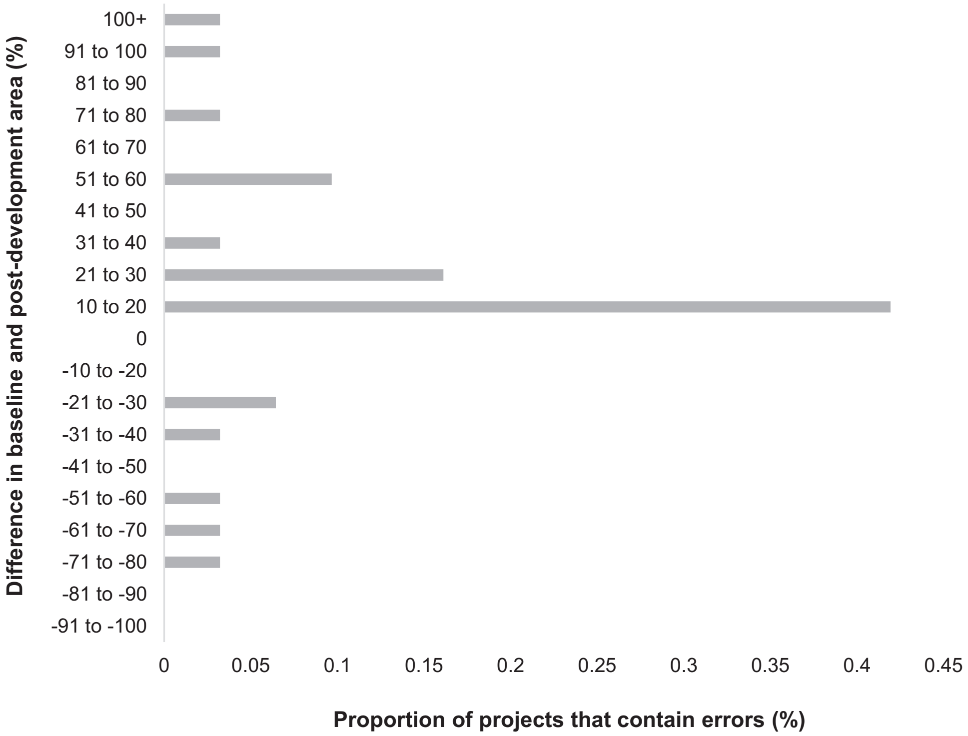

FIGURE 4 The proportion of infrastructure development projects with errors of ≥10% to ≤−10% in the areas of the sites between the baseline and postdevelopment area in the project plans.

(Robertson, 2021), plus, violations may not reach the legal threshold required for LPAs to launch enforcement action (zu Ermgassen et al., 2021). National and LPA authority guidelines and policies state that if an LPA decides to take enforcement action against developers, it should be undertaken on a "discretionary" basis and is essentially voluntary (Allison et al., 2020; LBE, 2021). This is particularly concerning in that LPAs will have little incentive to monitor BNG progress within on-site developments or to follow up with developers in cases of BNG failings. Our results demonstrate that at least 27% of all the biodiversity units delivered by the policy were exposed to these severe governance risks. This number is conservative because we only accounted for risks of not meeting the habitat condition level proposed in the BNG assessment and not the risk of the developers not delivering the habitat type proposed (i.e., habitat of a given distinctiveness score).

Should the government prioritize significantly increasing LPA resourcing and capacity to deliver more effective monitoring and implementation practices, such risks could be overcome and mandatory BNG may achieve its goals. If governance and standards were standardized for on-site and off-site gains (at the higher-quality standards of off-site gains), then there would be no risk of proponents undercutting standards by going down the less stringent route. We have seen equivalent leveling of the playing field in other compensation systems that experienced similar divergence in standards between developer-led and third-party-initiated compensation. For example, the 2008 compensation rule in the US wetland mitigation system addressed this divergence by closing the governance gap and ensuring that the same standards were applied across all forms of compensation (Hough & Robertson, 2009).

An alternative measure of exposure to governance risk is the time taken to deliver biodiversity units to achieve the desired condition. Just under one-half of all biodiversity units in our data set would take longer than 5 years to mature, and around one-quarter would take 20 years or longer to achieve their commitments of woodland enhancement and creation. It is highly unlikely that LPAs will have the resources to investigate and enforce violations of planning conditions from years in the past. Therefore, it is probable that the compliance risks of promised biodiversity units will rise further in the future of those units as they reach maturity. Challenges, such as organizational budget cuts for funding activities with short-term payoffs and the difficulty of evaluating the effectiveness of monitoring processes, can deplete the execution and incentive for monitoring habitats in the long-term (Biber, 2011). This tendency for biodiversity offsetting systems to compensate for certain losses today with uncertain future gains has long been identified as one of the most common delivery risks facing offsetting systems (Bekessy et al., 2010; Maron et al., 2012). The well-established solution is to establish habitat banks that deliver increases in biodiversity in advance of the biodiversity losses. In England, these habitat banks would be incentivized through policy initiatives that increase the demand for off-site biodiversity units. Hence, eliminating the policy's reliance on on-site gains, which are exposed to severe compliance risks, and replacing them with the relatively more secure off-site offsets could also mitigate the risks from promising to deliver biodiversity increases in the future.

Incentivizing conservation on private land

An alternative to on-site compensation would be to provide biodiversity units at high risk of governance failure through the offset market. Although off-site offsetting policies and procedures have received numerous criticisms regarding their ambiguity, lack of consistency, effectiveness, and ethics (Bull et al., 2013; Gardner et al., 2013), the governance mechanisms in place in the context of England's BNG policy are more comprehensive than those associated with on-site delivery. These include requiring that offsets be placed on the spatially explicit national net gain register, which requires regular submission of monitoring reports, creation of conservation covenants as a new legal mechanism for ensuring the conservation of private land, and introducing new legal powers to prosecute landholders who misrepresent the conservation activities implemented in offsets to generate units sold into the market (zu Ermgassen et al., 2021). If on-site units at risk of being unenforced were instead provided off-site, the total area of offsetting required to deliver BNG could rise by a factor of 4, drawing substantially more investment into delivering biodiversity gains on private land via the market for biodiversity units. If these investments were directed toward priority habitat landscapes in the LPAs proposed "local nature recovery networks" (Smith et al., 2022), the potential biodiversity benefits could be further enhanced by improving ecological characteristics, such as connectivity, which are poorly addressed in the BNG metric. A challenge to increasing off-site gains, however, is locating areas where gains can be achieved by creating or enhancing the habitat types. This is a known challenge in BNG and no net loss policies (Sonter et al., 2020). For example, finding land to implement countries' climate pledges without creating inequitable competing demands on land use is difficult (Dooley et al., 2022). The effectiveness of moving on-site offsets off-site could, therefore, be limited by the availability of appropriate land needed to secure offsets.

Limiting exposure to on-site governance risks

We found that on-site offsets are exposed to governance risks. Enhancing the ability of councils to address noncompliance on-site would reduce the exposure of these units to governance risk. By improving in-house ecological expertise for LPAs, the resource gap between developers and councils would be reduced. An increased capacity of LPAs to effectively evaluate BNG assessments would reduce the risk of accepting planning applications that overestimate units delivered on-site. Improved resources to conduct monitoring of on-site offsets would also enable LPAs to respond to instances of potential noncompliance. The LPAs could, therefore, respond more effectively to developments with on-site offsets that are not on track to meet stipulations in the BNG plan, particularly when enhancements are delivered far into the future. The Environment Act requires that development-associated habitat enhancements be secured for a minimum of 30 years (UK Government, 2021); yet, the time for the slowest maturing biodiversity units in the metric to reach their projected condition is >30 years. Therefore, it is unlikely that councils will take enforcement action at this time scale should developers fail to meet their obligations. Routine monitoring could address this temporal challenge because it would allow councils to detect when slow-maturing biodiversity units are not on-track to meet desired condition levels and to take action early.

Policy risks from applying standardized methods to diverse infrastructure types

Different development projects achieve their BNG objectives through a variety of strategies, each with varying implications and risks for biodiversity. Large infrastructure developments, including large housing developments and energy projects, are among those expected to deliver the majority of biodiversity units through on-site interventions, illustrating the relatively small demand for off-site biodiversity units in the data set. The BNG metric provides sufficient flexibility for large developments to meet most or all of their biodiversity liabilities on-site, whereas the majority of the demand for offset units comes from small developments associated with small offsetting liabilities. However, this study also reveals potential areas where the characteristics of infrastructure projects have not been sufficiently accounted for in the policy design. For example, in our sample, solar farms generated large biodiversity unit surpluses on-site. Within the metric, solar panels are not considered urban habitat, and the grass land cover underneath the panels was often reported as delivering increases in biodiversity units that contribute to the total required BNG. It may be possible to enhance shaded areas beneath solar panels to achieve species-rich grasslands (TBC, 2020). However, the success of such biodiversity interventions is highly dependent on species shade tolerance (Lambert et al., 2022), the project's vegetation management regime, and the availability of resources for long-term monitoring (Remazeilles et al., 2022). In addition, initial avoidance of damage to biodiversity-rich land cover is the most reliable and cost-effective way to reduce biodiversity risk of solar farms (TBC, 2020). Further research will be required to confirm whether the gains we found are credible or an artifact of the metric. This is especially important because the government has committed to building more solar farms to reach a target of 70 GW of generation capacity by 2035 (Whitlock, 2022).

High error rates and the need for greater investment in capacity and resources

Despite Natural England describing the biodiversity metric as a "simple assessment tool" (Panks et al., 2022), particularly in reference to metric 3.1, we found that one-fifth of all assessments contained errors in the site areas reported between the baseline and postdevelopment stages. Around one-quarter of all LPA-accepted assessments contained these errors. This could be interpreted as further evidence of severe capacity constraints in LPAs (Robertson, 2021) because these were errors that would be unlikely to occur if planners were given sufficient time and resources to scrutinize metric reports. By underfunding LPAs, BNG policy runs the risk of not having biodiversity outcomes prioritized in development decisions.

The BNG policy aims to tackle the ongoing twin policy challenges of preventing further biodiversity declines while enabling continued infrastructure expansion. Our results highlight considerable risks to the policy that could undermine its effectiveness. One of our most important findings was that just over one-quarter of the biodiversity units delivered through the policy fell within a critical governance gap, putting developments at substantial risk of noncompliance and nondelivery. Half the biodiversity units delivered mature >5 years in the future, which leaves them unlikely to be enforced under the current planning system. Specific infrastructure types generate large biodiversity unit surpluses with limited ecological justification. These factors, coupled with the high occurrence of basic errors in accepted BNG calculations, highlight the fundamental need for a greater investment in LPA capacity and skills to enable them to take action to mitigate the policy's biggest risks. In the absence of substantial increases in resources for LPAs that would enable the governance to deliver higher compliance rates, a shift in focus toward providing these risky biodiversity units through targeted off-site offsets could be justified. Replacing on-site units at severe risk of nondelivery with relatively more robust units delivered via offsets would, in our data set, increase the demand for offsets by a factor of 4. This would substantially increase the revenues raised by BNG for investment in conservation activities on private land. In the face of continued infrastructure expansion, it will be necessary to develop mechanisms that reconcile the biodiversity losses caused by development with biodiversity gains. If these gains fail to materialize, then governments risk falling short on their environmental policy goals and failing to achieve the grand 21st century challenge of achieving high living standards for all within Earth's ecological constraints.

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REFERENCES

Allison, C. (2020). *NAPE planning enforcement handbook for England*. Royal Town Planning Institute.

Apostolopoulou, E., & Adams, W. M. (2019). Cutting nature to fit: Urbanization, neoliberalism and biodiversity offsetting in England. *Geoforum*, *98*, 214–225. https://doi.org/10.1016/j.geoforum.2017.05.013

Bekessy, S. A., Wintle, B. A., Lindenmayer, D. B., Mccarthy, M. A., Colyvan, M., Burgman, M. A., & Possingham, H. P. (2010). The biodiversity bank cannot be a lending bank. *Conservation Letters*, *3*, 151–158. https://doi.org/10.1111/j.1755-263X.2010.00110.x

Betts, C., Hatfield, S., Holleran, C., Thomas, K., Durham, E., Farquharson, L., Gardner, C., Long, M., Scott, S., & Williams, J. (2022). *UK biodiversity indicators*. UK Government Department for the Environment, Food and Rural Affairs.

Bezombes, L., Kerbiriou, C., & Spiegelberger, T. (2019). Do biodiversity offsets achieve No Net Loss? An evaluation of offsets in a French department. *Biological Conservation*, *231*, 24–29. https://doi.org/10.1016/j.biocon.2019.01.004

Biber, E. (2011). The problem of environmental monitoring. *University of Colorado Law Review*, *83*, 1–9.

Bull, J. W., Suttle, K. B., Gordon, A., Singh, N. J., & Milner-Gulland, E. J. (2013). Biodiversity offsets in theory and practice. *Oryx*, *47*, 369–380. https://doi.org/10.1017/S003060531200172X

Carver, L., & Sullivan, S. (2017). How economic contexts shape calculations of yield in biodiversity offsetting. *Conservation Biology*, *31*, 1053–1065. https://doi.org/10.1111/cobi.12917

Damiens, F. L. P., Backstrom, A., & Gordon, A. (2021). Governing for "no net loss" of biodiversity over the long term: Challenges and pathways forward. *One Earth*, *4*, 60–74. https://doi.org/10.1016/j.oneear.2020.12.012

DCLG (Department for Communities and Local Government). (2017). *Fixing our broken housing market*. UK Government Department for Communities and Local Government.

Defra (Department for the Environment, Food and Rural Affairs). (2018). *Net gain: Consultation proposals*. UK Government Department for the Environment, Food and Rural Affairs.

Defra (Department for the Environment, Food and Rural Affairs). (2019a). *Biodiversity net gain and local nature recovery strategies: Regulatory policy review*. UK Government Department for the Environment, Food and Rural Affairs.

Defra (Department for the Environment, Food and Rural Affairs). (2019b). *Net gain: Summary of responses and government response*. UK Government Department for the Environment, Food and Rural Affairs.

Defra (Department for the Environment, Food and Rural Affairs). (2022). *Consultation on biodiversity net gain regulations and implementation*. UK Government Department for the Environment, Food and Rural Affairs.

Defra (Department for the Environment, Food and Rural Affairs). (2023). *Consultation on biodiversity net gain regulations and implementation*. UK Government Department for the Environment, Food and Rural Affairs. https://www.gov.uk/government/consultations/consultation-on-biodiversity-net-gain-regulations-and-implementation/outcome/government-response-and-summary-of-responses

DLUHC (Department for Levelling Up, Housing and Communites). (2012). *National Planning Policy Framework—Annex 2: Glossary*. Department for Levelling Up, Housing and Communites. https://www.gov.uk/guidance/national-planning-policy-framework/annex-2-glossary#footnote75

Dooley, K. (2022). *The Land Gap Report*. The Land Gap. https://www.researchgate.net/publication/365230999_The_Land_Gap_Report_2022

EFTEC (Economics for the Environment Consultancy Ltd). (2021). *Biodiversity net gain: Market analysis study*. Economics for the Environment Consultancy Ltd.

Elhacham, E., Ben-Uri, L., Grozovski, J., Bar-On, Y. M., & Milo, R. (2020). Global human-made mass exceeds all living biomass. *Nature*, *588*, 442–444. https://doi.org/10.1038/s41586-020-3010-5

Evans, M. C. (2023). Backloading to extinction: Coping with values conflict in the administration of Australia's federal biodiversity offset policy. *Australian Journal of Public Administration*, *82*, 1–20. https://doi.org/10.1111/1467-8500.12581

Gardner, T. A., VON Hase, A., Brownlie, S., Ekstrom, J. M., Pilgrim, J. D., Savy, C. E., Stephens, R. T., Treweek, J., Ussher, G. T., Ward, G., & Ten Kate,

K. (2013). Biodiversity offsets and the challenge of achieving no net loss. *Conservation Biology*, *27*, 1254–1264. https://doi.org/10.1111/cobi.12118

Gibbons, P., Macintosh, A., Louise, A., & Kiichiro, C. (2018). Outcomes from 10 years of biodiversity offsetting. *Global Change Biology*, *24*, 1–12. https://doi.org/10.1111/gcb.13977

Gordon, A., Bull, J. W., Wilcox, C., & Maron, M. (2015). Perverse incentives risk undermining biodiversity offset policies. *Journal of Applied Ecology*, *52*, 532–537. https://doi.org/10.1111/1365-2664.12398

Hannis, M., & Sullivan, S. (2012). *Offsetting nature? Habitat banking and biodiversity offsets in the English land use planning system*. Technical Report. Green House.

Hawkins, I., Smith, A., Addison, P., Malhi, Y., Whitney, M., & zu Ermgassen, S. O. S. E. (2023). *The potential contribution of revenue from Biodiversity Net Gain offsets towards nature recovery ambitions in Oxfordshire*. University of Oxford and the Oxfordshire Local Nature Partnership.

HM Government. (2022). *Levelling up the United Kingdom: Executive summary*. UK Government.

Hough, P., & Robertson, M. (2009). Mitigation under Section 404 of the Clean Water Act: Where it comes from, what it means. *Wetlands Ecology and Management*, *17*, 15–33. https://doi.org/10.1007/s11273-008-9093-7

Inkinen, V., Coria, J., Vaz, J., & Clough, Y. (2022). *Using markets for environmental offsetting: Evaluation of wetland area gains and losses under the US Clean Water Act*. University of Gothenburg.

Krausmann, F., Lauk, C., Haas, W., & Wiedenhofer, D. (2018). From resource extraction to outflows of wastes and emissions: The socioeconomic metabolism of the global economy, 1900–2015. *Global Environmental Change*, *52*, 131–140. https://doi.org/10.1016/j.gloenvcha.2018.07.003

Kujala, H., Maron, M., Kennedy, C. M., Evans, M. C., Bull, J. W., Wintle, B. A., Iftekhar, S. M., Selwood, K. E., Beissner, K., Osborn, D., & Gordon, A. (2022). Credible biodiversity offsetting needs public national registers to confirm no net loss. *One Earth*, *5*, 650–662. https://doi.org/10.1016/j.oneear.2022.05.011

Lambert, Q., Gros, R., & Bischoff, A. (2022). Ecological restoration of solar park plant communities and the effect of solar panels. *Ecological Engineering*, *182*, 106722. https://doi.org/10.1016/j.ecoleng.2022.106722

Laurance, W. F., Peletier-Jellema, A., Geenen, B., Koster, H., Verweij, P., Van Dijck, P., Lovejoy, T. E., Schleicher, J., & Van Kuijk, M. (2015). Reducing the global environmental impacts of rapid infrastructure expansion. *Current Biology*, *25*, 259–262. https://doi.org/10.1016/j.cub.2015.02.050

LBE (London Borough of Enfield). (2021). *London Borough of Enfield Planning Enforcement Policy 2021*. Enfield Council.

Maron, M., Hobbs, R. J., Moilanen, A., Matthews, J. W., Christie, K., Gardner, T. A., Keith, D. A., Lindenmayer, D. B., & McAlpine, C. A. (2012). Faustian bargains? Restoration realities in the context of biodiversity offset policies. *Biological Conservation*, *155*, 141–148. https://doi.org/10.1016/j.biocon.2012.06.003

Natural England. (2021a). *Biodiversity net gain for local authorities—Local government association*. Natural England. https://www.local.gov.uk/pas/topics/environment/biodiversity-net-gain-local-authorities

Natural England. (2021b). *Biodiversity 3.0 metric launched in new sustainable development toolkit*. Natural England. https://www.gov.uk/government/news/biodiversity-30-metric-launched-in-new-sustainable-development-toolkit

Panks, S. (2022). *Biodiversity Metric 3.1: Auditing and accounting for biodiversity—User guide*. Natural England.

Remazeilles, A., Montag, H., Carvalho, F., Parker, G., & Howell, B. (2022). *Applying Biodiversity Net Gain to solar parks in the UK*. EGU General Assembly.

Robertson, M. (2021). *The state of no net loss/net gain and biodiversity offsetting policy in English local planning authorities: Full report*. University of Wisconsin.

Samuel, G. J. (2021). *Independent review of the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act): Final report*. Department of Agriculture, Water and the Environment.

Smith, R. J., Cartwright, S. J., Fairbairn, A. C., Lewis, D. C., Gibbon, G. E. M., Stewart, C. L., Sykes, R. E., & Addison, P. F. E. (2022). Developing a nature recovery network using systematic conservation planning. *Conservation Science and Practice*, *4*, 1–12. https://doi.org/10.1111/csp2.578

Sonter, L. J., Simmonds, J. S., Watson, J. E. M., Jones, J. P. G., Kiesecker, J. M., Costa, H. M., Bennun, L., Edwards, S., Grantham, H. S., Griffiths, V. F., Jones, K., Sochi, K., Puydarrieux, P., Quétier, F., Rainer, H., Rainey, H., Roe, D., Satar, M., Soares-Filho, B. S., … Maron, M. (2020). Local conditions and policy design determine whether ecological compensation can achieve No Net Loss goals. *Nature Communications*, *11*, 1–11. https://doi.org/10.1038/s41467-020-15861-1

TBC (The Biodiversity Consultancy). (2020). *Solar energy: Managing biodiversity risks*. The Biodiversity Consultancy.

Theis, S., Ruppert, J. L. W., Roberts, K. N., Minns, C. K., Koops, M., & Poesch, M. S. (2020). Compliance with and ecosystem function of biodiversity offsets in North American and European freshwaters. *Conservation Biology*, *34*, 41–53. https://doi.org/10.1111/cobi.13343

UK Government. (2021). *Environment Act 2021*. London, UK.

UK National Ecosystem Assessment (UKNEA). (2014). *The UK national ecosystem assessment: Synthesis of the key findings*. UNEP-WCMC, LWEC.

UKHab. (2018). *The UK habitat classification—Habitat definitions version 1.0*. The UK Habitat Classification Working Group.

Walker, S., Brower, A. L., Stephens, R. T. T., & Lee, W. G. (2009). Why bartering biodiversity fails. *Conservation Letters*, *2*, 149–157. https://doi.org/10.1111/j.1755-263X.2009.00061.x

Whitlock, R. (2022). *UK Government ends uncertainty on solar farms*. Renewable Energy Magazine. https://www.renewableenergymagazine.com/pv_solar/uk-government-ends-uncertainty-on-solar-farms-20221207

zu Ermgassen, S. O. S. E., Baker, J., Griffiths, R. A., Strange, N., Struebig, M. J., & Bull, J. W. (2019a). The ecological outcomes of biodiversity offsets under "no net loss" policies: A global review. *Conservation Letters*, *12*, 1–17. https://doi.org/10.1111/conl.12664

zu Ermgassen, S. O. S. E., Devenish, K., Simmons, B. A., Gordon, A., Jones, J. P. G., Maron, M., Schulte To Bühne, H., Sharma, R., Sonter, L. J., Strange, N., Ward, M., & Bull, J. W. (2023). Evaluating the impact of biodiversity offsetting on native vegetation. *Global Change Biology*, *29*, 4397–4411. https://doi.org/10.1111/gcb.16801

zu Ermgassen, S. O. S. E., Drewniok, M. P., Bull, J. W., Corlet Walker, C. M., Mancini, M., Ryan-Collins, J., & Cabrera Serrenho, A. (2022). A home for all within planetary boundaries: Pathways for meeting England's housing needs without transgressing national climate and biodiversity goals. *Ecological Economics*, *201*, 1–33. https://doi.org/10.1016/j.ecolecon.2022.107562

zu Ermgassen, S. O. S. E., Marsh, S., Ryland, K., Church, E., Marsh, R., & Bull, J. W. (2021). Exploring the ecological outcomes of mandatory biodiversity net gain using evidence from early-adopter jurisdictions in England. *Conservation Letters*, *14*, 1–10. https://doi.org/10.1111/conl.12820

zu Ermgassen, S. O. S. E., Utamiputri, P., Bennun, L., Edwards, S., & Bull, J. W. (2019b). The role of "no net loss" policies in conserving biodiversity threatened by the global infrastructure boom. *One Earth*, *1*, 305–315. https://doi.org/10.1016/j.oneear.2019.10.019

SUPPORTING INFORMATION

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

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