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PRACTICE AND POLICY

Mining threats in high-level biodiversity conservation policies

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Abstract

Amid a global infrastructure boom, there is increasing recognition of the ecological impacts of the extraction and consumption of construction minerals, mainly processed as concrete, including significant and expanding threats to global biodiversity. We investigated how high-level national and international biodiversity conservation policies address mining threats, with a special focus on construction minerals. We conducted a review and quantified the degree to which threats from mining these minerals are addressed in biodiversity goals and targets under the 2011–2020 and post-2020 biodiversity strategies, national biodiversity strategies and action plans, and the assessments of the Intergovernmental Science–Policy Platform on Biodiversity and Ecosystem Services. Mining appeared rarely in national targets but more frequently in national strategies. Yet, in most countries, it was superficially addressed. Coverage of aggregates mining was greater than coverage of limestone mining. We outline 8 key components, tailored for a wide range of actors, to effectively mainstream biodiversity conservation into the extractive, infrastructure, and construction sectors. Actions include improving reporting and monitoring systems, enhancing the evidence base around mining impacts on biodiversity, and modifying the behavior of financial agents and businesses. Implementing these measures could pave the way for a more sustainable approach to construction mineral use and safeguard biodiversity.

KEYWORDS
Aichi biodiversity targets, cement, endangered species, environmental policy, extractive industries, impact mitigation, limestone, sand

INTRODUCTION

Contemporary societies and economic systems are quite literally built on concrete. The key mineral components of concrete—namely, sand, gravel, and limestone (hereafter construction minerals)—are strategic resources with environmental, social, and economic values essential for the achievement of the sustainable development goals (SDGs) (Bendixen et al., 2021; Thacker et al., 2019; Torres et al., 2021; zu Ermgassen, Utamiputri, et al., 2019). Rapid population growth, household proliferation, urbanization, and infrastructure development have accelerated their extraction in the last century (Krausmann et al., 2017). Construction minerals have become the most extracted solid raw materials (OECD, 2018) and account for nearly 90% of the world's anthropogenic mass, which in 2020 outweighed all Earth's living biomass (Elhacham et al., 2020). In an age where human activities increasingly transgress the planet's biophysical safe operating space, the expansion of concrete infrastructure—expected to double by 2060 (OECD, 2018)—comes with considerable ecological risks as a major driver of carbon emissions and biodiversity loss (Müller et al., 2013; Torres, zu Ermgassen, et al., 2022; zu Ermgassen, Drewniok, et al., 2022).

The mining of construction minerals has serious direct and indirect impacts on biodiversity through increased erosion, traffic, pollution, water stress, salinization, and land-use changes (Hughes, 2017; IPBES, 2019; Koehnken et al., 2020; Sonter et al., 2018). Torres, zu Ermgassen, et al. (2022) found over a thousand species on the International Union for Conservation of Nature (IUCN) Red List reported as threatened by mining construction minerals globally and many newly described species imminently threatened by this activity. Limestone quarrying is the most immediate threat to karst biodiversity in Southeast Asia (Clements et al., 2006; Hughes, 2017), where many species remain undescribed (Whitten, 2009). Likewise, reducing the overexploitation of aggregates is considered a top priority for slowing global freshwater biodiversity loss (Tickner et al., 2020).

Despite many calls from diverse voices to pay increasing attention to the impacts of humanity's reliance on construction minerals and to scaling up solutions (CBD, 2018; Hughes, 2019; Peduzzi, 2014; Torres et al., 2017; UNEP, 2022a, 2022b), it is unclear if these efforts have filtered through into conservation policy. The primary instrument for the international community's commitment to reverse biodiversity loss over the past decade has been the United Nations' Strategic Plan for Biodiversity 2011–2020 (Rogalla von Bieberstein et al., 2019), which was developed under the Convention on Biological Diversity (CBD), endorsed by all the biodiversity-related conventions, and adopted in 2010. Essential to the achievement of this plan and the associated global Aichi biodiversity targets is their implementation at the national level through the formulation of national biodiversity strategies and action plans (NBSAPs) and national targets. Effective implementation also relies on the identification of sector-specific actions and their monitoring to promote mainstreaming, ownership, and accountability (Perino et al., 2022). The CBD has reiterated the importance of mainstreaming biodiversity in the mining and infrastructure sectors with the Sharm El-Sheikh Declaration, adopted at the 14th Conference of Parties (COP14) in 2018 (CBD/COP/DEC/14/3). However, the degree to which nations are mainstreaming biodiversity across sectors varies substantially (Whitehorn et al., 2019). In December 2022, a new global framework for action on biodiversity conservation to 2030—the Kunming–Montreal Global Biodiversity Framework (GBF)—was agreed at the COP15. It builds on the results and call for transformative change of the global assessment of the Intergovernmental Science–Policy Platform on Biodiversity and Ecosystem Services (IPBES, 2019) and the lessons learned from the implementation of the Aichi targets or lack thereof.

We examined the extent to which the mining of construction minerals is considered by high-level national and international biodiversity conservation policies. We quantified the degree to which threats from mining these minerals are addressed in biodiversity goals and targets under the 2011–2020 biodiversity strategy; NBSAPs and associated national targets; regional and global assessments under IPBES; and the newly signed Kunming–Montreal GBF. In doing so, we investigated whether and how increased understanding of mining risks has permeated biodiversity conservation policies. We then highlight 8 key components for reducing biodiversity impacts of construction minerals mining and use.

METHODS

To investigate the degree to which threats posed by mining construction minerals are highlighted in biodiversity conservation policies, we conducted a review of the global Aichi biodiversity targets, all national targets for the 2011–2020 CBD framework, the latest version of all NBSAPs submitted to the CBD Secretariat, the global, regional, and land degradation and restoration IPBES assessments (https://ipbes.net/assessing-knowledge), and the global goals and targets under the Kunming–Montreal GBF (CBD/COP/DEC/15/4; https://www.cbd.int/doc/decisions/cop-15/cop-15-dec-04-en.pdf). Both national targets and NBSAPs in English, Spanish, French, Portuguese, and German were considered. National targets were downloaded from https://www.cbd.int/nbsap/targets/ in October–November 2022 for 176 countries, and the NBSAPs available in https://www.cbd.int/nbsap/search/ were downloaded for 181 countries (193 countries had submitted NBSAPs by November 2022). We used a text coding approach to identify the targets and documents that mentioned the topic of mining or specifically construction minerals mining (terms in Appendix S1). The terms *aggregates* or *sand and gravel* encompassed granular materials from multiple sources, including crushed rock and unconsolidated sediment deposits following UNEP/GRID-Geneva (2022). We classified mentions into 3 categories: those referring to general threats from mining as a whole or to the need for improved planning and management of mining activities to minimize trade-offs with biodiversity conservation; those mentioning threats from mining construction minerals; and those referring to the protection of sourcing ecosystems (e.g., sandbanks, sandy beaches, limestone hills). These categories elucidated for each target and NBSAP the relationship between biodiversity, mining, and construction sectors. The recognition of these relationships in the NBSAPs is a clear indication that countries acknowledge the need to integrate biodiversity concerns into planning of the construction and mining sectors; however, it cannot be interpreted as implementation of actions to address them.

We examined whether mentioning construction minerals in NBSAP or national targets was associated with country-level attributes through logistic regression models with a binomial distribution and logit link function with the glm function from the R stats package (R Core Team, 2021). We included as explanatory variables the interaction between country size and island status based on the UN list of Small Island Developing States (https://www.un.org/ohrlls/content/list-sids); GDP per capita in the most recent year for which there were data available (all between 2017 and 2020) calculated using GDP and population size data from the World Bank data (World Bank, 2021); average domestic extraction of construction minerals 2015–2019, calculated from the UNEP IRP Global Material Flows Database (https://www.resourcepanel.org/global-material-flows-database) with nonmetallic-minerals–construction-dominant flows; the percentage of species reported as affected by mining construction minerals of the total number of assessed species in the IUCN Red List by country (from Torres, zu Ermgassen, et al., 2022); and the length of the corresponding NBSAP. The significant threshold was $p < 0.05$. We estimated maximum likelihood pseudo r^2 using the pR2 function of the pscl package for R (Jackman et al., 2023). We present the results of the optimal model according to the lowest Akaike's information criterion corrected for finite sample sizes (AICc) (Anderson & Burnham, 2004).

Finally, we compiled policy interventions on other multilateral environmental agreements (MEAs) relevant to biodiversity conservation that include direct or indirect reference to the mining of construction minerals, from searches through policy documents, academic articles (Radzevičius et al., 2010; Weyman, 2016), and intergovernmental organization reports (e.g., UNEP, 2019).

RESULTS

Aichi targets and NBSAPs

Out of the 176 parties of the CBD examined, only 15 explicitly referred to mining in their national targets (Figure 1a; Appendix S2). Three countries, namely, Fiji, Kuwait, and Nepal, mentioned the extraction of sand, gravel, or limestone, and 4 countries (Guinea Bissau, Malaysia, Maldives, and Tajikistan) included the conservation of source ecosystems in the national targets. In contrast, the majority of NBSAPs acknowledged the threats posed by mining to biodiversity and the environment (85.6% of the countries with available NBSAPs [155 of 181]) (Figure 1b; Appendix S3), with 45.9% specifically mentioning mining of construction minerals (83 countries of 181). Of these, sand and gravel were the most mentioned construction minerals (75 countries, 41.4% of all NBSAPs reviewed), followed by limestone (31 countries, 17.1% of all NBSAPs reviewed). Habitats from where construction minerals can be sourced were mentioned across all NBSAPs.

The length of the NBSAPs had the most significant impact on the mentions of construction minerals; i.e. the longer assessments were more likely to address this threat (Table 1). Countries with a higher percentage of species affected by mining construction minerals as specified on the IUCN Red List were more prone to adopt targets and design strategies that consider construction minerals. This was the case in countries such as Vietnam, Bangladesh, Lebanon, Malaysia, and Nepal, where the threats posed by aggregates mining and rock quarrying have been extensively documented in scientific literature and media reports (e.g., Anthony et al., 2015; Darwish et al., 2011). These findings signal the influence of threats delineated in the IUCN Red List on the development of actions toward mining in NBSAPs and national targets.

Although the interaction between country size and island status was not significant, the marginal effect of the island status was significant. This suggests that irrespective of country size, there was a higher probability of mentioning construction minerals in policy documents of small island developing states than of mainland countries, which might result from perceived greater risks from mining, particularly of sands, for small islands (examples in Figure 1b). Being at the frontline of climate change impacts and natural disasters, their freshwater and coastal ecosystems—heavily reliant on sand resources—are critical for combatting erosion and mitigating flooding risks and are vulnerable to biodiversity loss (UNEP, 2023). Poorly planned mining can therefore undermine the communities' resilience and compromise mitigation and adaptation efforts because small countries are also susceptible to supply risks (ACP-EU, 2018; Komugabe-Dixson et al., 2019).

Finally, the volume of extraction of construction minerals was not associated with mentions in national targets or NBSAPs. Countries with the highest extraction volumes, including China and India, did not directly address construction minerals in their national targets or NBSAPs, which indicates a significant reporting gap.

IPBES assessments

The IPBES global and regional assessment reports identified mining as an industry associated with direct and indirect negative impacts on biodiversity, emissions, water quality, and human health (Appendix S4). Threats from extractive activities were predominantly described in sections referring to the drivers of biodiversity change and land degradation or to the status and trends of biodiversity and ecosystems. Although the reports featured other minerals more prominently (gold, diamonds, or coal), the global assessment on biodiversity and ecosystem services (IPBES, 2019) and on land degradation (IPBES, 2018) recognized sand and gravel mining as an indirect driver of

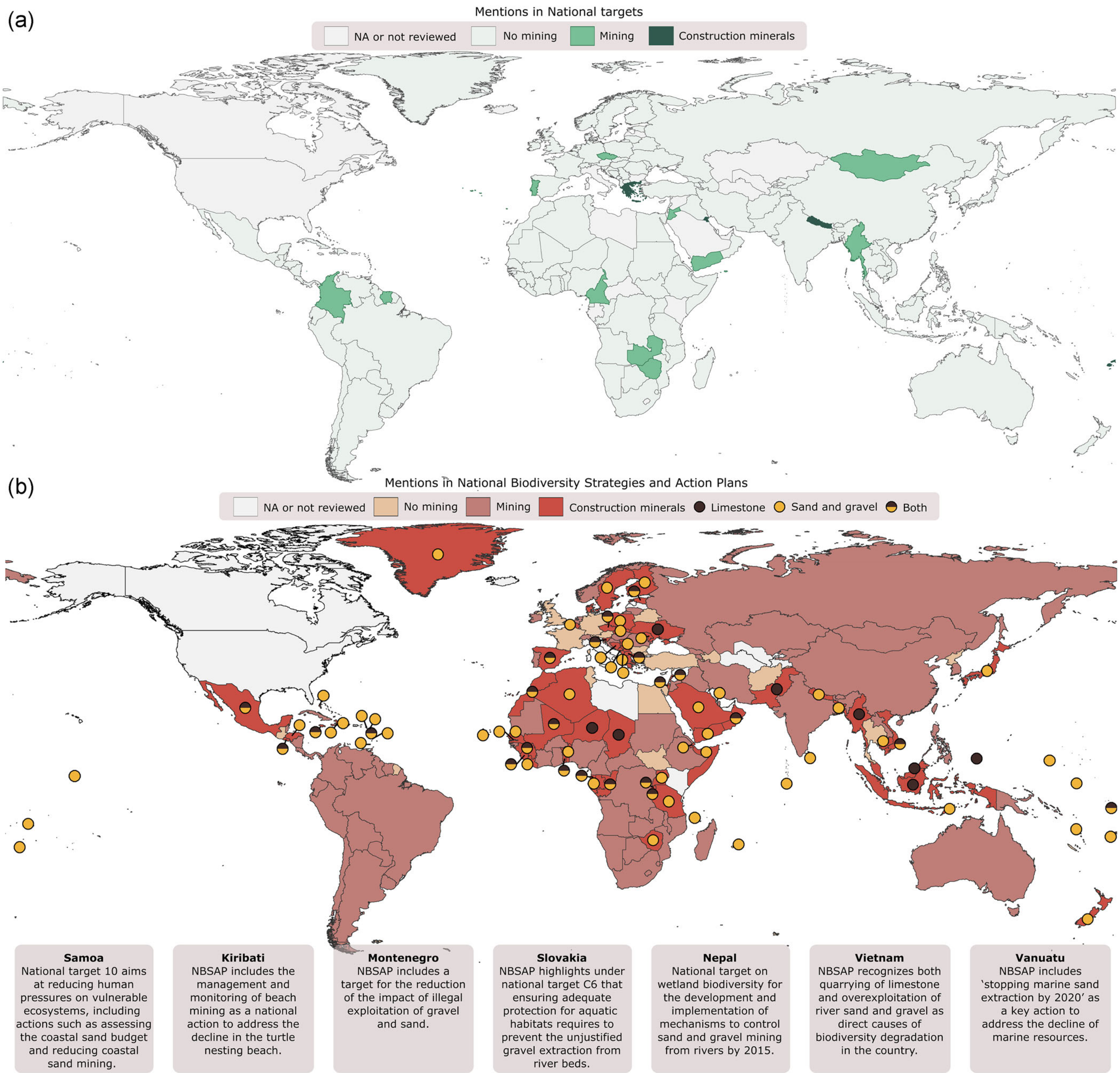

FIGURE 1 Coverage of (a) national targets for the 2011–2020 biodiversity framework of the UN Convention on Biological Diversity (CBD) and (b) national biodiversity strategies and action plans (NBSAPs) mentioning threats from or actions toward mining of construction minerals, including examples (circles, specific type of mineral mentioned for those countries with NBSAPs that refer to construction minerals). The United States of America, Andorra, South Sudan, and the Holy See (the Vatican) are not Parties to the CBD. Full details of the targets and NBSAPs mentioning construction minerals are in Appendix S3.

wetlands loss and degradation, soil erosion, and changed flood patterns and cement production as a key contributor to carbon emissions. All regional assessments considered construction minerals mining a threat to some extent; however, the issue of construction minerals stood out prominently in the Asia-Pacific assessment. The region's rapid urbanization and industrialization and associated mining are described as resulting in serious impacts on biodiversity. Those range from devastating consequences for global endemicity hotspots in karstic areas, where quarrying is considered the main threat to species survival (Clements et al., 2006; Hughes, 2017), to the extraction of aggregates destroying critical marine habitats, such as seagrass, and accelerating coastal erosion (Peduzzi, 2014; Thaman, 2013; UNEP/UNCTAD, 2014).

Other MEAs

In addition to the CBD, there are other MEAs related to biodiversity conservation for which the extraction of construction minerals is relevant (Figure 2; Appendix S5), including the SDGs, conventions to minimize the impact of aggregates

TABLE 1 Results of the logistic regression model between including mentions of construction minerals in national targets or national biodiversity strategies and action plans (NBSAPs) and country-level characteristics (pseudo $r^2 = 0.33$).

Parameter	Estimate	SE	Z	p[a]
Intercept	−2.483	0.609	−4.076	<0.001**
Country size	-4.9×10^{-7}	3.1×10^{-7}	−1.560	0.118
Island status	1.365	0.571	2.388	0.017*
Domestic extraction of construction minerals[b]	-1.4×10^{-9}	1.4×10^{-9}	−1.036	0.300
Percentage of IUCN Red List species affected[c]	1.794	0.761	2.357	0.018*
NBSAP's length[d]	0.015	0.003	4.504	<0.001**
Country size × Island status[e]	-2.0×10^{-5}	1.8×10^{-5}	−1.153	0.249

[a]Significance: *<0.05; **<0.01.

[b]Average domestic extraction of construction minerals 2015–2019, calculated from the UNEP IRP Global Material Flows Database (https://www.resourcepanel.org/global-material-flows-database).

[c]Assessed at the IUCN Red List according to Torres, zu Ermgassen, et al. (2022).

[d]Length of the corresponding national biodiversity strategy and action plan (NBSAP).

[e]Status of Small Island Developing States based on the UN list (https://www.un.org/ohrlls/content/list-sids).

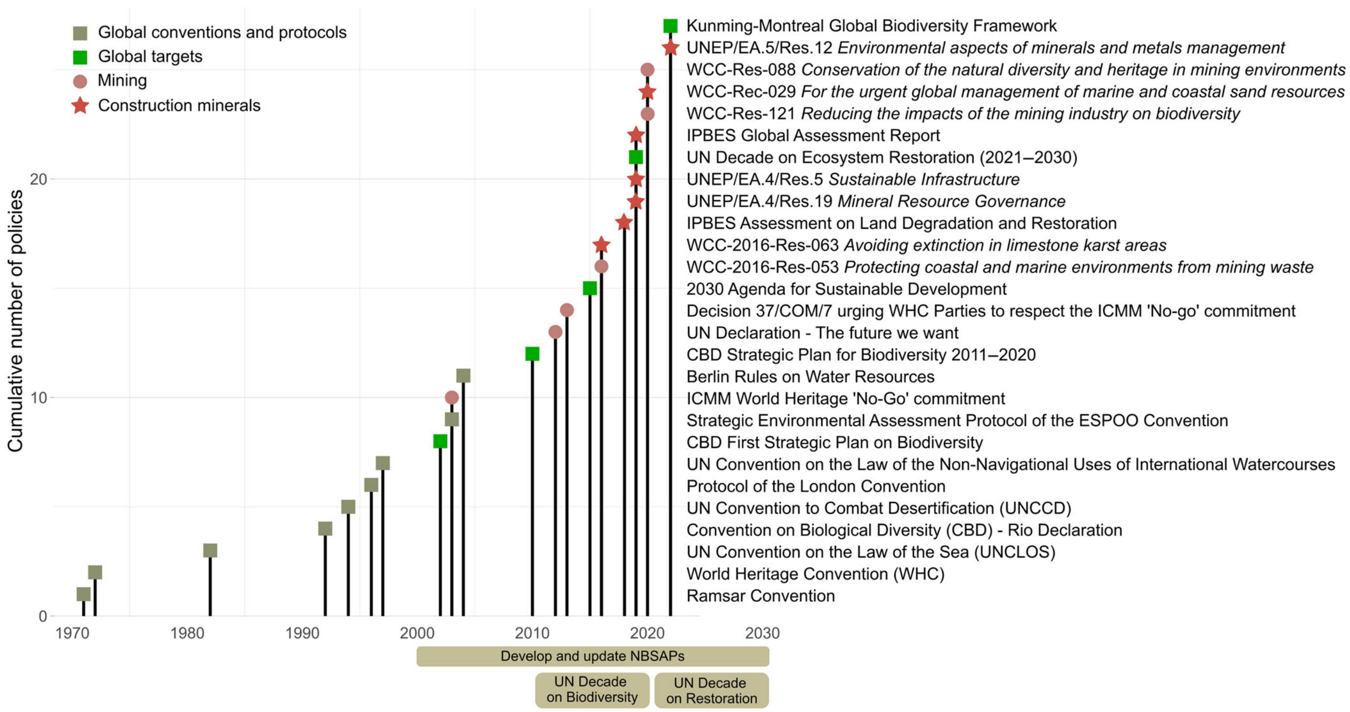

FIGURE 2 Chronology of multilateral environmental agreements relevant for the nexus between construction minerals and biodiversity over the last 50 years (gray squares, global conventions or associated protocols; green squares, global strategy and targets; dots, policy instruments that mention mining; stars, policy instruments that mention construction minerals; ESPOO, Convention on Environmental Impact Assessment in a Transboundary Context; ICMM, International Council on Mining and Metals; IPBES, Intergovernmental Science–Policy Platform on Biodiversity and Ecosystem Services; UN, United Nations; UNEP, UN Environment Program; WCC, IUCN World Conservation Congress). Since 2000 and even earlier, Parties to the CBD develop and update national biodiversity strategies and action plans (NBSAPs). Full details of the listed policies and their relevance are in Appendix S5.

mining on wetlands and marine areas, and policy instruments for environmental assessment. Interestingly, the saliency of the theme of construction minerals in the international community increased recently, with 3 resolutions of the UN Environmental Assembly and one resolution and one recommendation of the IUCN World Conservation Congress that directly address construction minerals adopted since 2016. The increased saliency of the theme in high-level biodiversity conservation policies does not necessarily translate into increased implementation efforts. Nevertheless, by design, the 2011–2020 strategic plan for biodiversity supports the mapping of targets across conventions and cooperation for their effective implementation (Rogalla von Bieberstein et al., 2019), which should be reflected in the NBSAPs and have been captured by our analyses.

Post-2020 Global Biodiversity Framework

The Kunming–Montreal GBF aims at halting biodiversity loss, and driving its recovery, while accounting for the benefits that humans and society derive from healthy and sustainably used ecosystems. Three of the framework's targets were of relevance regarding construction minerals. Target 12 focused on the "green and blue spaces in cities," "biodiversity-inclusive urban planning," and "sustainable urbanization," but it did not account for the off-site impacts of urban development, such as provisioning construction minerals. Target 14 on biodiversity mainstreaming into "policies, regulations, planning and development processes" would likely call for such mainstreaming within the mining sector. Indeed, the draft GBF produced by OEWG4 in July 2022 listed mining and deep-sea mining; however, the text was not retained in the final version. Lastly, target 15 indicated that businesses and financial institutions must assess and report on their impacts on biodiversity and strive for full sustainability of their activities. The first draft of the target included "extraction practices," but the term was dropped. The absence of a clear reference to mining carries a risk of construction mineral mining being overlooked in future NBSAPs derived from the GBF.

DISCUSSION

Hard problems, concrete solutions

The –Kunming-Montreal GBF is built around a theory of change that acknowledges the need for urgent policy action globally, regionally, and nationally to transform economic, social, and financial models for stabilizing biodiversity loss trends by 2030, with net improvements by 2050. However, the demand for construction minerals is projected to double by 2060 (OECD, 2018), leading to mining expansion into biodiversity-rich areas (e.g., Hughes, 2019). Recent assessments and resolutions stress the need to promote transitions to sustainable pathways, including for cities and infrastructure development (CBD, 2020; Díaz et al., 2019). Although discussions on the sustainable cities transition center on green infrastructure and nature-based solutions, these documents also advocate for sustainable materials and improved spatial planning that accounts for the impact of urban communities on nearby and distant ecosystems, following the metacoupling framework (Liu, 2017). Yet, the full reach of the threat posed by mining construction minerals to biodiversity remains uncertain due to knowledge and data gaps (Cooke et al., 2023; Torres, zu Ermgassen, et al., 2022). Our results show that current policies still fall short of clear statements and outcomes regarding the reporting and monitoring of mining threats, especially related to construction minerals. We outline 8 key components that we consider essential to effectively mainstream biodiversity conservation into the extractive, infrastructure, and construction sectors (Figure 3).

Enhance taxonomic and impact assessment practices to describe and protect the unknown

Sound conservation decisions require knowledge of the species present. Yet, mining construction minerals sometimes affects ecosystems that host numerous undescribed species of poorly known groups, such as invertebrates, fungi, and plants (Reddy, 2014; Torres, zu Ermgassen, et al., 2022). The dire need to catalog, study, and protect species and their habitats in mining frontiers clashes with a stagnation in the number of taxonomists, funding, and training (Drew, 2011; Sluys, 2013). Bebber et al. (2014) estimated that the average lag between collecting a plant specimen and publishing the species description was 35 years. Given the rapid development rates, even a fraction of that time would mean that many species may become extinct during the description process. Molecular approaches, such as DNA barcoding and metabarcoding, aid in estimating biodiversity but require resources not universally available and procedures not explicitly designed to describe species. Governments, academic institutions, and conservation organizations must ensure funding for taxonomic research and training, and foster collaboration between taxonomists and red-list assessors to provide red-list assessments as part of taxonomic descriptions (Hochkirch et al., 2021; Tapley et al., 2018). By solely prioritizing red-list species when determining the risks of new developments, the environmental impact assessment (EIA) process overlooks vulnerable, unassessed, or poorly assessed species, potentially neglecting their conservation (Martín-López et al., 2011; Simmonds et al., 2020). To address this gap, governments and networks of EIA practitioners should set good practice in impact assessment following a risk-based approach when extractive industries enter areas with poorly documented species: "If a species is potentially new to science or globally threatened and has highly restricted range and knowledge of its distribution, ecology, and restoration needs is lacking, the precautionary principle should apply and impacts on it should be avoided. If all actors decide avoidance is not feasible, it should not be translocated, moved, or destroyed until its requirements are researched and effective techniques are available" (J. Treweek, personal communication 2022).

Advance and apply the evidence base on biodiversity responses to mining and restoration

Despite decades of developments in the practice of EIA and numerous guidelines (Gillieson et al., 2022; IUCN, 2014; Sanchez & Lobo, 2018; UNEP, 1990), severe knowledge gaps persist regarding how to mitigate development impacts on ecosystems and restoring or offsetting biodiversity after mining (Boldy et al., 2021; Christie et al., 2020; Hunter et al., 2021; Martins et al., 2020; zu Ermgassen, Baker, et al., 2019), which limits the success of mitigation efforts. The current system for enhancing the evidence base is haphazard and inefficient. The majority of postintervention monitoring remains unpublished, and there are suspected low compliance rates with

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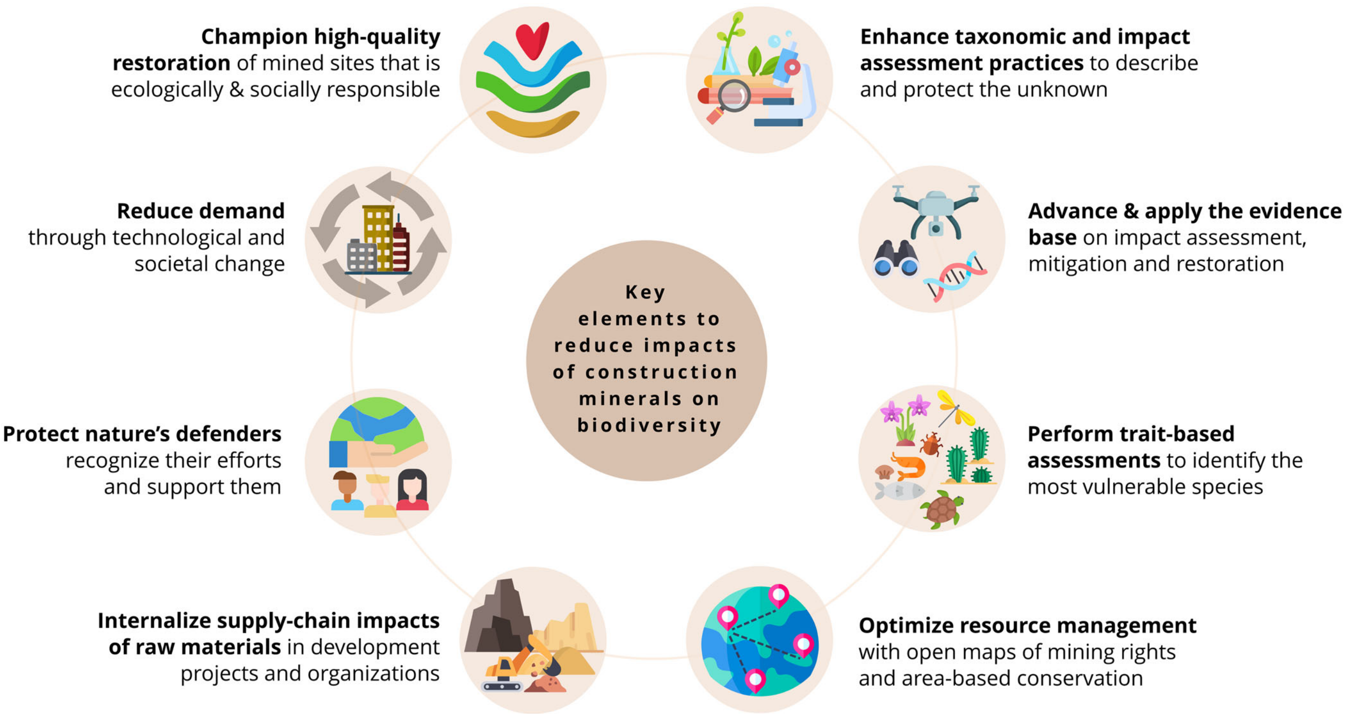

FIGURE 3 Eight key components for addressing the impacts of mining activities and the use of construction minerals on biodiversity over space and time. The successful implementation of actions along these components hinges on strengthening engagement across sectors and actors to create a community of practice. Icons: https://flaticon.com and https://www.decadeonrestoration.org/.

mandated mitigation measures because of a lack of third-party enforcement (Tischew et al., 2010; zu Ermgassen, Baker, et al., 2019). Baseline surveys in EIA should provide transparent and evidence-based information on biodiversity impacts and mitigation recommendations (Brownlie & Treweek, 2018; Sanchez & Lobo, 2018). Maximizing the technical quality and scientific value of the follow-up monitoring of mining projects to assess the effectiveness of mitigation, restoration, and offsetting actions (e.g., integrating field surveys with environmental DNA and remote sensing) would improve the volume of new evidence (Dias et al., 2019; Gillieson et al., 2022; Lindenmayer & Likens, 2009). An ideal system for mitigating impacts and iteratively enhancing the evidence base would involve routine public reporting of monitoring outcomes aligned with the FAIR (findable, accessible, interoperable, and reusable) principles (Wilkinson et al., 2016) and open practices (e.g., published in Conservation Evidence database, mobilizing data to GBIF; King et al., 2012). Such efforts will help identify what works and under which conditions and how efforts can be scaled up and contribute to the accountability of the mining sector (Perino et al., 2022). For that system to succeed, authorities must empower local institutions and organizations to access, apply, and contribute up-to-date knowledge to inform environmental assessments, decision-making, and mitigation strategies (UNEP, 2022a). Improved and independent funding mechanisms are needed, and extractive industries should also contribute resources for site-based research.

Perform trait-based vulnerability assessments

In parallel to efforts to boost the reporting of mining threats on particular species, research approaches based on traits (behavioral responses or life-history traits) can help identify species that will be most affected by construction minerals mining in a timely manner for conservation and management (Bland & Böhm, 2016; Jarić et al., 2019; Kopf et al., 2017). This would shed light into the mechanisms that contribute to imperilment, making predictions for unassessed species, and ranking species based on their relative vulnerability. The database of species produced by Torres, zu Ermgassen, et al. (2022) can be a starting point to use as a Robin Hood approach (sensu Punt et al., 2011), where available assessments are used to examine species that are information poor.

Optimize resource management with open-access maps of mining rights, spatial planning, and area-based conservation

Mining rights for aggregates or limestone are barely represented in global mining databases (SNL Metals and Mining or S&P Global Market Intelligence databases) or land-cover data sets and insufficiently covered by many national data sets. The lack of comprehensive mapping might easily downplay the environmental and social risks posed by mining (Maus & Werner, 2024). Governments, in cooperation with the mining and quarrying industry, must create publicly available spatially explicit databases of mining rights including construction minerals. Such effort would be imperative for grasping the extent and distribution of biodiversity threats and for identifying restoration opportunities. Spatial planning is also crucial before mining takes place to designate areas suitable for mining and areas where mining should not occur because they are critical to conservation (Siqueira-Gay et al., 2022), commonly known as no-go areas. The International Council on Mining and Metals committed in 2003 to considering World Heritage sites off-limits to mineral development (Figure 3). Certain rare, fragile, and unique ecosystems, such as areas with caves and other karst features, might be deemed inappropriate for mining as well (Gillieson et al., 2022). Nonkarstified limestone formations could be suitable, provided other important biodiversity values are not present. Furthermore, environmental assessments must adopt an ecosystem-based approach, considering effects beyond the mining site through to landscape-scale processes (Gillieson et al., 2022; Sanchez & Lobo, 2018), often overlooked in the mining sector (see Torres, Patterson, et al. [2022] for landscape fragmentation). Otherwise, assessments will fail to determine population-level implications and the appropriate scope for implementing mitigation measures. Strategic land-use planning should also consider cumulative effects from existing and anticipated future stressors (Siqueira-Gay et al., 2022).

Account for supply-chain impacts of raw materials when financing development projects and assessing organizational biodiversity footprints

Including the impacts of mining construction minerals and their supply chains within the scope of multilateral and private finance environmental safeguard policies would internalize the ecological costs of extraction. As it stands, major multilateral development banks' safeguard policies hold their clients responsible for some supply-chain impacts of the projects they help finance, but often inanimate raw materials are excluded (Table 2). A simple wording change, adopting the World Bank safeguards' definition of raw materials (which explicitly includes construction minerals), could be a valuable leverage point, laying the groundwork for internalizing the supply-chain impacts of construction minerals' consumption into tens of billions of dollars' worth of project financing each year. Likewise, financial institutions need to assess their exposure to environmental risks associated with investments reliant on dredging marine aggregates (e.g., land reclamation projects) as highlighted by UNEP Finance Initiative (UNEP, 2022b). As organizations and international institutions also strive to deliver nature-positive outcomes, there is a growing focus on addressing supply-chain impacts through organizational sustainability strategies (zu Ermgassen, Howard, et al., 2022). The little work that has been done reveals substantial impacts of construction mineral supply chains. In an analysis of the University of Oxford's biodiversity footprint, the biodiversity impacts and emissions embedded in construction supply chains were one of the largest categories of the organization's impacts, with construction and cement use ranking as major drivers of water consumption, acidification, and eutrophication (Bull et al., 2022). However, methodological gaps remain. Determining footprints largely relies on impact estimates averaged across a bundle of related economic activities (e.g., those in databases like Exiobase) and lacks spatial considerations.

Protect nature's defenders

Target 22 of Kunming–Montreal GBF recognizes the rights of Indigenous Peoples and local communities and emphasizes the need to ensure the protection of environmental human rights defenders. The murder of land and environmental defenders is a widespread and growing phenomenon, with the mining sector reporting the highest number of murders (Global Witness, 2020; Zeng et al., 2022). While conflicts affecting the metal and precious minerals mining industry frequently involve social resistance to large-scale operations and major corporations, conflicts associated with construction minerals are often linked to instances of illegal or illicit activities, which should be distinguished from informal mining (Magliocca et al., 2021). The aggregates sector is particularly prominent in this regard. Reports by journalists, activists, nongovernmental organizations, and grassroots organizations of threats, violence, and murders around the sand mining sector in the Global South are numerous (Bisht, 2021; Constable, 2017; REFORMA, 2019; SANDRP, 2019). Such is the case in India, where multiple independent sand mafias control sand flows and are responsible for the intimidation, injury, and murder of numerous activists, journalists, and police officers (Magliocca et al., 2021) and where sand resources are behind most mining conflicts (Bisht & Gerber, 2017). Without ensuring the safety of nature defenders, it becomes nearly impossible to gather accurate information on the biodiversity risks from mining construction minerals. Urgent government protection, local support, international recognition, and the mobilization of human rights mechanisms are needed to address these issues and underlying factors (Bille Larsen et al., 2021; Glazebrook & Opoku, 2018).

Reduce demand through technological and societal change

The previous components are likely insufficient on their own without addressing the rapid growth in demand for construction minerals. Global material stocks are projected to increase by 66% from 2015 to 2035, despite scientists warning that the global economy is consuming materials in excess of that required to remain within Earth's "safe-operating space" (Bringezu, 2015; Wiedenhofer et al., 2021). Haberl et al. (2019) show that there is a nonlinear relationship between national concrete stocks and material improvements in people's wellbeing. The satiation point is around 50 t concrete/capita, suggesting that increasing concrete stocks in infrastructure-rich nations may be unnecessary for meeting people's fundamental

TABLE 2 Coverage of construction minerals in major multilateral development banks' safeguard policies.

Environmental safeguard policy	Estimated value of project financing	Policy wording	Construction minerals included
International Finance Corporation	Raised US$11.3 billion in 2020 (IFC, 2020)	Performance Standard 6 (IFC, 2012), paragraph 30: "Where a client is purchasing primary production (especially but not exclusively food and fiber commodities) that is known to be produced in regions where there is a risk of significant conversion of natural and/or critical habitats, systems and verification practices will be adopted as part of the client's ESMS to evaluate its primary suppliers. The systems and verification practices will (i) identify where the supply is coming from and the habitat type of this area; (ii) provide for an ongoing review of the client's primary supply chains; (iii) limit procurement to those suppliers that can demonstrate that they are not contributing to significant conversion of natural and/or critical habitats (this may be demonstrated by delivery of certified product, or progress towards verification or certification under a credible scheme in certain commodities and/or locations); and (iv) where possible, require actions to shift the client's primary supply chain over time to suppliers that can demonstrate that they are not significantly adversely impacting these areas. The ability of the client to fully address these risks will depend upon the client's level of management control or influence over its primary suppliers."	No, primary production only
The Equator Principles	Unknown, >90 private banks and financial institutions are signatories	Principle 3 (The Equator Principles Association, 2020): "The EPFI will, with supporting advice from the Independent Environmental and Social Consultant where applicable, evaluate the Project's compliance with the applicable standards as follows: 1. For Projects located in Non-Designated Countries, compliance with the applicable IFC Performance Standards on Environmental and Social Sustainability (Performance Standards) and the World Bank Group Environmental, Health and Safety Guidelines (EHS Guidelines) (Exhibit III). 2. For Projects located in Designated Countries, compliance with relevant host country laws, regulations and permits that pertain to environmental and social issues."	Ambiguous—no if aligned with IFC standards, yes if aligned with WB standards
Asian Development Bank	Committed to $48 billion of project financing in 2020 (Asian Development Bank, 2021)	Supply chain impacts not currently included in safeguard policy. Safeguard policy currently under review, due to be revised October 2023.	No
Inter-American Development Bank	Delivered $13.9 billion of project loans and guarantees in 2020 (IDB, 2021)	Environmental and Social Performance Standard 6 (IDB, 2020), paragraph 29: "Where a Borrower is purchasing primary production (especially but not exclusively food and fiber commodities) that is known to be produced in regions where there is a risk of significant conversion of natural and/or critical habitats, systems and verification practices will be adopted as part of the Borrower's ESMS to evaluate its primary suppliers. The systems and verification practices will (i) identify where the supply is coming from and the habitat type of this area; (ii) provide for an ongoing review of the Borrower's primary suppliers; (iii) limit procurement to those suppliers that can demonstrate that they are not contributing to significant conversion of natural and/or critical habitats (this may be demonstrated by delivery of certified product, or progress towards verification or certification under a credible scheme in certain commodities and/or locations); and (iv) where possible, require actions to shift the Borrower's primary suppliers over time to suppliers that can demonstrate that they are not significantly adversely impacting these areas. The ability of the Borrower to fully address these risks will depend upon the Borrower's level of management control or influence over its primary suppliers."	No, primary production only

(Continues)

TABLE 2 (Continued)

Environmental safeguard policy	Estimated value of project financing	Policy wording	Construction minerals included
World Bank	$77.1 billion of project financing in 2020 (including IFC lending) (World Bank, 2020)	Environmental and Social Standard 1 (World Bank, 2017): "Assessment and Management of Environmental and Social Risks and Impact." See associated Guidance note 34.1 (World Bank, 2018a): "The requirements in paragraph 34 regarding primary suppliers apply to ongoing, extended contractual relationships between the project and the supplier, through which the Borrower has the potential to influence the supplier's operational practices. The environmental and social assessment should consider the nature and potential sources of goods and materials that are required for critical project activities. This may include, for example, timber for railroad ties, or gravel and asphalt for road construction." Environmental and Social Standard 6 (World Bank 2017): "Biodiversity Conservation and Sustainable Management of Living Natural Resources," paragraphs 38–39: "Where a Borrower is purchasing natural resource commodities, including food, timber and fiber, that are known to originate from areas where there is a risk of significant conversion or significant degradation of natural or critical habitats, the Borrower's environmental and social assessment will include an evaluation of the systems and verification practices used by the primary suppliers. 39. The Borrower will establish systems and verification practices which will: (a) identify where the supply is coming from and the habitat type of the source area; (b) where possible, limit procurement to those suppliers that can demonstrate that they are not contributing to significant conversion or degradation of natural or critical habitats; and (c) where possible and within a reasonable period, shift the Borrower's primary suppliers to suppliers that can demonstrate that they are not significantly adversely impacting these areas." See associated Guidance note 38.1 (World Bank, 2018b): "Examples of natural-resource commodity production that may involve significant conversion or degradation of habitats include unsustainably harvested wood products, gravel or sand extraction from riverbeds or beaches, plantation crop production resulting in deforestation, and aquaculture that displaces mangroves or natural wetlands."	Yes, sand and gravel explicitly mentioned in safeguard guidance notes
European Bank of Reconstruction and Development	Invested €11 billion in 2020 (European Bank of Reconstruction & Development, 2021)	Environment and Social Policy 2019, Performance Requirement 6 (European Bank of Reconstruction & Development, 2019), paragraphs 27–29: "Where the client is purchasing natural resource commodities, including food, timber and fibre that are known to originate from areas where there is a risk of significant conversion or degradation of priority biodiversity features and/or critical habitats, the client's environmental and social assessment will include an assessment of the systems and verification practices used by the primary suppliers. The clients will also give preference to purchasing living natural resources that are produced in accordance with internationally recognized principles and standards of sustainable management, where available for the product being purchased. At a minimum, the client will establish policies, procedures and verification practices which will: • identify the origin of the supply and habitat type of the source area; • avoid procurement from suppliers that are contributing to significant conversion or degradation of priority biodiversity features, critical habitats and/or designated protected areas; and • provide for an ongoing review of the client's primary suppliers. The ability of the client to fully address these risks will depend upon the client's level of control or influence over its primary suppliers."	Ambiguous, do not define natural resource commodities, but further references are to "living natural resources," which would exclude construction minerals

needs. There is increasing recognition that society experiences high-carbon lock-in effects (i.e., society has become dependent on, and essentially locked into, high-carbon infrastructure, which makes it challenging to transition to low-carbon alternatives) at least partly because of an overriding political economy that favors high-resource consumption pathways (reviewed for the automobile and housing sectors in Mattioli et al. [2020] and zu Ermgassen, Drewniok, et al. [2022]). Addressing these and reducing materials demand is an essential component of achieving sustainable levels of construction mineral mining and consumption (Bisht, 2022; Creutzig et al., 2018). This requires rapid rates of innovation-driven dematerialization that mainstreams the use of secondary (e.g., construction and demolition waste) (UNEP, 2022a) and alternative materials such as byproducts of other industries (e.g., ore-sand from iron ore mines [Golev et al., 2022]). These efforts must be coupled with changes in economic systems, such as making more efficient use of existing infrastructure instead of satisfying further demand solely through infrastructure expansion (IRP, 2019; Zhong et al., 2022).

Champion the high-quality ecological restoration of mining sites

The UN's General Assembly has proclaimed the UN Decade on Ecosystem Restoration 2021–2030, and the Kunming–Montreal GBF is setting a target for the effective restoration of at least 30% of degraded ecosystems by 2030. The vast anthropogenic mass of the planet is mostly made of construction minerals that have been predominantly extracted over the last 4 decades (Elhacham et al., 2020). The restoration of those and future mining settings is crucial for reversing land degradation and boosting biodiversity. The construction minerals industry has an unparalleled opportunity to champion and mobilize societal, technological, and financial resources to implement high-quality restoration. Recent industry initiatives show commitment to meet this challenge (e.g., CEMBUREAU, 2022; Heidelberg Materials' 2030 Sustainability Commitments). The international principles and standards for the ecological restoration and recovery of mine sites (Young et al., 2022) can assist the industry and stakeholders in tackling the challenges associated with ecological restoration of mined landscapes and improving restoration outcomes. Various cases also show the potential of collaborative research for establishing meaningful conservation and restoration targets and defining priorities to allocate resources (BirdLife Europe and Central Asia & HeidelbergCement, 2017; MPA, 2021; Salgueiro et al., 2020). Long-term relationships between mining companies and research projects can address knowledge gaps by using powerful study designs (before–after, control–impact designs or randomized experiments), thereby increasing the inferential strength of assessments and informing strategies along the mitigation hierarchy (Sanchez & Lobo, 2018). However, research institutions must be careful not to legitimize malpractice—research funds are no substitute for impact avoidance when mining impacts threatened biodiversity or poorly known biodiversity.

Following the adoption of the Kunming-Montreal GBF, countries will develop or revise their national biodiversity strategies. We encourage policymakers to incorporate the proposed elements into their policies and strategic plans for reducing the biodiversity impacts of mining construction minerals over time. Some of the points raised are not unique to the construction minerals sector; rather, they represent systemic changes needed that affect the broader mining industry. Initiatives aimed at addressing data and knowledge gaps will help improve the scientific knowledge that underpins policies governing mineral resources through international treaties and national and subnational policies and strategies across sectors such as nature conservation and restoration (e.g., SDG 14 and 15) and urban sustainability (SDG 11). Implementing the recommended actions will contribute to securing the social license to operate, empowering industry, authorities, and civil society to cultivate stronger relationships that drive systemic improvements throughout industry and hold key stakeholders accountable. These actions must be part of a wider transformative change to transition to less resource-intensive economies for addressing society's infrastructure needs.

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SUPPORTING INFORMATION

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

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