Quantifying the "avoided" biodiversity impacts associated with economic development

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Achieving global sustainability objectives such as the UN Sustainable Development Goals or Aichi Targets, including remaining within planetary boundaries, necessitates proactively avoiding a proportion of the environmental impacts otherwise expected to result from economic development. Quantifying these "avoided" impacts is important for monitoring progress toward meeting sustainability objectives, but doing so in a consistent way is fraught with difficulty. Using the mitigation of biodiversity impacts by development projects as an example, we explored the challenges of defining and measuring impact avoidance. Avoidance can be defined as either action-based or outcome-based, and classified by whether it is achieved through project cancellation, spatial avoidance, design-based avoidance, or temporal avoidance. We also examined what drives different types of project proponents to implement avoidance measures. To support empirical quantification of the contribution that avoidance makes toward conservation goals, we present a framework for structuring assessments of biodiversity impact avoidance. Our framework has widespread applicability in conservation science, policy, and practice, as well as relevance for broader policies that seek to avoid environmental and social impacts.

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Despite ostensibly facilitating improved human livelihoods and well-being, economic development can also contribute substantially to global environmental degradation, although the impacts vary by economic sector. Economic development is therefore given careful consideration when establishing sustainability objectives such as the Aichi Targets and the UN Sustainable Development Goals (Díaz *et al*. 2019). Various impact mitigation hierarchies exist to reduce these impacts. For example, the biodiversity "mitigation hierarchy" is among the best known, consisting of sequentially preferred measures (often formulated as "avoid, minimize, remediate, offset") applied to the predicted biodiversity losses from development projects, with the objective of attaining "no net loss" (NNL) of biodiversity or better (BBOP 2012; zu Ermgassen *et al*. 2019). Such hierarchical approaches underpin environmental impact assessments (EIAs). Analogous hierarchies are commonly applied to mitigate other environmental aspects (eg waste production – "reduce, reuse, recycle, recover"; Hultman and Corvellec 2012), or implicitly for net zero greenhouse-gas (GHG) emissions (avoidance of emissions through resource use efficiency and offsetting emissions; Rockström *et al*. 2017). Similar logic is applied to managing impacts from accidental pollutant release, as under US natural resource damage assessment (NRDA) or the EU Environmental Liability Directive (Dunford *et al*. 2004; Martin-Ortega *et al*. 2011; Bas *et al*. 2013). Some social impacts are also managed in this way by compensating physical and economic displacement when it cannot otherwise be avoided. Mitigation hierarchies are also finding their way into new accounting frameworks for business (Houdet *et al*. 2020).

In a nutshell:

- Economic development projects can have detrimental effects by contributing to global environmental degradation, including through negative impacts on biodiversity
- Projects can be modified at early stages to "avoid" such impacts, and this will likely make an important contribution toward achieving global environmental objectives; however, avoidance of an impact is difficult to quantify and therefore is often not reported
- We developed a comprehensive framework that can be used to quantify the amount of biodiversity conserved through avoidance, demonstrating its importance to the well-established biodiversity impact mitigation hierarchy
- The framework not only captures *what* is avoided, *how* and *why* this is done, and by *whom*, but also enables comparable empirical quantification of avoided biodiversity impacts, driving real conservation action through improved transparency and effectiveness assessments

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Across impact mitigation hierarchies, the preventative steps – avoidance and minimization – are often prioritized, under the assumption that "prevention is better than cure". Other steps – remediation and offsetting – are compensatory, aimed at reversing or fully compensating for any residual impacts, respectively. The potential power of avoidance is substantial: for example, avoiding tropical deforestation could prevent up to a quarter of anthropogenic carbon emissions, at competitive economic costs (Kindermann *et al.* 2008). In addition, from the perspective of guaranteeing sustainability outcomes, preventative measures are often seen as less risky and having a lower chance of failure than compensatory measures, and are essential where insufficient land is available for compensation (Sonter *et al.* 2020). The difficulty and expense of compensatory measures ideally incentivize more rigorous application of impact prevention; but in practice, to the contrary, compensation is often given far greater priority and scrutiny than is prevention. This is in large part due to a lack of standard approaches for quantifying avoidance, so the extent to which such incentivization occurs is unknown and opaque, and quantification of the preventative steps in the hierarchy remains fraught. Here, we present a framework to enable such assessments and inform improvements to policy design and implementation.

We focus on avoidance of biodiversity losses, which are currently considered one of the primary risks to global society (World Economic Forum 2022). Avoidance is preferred over often-controversial compensatory measures for achieving the desired net biodiversity outcomes (CSBI 2015; Phalan *et al.* 2018). There is little understanding of how widely implemented or effective avoidance measures have been. Clare *et al.* (2011) interviewed actors involved in mitigating wetland impacts in Canada and concluded that avoidance is not easily defined and is "ignored more often than it is implemented", while Bigard *et al.* (2018) found similar challenges in France. Conversely, Pascoe *et al.* (2019) assessed developer behavior in response to Australian biodiversity offset requirements, suggesting that high offset costs could be incentivizing increased impact avoidance, whereas Phalan *et al.* (2018) examined how avoidance of biodiversity impacts could be improved through strengthened design and enforcement, and reviewed possible reasons (for instance, political will, regulatory weaknesses, poor process, and shortfalls in capacity and technical expertise) for the failure to avoid impacts.

To the best of our knowledge, only one assessment has empirically evaluated the implementation of biodiversity impact avoidance relative to other stages in the mitigation hierarchy, finding that preventative measures contributed substantially to impact mitigation ("restoration" was the greatest contributor; Sahley *et al.* 2017). Clearly, it is not yet possible to draw generalizations. A prerequisite for broader quantification of avoidance across contexts is to qualify what constitutes "avoidance", which has yet to be explored in detail and stated precisely in the scholarly literature.

Here, we introduce a conceptual framework for categorizing and evaluating biodiversity impact avoidance measures relative to the mitigation hierarchy. We propose a method to standardize how avoidance is quantified and claimed, enabling direct comparison across projects and contexts, as well as more robust implementation of mitigation across sectors and countries. This method can then be applied to other types of environmental and social impacts.

A starting point for avoidance

Avoidance of impacts must be considered relative to the impacts caused by some initially proposed version of the development project in question. Defining the "initial" version of a project is not trivial: for instance, EIA procedures typically require some analysis of project alternatives, which incorporates multiple possible initial designs to demonstrate that, within reason, the alternative with the smallest negative impacts was selected. This might include considerations of projects outside the proponent's scope (eg improving the performance of existing facilities, rather than creating new ones) and a "no project" option. These requirements are often met only superficially in practice (Steinemann 2001; Smith 2007; Jiricka-Pürrer *et al.* 2018). Nonetheless, we assume some initial design – for instance, an initial version of the project that maximizes net present value before environmental externalities are assessed – that is then modified to avoid impacts. Equally, we note that accurate estimation of impacts is a necessary precursor to quantified avoidance, yet this is not often done for biodiversity (eg Simmonds and Watson 2019), particularly for indirect and cumulative impacts (Masden *et al.* 2010; Raiter *et al.* 2014; Siqueira-Gay *et al.* 2020). Moreover, there is usually substantial disagreement on the actual significance of impacts due to vested interests in estimating lesser or greater impacts on the part of project proponents and project opponents, respectively (where "significance" in this context is a formal term, regularly applied in EIA to denote impacts likely to substantially affect some environmental receptor; Jones and Morrison-Saunders [2016]). However, we focus here on methodically categorizing avoidance measures for support of systematic empirical evaluation.

Categorizing avoidance measures

Change in an environmental feature ("what")

First, *what* precisely is the change attributable to avoidance measures? Avoidance in general can be considered a foregone negative impact on biodiversity. There are, however, multiple ways of measuring change associated with conservation efforts (Butchart *et al.* 2010). Equally, avoidance must be readily distinguishable from other preventative measures (ie minimization). Categorizing avoidance as either *action-based* or *outcome-based* can help clarify both points.

One common interpretation of avoidance is that it means taking measures that, once implemented, require no further action from the proponent to prevent predicted biodiversity impacts (CSBI 2015). For instance, after a shift in the planned spatial footprint of a project away from areas of high biodiversity value, no further action is required to ensure that direct impacts on those areas are prevented. Under this interpretation, avoidance is distinct from minimization in that the latter requires ongoing management to prevent impacts (for example, requiring contractors to follow open-ended operational protocols). This represents an action-based interpretation of impact avoidance that is quantifiable in terms of the effort made to prevent impacts, as used by some regulators (Clare *et al*. 2011).

Alternatively, avoidance can be interpreted in terms of outcomes; that is, successful avoidance by definition is the prevention of 100% of predicted impacts on a given biodiversity feature (eg threatened species habitat), whereas anything less than 100% would be minimization. Avoidance can then be quantified in terms of averted change in environmental outcomes, regardless of the measures taken to achieve it; this would constitute an outcome-based form of avoidance. Evidence for actual avoidance of impacts again requires outcomes to be measured and compared to estimates of outcomes under a project's initial version.

Beyond considering actions versus outcomes, one key issue is that some development projects have greater indirect than direct impacts (eg environmental impacts caused by an influx of people attracted to employment opportunities offered by a new development). While avoiding direct impacts mostly results in avoided indirect impacts as well, there may be cases where this causes *increased* indirect impacts ("leakage"). For example, areas of habitat may be protected from encroachment while remaining within the boundary of a forthcoming industrial project, but considered open to third parties once avoided by the proposed project. In practice, the mitigation hierarchy is not widely applied to indirect or cumulative impacts on biodiversity, even where required by regulations or guidelines, because of the difficulties in estimating and monitoring indirect impacts and assigning shared responsibilities for cumulative impacts.

Finally, to enable quantitative assessment of potential impacts and their avoidance, "biodiversity" has to be tied to specific indicators (eg conservation status of endangered species of flora and fauna, or their habitat availability), which can also be used as proxies for total biodiversity. In cases where proxies are used to monitor biodiversity losses and impact mitigation measures are designed around those proxies, the true extent of negative impacts may not be captured by EIAs (Simmonds *et al*. 2019). This might also be because only "significant" impacts are required to be mitigated and because thresholds of significance may be set inappropriately (Clarke Murray *et al*. 2018). Finding suitable biodiversity indicators (although not explored here) is a much broader challenge and further complicates efforts to measure biodiversity impact avoidance.

Types of avoidance measures ("how")

Next, we explore *how* avoidance can be achieved. Consider project cancellation: avoided impacts might include those associated with a project being abandoned early on, which could be considered the ultimate form of avoidance (eg Smith 2007). Projects are cancelled for numerous reasons, many of which have nothing to do with predicted biodiversity impacts or even environmental issues generally (WebPanel 1). However, in line with the outcome-focused definition of avoidance, we still consider that project cancellation is a form of impact avoidance. The loss–gain balance for any project is calculated based on predicted impacts if the project goes ahead, so in the simplest case (no biodiversity impacts prior to cancellation) project cancellation results in full avoidance (Figure 1). However, biodiversity impacts might have occurred prior to cancellation (eg clearance of habitat during preliminary exploration for subterranean resources); in this case, claiming NNL would require those impacts to be mitigated despite project cancellation. This would not necessarily apply if the project's cancellation makes land available for other development options that were previously not considered for lack of available space.

Beyond project cancellation, Phalan *et al*. (2018) and CSBI (2015) recognized three types of avoidance measures: (1) site selection (to avoid spatial overlap between impactful project activities and biodiversity features), (2) project design (to avoid impacts through selection of technologies used in a project), and (3) scheduling (timing project activities so that they do not overlap with sensitive times for biodiversity features, such as breeding seasons). More recently, the Government of France released the first detailed typology of avoidance measures tied to national policy, consisting of re-siting, geographical avoidance, technological controls, and temporal avoidance. Consequently, a consistent typology of avoidance measures that draws upon science, policy, and practice classifies avoidance as one of (1) project cancellation, (2) changed spatial location, (3) altered project design, and (4) temporal avoidance. This typology is directly applicable to avoidance of biodiversity losses, but could also provide a conceptual basis for categorizing avoidance measures for other mitigation policies (eg all categories are relevant to the avoidance of GHG emissions, waste, and other "receptors" identified in EIA processes).

Incentives for avoidance ("why")

We categorize possible drivers for avoidance into those that are physical, social, economic, or institutional. This framing was suggested by Ferraro and Pattanayak (2006) and subsequently employed for terrestrial NNL biodiversity policy (Bull *et al*. 2015) and fisheries management (Bladon *et al*. 2018). Although this could also be applied to multiple environmental impact types (including GHG emissions and waste production), here we focus on biodiversity.

Physical drivers for avoiding impacts include limitations to proposed development arising from landscape structure (topography, soil stability, and so on), practical availability

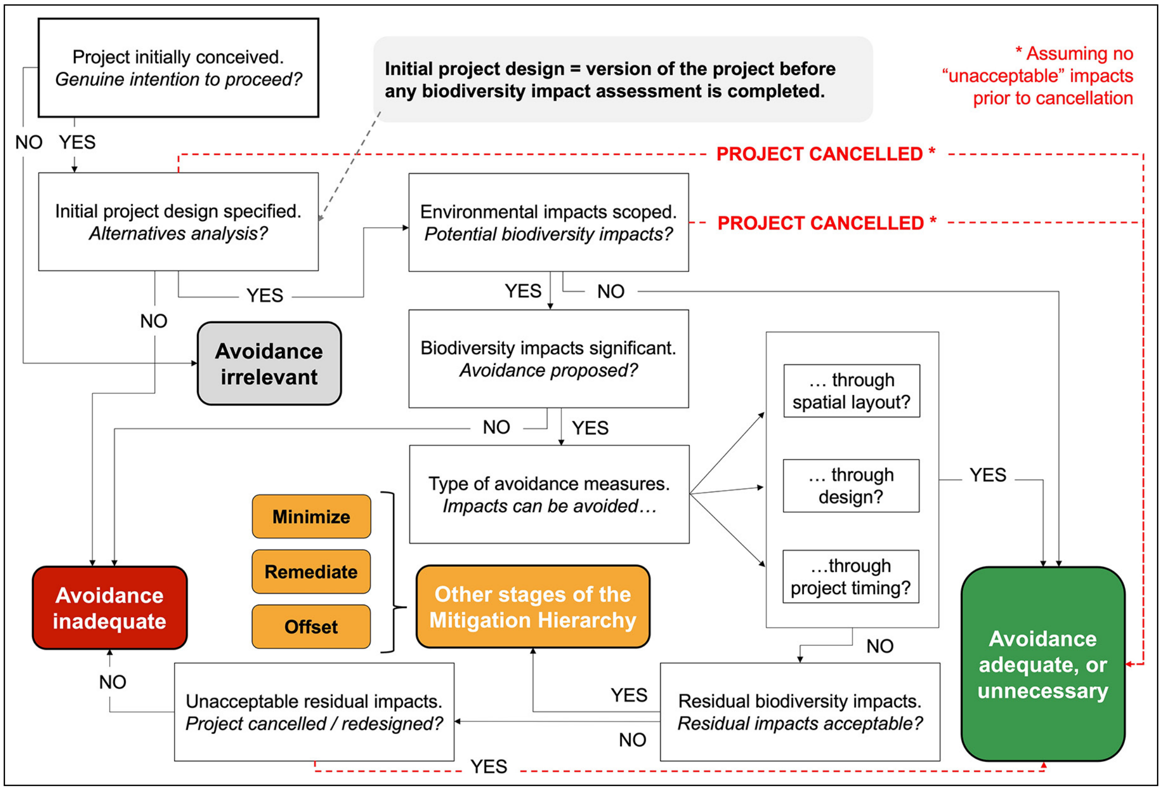

Figure 1. Generalized overview of the relevance of avoidance at various stages in the project development and biodiversity impact assessment process, starting from the top left. Although the question of how to define which residual impacts are "unacceptable" (that is, require avoidance) is an entire topic of study in itself, it is linked in part to the choice of biodiversity indicator. "Significance" in this context is as specified in the main text.

of key materials, and physical processes related to climate change. For example, impacts might be avoided due to topographic constraints on where infrastructure could be located.

Social drivers would include impacts avoided due to such factors as public opposition in cases where proposals impact biodiversity features representing important cultural heritage (Griffiths *et al.* 2019) or indispensable ecosystem services (Sonter *et al.* 2018). Social values placed on biodiversity might rule out projects at an early stage, even if biodiversity impacts are only one of several concerns of project opponents toward proposals. This category would include cases in which project proponents or other stakeholders in the planning system are personally motivated by conservation of nature as an ethical consideration. In practice, ethics are often at the forefront of arguments advanced by those seeking to prevent project impacts. It would be fascinating to analyze how often ethical arguments lead to avoidance, especially given rapidly changing social norms about the environment (Otto *et al.* 2020).

Economic drivers capture cases in which, for example, abrupt changes in commodity prices qualitatively alter financial feasibility. These would include cases in which biodiversity offsets are costly to such an extent that project proponents instead reduce residual impacts despite no absolute requirement for avoidance, instances of which have been observed (Gibbons *et al.* 2017; Pascoe *et al.* 2019). Note that economic drivers likely often lag behind project cancellations, along with any avoided impacts claimed as a result. Economic drivers also influence other forms of avoidance (that is, design: spatial and temporal) and interact strongly with the other drivers discussed here: for instance, the nature of the technological constraints acting upon a project (physical drivers) depends partly on the affordability of engineering solutions (Gallardo and Sánchez 2004). In addition, public opposition (social drivers) may in turn become financial risks due to the potential for project delays, legal costs, or investors reluctant to provide funding due to image concerns (Franks *et al.* 2014).

Finally, under the category of institutional drivers is the wealth of policy and legislation that requires project proponents to avoid impacts on certain biodiversity features (Phalan *et al.* 2018; IUCN 2020). This is likely a key driver not only for project proponents to avoid impacts in jurisdictions where environmental regulation is upheld in courts but also of other biodiversity impact mitigation measures (Bull and Strange 2018). Similarly, impact avoidance might result from environmental safeguards required by project financiers (eg IFC 2012) or necessary to align with preferences of institutional investors and shareholders. Other regulations that are not primarily biodiversity-focused, such as land-use planning that restricts specific development (eg infrastructure construction in areas of high flood risk), may achieve avoidance. Strategic plans for development governing a given jurisdiction – for instance, where direct financial support, fiscal incentives, or other enabling conditions favorable to projects are conditional on incorporating certain environmental constraints (such as agri-environment schemes) – can also lead to avoided impacts. Again, there is interaction with other drivers, such as financial issues driving the need to turn to lenders with safeguard policies (economic drivers).

Actor responsible for implementation ("who")

To fully characterize avoidance, we included a fourth category: *who* is responsible for implementing avoidance measures. An extremely wide range of actors may be responsible – on different spatial scales and points in the project lifecycle – for designing, directing, or implementing mitigation measures associated with a project. Esmail (2017) categorized those stakeholders into 11 groups, which we condense for generality here to government, lenders and investors, parent companies (project sponsors), implementing agencies (project managers), contractors, clients, and others (including nongovernmental advocacy groups).

The implementing agency or its contractors are often responsible for designing and delivering avoidance measures during construction and operation. These are perhaps how avoidance measures often begin, by avoiding project-specific biodiversity impacts (eg via implementation of a biodiversity action plan). Certain financial institutions and jurisdictions may have specific requirements on the roles and responsibilities of project sponsors, advisors, contractors, and so forth for public work or public–private partnerships, notably to manage conflicts of interest when managing public funds. However, regional or national government agencies may drive avoidance of biodiversity impacts at larger scales through spatial planning, including the designation of protected areas with varying levels of restrictions on development projects or via strategic environmental assessments. Avoidance of impacts at these larger scales may not relate to specifically proposed projects (as per our conceptualization in the section "A starting point for avoidance" above) but rather to certain *classes* of projects (eg extractive sector projects) that might otherwise be likely in the absence of spatial restrictions.

Similarly, lenders or investors may develop safeguards to ensure finance is directed to lower the impact of projects (facilitating some avoidance at larger scales) and audit their clients against detailed environmental action or management plans, with noncompliance potentially invoking financial and reputational consequences. The role of investors in achieving sustainability objectives has expanded after the strengthening of environmental disclosure rules for publicly listed firms, but with limited evidence of effectiveness to date insofar as biodiversity is concerned (de Silva *et al*. 2019). Final clients (end users) may influence avoidance of impacts if demand is sufficiently segmented that there could be commercial consequences (eg boycotts) for developing a project with large biodiversity impacts, or if they are willing to pay a premium for the product of avoided impacts (eg housing developments adjacent to fully retained natural habitat). Finally, the "other" category might include judges imposing decisions on project sponsors following court cases brought by independent third parties such as conservation nongovernmental organizations (NGOs). In practice, fear of prosecution likely often drives avoidance and enables social and institutional drivers to affect decisions about projects.

Avoidance across sectors and scales

Many other aspects of development projects will influence the nature of avoidance, including size, economic sector, and the type and degree of regulation that applies. For instance, consider the difference between a typical major resource extraction project and a transport infrastructure project: the proponent in the former case might conduct much more extensive and impactful exploratory work to gather information on available resources before the project itself is designed (eg habitat clearance for seismic testing for hydrocarbons), meaning that the point at which avoidance deserves attention in the development process could fall at a much earlier date than for a road construction project. However, the road project might involve far greater use of imported materials, with substantial embodied biodiversity losses (along with GHG emissions, water use, and so forth) – meaning that avoidance of impacts far up the project supply chain becomes the dominant concern. This influences what can be considered the initial project design that acts as the reference against which avoidance is evaluated (Figure 1). A degree of uncertainty is inevitable, but the key points are (1) initial project design is a version of the project before any impact assessment has been specifically carried out, and (2) avoidance measures apply to any impacts that occur between project conception and final project design (eg in the case of resource exploration).

We return briefly to the issue of the possible displacement (including leakage) of impacts as opposed to true avoidance, because it is pertinent to considering avoidance at larger scales. How can we treat impacts that, for instance, are avoided by relocating a development project, only to cause additional impacts in the new location, which may be in the same or a different jurisdiction? Assuming the same drivers apply across a jurisdiction, displacing a project *within* a jurisdiction is less problematic than when a project is relocated to a different jurisdiction, where the same environmental standards might not apply. The latter is true leakage. The possibility of leakage provides another argument for clearly defining the scope and scale of any assessment of avoided impacts: it can never be assumed that avoiding environmental impacts within a certain jurisdiction will lead to their universal avoidance, in space and over time.

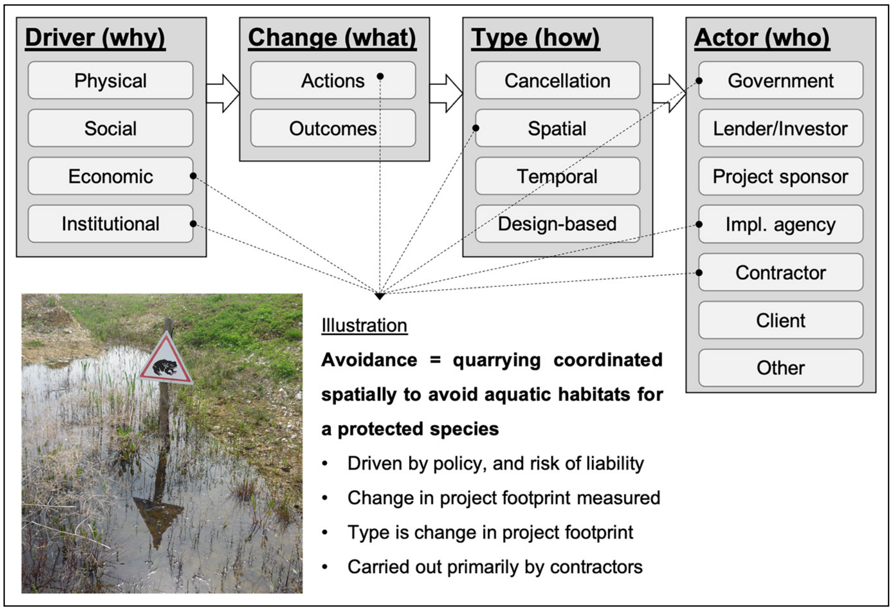

Figure 2. Schematic of our conceptual framework capturing different categories of environmental impact avoidance (gray boxes), including drivers for avoiding impacts, change resulting from avoidance measures, type of avoidance measures, and the actor responsible. Photograph represents an illustrative example, that of avoidance of biodiversity impacts on aquatic habitat for the natterjack toad (*Epidalea calamita*) at a quarry in France's lower Seine Valley. Image credit: T Flavenot.

Quantitatively evaluating different categories of avoidance

Avoidance measures can be comprehensively structured into four classes (Figure 2): (1) change resulting from avoidance (*what* impacts are avoided), (2) type of avoidance (*how* those impacts are avoided), (3) drivers for avoidance (*why* avoidance is taking place), and (4) those responsible for avoiding impacts (*who*). This conceptual framework aids quantitative assessment of biodiversity impact avoidance (and avoidance of environmental impacts more generally). Starting from our summary of where avoidance can arise in the development process (Figure 1), an assessor would explicitly state which components within the framework are being included in a given avoidance assessment, thereby making explicit any gaps and the degree of comparability between different assessments. Regarding metrics, avoidance would be quantified on the basis of "actions taken" (eg number and type of management measures implemented), "outcomes" (eg state of receptors such as habitats or species), or both.

For example, imagine avoided impacts were assessed for a group of development projects via a review of impact mitigation measures detailed in EIAs, as a response to institutional requirements governing biodiversity impacts, alongside social considerations through stakeholder engagement. In the UK, which is launching Biodiversity Net Gain legislation (that ostensibly requires biodiversity impacts to be mitigated and over-compensated for most development projects; zu Ermgassen *et al.* [2021]), this would typically involve a statement of *actions* taken to reduce impacts on biodiversity features. This addresses widespread concerns that project proponents are not encouraged to treat impacts as "avoidable" and instead default to offsetting (Sullivan 2013). Those statements are unlikely, however, to include consideration of indirectly avoided impacts on biodiversity arising from non-biodiversity mitigation measures. EIAs are often documented for UK projects that are rejected and therefore cancellations could also be captured, as could all other avoidance measures (Bigard *et al.* 2017; Wawrzyczek *et al.* 2018). Because mitigation of impacts was being delivered in response to project-specific EIAs, it would mean avoidance measures therein were the result of a process involving the proponent, its advisors, financial backers, permitting authorities, and various consultative bodies. In addition, in many jurisdictions the process also involves public consultation. Avoidance measures attributable to the biodiversity impact mitigation measures captured by such assessments are shown in Figure 3.

Conversely, consider evaluation of avoidance under US policies based on observed trends in habitat for protected species (Sonter *et al.* 2019) or wetland coverage (Bull and Milner-Gulland 2020). Both capture changes in biodiversity variables related to outcomes (habitat condition and area) and for all possible drivers of avoidance, but both fail to capture any information about specific types of avoidance measures or the actors implementing them (Figure 4). Whereas the UK example involves documented statements of avoidance actions taken for each project, the US example potentially involves a statement of the avoided impacts attributable to the NNL policy at the landscape scale. Again, this is crucial to evaluating whether the US is delivering on its long-stated NNL of wetlands objective (Clare *et al.* 2011).

The fact that both assessments in Figures 3 and 4 fail to capture all categories within our conceptual framework demonstrates how certain elements of avoidance can be easily overlooked. Similarly, our framework highlights where such analyses might overlap, which can be useful regarding any comparison of the degree of avoidance achieved across different impact mitigation policies. In the case of Figures 3 and 4, it is immediately clear that the UK and US examples would differ in using action-based and outcome-based measures of avoidance, respectively; furthermore, whereas the UK analysis more comprehensively captures types of avoidance measures, the US analysis better captures drivers for avoidance. Although here we apply the framework to avoided biodiversity losses, it could also be applied to quantifying other environmental outcomes, such as the avoidance of GHG emissions under climate-change policies.

Conclusion

A growing number of countries, companies, and financiers have committed to applying a form of mitigation hierarchy, in which "avoidance" of losses is the first step. Avoidance is assumed to be the most reliable way to achieve mitigation of impacts on biodiversity because it leads to more predictable outcomes than, for instance, attempting to reintroduce or restore those features once they are gone (which can be infeasible; eg following a species extinction). Therefore, even if it is overwhelmingly expensive (though indeed it may often be the most competitive option), avoidance is considered imperative by most scientists, NGOs, and civil society, and is formally prioritized in most regulations and guidance. To the best of our knowledge, no comprehensive framework – one that captures what constitutes avoidance measures in impact mitigation, and provides a means for quantitatively and comparably evaluating impact avoidance achieved across projects – has been available, up to now. We present such a framework here, applicable to biodiversity loss as well as to avoidance of other environmental or even social impacts. We propose a simple approach for categorizing forms of avoidance based on well-known constituent concepts. This will also facilitate comparison of the outcomes achieved by avoidance efforts to those achieved through other stages of the mitigation hierarchy. Eventually, it will enable the next important steps: quantification of avoided impacts, evaluation of the contribution of avoidance measures to environmental objectives, and exploration of the cumulative outcomes of multiple avoidance measures.

Our review demonstrates why defining "avoidance" is challenging, and why interpretations vary among jurisdictions, sectors, and projects. This, alongside a lack of monitoring and reporting for biodiversity outcomes more generally (Bull and Strange 2018), is an important barrier to true quantitative assessment of the degree to which impact avoidance takes place. Impact avoidance consequently remains understudied, despite its importance to achieving desirable conservation outcomes from mitigation hierarchies.

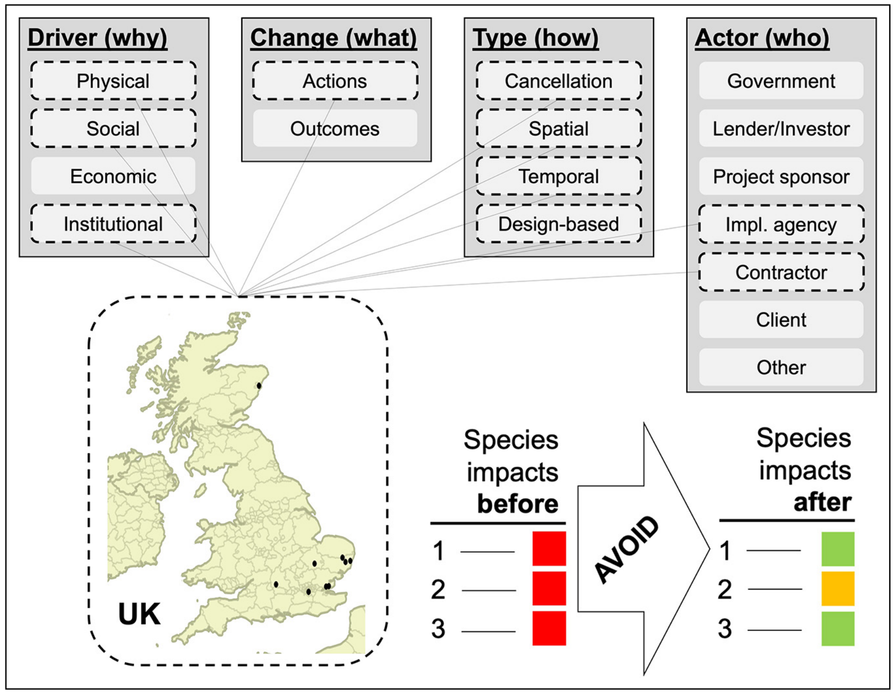

Figure 3. Illustrative application of the framework evaluating biodiversity impact avoidance measures based on a review of environmental impact assessment statements (UK setting; relevant categories are ringed in black dashed lines), linked to few existing biodiversity offsets (black circles on map; data from Bull and Strange 2018). The UK application results in a listing of avoided impacts on a project-by-project basis.

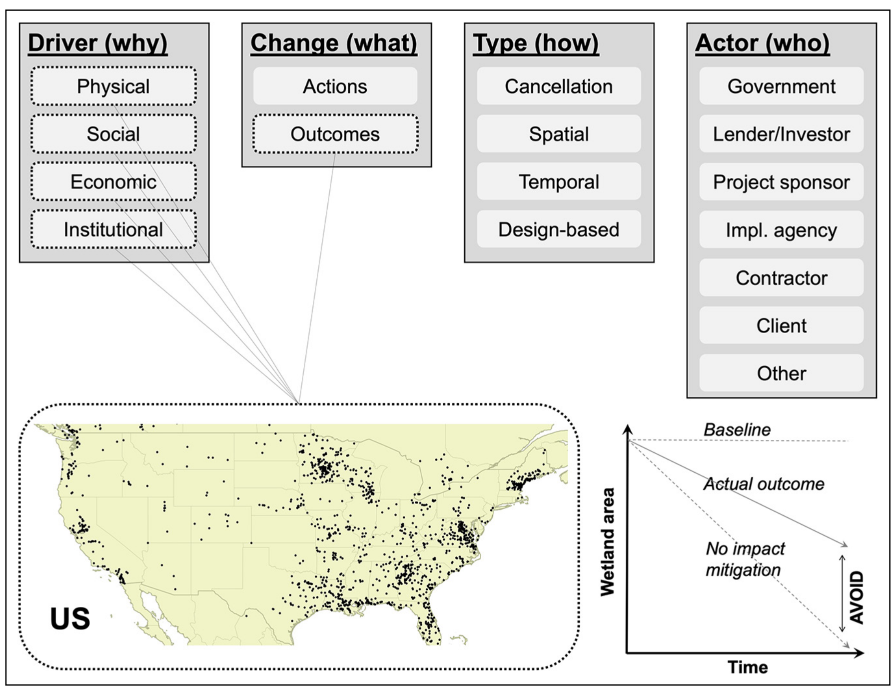

Figure 4. Illustrative application of the framework evaluating biodiversity impact avoidance measures based on an analysis of trends in biodiversity features (wetlands) subject to net outcome type policies (US setting; relevant categories are ringed in black dotted lines), linked to hundreds of known wetland offsets (black circles on map are offsets; data from Bull and Strange 2018). The US application results in landscape assessment of avoidance against a background trend in wetland area.

As noted, this is relevant to avoidance of numerous other types of environmental and social impact; our approach is applicable to these other impact types as well, and should be explored as a priority for further research. Nonetheless, our framework provides an important step toward conducting more systematic, detailed, and comprehensive quantitative assessments of biodiversity impact avoidance – in NNL policy and beyond.

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Data Availability Statement

Data used in this study are already published, with those publications cited in this submission.

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