Biological Conservation 277 (2023) 109831

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Mainstreaming biodiversity in business decisions: Taking stock of tools and gaps

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ARTICLE INFO

Keywords:
Corporate environmental management
Corporate biodiversity management
Biodiversity metrics
Biodiversity tools
Certifiable standards

ABSTRACT

Most businesses depend on biodiversity, either directly, indirectly as ecosystem services, or through their supply chains. In negatively impacting biodiversity, businesses risk losing essential resources and services. As a result, it is important for the private sector to demonstrate strong and improved performance on biodiversity.

This paper reviews and compares tools and approaches that help businesses measure their performance on biodiversity issues. Through a literature review and interviews of tool developers, we assess how tools are constructed, how they measure biodiversity performance, how and where they are being used by different businesses and how they contribute to achieving international targets for biodiversity. We found that tools perform a range of functions and are mostly applied at product, site, and supply chain level. Further efforts are needed to align tools with global biodiversity goals. Key knowledge gaps remain to better capture dependence on biodiversity and spatial spillover effects.

1. Introduction

Tools for mainstreaming biodiversity into business decisions are increasingly being adopted in a variety of sectors as a basis for promoting sustainable business (UNEP/WCMC, 2020). By allowing producers and companies to compete on non-price factors, including social, economic, and environmental sustainability (Boiral and Heras-Saizarbitoria, 2017), they have the potential to create systemic and enduring economic incentives for the adoption of sustainable practices and play a major role in biodiversity conservation (Global Commons Alliance, 2020).

In the past five years, there has been a proliferation of research and practice multistakeholder initiatives, platforms, and coalitions to advance the development and uptake of biodiversity measurement approaches and tools by businesses and financial institutions (Beck-O'Brien and Bringezu, 2021). These include the European Business and Biodiversity Platform (EU B@B Platform), the Global Partnership for Business and Biodiversity hosted by the Convention on Biological Diversity (CBD), and the work programme on Business and Biodiversity by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), among others. Other consortia have also recently developed guidance to assist companies in the assessment of the risks and opportunities that biodiversity presents to an organisation's strategy within a broader sustainability scope, such as the Climate Disclosure Standards Board (CDSB, 2021), the ISEAL Alliance (ISEAL, 2020) the International Institute for Sustainable Development (IISD, 2017) and the Taskforce on Nature-related Financial Disclosures' LEAP approach (TNFD, 2022). The mobilization of business at scale is increasingly a matter of urgency as none of the CBD's 2010 targets were fully satisfied (CBD, 2020).

Despite these initiatives, for the most part these tools continue to be driven by, and for, private actors. As a result, they are often developed at arm's length from public policymakers, giving rise to a high degree of variability among the tools themselves with little opportunity for alignment or comparison among the differing methodologies. Amid the growth in tool availability, a lack of methodological standardisation means that aligning tool selection with user requirements is not always straightforward. Many tools use proxies or processes such as the status of natural capital or pollution levels, and habitat loss to estimate biodiversity impacts (Wolff et al., 2017), but they may miss local spatial factors that influence biodiversity (Eigenbrod et al., 2010). Current use of these tools is limited by a lack of broadly accepted (biodiversity) measurement approaches to underpin them, and by a disconnect between policy objectives and the proponents of these initiatives themselves (IISD, 2017).

Notwithstanding their limitations, these tools establish an

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https://doi.org/10.1016/j.biocon.2022.109831
Received 3 June 2022; Received in revised form 4 November 2022; Accepted 28 November 2022

increasingly sophisticated infrastructure for identifying, enforcing, and measuring levels of compliance with best practices that can assist policymakers in their efforts to implement, monitor, and regulate biodiversity conservation. As approaches develop and tools emerge, it is important that they are broadly consistent, scientifically robust, and pragmatic (Sobkowiak, 2022). While some reviews have identified common aims among these tools, further research is needed to explore challenges on data, metrics, boundaries and baselines, business applications, and more importantly, opportunities for these tools to support the private sector to implement the Post-2020 Global Biodiversity Framework (Addison et al., 2018; Addison et al., 2020; Lammerant et al., 2021).

This paper seeks to provide a basis for more strategic selection and use of these tools in the promotion of biodiversity conservation. It offers a broad overview of current trends across a selection of tools that assess businesses' biodiversity performance by measuring risk, dependencies, and impacts (positive and negative) for internal decision-making (e.g., relating to risk management and accounting), and/or to meet a variety of external reporting requirements (e.g., certification, non-financial disclosure, and regulation). We start by comparing and critically assessing the tools according to how they operationalise different concepts of biodiversity in a way that supports 'mainstreaming' of biodiversity-based decisions and how they align with the Post-2020 Global Biodiversity Framework's 2030 Action Targets (CBD, 2021). For this task, we reviewed guidance documents from the producers of such tools, reports from the businesses using them, journal articles, and other reports and guidance documents. We also conducted in-depth interviews with a selected group of tool developers on current and emerging practices of business biodiversity reporting and disclosure. We then identify methodological limitations to the applicability of the tools in terms of characterisation of impacts, choice of indicators, spatial and temporal scales, and the knowledge base and skills required to utilise them. Finally, we propose recommendations into how these tools have the greatest potential to contribute to biodiversity conservation and where the most important knowledge gaps to the optimal use of such tools reside.

The rest of the paper is structured as follows. Section 2 describes the methods used to critically review the tools. The results are then presented and discussed in Section 3. Finally, the main conclusions are reported in Section 4.

2. Material and methods

In this paper, we define tools in a broad sense as reflecting discrete methodologies which accept information on user activities and their relevant regional context. All tools have similar broad aims of providing a score or assessment of the impact associated with an organisation's activities and/or performance. These may be translated into a biodiversity impact score based on either a characterisation process (assuming a defined relationship between activity and impact) or performance against established threshold conditions (e.g., number of endangered species). Tools may have additional objectives, associated with determining dependence on biodiversity or impact of conservation or restoration activities.

Our underlying theoretical framework (Fig. 1) is based on a company-centred intra-organisational value creation model, building on sustainable business model and entrepreneurship research, and focusing on the links between business strategy, opportunities, value propositions, primary customers, key activities, and services offered and resources and costs (Feger and Mermet, 2022). To theorise the rationale for companies to respond strategically to biodiversity risk, we start with the lens of the natural resource-based view of the firm (Hart, 1995). This business approach to natural capital has recently risen to prominence, exemplified by the Natural Capital Protocol (Natural Capital Coalition, 2016) and expanded to pay a more deliberate attention to both impacts and dependencies on natural capital as equally important strategic

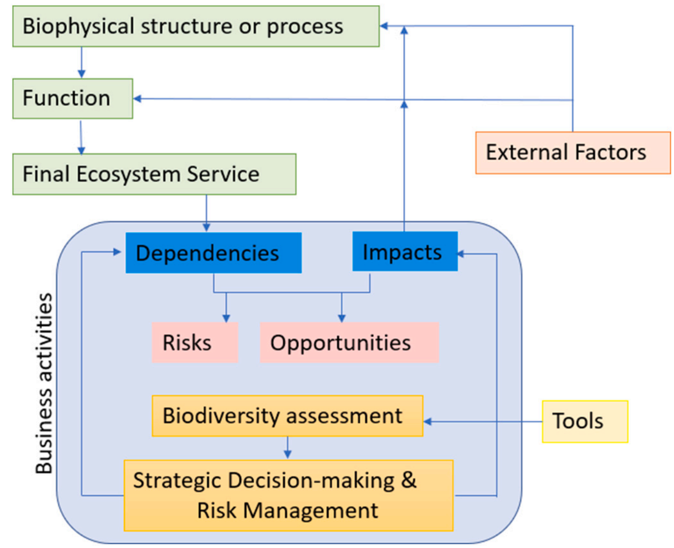

Fig. 1. Theoretical framework on the role of tools in the mainstreaming of biodiversity by businesses.
Adapted from CDSB (2021).

constraints. Business impacts and dependencies on biodiversity and final ecosystem services are sources of risks and opportunities for the organisation's future financial position and financial performance (CDSB, 2021). This framework places business activities within a systems perspective where businesses may also seek to compensate for, offset and mitigate their impacts. Biodiversity impact assessment therefore needs to have a robust concept of biodiversity and generate results or insights that can be directly actionable within a decision-making framework. This study seeks to provide a critical assessment of tools that support businesses in different ways to consider the risks associated with resources that are critical to their operation; and their corollary, the opportunities for competitive advantage that can arise for companies that are better able to manage these risks and exploit new opportunities.

The analytical framework applied in this paper (Fig. 2) follows a 6-step process and draws from existing qualitative assessments of sustainability tools in different contexts (Janker and Mann, 2020; Sharifi, 2016) as well as reviews of biodiversity focused tools (Lammerant et al., 2021). In the first step, a total of 33 tools (active by February 2022) were identified for a rapid scoping exercise (Step 2) (see Table A1 in Appendix A for the full list of the tools considered). The rapid scoping characterised the tools according to function, scale, and sector of interest (see Table A2 in the Appendix A for explanation of these criteria).

In a third step, a representative sample of 14 tools was selected (see criteria for selection in Fig. 2) for an in-depth review. This selection was intended to enable comparison of tools that perform similar functions and aimed to include three sectors: i) agriculture (which represents the greatest driver of biodiversity loss), ii) forestry (since forests are critical habitats for biodiversity and are often considered in voluntary standards and certifications), and iii) use of freshwater ecosystem services (because wetlands are the most endangered habitat and are experiencing high losses of biodiversity).

The in-depth review (step 4) relied on publicly available guidance provided in tools' websites, supplemented by insights from semi-structured interviews (see interview questionnaire in Table A4) of developers of four of the tools who were available to discuss the tools they provide with the research team (LAND360, LEAF, LIFE and UEBT). This step aimed to:

(i) Describe the functions the tools perform.
(ii) Compare the tools according to how they support mainstreaming of biodiversity considerations in business decisions.

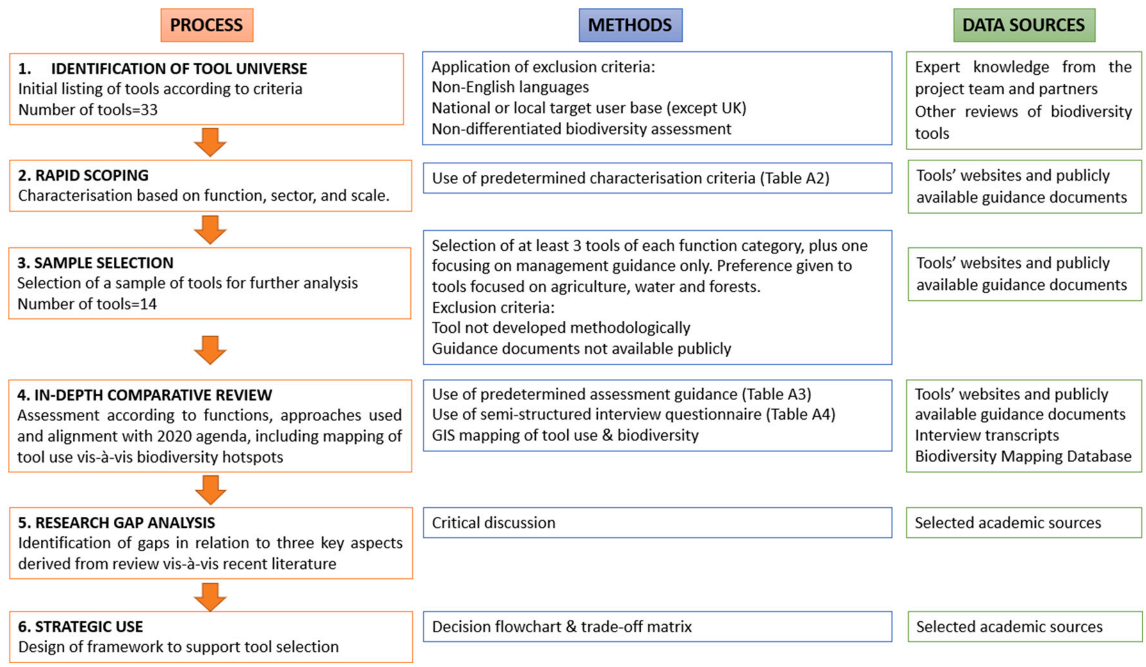

Fig. 2. Overview of the research process with corresponding methods.

(iii) Assess their alignment to the Post-2020 Global Biodiversity Framework's 2030 Action Targets on "Tools and solutions for implementation and mainstreaming" (CBD, 2021).

(iv) Explore the extent to which the user base of these tools is in proximity to biodiversity "hotspots" (Krause and Matzdorf, 2019). We used businesses certified by Lasting Initiative for Earth (LIFE) Key in Brazil and Linking Environment and Farming (LEAF) Marque in the United Kingdom as examples. The locations of LIFE's users were shared by LIFE's management for the purposes of this research and is not publicly available. The locations of LEAF's users were derived by geolocalising the list of certified companies, publicly available from the LEAF website in the following address: https://leaf.eco/farming/leaf-marque/leaf-marque-documents-and-downloads. We mapped the locations on LIFE's and LEAF's users against biodiversity richness, which reflects the diversity extent of mammals, birds, and amphibians. The biodiversity richness data were obtained from the BiodiversityMapping database (https://biodiversitymapping.org/; Jenkins and Van Houtan, 2016). This data were derived by overlaying range maps of various species held in the IUCN database (https://www.iucnredlist.org/) for mammals and amphibians, and BirdLife International (http://datazone.birdlife.org/) and NatureServe (https://www.natureserve.org/) databases for birds.

Finally, we identify the main methodological gaps and limitations in tools' use (step 5) and suggest a basis for a more strategic selection of these tools in the form of a decision flowchart and trade-off navigation framework (step 6).

3. Results and discussion

The initial rapid scoping exercise highlighted the high diversity of approaches currently being used by businesses and different sectors to mainstream biodiversity, and the extent to which biodiversity itself is represented in different ways. Although using different frameworks, methods, and guidance, all the tools aim at supporting business decision-making and actions that reduce negative impacts on biodiversity. There is also wide variation in the scale used by the tools (from farm to corporate to value chain) as well as the sectors which are targeted by the tools (from agriculture to water and biofuels, among others). The characterisation of the 33 initial tools is reported in Table A1 of Appendix A. The following sections synthetise results of the in-depth assessment in step 4. Detailed assessments of each of the 14 tools can be found in the Supplementary Materials.

3.1. Functions of tools reviewed

The 14 tools selected for the in-depth review provide a range of functions; some only offer one of these functions, while most combine various functions (Table 1).

A business activity can be a biodiversity pressure or impact driver (either through an input, such as material used, or a non-product output, such as air or water pollution, either released directly or embodied along the value chain supporting each organisation). This generates changes in the state of biodiversity (impacts), which in turn can affect the organisation or society. Dependencies, often integrated along this pathway due to their interconnections with impacts, show how a particular business activity depends upon specific features of biodiversity and how changes in biodiversity affect business costs and/or benefits (CDSB, 2021). This is particularly relevant when multiple actors share a dependence on a shared, locally defined resource, including local actors whose livelihood may be dependent on biodiversity.

The tools reviewed assist with the process of assessment of biodiversity-related impacts and dependencies, following different approaches to guide this process. What aspect of biodiversity is being measured, and how, depends on the intended applicability of the results of the tool for decision-making. All tools reviewed enabled businesses to assess (directly or indirectly) at least one driver of biodiversity loss ('pressures'). Some tools are guided by the Driver-Pressure-State-Impact-Response (DPSIR) framework, which seeks to capture (partially or fully) the interconnections between business activity, biodiversity impacts, and impacts on business.

3.1.1. Assessment of actual or potential negative impacts on biodiversity

Most tools include some assessment of the status of or impacts on biodiversity associated with the business, such as the likely presence of protected species. However, tools vary in how this is done, and the times

Table 1
Main functions of the tools reviewed.

	Impact metrics	Mitigation metrics	Biodiversity dependence	Sustainability standards	Management guidance
1. Lasting Initiative for Earth (LIFE) Key	X	X	X	X	X
2. International Biodiversity Assessment Tool (IBAT)	X				X
3. Biodiversity Impact Metric (BIM)	X				X
4. Species Threat Abatement and Recovery (STAR)	X	X			X
5. Biodiversity Performance Tool and Monitoring System (BPT)				X	X
6. Science Based Targets for Nature (SBTN)					X
7. Rainforest Alliance Certification				X	X
8. Roundtable on Sustainable Palm Oil (RSPO) Certification				X	X
9. Linking Environment and Farming (LEAF) Marque				X	X
10. Forest Stewardship Council (FSC) certification				X	X
11. Textile Exchange Biodiversity Benchmark Textile Exchange			X		X
12. Land360/Defra Biodiversity Metric 3.0		X			X
13. Exploring Natural Capital Opportunities, Risk and Exposure (ENCORE)			X		X
14. Union for Ethical BioTrade (UEBT) Standard			X	X	X

scales involved. Different tools incorporate proxies in lieu of more direct measurement.

Tools like the Integrated Biodiversity Assessment Tool (IBAT), Biodiversity Impact Metric (BIM) and Defra Biodiversity Metric 3.0 assess the biodiversity status in a specific geographic location, and thus implicitly the biodiversity that may be lost if that location is developed or saved if the location is conserved. The degree of specificity of this geospatial biodiversity assessment varies considerably between tools. Those with global application, such as IBAT, provide proximity indices of likely presence of threatened species or protected areas with a range of distances from a point location. This can generate quite long lists of threatened species and sites, that depends on the precision of the underlying databases that is drawn upon. Expert interpretation of the results is required, as the proximity reports often include a number of species that may not be relevant, such as marine species for a terrestrial location if the range overlaps the coast. It appears the main intention is to inform selection of sites for development such that they avoid areas of importance for biodiversity.

BIM assesses the biodiversity value of the land occupied and the degree of biodiversity loss, according to the relative biodiversity of the natural vegetation compared to what is replacing it. This is done against a global database and depends on availability of spatial location and land area occupied. The Defra Biodiversity Metric 3.0 is specific to the United Kingdom but, similarly to BIM, it assesses the biodiversity value by habitat category, based on their scarcity and the condition of the habitat, and the potential biodiversity loss if the land is proposed for development. As applied under LAND360, it can also be used to simply assess the biodiversity value of current landholdings and identify areas of high biodiversity value. In all these cases, the assessments are seeking to either assess likely biodiversity loss of development or more often inform site selection where development should occur to avoid biodiversity loss. The LIFE Biodiversity Pressure Index also assesses biodiversity in terms of the biodiversity value of land occupancy but combines this with other factors related to environmental impacts such as use of water, energy, and production of waste and greenhouse gases. Other tools such as the Biodiversity Performance Tool (BPT), utilise small/farm scale habitat and agronomic management data to generate "traffic light" scores based on graduated performance.

3.1.2. *Assessment of potential or actual mitigation of biodiversity losses*

There is a similar set of tools to assess actual or potential improvements in biodiversity that may mitigate losses.

Some of the tools assess the presence of actions taken towards the management of biodiversity impacts based on a mitigation hierarchy (such as the Science Based Targets for Nature and Textile Exchange Biodiversity Benchmark), consisting of four stages:

1. Avoid impacts on biodiversity;
2. Reduce biodiversity impacts as far as possible;
3. Restore/remediate impacts that are immediately reversible; and.
4. Offset residual impacts to achieve a desired net outcome.

Other tools not only acknowledge options to manage impacts, but they also assess the potential impacts of such actions, such as LIFE Key.

The STAR (Species Threat Abatement and Restoration) tool provides geospatial estimates of the potential to reduce (abate) threats to endangered species or undertake habitat restoration. This can be used in a default mode or applied to local data on selected threatened species to assess the effects of conservation actions on threatened species' populations. Thus, it could be used to select areas to invest in improving biodiversity or monitor actual effects of current actions. The Defra Biodiversity Metric 3.0, and in particular its application under LAND360, assesses the potential to improve the biodiversity status of different habitat elements through conservation investments. These conservation improvements can then be used to offset losses due to development elsewhere, either within the same landholding, or potentially be sold to other landholders as biodiversity credits. The LIFE Biodiversity Positive Performance tool assesses the "value" of conservation investments, in terms of the importance of the habitat or species being conserved and influence on broader policy and practice. The assigned value of Biodiversity Positive Performance is compared to the Biodiversity Minimum Performance, calculated from the Biodiversity Pressure Index as a function of the turnover of the business, to assess whether negative impacts are being "compensated" by positive actions. Where companies have a substantially greater Positive Performance compared to the Minimum, LIFE Key are considering the possibility of offering the balance under a "biodiversity credit" system. Biodiversity credits are an emerging market proposition and, in the future, may be available in a similar way to carbon credits to verify the positive outcomes of a project.

3.1.3. *Assessment of dependence on biodiversity*

Biodiversity dependence is a reliance on or use of biodiversity, including biological resources (e.g., materials, liquids, genetic resources) from both species and interactions with various ecosystem processes and services (e.g., pollination, water filtration, crop pest/disease control or water flow regulation). Dependence on biodiversity is not explicitly measured by any of the tools but is often included in the criteria for management decisions and/or assessed indirectly in the activities that may also be considered as constituting an impact pathway. This may be because generally the dependence is upon the ecosystem services provided by biodiversity, rather than biodiversity per se, although non-appropriative commercial activities such as eco-tourism often directly depend on high levels of biodiversity (Brandt and Buckley, 2018).

Science Based Targets for Nature (SBTN) includes criteria for business to assess their dependence on "Nature", which we take to mean a combination of ecosystem services and natural capital including biodiversity. The Exploring Natural Capital Opportunities, Risk and Exposure (ENCORE) tool supports businesses in assessing their dependence on ecosystem services and natural capital, among the categories of natural capital are "species" and "habitats", both of which are expressions of biodiversity. Similarly, within ecosystem services some are direct services from biodiversity such as pollination or pest control, although all the services depend on a functioning biome. The services provided by biodiversity to businesses are valued and scored in relative terms and based on expert opinion. Similar to SBTN, the LIFE Biodiversity Management Indicators include criteria whereby businesses identify their dependence on ecosystem services and put in place actions to ensure the continued provision of those services. The one sustainability standard that explicitly considers dependence on biodiversity is the Union for Ethical BioTrade (UEBT) Standard, which in addition to the agronomic and management practice-based scoring and explicit consideration for wild collection, has criteria to ensure that populations of target species are monitored and not over-exploited, and dependence of the business upon them is recognised.

3.1.4. *Sustainability standards that assess effects on biodiversity*

A distinct approach to assessing potential effects on biodiversity is employed by sustainability standards, such as the Roundtable Sustainable Palm Oil (RSPO) Certification, the Forest Stewardship Council (FSC) Certification, the Rainforest Alliance Certification, LEAF Marque, the UEBT Standard and the LIFE Biodiversity Management Indicators, which assess likely effects on biodiversity based on farming or land management practices employed. These generally include a combination of criteria about conservation of biodiversity, and natural and semi-natural habitats (especially identification of High Conservation Value areas), identification and protection of endangered species, and a suite of good agronomic practices that should reduce impacts on biodiversity, such as rational use of agrochemicals, and prioritising use of non-chemical pest control or management, where feasible. Compliance with the habitat and species protection criteria should conserve or possibly improve conditions for biodiversity, while the good agricultural practices seek to reduce negative impacts on biodiversity and potentially promote biodiversity-based ecosystem services that the production system depends upon, therefore advocating sustainable use of biodiversity.

3.1.5. *Management guidance*

All the tools seek to inform management decisions at different (temporal and spatial) scales with respect to biodiversity, although the guidance supporting tool use varies considerably in depth and detail. The frameworks used to develop and evaluate actions to mitigate biodiversity risks/impacts associated with business activities vary greatly. The approaches used to support action range from only assessing the biodiversity impacts of mitigation/conservation plans (such as STAR), to providing platforms or dashboards that fully integrate biodiversity state and pressure measurement with responses and multiple other considerations (such as LIFE Key), and frameworks that comprehensively cover the whole mitigation hierarchy, thus incentivising prevention over mitigation (such as LIFE Key, SBTN's AR3T framework, and its adapted version by the Textile Exchange Biodiversity Benchmark).

Some tools, such as IBAT and STAR, provide a brief set of principles and examples of how the metrics provided can inform business decisions. The Defra Biodiversity Metric 3.0 is a tool to support a defined UK policy of biodiversity offsetting for land development, with LAND360 providing a service to develop a supply of biodiversity credits and to enable landowners to assess their cost versus value. The sustainability standards are intended to recognise good practice and incentivise continuous improvement through the market advantage of being certified. The scale of applicability determines the guidance provided. For example, the BPT provides guidance based on farm level agricultural practices, whereas the UEBT Standard seeks to inform how value chains are organised.

Other tools have more developed management processes. SBTN prescribes a process for assessing biodiversity impacts and dependencies, interpreting and prioritising key issues, setting and measuring specific targets, undertaking action to avoid, reduce, regenerate, restore, and transform, and track progress towards targets. Assessing impacts and tracking progress can be done using a selection of appropriate metrics such as those described in the previous sections, but also others such as the natural capital protocol or the International Union for Conservation of Nature (IUCN) standard for nature-based solutions. The Textile Exchange Biodiversity Benchmark largely follows this same SBTN process. A key element in these processes is also identifying risks to the business, either due to dependence or reputational risk from generating negative impacts on biodiversity. The ENCORE platform has just introduced a new module for assessment of biodiversity-associated risk among investments for the financial sector. The LIFE Biodiversity Management Indicators cover nine principals that require businesses to effectively manage their biodiversity impacts based on the LIFE Key metrics, but also compliance with the Convention of Biological Diversity (CBD), scientific, ethical, and social standards, with indicators under each principal for minimum immediate compliance, and others where compliance is required over time as part of continuous improvement. This process requires businesses to attain a defined minimum biodiversity conservation action score, which is calculated for each organisation based on their quantified biodiversity pressure score and the size of their organisation.

3.2. *Approaches used for biodiversity mainstreaming*

3.2.1. *Type of inputs required*

The type of inputs is dependent on the objectives of each specific tool. In some instances, they include elements at different scales, such as the extent and condition of immediate land use and associated vegetation, species population data, appropriation of natural capital and resource consumption, greenhouse gas emissions, and waste generation. For more sectoral specific cases, they reflect defined practices (such as fertiliser application rates or mowing frequency in the case of tools intended for on farm use). The presence of organisational policies to address biodiversity loss or share good practice can also be an input. Tools may be focused on conditions within the site of an activity or development or seek to incorporate activities along the supply chain.

Many tools require significant and diverse information across a range of activities to generate meaningful results. Many inputs are routinely represented in environmental management systems, and therefore may be available at the site level but are more difficult to obtain (even on a qualitative basis) for tools that consider performance along a value chain. This is particularly the case for the tools other than the sustainability standards, which require substantial effort (in terms of time and expertise) and a certain level and organisation of internal environmental data, mostly applicable to large companies. Standards and benchmarks tend to require less quantitative environmental data and are thus easier to use by companies of all sizes, as they are mostly practice-based and situated within a broader process of support. Additionally, some tools (such as LIFE Key) can be implemented as part of a certification process, which assists in validating a company's inputs or overcoming data gaps.

3.2.2. *Consideration of biodiversity pressures*

It is worth noting that not all drivers of biodiversity loss ('pressures') are material for a company. Businesses will look for a tool or combination of tools that covers those pressures which are material from the company's perspective (Lammerant et al., 2021). The spectrum of pressures covered by the different tools ranges from only one pressure (e.g. land use) to multiple pressures. We found that the tools assessed covered land use change, pollution, and direct exploitation (especially through water use). Some also considered invasive alien species (such as

STAR and BPT), erosion and pesticide use (such as BPT and LEAF Marque), and solid waste disposal (such as LIFE Key). Biodiversity pressures are directly measured by those tools which assess the effect of restoration to compensate pressures (such as STAR, Defra Biodiversity Metric 3.0 and LIFE Key) and by tools for certification which are directly linked to a specific natural resource use and exploitation, such as the case of trees (FSC and UEBT Standard).

In the case of LIFE Key, pressures are integrated into one index (the Biodiversity Pressure Index). This has an underlying assumption that the use of energy and water, GHG emissions, waste generation (and disposal), and land occupancy can represent the main impacts upon biodiversity. The scoring and metrification of these generates a biodiversity pressure index (BPI) score. As with all integrated single scores there is a risk of commensurability when viewing results only in terms on a final score whereby performance in one area may compensate for performance in another, however guidance and commentary on separate impact categories is part of the process (see Section 3.2.4). While based on a sound rationale from expert opinion, it has no scientific mechanistic link to the quantified biodiversity impact (such as species loss). The process is mathematically moderately complex but uses data most responsible companies ought to register and in that sense is pragmatic.

Nevertheless, there is potential for decision rationales that are primarily a consequence of the construction of the metric rather than any real reduction in biodiversity impact. Knowing how likely this is would require a broad monitoring of how companies have used and interpreted the metric. The potential for "perverse" decisions should however be considerably moderated by the detailed and comprehensive Biodiversity Performance indicators that inform the management decision processes. The Biodiversity Performance Indicators are set of qualitative management indicators that qualify but also orient how the business assesses and makes decisions about its biodiversity impact. This includes the interpretation of the Biodiversity Pressure Index (which is a separate quantitative index) and its component parts, but also includes a much broader range of principles and criteria that include compliance with legal obligations, and broader social and environmental responsibilities. This is a recent addition to the LIFE methodology and was developed in recognition of the need to have management processes to manage the results of assessment of biodiversity pressures (and conservation actions), but furthermore put these into a broader socioecological and political context.

The standard-type tools indirectly capture pressures through the assessment of activities, measures, or interventions which may affect pressures (LEAF Marque, RSPO Certification and Rainforest Alliance Certification). For instance, LEAF Marque's control points refer to actions taken to protect or enhance biodiversity. One point was added in the last update of the tool (version 15 – 2020) on whether at least one representative species or habitat is being monitored on the farm. This incorporation of outcomes alongside the existing practice-based approach signals the transition of the standard towards a hybrid approach.

3.2.3. *Type of results generated*

The results generated vary according to the objectives of the tools. Those that aim to provide certification usually generate results that indicate whether the business is compliant with a range of criteria. Many of these sustainability standards offer complementary tools to enable businesses to monitor their performance, identify strengths and weaknesses as well as set targets for improvement across the business (for example, the LEAF Sustainable Farming Review supports businesses to obtain the LEAF Marque certification).

Many tools express their results (either of pressures, impacts, or action) in terms of scores or indices, such as pressure indexes or performance indicators. Some tools aggregate results in integrated scores such as LIFE's "Biodiversity pressure index", whereas others (such BPT) provide an indicator of performance across specific categories. This allows to consider the multifaceted nature of interlinkages between biodiversity and businesses' activities and results. In addition, the use of scores seems to be easier to understand and communicate to business managers and to assess progress over time (or towards targets) and to allow comparison across companies, particularly within a specific sector (such as the Textile Exchange Biodiversity Benchmark).

3.2.4. *Approaches used to link biological, ecological, socio-economic factors & assessing trade-offs*

Most approaches do not explicitly calculate trade-offs, but these could be derived from their application. In the case of LIFE Key, interactions between human well-being, biodiversity, ecosystems, and natural capital are considered (including in the calculation of mitigative action considered necessary to meaningfully compensate for the BPI score). Although the term trade-offs is not used, it is implicit and if the criteria are followed this should reveal any trade-offs. In the case of LEAF Marque, key elements of integrated farm management are assessed so different aspects of biodiversity are considered across the whole farm including Organisation and Planning, Soil Management and Fertility, Crop Health and Protection, Pollution Control and By-Product Management, Animal Husbandry, Energy Efficiency, Water Management, Landscape and Nature Conservation and Community Engagement.

3.2.5. *Managing the implications of indicator aggregation*

The issue of trade-offs is directly related to the risks of commensurability when designing an integrated indicator, as mentioned in Section 3.2.2 above. Whilst this issue has long been identified with sustainability indicators (Morse et al., 2001), it is arguably especially pertinent for consideration within the context of business orientated biodiversity impact tools. Within that context, the value of a single integrated 'headline' indicator should not be discounted as it can be readily used to compare performance over a time period or against targets. This is highly attractive from the perspective of corporate reporting and communication. However, there are potential risks of misrepresentation.

In the first instance, a single score cannot point to any actionable mitigation beyond reducing absolute activity or demands. The use of proxies for biodiversity impact can exacerbate this issue, as the relationship between biodiversity may be non-linear whereby, the 'real' or achievable benefit or impact of an activity may only be observed once an absolute threshold has been passed. Therefore, there is a risk that a tool that simply scales impact or performance to the level of activity/input will be misrepresentative. This may be the case when a moderate reduction in harmful activities results in an improved score but there is no guarantee the scale of the impacts are sufficient to effect a meaningful change in biodiversity outcomes. Elements such as ecosystem fragmentation mean that beneficial and damaging aspects (such as habitat removal and restoration) may have threshold levels which can be irreversible. This is highly important when viewed within an integrated indicator, as a combined score may mask where such a threshold is being passed within a single sub-indicator. In effect, the real impact of some activities cannot be compensated for, irrespective of the scale of the remediation.

Within tool design there are options to mitigate this issue. Tools such as the BPT allow for grading performance across each indicator against specific threshold criteria for performance. Whilst such criteria have specific applicability, in principle allowing for performance to be assessed at a high degree of granularity as opposed to benchmarking an aggregated indicator score, can help uncover areas of critical concern.

Additionally, tools such as the LIFE Key, which are currently undergoing regional calibration, can help identify critical elements to better reflect the receiving environment. Equally, the communication associated with the certification process means that the user must account and consider all the aspects that contribute to the overall BPI score. This less standardised aspect of tool deployment is arguably more important than the actual generation of a performance score and presents a caveat when tools (in general) are applied in the absence of dedicated support. In this regard, it is important that tools incentivise as full an engagement as possible. Some tools can generate a score with minimal coverage of the whole input range. Requiring a minimum viable coverage of scoring criteria would incentivise a more robust evidence base and help at least to identify which activities are likely to represent trade-offs and therefore may have implications for how meaningful any overall score may be when viewed in isolation.

3.3. Alignment with the Post-2020 Global Biodiversity Framework

In 2021, the CBD published the first draft of the Post-2020 Global Biodiversity Framework (CBD, 2021). The overarching objective is to provide a commonly agreed framing for actors at different scales (but primarily governments) to mobilise actions towards halting and reversing biodiversity loss. The framework is built upon 4 long-term goals to be achieved by 2050, reflecting the 2050 Vision for Biodiversity. Each 2050 goal is supported by a number of intermediate milestone targets for assessment by 2030.

We mapped the 14 tools reviewed in-depth to the 2030 Action Targets proposed by the Post-2020 Global Biodiversity Framework under the category "Tools and solutions for implementation and mainstreaming" (Table A5 in Appendix A). The alignment of the tools was classed as either 'primary' – suggesting the tools are of direct relevance to the Target, 'indirect' – suggesting their relevance or importance is less direct, and 'not aligned or unclear' if there was insufficient information publicly available to make a robust classification.

The level of alignment of each tool is shown by the mapping wheel in Fig. 3. The majority of tools are in alignment (either primarily or indirectly) with the Targets 14, 15, and 16 which aim to include biodiversity values in policy, support the assessment of business impacts and dependencies on biodiversity, and advocate for responsible consumption, respectively. Integration of local knowledge and support of local participation which are advocated by Target 20 and Target 21 are not clearly supported by the 14 tools that were selected for the in-depth review. However, we found that in half of the tools, local or indigenous knowledge can be integrated, even if it is not explicitly recommended by the tool's guidance. Approximately half of the tools are directly or indirectly aligned to Target 18, which aims to reduce incentives harmful for biodiversity, and to Target 19, which calls for an increase in financial support for biodiversity conservation. Finally, only one tool is indirectly aligned to Target 17, which supports the reduction of potential adverse impacts of biotechnology on biodiversity. This is arguably unsurprising given the emergent and complex nature of biotechnological developments and may point to potential prioritisation for future tool development. The other 11 tools do not explicitly mention how to prevent and control those impacts.

While the diversity of these tools has enabled much-needed innovation in the definition and monitoring of impacts on biodiversity (as shown by almost all tools aligned with Target 15), it has also given rise to its own set of questions, such as: what are the actual impacts of these initiatives on biodiversity, and where are these impacts occurring? Although this paper does not aim to answer this question definitively, it does provide a starting point for making such determination. By linking the latest information on tool use with commonly used indicators of the state of biodiversity, we offer a first step to understanding the potential contribution of the tools to biodiversity conservation. We mapped out the use of two tools and bird/mammalian biodiversity in two countries: LIFE Key in Brazil and LEAF Marque in the United Kingdom (Fig. 4). In both cases, the locations where tool use is concentrated overlap with certain biodiversity hotspots. The concentration of tool use in these regions aligns well with strategic priorities for reducing global biodiversity threats. On the other hand, given the prominence of agricultural production and natural resource encroachment in other biodiversity hotspots in these countries, there exist major areas of opportunity for more proactive adoption of standard-compliant production and business

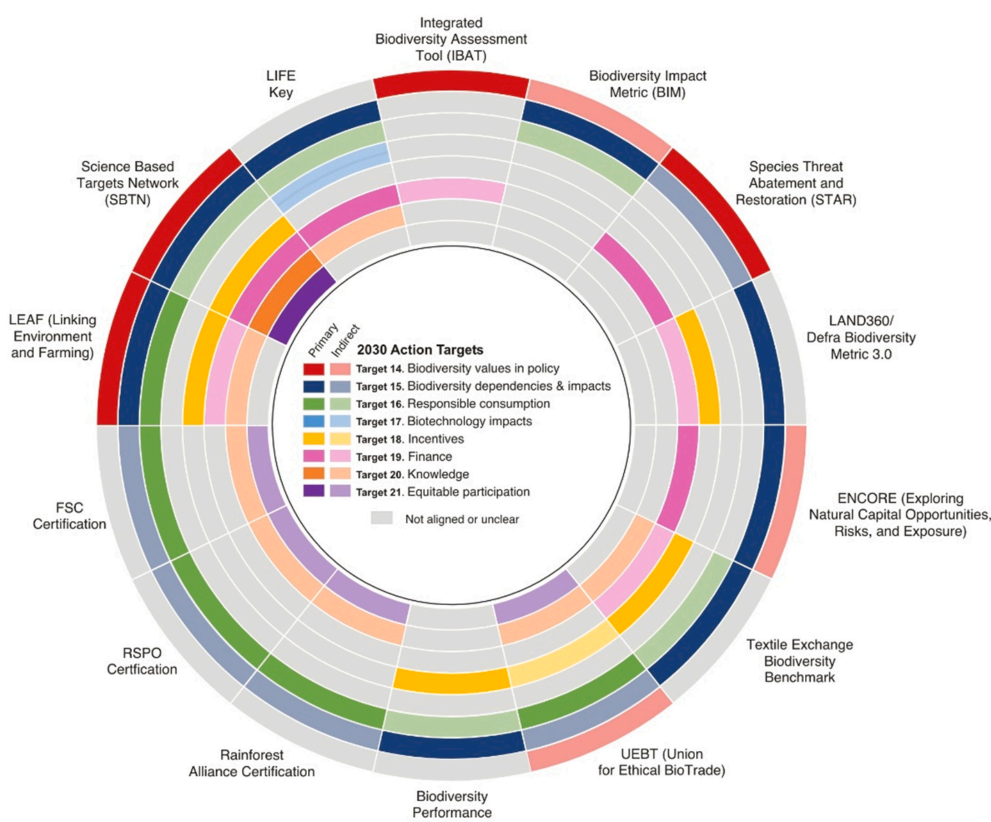

Fig. 3. Mapping of tools to the 2030 Action Targets.

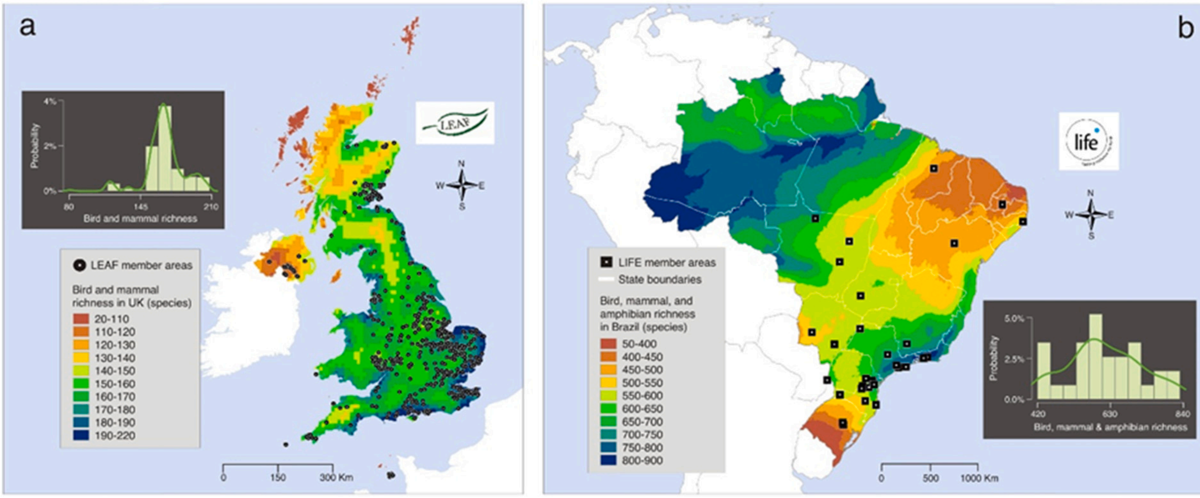

Fig. 4. Businesses certified by LEAF Marque (a) and LIFE Key (b) mapped against bird and mammal richness in the United Kingdom, and bird mammal and amphibian richness in Brazil respectively.
(Sources: https://biodiversitymapping.org/, https://www.iucnredlist.org/, http://datazone.birdlife.org/, https://www.natureserve.org/, https://leaf.eco/farming/leaf-marque/leaf-marque-documents-and-downloads, personal communication with LIFE Institute).

activity (Reale et al., 2022).

3.4. Gaps and recommendations for further research

3.4.1. Spatial and temporal scales and spillover effects

Most tools characterise biodiversity conditions within a business or landscape unit, utilising empirical spatial data. This type of approach is a major strength as it moves beyond the conventional quality-based assessment towards evidence-based assessment, thanks to the increased availability of landscape datasets derived from remote sensing. Despite this progress, most tools we evaluated do not assess the spillover effect of business activities to the broader ecosystem beyond the farm boundaries or the surrounding areas, whether it is negative or positive. Businesses may comply with environmental and sustainability standards within their farms, but ecosystem functioning often operates at a broader spatial scale and transboundary negative effects of anthropogenic activities are often inevitable (Didham et al., 2015; Heilmayr et al., 2020). In some instances, improving efficiency at site/farm level may increase pressure on adjacent natural systems.

Studies from development settings have shown that intensive extraction of natural resources by businesses can lead to broader environmental degradation, such as deterioration in the quality of waters in streams and soils and the concomitant loss of biodiversity that supports local livelihoods (Blitzer et al., 2012; van Schalkwyk et al., 2020). These activities can potentially lead to the exacerbation of social inequality among communities (between those who benefit from the resource extraction within the business unit and those who do not), creating pockets of extreme poverty and gated communities (D'Odorico et al., 2017; Liao et al., 2020). On the other hand, business activities that promote biodiversity maintenance or improvement, such as through the creation of hedgerows, wildlife corridors, and forest conservation, can create positive effects on the surrounding landscapes and communities (Batáry et al., 2011; Aldieri et al., 2021). However, the effectiveness of such mitigative measures requires consideration of the scale needed and the presence of compatible (viable) habitats in connectable proximity (Liu et al., 2018). Consideration of specific regional habitat conditions is difficult to represent in tools intended for more generalist application.

Most of the tools we evaluated provide current spatial snapshots of biodiversity conditions. They do not estimate the historical change in biodiversity and drivers of these changes using empirical data. Whilst many tools can be used retroactively (depending on data availability) to compare trends in previous performance, without clearly defined parametrisation of impacts, this may not indicate when an important threshold (such as a critical reduction in semi natural habitats) has been passed. This impedes robust development of analysis and models to reliably inform future biodiversity risk or trajectories within a business or landscape unit, and therefore hampers the design of tangible plans for biodiversity compensation or offsetting mechanisms (Mihoub et al., 2017). This is a missed opportunity, considering that various time series landscape datasets (Hansen et al., 2013; Liu et al., 2021) with relatively fine spatial and temporal resolution have been developed in recent years, making it feasible to conduct such rigorous analysis.

3.4.2. Biodiversity indicators

The tools we evaluated generally use biodiversity proxies related to ecosystem functioning and landscape metrics, such as forest cover, soil conditions, land degradation, and habitat connectivity, as opposed to actual biodiversity measures such as species richness, occurrence rates, and abundance. The use of these proxies has strengths and limitations. Landscape-based proxies are typically readily available from remote sensing data, they have good coverage for most parts of the world and provide relatively accurate representations of the reality on the ground. Comparatively, biodiversity datasets rely primarily on field surveys of certain species and are often not so rigorously sampled across the species range, especially in remote and difficult to assess areas. Furthermore, some species can often be difficult to detect due to their cryptic behaviour (Vodă et al., 2015; Williams et al., 2018), and species detection can vary by surveyor skills and local ecological knowledge and survey frequency (Guillera-Arroita, 2017; Camino et al., 2020). Limited survey coverage and surveyor skills can hamper reliable biodiversity assessment. Landscape indicators therefore provide the most pragmatic proxies for assessing biodiversity. Nonetheless, these indicators have limitations by providing uniform measures across different areas, despite biodiversity conditions being inherently different in different regions (by latitude and ecoregion). Furthermore, although reforestation can contribute to increased biodiversity several years after the trees are planted (by attracting insects, birds, and other animals), biodiversity takes a very long time to develop and recover to its original pristine state after reforestation and may not return to the original state through mono-culture reforestation (Martin et al., 2013; Rozendaal et al., 2019).

Whilst all tools have some conception of high biodiversity impacts, the methods rarely explicitly reflect irreplaceable loss of biodiversity. In some instances (such as the number of semi natural habitat types as measured by the BPT), total absence and paltry presence results in an equivalent score, despite both conditions arguably having different implications for restoration and conservation.

Relatively few tools express impact per unit of output (allowing for some degree of direct comparability), although existing impact assessment models used in Lifecycle assessment (LCA) attempt to translate pollution and resource consumption into units of biodiversity impact, by expressing the % of potentially disappeared (PDF) species per area (Verones et al., 2017). However, such results are considered susceptible to high uncertainty, due to the very generalised pathway between material flow and biodiversity impact. This relates to issues of scale, as a process can be less impactful per unit of output, but activity at a large scale can concentrate impact beyond the local carrying capacity.

The over reliance on landscape proxies can lead to unrealistic biodiversity recovery targets and policies and erroneous offsetting mechanisms (i.e., development in pristine forest allowed with the offset of planting trees elsewhere) (Curran et al., 2014; Holl and Brancalion, 2020; Martin et al., 2021). While acknowledging that biodiversity can be quite complex to measure, tools to inform business decision-making need to move beyond landscape indicators as proxies (de Silva et al., 2019). Biodiversity repositories storing citizen-science datasets of various species collected by researchers and the public have increased in the recent decade (Chandler et al., 2017; Moussy et al., 2022). Along with a proper analytical approach, these data open a way to estimate the historical change of biodiversity to inform business (Isaac et al., 2020; Johnston et al., 2022).

3.4.3. Heterogeneity in biodiversity pressures

In many of the tools we evaluated, the magnitude of pressures or threats to biodiversity is defined based on expert opinion (in a form of weighting). Ideally, the magnitude of threats to biodiversity is estimated by correlating the change in species occurrence collected via field survey with the change in landscape derived from remote sensing. However, as time series data on species occurrence are often not available to generate such estimates, expert opinion becomes the most pragmatic approach. Expert opinion is acceptable when dealing with well-studied ecosystems (expert opinion could approximate well the actual conditions). However, it can be unreliable for ecosystems that are not so well-studied and encompass large areas, particularly where the extent of the area is too spatially and temporally complex to be understood by experts who tend to focus on a specific geographical area and scope of research (Costello, 2015; McNellie et al., 2020). Such uncertainties can potentially generate erroneous predictions of biodiversity risk (Dorrough et al., 2019).

Tools have generally applied a fixed weighting value to different indicators of biodiversity impacts, either based on expert opinion or empirical estimates derived from sampled areas. This is an acceptable approach for a relatively narrow spatial extent or homogenous ecosystems. However, it can be a problem when the extent of the unit evaluated is broad and encompasses multiple ecosystem regions with differing biodiversity and anthropogenic characteristics and contexts, as pressure to biodiversity can vary substantially in different regions. Applying a fixed weighting can also potentially result in one-size-fits-all policies across different regions, despite marked differences in the actual threats to biodiversity.

3.5. Strategic selection of tools

Drawing on the logic of business management and sustainability processes (Addison et al., 2020), we present a framework that can guide businesses through the development and use of biodiversity tools for decision-making. The first step of the framework involves articulating the decision context and asking questions to ensure the indicators will meet a business's decision-making needs (Addison et al., 2018) such as why the business wants to assess the state of biodiversity, how often and how detailed will the assessment be, who will the audience be for communicating the state of business-relevant biodiversity, etc. (Fig. 5).

After a selection of appropriate tools is selected, the next step is represented by a trade-off navigation framework consisting of input data and a trade-off analysis of the performance of alternative tools according to pre-determined criteria. Selection of the key criteria should be based on the contextual settings, i.e., aligned with the company's strategy and

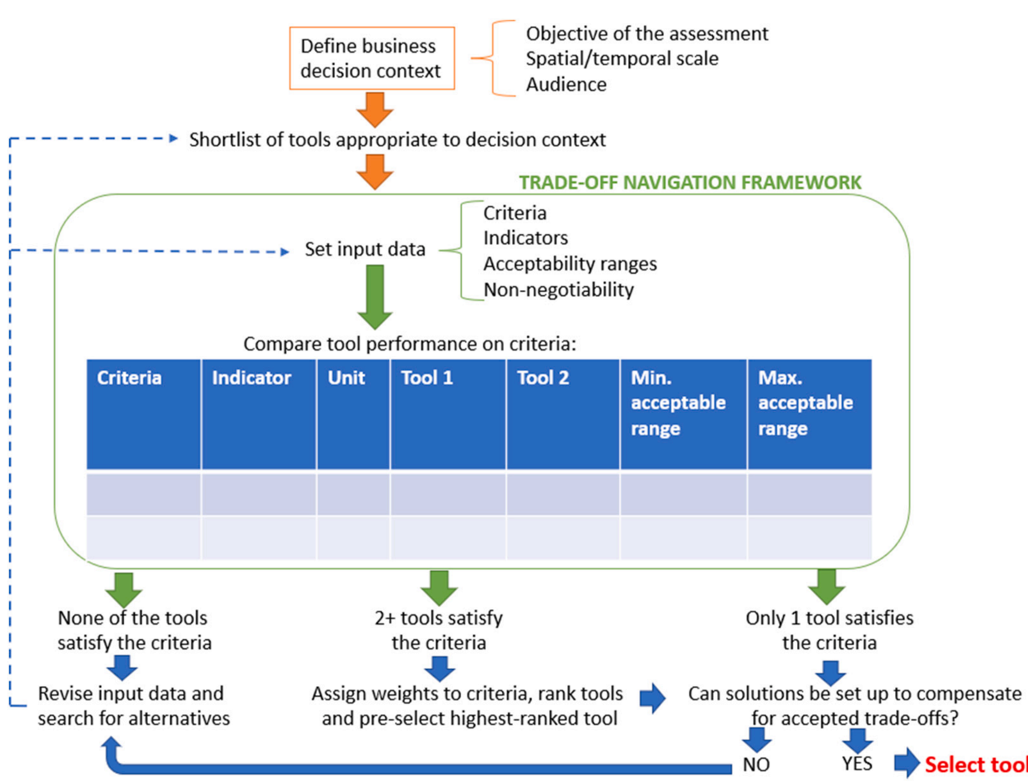

Fig. 5. Decision flowchart and trade-off navigation framework to support tool selection.

objectives, corporate approach to sustainability, specifics of the products and processes, or driven by the results of past impact assessments. Broadly, criteria related to feasibility (ease and cost of implementation), scalability (applicable in a standard and additive way), granularity (scale appropriate for decision-making) and validity (unbiased representation of biodiversity) may be appropriate to include. These criteria can often be expressed as either qualitative or quantitative indicators, which serve as decision criteria to guide evaluation of the 'best' initiative, i.e., the solution with the highest potential, or performance. For each indicator (or criterion), acceptable ranges should be specified. These might consist of a minimum and maximum value that sets lower or higher limits for acceptable performance on the key indicators. Acceptable ranges should be defined considering internal and external sources for sustainability requirements that should guide the decision, such as strategic business vision and goals and customer, technical or legal requirements.

In a final step, three scenarios may emerge. If none of the alternative tools satisfies the criteria, it is necessary to return to the input data and re-evaluate: (i) acceptability ranges; (ii) considered alternatives; and (iii) number and type of key criteria for decision-making. If two or more tools satisfy the criteria, weights should be assigned to criteria and tools ranked. The trade-offs in selecting the highest ranked tool should be considered and if a solution can be implemented to compensate for them, then the tool should be selected. Otherwise, input data should be revised. In the third scenario, only a tool satisfies the criteria and undergoes the same step of considering compensating actions to alleviate trade-offs.

4. Conclusions

In recent years, there has been a **pronounced increase in the demand from businesses for tools** (methods, criteria, and standards) that enable them to account for their impacts on biodiversity and the goods and services derived from nature into business decisions. At the same time, businesses are faced with a **fast-evolving set of tools and processes** to assess and manage their interactions with biodiversity. Understanding the strengths and limitations of each, and how they might respond to a business's needs, is not straightforward for companies who are not specialists in the area.

The tools reviewed perform a range of functions including assessing potential or actual negative effects on biodiversity of business activities, assessing potential or actual effects on biodiversity of restoration activities, assessing compliance with sustainability standards that include biodiversity aspects, identifying business dependencies on biodiversity, and providing guidance to manage all of the aforementioned aspects. However, any business decisions will also rely on other ecological and socio-economic considerations. Thus, supporting and requiring businesses to internalise externalities and integrate their impact and dependencies on biodiversity in decision-making requires a scale-up of efforts for the development and operationalisation of **frameworks to harmonise methods and standards within an integrated business management approach**, rather than an isolated or ad-hoc approach to tool use.

While these tools contain significant requirements related to biodiversity conservation, their implementation, being driven by market forces, is, at best, only **partially aligned with global targets for biodiversity protection**. There is a growing need to develop a common view among key stakeholders on the measurement, monitoring and disclosure of corporate biodiversity impact and dependencies to help integrate more credible and comprehensive indicators of corporate contribution to global biodiversity goals into corporate reporting and global policy frameworks.

Exciting initiatives are arising to align measurement approaches and address key barriers to broader uptake through **concerted multi-stakeholder efforts**. For instance, while the focus so far has been on the development of tools for individual business use, we are now witnessing emerging initiatives for the collective application of tools to mainstream biodiversity considerations to advance conservation as a territorial or sectoral endeavour, such as the International Standard for Sustainable Territorial Management developed by the LIFE Institute.

Further research is urgently needed to investigate how policymakers can facilitate the strategic implementation of tools in areas where biodiversity concerns are greatest through joint planning and financial support. **Key policy options** include collaborating with tool developers to facilitate and provide incentives for adoption in areas where they will have maximum impact; and providing research financing to determine the biodiversity impacts of tool use as a basis for continual improvement and for determining the strategic application of policy support to such initiatives. While we work to close the valuation and decision support gap for biodiversity, extensive **capacity building** across the business sector is equally urgently needed if we are to fully mobilise them towards sustained biodiversity-positive outcomes. Future research efforts should also focus on generating evidence on how to assess and address these capacity gaps.

CRediT authorship contribution statement

Pamela Katic: Conceptualization, Supervision, Methodology, Investigation, Writing-Original Draft Preparation & Reviewing. **Jeremy Haggar**: Conceptualization, Methodology, Investigation, Writing-Original draft preparation. **Conor Walsh**: Methodology, Investigation, Writing- Original draft preparation & Reviewing. **Truly Santika:** Methodology, Software, Visualization, Investigation, Writing-Original Draft Preparation & Reviewing. **Stefania Cerretelli:** Investigation, Data Curation, Writing- Original Draft Preparation and Editing,

Declaration of competing interest

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

Data availability

We have included the exact location of the data used that is publicly available.

Acknowledgements

We would like to thank our partners ISEAL Alliance and the LIFE Institute, for their invaluable feedback and support during the review process. We would also like thank the various people and organisations that facilitated our data collection process, especially Fera, LEAF and the LIFE Institute; and all the people that attended the webinar "Mainstreaming biodiversity in business decisions: taking stock of tools and gaps", hosted by ISEAL's Evidensia Platform on 27th April 2022.

Funding: This work was supported by the United Kingdom's Natural Environment Research Council (NERC) and the Economic and Social Research Council (ESRC) under the Economics of Biodiversity Programme [Grant Reference: NE/W007436/1].

Appendix A

Table A1
Summary of the rapid scoring exercise (in bold, the tools selected for the in-depth review).

Tool	Sector							Scale						Function					Description	Reference website
	Agriculture	*Forests*	*Water*	*Fisheries*	*Biofuels*	*Other*	*All*	*Site*	*Landscape/ Jurisdictional*	*Business unit*	*Corporation*	*Product*	*Value/ Supply chain*	*Impacts Metric*	*Mitigation Metric*	*Biodiversity dependence*	*Sustainability Standard*	*Management Guidance*		
Lasting Initiative for Earth (LIFE) Key	x	x	x		x	x	x		x	x				x	x	x	x	x	Helps organisations in identifying their impacts and designing a strategic plan to reduce, mitigate and compensate for them.	https://institutolife.org/
Textile Exchange Biodiversity Benchmark						x			x			x	x			x		x	Enables companies to understand their impacts and dependencies on nature in their materials sourcing strategies and benchmark their progress	https://mci.textileexchange.org/biodiversity/
Species Threat Abatement and Restoration Metric (STAR)	x	x						x	x	x				x	x			x	Measures the contribution that investments can make to reducing species extinction risk.	https://www.ibat-alliance.org/star?locale=en
Biodiversity Impact Metric (BIM)	x				x				x	x	x	x	x	x				x	Assesses the impacts of a company's activities from raw material sourcing. It provides information of how and where the company can reduce their impact.	https://www.cisl.cam.ac.uk/resources/natural-resource-security-publications/measuring-business-impacts-on-nature
Global Biodiversity Score (GBS)	x	x	x		x	x	x			x			x	x				x	It provides an overall and synthetic vision of the biodiversity footprint of economic activities. It is measured by the mean species abundance.	https://www.mission-economie-biodiversite.com/

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Table A1 (*continued*)

Tool	Sector							Scale						Function					Description	Reference website
	Agriculture	*Forests*	*Water*	*Fisheries*	*Biofuels*	*Other*	*All*	*Site*	*Landscape/ Jurisdictional*	*Business unit*	*Corporation*	*Product*	*Value/ Supply chain*	*Impacts Metric*	*Mitigation Metric*	*Biodiversity dependence*	*Sustainability Standard*	*Management Guidance*		
Biodiversity Guidance Navigation Tool							x			x						x		x	Set of questions to define how a business incorporates biodiversity value and dependences (natural capital).	https://capitalscoalition.org/tools/navigation-tool/
Exploring Natural Capital Opportunities, Risk and Exposure (ENCORE)							x			x						x		x	Informs businesses about their exposure to nature (natural capital and the ecosystem services it provides) and the associated risks, dependencies. and opportunities.	https://encore.naturalcapital.finance/en
Agrobiodiversity Index							x		x	x	x			x				x	Assesses risks in food and agriculture related to low agrobiodiversity. Index based on 33 indicators.	https://www.agrobiodiversityindex.org/
Integrated Biodiversity Assessment Tool (IBAT)							x	x	x					x				x	Assesses risks in food and agriculture related to low agrobiodiversity, based on 33 indicators.	https://www.ibat-alliance.org/
LandScale	x	x	x		x		x		x								x	x	Assessment tool that generates landscape-level insights about sustainability.	https://www.landscale.org/
Science Based Targets for Nature (SBTN)	x						x			x	x		x					x	Provides guidance in the form of steps for companies to set targets to ensure their activities operate within the limits of all earth systems including biodiversity.	https://sciencebasedtargetsnetwork.org
Nature and Biodiversity Benchmark	x	x	x				x				x		x					x	Using 19 indicators, it assesses	https://www.worldbenchmarkinga

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Table A1 (*continued*)

Tool	Sector							Scale						Function					Description	Reference website
	Agriculture	*Forests*	*Water*	*Fisheries*	*Biofuels*	*Other*	*All*	*Site*	*Landscape/ Jurisdictional*	*Business unit*	*Corporation*	*Product*	*Value/ Supply chain*	*Impacts Metric*	*Mitigation Metric*	*Biodiversity dependence*	*Sustainability Standard*	*Management Guidance*		
																			companies on their contributions to stable and resilient ecosystems through adequate governance, biodiversity and environmental management, social inclusion and community impact.	lliance.org/nature-benchmark/
Biodiversity Metric 3.0	x	x				x		x							x			x	Designed to assess impacts of land development and inform planning consent processes based on assessment of habitat value.	http://nepubprod.appspot.com/publication/6049804846366720
Union for Ethical Biotrade (UEBT) Standard	x	x										x				x	x	x	Establishes good practice guidance on the way companies source ingredients from biodiversity. It includes good practices on biodiversity conservation, good agricultural practices, fair prices and decent wages.	https://uebt.org/setting-the-standard
LAND360	x	x						x							x			x	Maps and quantifies natural capital by land parcels across the landscape or farm and identifies opportunities to improve biodiversity.	https://www.fera.co.uk/land360-land-management
Rainforest Alliance Certification	x				x			x	x			x					x	x	Certification scheme for agricultural commodity production and supply chain (mainly cocoa,	https://www.rainforest-alliance.org/

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Table A1 (*continued*)

Tool	Sector							Scale						Function					Description	Reference website
	Agriculture	*Forests*	*Water*	*Fisheries*	*Biofuels*	*Other*	*All*	*Site*	*Landscape/ Jurisdictional*	*Business unit*	*Corporation*	*Product*	*Value/ Supply chain*	*Impacts Metric*	*Mitigation Metric*	*Biodiversity dependence*	*Sustainability Standard*	*Management Guidance*		
																			coffee, tea, and banana).	
Roundtable on Sustainable Palm Oil (RSPO) Certification	x				x			x	x	x	x	x	x				x	x	Certification scheme for palm oil production and its supply chain.	https://rspo.org/certification
Roundtable on Sustainable Biomaterials (RSB) Certification	x				x			x		x	x	x	x				x	x	Certification system based on sustainability standards encompassing environmental, social and economic principles and criteria.	https://rsb.org/
Better Cotton	x							x		x		x	x				x	x	Standard System to sustainable cotton production which covers all three pillars of sustainability: environmental, social and economic.	https://bettercotton.org/
Forest Stewardship Council (FSC) Certification		x						x		x		x	x				x	x	Covers ten principles which any forest operation must adhere to before it can receive FSC certification.	https://fsc.org/en
Marine Stewardship Council (MSC) Certification				x						x		x	x				x	x	The MSC Fisheries Standard certifies fisheries against the world's leading standard for sustainable wild-capture fisheries and the MSC Chain of Custody Standard is intended for certification of seafood supply chain organisations with single or multi-site operations, trading MSC certified seafood.	https://www.msc.org/uk

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Table A1 (*continued*)

Tool	Sector							Scale						Function					Description	Reference website
	Agriculture	*Forests*	*Water*	*Fisheries*	*Biofuels*	*Other*	*All*	*Site*	*Landscape/ Jurisdictional*	*Business unit*	*Corporation*	*Product*	*Value/ Supply chain*	*Impacts Metric*	*Mitigation Metric*	*Biodiversity dependence*	*Sustainability Standard*	*Management Guidance*		
International Sustainability & Carbon Certification (ISCC)	x				x			x		x		x	x				x	x	International certification system covering all kinds of bio-based feedstocks and renewables catering to energy, food, feed, and chemicals sectors.	https://www.iscc-system.org/
Roundtable on Responsible Soy (RTRS) Certification	x				x			x		x		x	x				x	x	Holistic certification scheme including five principles and 108 mandatory and progressive compliance indicators.	https://responsiblesoy.org/?lang=en
Biodiversity Performance Tool and Monitoring System	x							x					x				x	x	Identifies and assesses the state of potential for biodiversity on a farm in order to propose an action plan to preserve or promote biodiversity.	https://www.biodiversity-performance.eu/
Alliance for Water Stewardship (AWS) Standard		x						x									x	x	Certifies sites using indicators of good water stewardship performance.	https://a4ws.org/the-aws-standard-2-0/
Climate, Community, and Biodiversity (CCB) Standards							x	x	x								x	x	Used to identify projects that simultaneously address climate change, support local communities and smallholders, and conserve biodiversity	https://www.climate-standards.org/ccb-standards/
FAIRTRADE	x											x					x	x	Provides a framework for small-scale producers to build resilient and inclusive organisations, improve their farming performance, and generate more	https://www.fairtrade.org.uk/

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Table A1 (*continued*)

Tool	Sector							Scale						Function					Description	Reference website
	Agriculture	*Forests*	*Water*	*Fisheries*	*Biofuels*	*Other*	*All*	*Site*	*Landscape/ Jurisdictional*	*Business unit*	*Corporation*	*Product*	*Value/ Supply chain*	*Impacts Metric*	*Mitigation Metric*	*Biodiversity dependence*	*Sustainability Standard*	*Management Guidance*		
																			benefits for their members and their communities.	
GLOBALG.A.P.	x											x					x	x	Covers the certification of the whole agricultural production process of the product from before the plant is in the ground or from when the animal enters the production process to non-processed product.	https://www.globalgap.org/uk_en/
EcoVadis	x	x	x										x					x	Evaluates how well a company has integrated the principles of Sustainability/ CSR into their business and management system. It is built on other international sustainability standards.	https://ecovadis.com/
Program for the Endorsement of Forest Certification (PEFC)		x											x				x	x	Endorses national forest certification systems developed through multi-stakeholder processes and tailored to local priorities and conditions.	https://www.pefc.org/
Linking Environment and Farming (LEAF) Marque	x							x									x	x	Environmental assurance system recognising more sustainably farmed products. Certification covers the whole farm businesses and applies to all products from the business.	https://leaf.eco/

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Table A1 (*continued*)

Tool	Sector							Scale						Function					Description	Reference website
	Agriculture	*Forests*	*Water*	*Fisheries*	*Biofuels*	*Other*	*All*	*Site*	*Landscape/ Jurisdictional*	*Business unit*	*Corporation*	*Product*	*Value/ Supply chain*	*Impacts Metric*	*Mitigation Metric*	*Biodiversity dependence*	*Sustainability Standard*	*Management Guidance*		
GRI Standards							x			x			x				x	x	The main voluntary reporting standards used by companies around the world. These include standards and indicators related to biodiversity.	https://www.globalreporting.org/standards/
Soil Association Organic Standards	x	x				x						x	x				x	x	Looks at all aspects of organic food manufacturing and production, storage and sales. They consider everything from packaging to animal welfare and wildlife conservation.	https://www.soilassociation.org/our-standards/read-our-organic-standards/

Table A2
Criteria used for the rapid scoping exercise.

Function	Biodiversity impact metric or indicator
	Standard based on practices
	Offsetting, mitigation, or compensation measure
	Guidance and frameworks
	Biodiversity dependence metric or indicator
Type of metric applied	Simple Metric or indicator
	Composite metric based on multiple (3+) indicators
	Metrics mainly proxies for biodiversity impacts
	Metrics mainly relative scores of impacts
	Metrics include real biodiversity indicators
	Metrics consider threshold impacts
Decision scope	Assessment of Biodiversity impacts and options for reduction of impacts
	Assessment of Biodiversity dependence and management
	Assessment of Biodiversity benefits generated as conservation actions or offsetting
	Corporate level communication or external disclosure of biodiversity management & performance
	Third-party biodiversity performance assessment / rating of biodiversity management and performance
Scale	Site
	Landscape or jurisdictional
	Business unit
	Corporation
	Product
	Value chain
Business Application	Monitoring and evaluation of the effectiveness of management interventions
	Ex-ante or ex-post impacts of investments (at a range of scales and/or over a range of timeframe)
	Screening and assessment of biodiversity risks and opportunities of future projects operations
	Share information on corporate performance, to demonstrate effective management of impacts and/or risks and/or opportunities
	Certification of products as sustainable to consumers
	Offsetting biodiversity impacts to facilitate business development
Sector	Agriculture
	Forests
	Water
	Fisheries
	Biofuels
	Other
	All

Table A3
In-depth assessment guidance.

Categorise tools according to six elements of use	(i) Why?: What is the context and objective for use of the tool?
	(ii) What?: What aspect of biodiversity is being assessed and for what objective?
	(iii) When?: Is the tool informing current or future operations?
	(iv) For who?: What is the primary audience that uses the result of tool?
	(v) How often?: What is the frequency of use of the tool?
	(vi) How detailed? The *spatial scale* of tool use
Compare the tools according to how they support mainstreaming of biodiversity considerations in business decisions	(i) linking biological, ecological, socio-economic factors;
	(ii) creating indicators as proxies for biodiversity;
	(metrics criteria in rapid scoring exercise; qual v. quant)
	(iii) quantifying and valuing biodiversity impacts;
	(do they quantify impacts or provide guidance on how to quantify impacts? Do they value impacts?)
	(iv) screening biodiversity risks and tipping points,
	(v) assessing trade-offs between different types of capital.
Identify gaps/shortcomings of the tools	(i) The *methodologies* used for assessing biodiversity performance
	(descriptive (or observable) measurements (that do not consider external factors that may contribute to observed conditions) v. causal (model-based) methods based on rigorous impact evaluation techniques (like randomized control trials).
	(ii) The *indicators* used
	(their degree of representation, trade-off capturing biodiversity complexity v. useable by businesses).
	(iii) The *capacity or skills* required to use the tool
	(potential to be used by small and medium enterprises?)
Evaluate whether/how tools are aligned with the 2030 Action Targets	Target 14
	Target 15
	Target 16
	Target 17
	Target 18
	Target 19
	Target 20
	Target 21

Table A4
Interview questionnaire.

What is the rationale in developing a tool that identifies biodiversity impacts?
How do you in practical terms differentiate between biodiversity and other environmental impacts?
What kind of information/processes were considered essential to use the tool?
How does the tool reflect areas of increased biodiversity value or impact thresholds?
Does the tool evaluate positive biodiversity impacts or offsetting? How?
How would describe the sequential process of using this tool?
Ideally how would you envision the results of this tool being used?
Can you provide examples of applications of the tool leading to significant changes in business practices (related to biodiversity)?
What are your future plans in terms of tool development/updating (biodiversity sections)?

Table A5
Definition of the 2030 Action Targets considered by this study (CBD, 2021).

Target	Definition
14	"Fully integrate biodiversity values into policies, regulations, planning, development processes, poverty reduction strategies, accounts, and assessments of environmental impacts at all levels of government and across all sectors of the economy, ensuring that all activities and financial flows are aligned with biodiversity values."
15	"All businesses (public and private, large, medium and small) assess and report on their dependencies and impacts on biodiversity, from local to global, and progressively reduce negative impacts, by at least half and increase positive impacts, reducing biodiversity-related risks to businesses and moving towards the full sustainability of extraction and production practices, sourcing and supply chains, and use and disposal."
16	"Ensure that people are encouraged and enabled to make responsible choices and have access to relevant information and alternatives, taking into account cultural preferences, to reduce by at least half the waste and, where relevant the overconsumption, of food and other materials."
17	"Establish, strengthen capacity for, and implement measures in all countries to prevent, manage or control potential adverse impacts of biotechnology on biodiversity and human health, reducing the risk of these impacts."
18	"Redirect, repurpose, reform or eliminate incentives harmful for biodiversity, in a just and equitable way, reducing them by at least US$ 500 billion per year, including all of the most harmful subsidies, and ensure that incentives, including public and private economic and regulatory incentives, are either positive or neutral for biodiversity."
19	"Increase financial resources from all sources to at least US$ 200 billion per year, including new, additional and effective financial resources, increasing by at least US$ 10 billion per year international financial flows to developing countries, leveraging private finance, and increasing domestic resource mobilization, taking into account national biodiversity finance planning, and strengthen capacity-building and technology transfer and scientific cooperation, to meet the needs for implementation, commensurate with the ambition of the goals and targets of the framework."
20	"Ensure that relevant knowledge, including the traditional knowledge, innovations and practices of indigenous peoples and local communities with their free, prior, and informed consent, guides decision-making for the effective management of biodiversity, enabling monitoring, and by promoting awareness, education and research."
21	"Ensure equitable and effective participation in decision-making related to biodiversity by indigenous peoples and local communities, and respect their rights over lands, territories and resources, as well as by women and girls, and youth."

Appendix B. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.biocon.2022.109831.

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