INSPIRE

NGFS
Central Banks and Supervisors
Network for Greening the Financial System

NGFS Occasional Paper

Central banking and supervision in the biosphere:

An agenda for action on biodiversity loss, financial risk and system stability

Final Report of the NGFS-INSPIRE Study Group on Biodiversity and Financial Stability

About the NGFS

The Network for Greening the Financial System (NGFS), launched at the Paris One Planet Summit on 12 December 2017, is a group of central banks and financial supervisors, which on a voluntary basis are willing to share best practices and contribute to the development of environment and climate risk management in the financial sector, and to mobilise mainstream finance to support the transition towards a sustainable economy. The NGFS brings together 108 central banks and financial supervisors and 17 observers. Together, they represent five continents and countries which produce over 85 per cent of global greenhouse gas emissions and are responsible for the supervision of all of the global systemically important banks and two thirds of global systemically important insurers. The NGFS is chaired by Ravi Menon, Managing Director of the Monetary Authority of Singapore. The Secretariat, headed by Jean Boissinot, is provided by Banque de France.

About INSPIRE

The International Network for Sustainable Financial Policy Insights, Research, and Exchange (INSPIRE) is an independent research network built to support the central banks and financial supervisors of the NGFS in its work to manage climate and environmental risks and mobilise finance to support the transition to a sustainable economy. The INSPIRE secretariat is co-hosted by the Grantham Research Institute on Climate Change and the Environment at the London School of Economics and Political Science and the ClimateWorks Foundation. It is guided by an Advisory Committee and has commissioned over 30 research projects across a range of critical themes.

About the NGFS-INSPIRE Study Group on Biodiversity and Financial Stability

The study group was established in April 2021 to develop a research-based approach to how central banks and supervisory authorities can fulfil their mandates in the context of biodiversity loss. It is co-chaired by Dr MA Jun (Special Advisor to the Governor of the People's Bank of China and Chair of the NGFS Workstream on Research) and Professor in Practice Nick Robins (London School of Economics and INSPIRE). This study group comprises 103 individuals from 25 NGFS members and observers and 28 academic and professional institutions.

About this report and acknowledgements

This report is the third output of the Joint NGFS-INSPIRE Study Group on Biodiversity and Financial Stability, following the publication of a Vision Paper in June 2021 and Interim Report in October 2021. The report was prepared by the Study Group and primarily authored by Elena Almeida (LSE), Simon Dikau (LSE), Erlan Le Calvar (Banque de France and NGFS Secretariat), MA Jun (People's Bank of China, NGFS, and Institute of Finance and Sustainability), Natasha Kunesch (LSE consultant), Mark Nicholls (LSE consultant), Nick Robins (LSE), Mathilde Salin (Banque de France), Tianyin SUN (Tsinghua PBC School of Finance and NGFS) and Romain Svartzman (Banque de France and NGFS Secretariat). Georgina Kyriacou (LSE) copy-edited and formatted the report.

The report draws from and builds on the input and summary papers that were prepared by the Study Group members as fundamental background material to inform the report. All special contributions are referenced accordingly and are listed in Appendix 2. The following Study Group members have significantly contributed to the report through these direct written contributions, as well as through extensive comments: Maud Abdelli (WWF Switzerland), Elías Albagli (Banco Central de Chile), Silvio Arduini (Banco Central do Brasil), Keshia Jasmine Ashaari (Bank Negara Malaysia), Renita Au (Hong Kong Monetary Authority), Yunwen BAI (Institute of Finance and Sustainability), Prajwal Baral (UNDP Sustainable Insurance Forum), Rodrigo Cassola (UN Environment Programme World Conservation Monitoring Centre), Hugues Chenet (University College London), Chiara Colesanti Senni (Council on Economic Policies), Jessica Dempsey (University of British Columbia), Clément

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The report benefitted from inputs, contributions and comments by the Study Group Members, including Spyridon Alogoskoufis (European Central Bank), Irene Alvarado Quesada (Central Bank of Costa Rica), Géraldine Ang (OECD), Theodora Antonakaki (Bank of Greece), Antoine Boirard (Banque de France), Ricardo Bayon (Encourage Capital and Brown University), Jennifer Bell (Bank of England), Pietro Calice (World Bank), Fanny Cartellier (CREST-ENSAE), Odile Conchou (Agence Française de Développement), Clément Bourgey (Banque de France and NGFS Secretariat), James d'Ath (Sustainix), Stéphane Dees (Banque de France), Rafael del Villar Alrich (Banco de México), Charlie Dixon (Finance for Biodiversity), Perry Edward (OECD), Clementine Fournier (UN Environment Programme World Conservation Monitoring Centre), Audrey Irvine-Broque (University of British Columbia), Benjamin Filewod (LSE), David Gayle (Bank of England), Ricardo Gimeno (Banco de México), Sina Hbous (Financial Regulatory Authority of Egypt), Anna Hyrske (Bank of Finland), Esmyra P. Javier (Asian Development Bank), Katia Karousakis (OECD), Danae Kyriakopoulou (LSE), Duncan A. Lang (Asian Development Bank), Natalie Lau (Hong Kong Monetary Authority), Frank Leung (Hong Kong Monetary Authority), Harold Levrel (AgroParis Tech), Catriona Marshall (OECD), Annelie Miller (Cornell University), Patricia Moles (Banco de México), María Nieto (Banco de España), Stephan Nolan (UNDP Sustainable Insurance Forum), Clément Payerols (Banque de France), Danijela Piljic (De Nederlandsche Bank), Kosintr Puongsophol (Asian Development Bank), Alexandre Rambaud (AgroParisTech), Giovanni Ruta (World Bank), Edo Schets (Bank of England), Sha Song (World Economic Forum), Richard Senner (Swiss National Bank), Matthias Täger (LSE), Tetsutaro Shindo (World Bank), Fiona Stewart (World Bank), Jakob Thoma (2DII), Shu Tian (Asian Development Bank), John Tobin (Cornell University), Joris van Toor (De Nederlandsche Bank), Gabriel Wu (Hong Kong Monetary Authority), Ji Xi (University of Peking), Robert Youngman (OECD), Warwick Yuen (Hong Kong Monetary Authority), Chunquan Zhu (World Economic Forum).

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LSE THE LONDON SCHOOL OF ECONOMICS AND POLITICAL SCIENCE

Grantham Research Institute on Climate Change and the Environment

Foreword

Biodiversity supports all life on our planet. But we are eroding this biodiversity at a pace that is severely damaging the natural ecosystems that provide us with food, water and clean air. This in turn could pose significant risks to economic, financial and social stability.

While governments bear the primary responsibility for mitigating and reversing biodiversity loss, the financial sector too has an important role. It should align itself with the transformations that are necessary to deliver a global economy that is positive for nature. Financial regulators and central banks can and must enable the greening of the financial system; this role is not inconsistent with their mandates for price and financial stability.

The joint NGFS-INSPIRE Study Group has provided us with deep insights to better understand the role that central banks and supervisors need to play with regard to the financial and economic risks stemming from biodiversity loss. The group's Vision Paper, published in June 2021, set out the links between biodiversity loss and the macroeconomic and financial systems, raising awareness of an issue that has thus far barely been addressed by central banks and supervisors. The Interim Report, published in October 2021, delved into the assessment of such links and their economic and financial sector impacts.

This Final Report explores in greater depth the issues raised in the earlier reports and analyses different approaches to the design of nature-related scenarios. It also considers current gaps in knowledge, sets out a research agenda, identifies near-term policy options, and makes recommendations for action by central bankers and supervisors on biodiversity loss. In line with scientific consensus, it emphasises the need to consider the nexus between climate and biodiversity so that we can develop coherent strategies to address these environmental issues.

On the basis of the rigorous research in these three reports, the NGFS has issued a clear Statement: *"Biodiversity loss could have significant macroeconomic implications. Failure to account for, mitigate, and adapt to these implications is a source of risks relevant for financial stability."* The NGFS's interest in biodiversity is consistent with its Charter, which addresses environmental risks beyond climate change.

I would like to thank all those who have contributed to this Final Report. They have helped define what we central banks and supervisors can do, within the remit of our mandates, to address the urgent challenge of biodiversity loss.

Ravi Menon

Chair of the Network for Greening the Financial System

Foreword

In December 2021, the great American scientist E. O. Wilson passed away after a lifetime of expanding our understanding of the biosphere we inhabit. Often described as the 'father of biodiversity', Wilson saw biodiversity as "the totality of all inherited variation in the life forms of Earth, of which we are one species. We ignore it to our great peril."

The stark reality is that our economies and financial systems continue to ignore the value of biodiversity. The sixth mass extinction is underway as a result of human impacts and we have now crossed the planetary boundary for biosphere integrity. The result is truly imperilling future prosperity and risking disruption across the world of finance.

The idea for establishing a study group on the implications of biodiversity loss for financial stability was born in 2020. Over the preceding five years, central banks and financial supervisors had been intensifying action to confront the existential challenge of climate change. Now there were signs that wider environmental threats, such as biodiversity loss and degradation of nature more broadly, were also coming onto their risk radar. But there was no global baseline setting out why financial authorities should act and what they could do. The Study Group aimed to fill this gap, bringing together members and observers from the Central Banks and Supervisors Network for Greening the Financial System (NGFS), as well as academics and experts from the International Network for Sustainable Finance Policy, Insights, Research and Exchange (INSPIRE).

When we started work in early 2021, only a handful of central banks and supervisors were looking at biodiversity loss as a source of financial risk. Initially, we expected the study group to comprise perhaps 10 experts. Over the past year, the Study Group has grown to include 25 NGFS members (central banks and supervisors) and observers, as well as 28 research and other institutions. In all, it has involved over 100 participants who have shared their expertise, produced input papers, and reviewed and shaped the three reports that we have produced. As Co-Chairs we are extremely grateful to these Study Group members for their dedication and contribution to this global effort, which we believe is a milestone in raising awareness and forging consensus on this topic and paving ways for future work by the NGFS and its members. The result of these great efforts is this Final Report, with its evidence base and five core recommendations for action.

The Study Group has taught us many things. Biodiversity is certainly a complex subject for central banks and supervisors, but it is entirely possible to make it manageable both analytically and in terms of the practical steps that can be taken. We learned that climate change and biodiversity are inextricably linked, creating the potential for risks to compound and create systemic dislocations: an integrated approach to these twin threats is essential. We found that more is happening than we expected, but that much more still needs to be done. We saw how the collaborative model of the Study Group comprising both central bankers and academics added real value. We were also pleased to see how the Study Group's work stimulated action: for example, China's Green Finance Committee is setting up its own initiative on biodiversity inspired by the international example of the Study Group.

Our core finding is that biodiversity loss is a source of financial risk that can be a threat to financial stability and thus falls within the mandates of central banks and financial supervisors. We are delighted to see the formal response from the NGFS to this report. This response is very timely, given that the new Global Biodiversity Framework is scheduled to be finalised at COP 15 this year.

We hope this 100-page report will inspire more concrete steps by central banks and regulators in the coming few years to align our financial system with the future health of the planet and to address an Anthropocene reality with complex and dynamic interactions between people and nature.

Dr MA Jun

Co-chair, Joint NGFS-INSPIRE Study Group on Biodiversity and Financial Stability

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Supporting central banks and supervisors to understand biodiversity-related risks to financial systems

Biodiversity is a major factor in the regulation of the Earth system, whose destabilisation could threaten the planet's habitability. As a result of the biosphere's continuous interactions with the non-living compartments that comprise the Earth system (the atmosphere, cryosphere, hydrosphere and lithosphere), biodiversity loss could contribute to destabilising this system. Critically, the stability of the Earth system over the past 10,000 years has enabled the development of modern societies. Biosphere integrity and four other planetary boundaries – the environmental limits within which science assesses that humanity can safely operate – have been crossed, implying that the stability of the Earth system is at risk.

As with climate change and in interaction with it, the extent and severity of the threats to sustainable development posed by biodiversity loss are subject to uncertainty. However, despite uncertainty about the scale and magnitude of these threats, **there is sufficient evidence to suggest that the problem could be systemic, and mitigation requires urgent 'transformative changes' in our socioeconomic and financial systems.** This requires policymakers and regulators, including central bankers and financial supervisors, to develop comprehensive strategies to manage nature-related financial risks. These risks include those related to the interactions between climate change and biodiversity loss, and to biodiversity loss resulting from other human pressures such as habitat degradation and over-exploitation.

This is the final report from the Joint NGFS-INSPIRE Study Group on Biodiversity and Financial Stability, which was established to help central banks and financial supervisors fulfil their mandates of price and financial stability in the face of financial risks stemming from biodiversity loss, or 'biodiversity-related risk'. **The report is designed to help central banks and financial supervisors understand the issues in the context of existing science, theory, policy and practice, and to recommend steps that could begin to address biodiversity-related risks in financial systems.**

How does biodiversity loss threaten financial stability?

Biodiversity loss is a potentially significant threat in two main ways:

- **First, economic activity and financial assets are dependent upon the ecosystem services provided by biodiversity and the environment:** this raises the prospect of physical risks to finance if these services are undermined.
- **Second, economic activity and financial assets in turn have impacts on biodiversity and could therefore face risks from the transition to a nature-positive global economy.**

These risks interact profoundly with climate change: climate change is a major driver of biodiversity loss, key activities (such as land-use change and deforestation) contribute to both threats, while healthy ecosystems provide resilience to growing climate shocks. As a result, the physical and transition risks generated by biodiversity loss could interact and compound to generate systemic risks.

These physical and transition risks can be transmitted through various channels (impacting households, firms and sovereigns alike) and could translate into various forms of financial risks such as credit, market, liquidity and operational risks. Equally, financial institutions not only face material risks from environmental issues such as biodiversity loss, but also contribute to the accumulation of these risks through the activities they finance.

Addressing biodiversity-related financial risks falls within the mandates of central banks and financial supervisors, as a consequence. However, it is also clear that these risks present unique features. Some of these features, such as the fundamental uncertainty around the timing and severity of impacts, the non-linearity of natural processes and the possibility of crossing irreversible tipping points, are similar to the challenges posed by climate change. Others, such as the fact that biodiversity cannot be measured through a single indicator such as CO_2-equivalent for climate change, call for different approaches.

Understanding and acting on the risks: approaches, methods and tools

While still limited and incomplete, tailored conceptual frameworks, models, tools and data are becoming increasingly useful to central banks and financial supervisors in their efforts to understand biodiversity-related financial risks. There is a growing body of empirical evidence of the dependencies and impacts of firms, sectors and countries on biodiversity and ecosystem services. Several approaches and methods are available and there are some initial assessments of financial systems', central banks' and sector-specific exposures to biodiversity-related risks that are starting to provide lessons and to sign-post the way forward.

Given the nature of biodiversity-related financial risks, central banks and financial supervisors will need to take forward-looking approaches to understanding the risks involved. As with climate change, scenario analysis is likely to be a valuable tool to help understand biodiversity-related risks for the economy and the financial system. Creating such scenarios will be challenging, but some lessons learnt from their application to climate change could be applied to biodiversity risk. It is nevertheless critical to assess biodiversity-related financial risks in their own right while building integrated climate–biodiversity scenarios where climate-related risks could also be impacted by biodiversity-related dynamics, and vice versa.

Evidence is emerging of the relationships between biodiversity and price stability, although much more work is required on this topic. Extreme biodiversity-related events could have a significant impact on inflation, while measures taken to address biodiversity loss, such as bans on importing timber sourced using unsustainable forestry practices, could have impacts on the price of the goods and services that use natural resources.

Overcoming the physical and transition risks related to biodiversity loss requires action across the financial system. There are several priority areas that may not fall directly within the mandates of central banks and financial supervisors, but where they can contribute to the design and delivery of effective solutions. These include topics such as environmental disclosure, conservation finance, market conduct and environmental crime, and how biodiversity risks are transmitted through international financial flows and trade. Central banks and supervisors need to consider their role in addressing these factors as they attend to biodiversity-related financial risks.

Based on emerging practices, this report offers a broad toolbox of options for action by central banks and financial supervisors, covering seven areas of activity. These seven areas are: initial research, assessment and signalling; contributing to the financial architecture; prudential policies and instruments; financial market conduct; monetary policy; central bank non-monetary policy portfolios; and policy liaison and coordination.

These options for action are informed by a groundswell of activity from central banks and financial supervisors around the world as they take their first steps to respond to biodiversity-related financial risk. Despite the immaturity of the field, and the prevailing uncertainty around many elements of measuring and understanding biodiversity-related risk, central banks and supervisors are undertaking research, introducing policies, and engaging on policy related to biodiversity. We are aware of at least 45 such actions by central banks and financial supervisors around the world.

Recommendations for central banks and financial supervisors

Building on the real-world action that is starting to happen and in response to the severity of the biodiversity crisis, five recommendations follow that are applicable to all central banks and financial supervisors.

1. **Recognise biodiversity loss as a potential source of economic and financial risk and commit to developing a response strategy.** Financial authorities could include biodiversity loss within green finance and environmental risk management strategies, taking an integrated approach that highlights the links with climate change as well as the specific threats that biodiversity loss might pose to financial and price stability.

2. **Upon identifying biodiversity-related financial risks, build the skills and the capacity to analyse and address those risks** among central bank and supervisory staff, market participants and other stakeholders, and participate in related research. As interactions among key factors in the regulation of the Earth system, notably biodiversity loss and climate change, have potential implications for financial stability, integrated approaches to assessing biodiversity- and climate-related financial risks should also be developed.

3. **Assess the degree to which financial systems are exposed to biodiversity loss** by, for example, conducting assessments of impact and dependency, developing biodiversity-related scenario analysis and stress-tests, and helping to create a dashboard of biodiversity metrics as part of an integrated approach.

4. **Explore options for supervisory actions on managing biodiversity-related risks and minimising negative impacts on ecosystems.** This could include reviewing existing supervisory frameworks and developing supervisory expectations and assessment programmes that address financial institutions' governance, risk management (including risk assessment and the use of scenario analysis) and strategy, disclosure and financial conduct as they relate to biodiversity risks.

5. **Help build the necessary financial architecture for mobilising investment for a biodiversity-positive economy, including by considering how central banks' own operations should be conducted in the context of biodiversity loss.** This could include contributing to, or leading on, the development of biodiversity taxonomies, encouraging environmental, social and governance (ESG) ratings to include biodiversity, exploring options for integrating biodiversity-related considerations into monetary policy, and incorporating biodiversity protection into central bank investment portfolios.

1. Introduction

This report is the final output of the NGFS-INSPIRE Study Group. The Study Group was set up in 2021 to establish an evidence-based approach for central bankers and financial supervisors to consider biodiversity loss in the context of their mandates to protect price and financial stability.

This introductory chapter sets out the strategic challenge posed by biodiversity loss to the global economy and financial system, drawing on the key findings of the Study Group's two previous reports , which serve as background to this Final Report.

1.1. Purpose and approach

Concern about the threats posed to the economy and financial system by biodiversity loss is rising among central banks and financial supervisors. This awareness is building following their work in recent years to assess and manage the financial risks posed by climate change. Central banks therefore need to ensure the maintenance of financial stability in the face of biodiversity loss. Financial stability is understood as "a condition in which the financial system – which comprises financial intermediaries, markets and market infrastructures – is capable of withstanding shocks and the unravelling of financial imbalances" (European Central Bank [ECB], 2021a).

This report builds on a Vision Paper published in June 2021 and an Interim Report published in October 2021 (NGFS and INSPIRE, 2021a, b). These made the case that biodiversity loss, and misalignment of economic actors with efforts to stop and reverse this biodiversity loss, pose physical and transition risks respectively that could significantly affect economic and financial actors. The materialisation of these risks could go as far as to threaten financial and price stability, making them of direct concern to central banks and financial supervisors.

The report focuses primarily on biodiversity-related financial risk and stability, although references to price stability are also made where deemed useful. Fewer studies exist that address price stability, but central banks and financial supervisors should be alert to threats from biodiversity loss to price stability where such threats can reasonably be expected to be material.

This Final Report provides the Study Group's conclusions on the scale of the threats, and reviews the actions that central banks, supervisors and other financial actors are already taking in response. It identifies a suite of policy options for central bankers and financial supervisors to evaluate and mitigate financial risks arising from biodiversity loss and makes recommendations for near-term action. It also includes a research agenda to respond to the gaps in knowledge and understanding. The report builds on and draws sections from the Input Papers provided by the Study Group (listed in Appendix 2).

The Study Group considered biodiversity loss in the broader framework of addressing environment-related financial risks within the financial system.

- ***Environment-related financial risk*** is defined by the NGFS as risk posed by the exposure of financial institutions to activities that may potentially cause or be affected by environmental degradation and the loss of ecosystem services (NGFS, 2019).
- ***Environment-related financial risk*** also includes climate change, which is a key driver of biodiversity loss and shares a number of characteristics with it.

- ***Environmental degradation*** includes the loss of biodiversity, which is the variability among living organisms and the ecological communities of which they are part (Convention on Biological Diversity [CBD], 2006).

In policy and finance circles there is growing use of the word 'nature' in place of environment and/or biodiversity. For the sake of clarity, we favour referring to the specific concepts of biodiversity and ecosystems wherever possible, while acknowledging that the concept of 'nature', as being defined in various fora, encompasses these concepts. Box 1 elaborates on these definitions and more.

This report is published ahead of the second phase of the 15th United Nations Conference of the Parties (COP15) to the Convention on Biological Diversity (CBD) in 2022 and aims to contribute to the evolving policy and market agenda around halting biodiversity loss.

1.2. Understanding biodiversity loss

Biological diversity is the variability among living organisms and the ecological communities of which they are part. This includes genetic diversity within species, between species, and of ecosystems – that is, the diversity of ecosystems themselves, the functional diversity within each ecosystem and the interrelations and interactions between organisms within diverse ecosystems. The loss of biodiversity undermines the ability of nature to provide ecosystem services on which human society, economies and other species rely. These ecosystem services include: provisioning services, such as food, raw materials and fresh water; maintenance and regulating services, such as climate, water and air quality regulation, pollination, and pest and disease control; and cultural services, supporting recreation, mental and physical health, and spiritual and religious values. These services are enabled by supporting services, such as nutrient cycling and soil formation.

The importance of these ecosystem services is such that human society and the global economy could not exist without them. Humanity is "embedded in Nature" (Dasgupta, 2021). A number of studies have attempted to quantify the dependence of economic activity on biodiversity and the provision of ecosystem services. For example, Herweijer et al. (2020) estimate that US$44 trillion of economic value generation, or more than half of global GDP, is moderately or highly dependent on nature. A study by Costanza et al. (2014) estimated that the annual value of ecosystem services amounted to US$125 trillion, i.e. about 1.5 times global GDP, at the time of the study. Such assessments should not make us lose sight of the fact that most of nature's contributions to human societies are not fully replaceable, while some are irreplaceable (such as phylogenetic diversity that is critical to medicinal, biochemical and genetic resources in addition to ecosystem functionality) (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services [IPBES], 2019). Overall, biodiversity loss could give rise to "existential risks" for humanity (Dasgupta, 2021), let alone for multiple other species.

The scientific evidence for unprecedented biodiversity loss driven by human activities has become overwhelming in recent years. Around 1 million plant and animal species face extinction, and the global rate of species extinction is tens to hundreds of times higher than it has averaged over the past 10 million years. This is according to a landmark study from the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (2019), which finds that the majority of ecosystem and biodiversity indicators are in decline. Vertebrate populations tracked from 1970 to 2016 have declined in size by an average of 68 per cent (World Wide Fund for Nature [WWF], 2020). Planetary boundaries related to negative trends in biosphere integrity (species diversity and functional biodiversity), biochemical flows (nitrogen and phosphorus) and novel entities (chemicals

Box 1 | Defining our terms

Biodiversity is defined in Article 2 of the Convention on Biological Diversity as "the variability among living organisms from all sources including, *inter alia*, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems" (CBD, 2006). [See Box 2 for more detail.]

Biodiversity loss is an *average* loss in biological diversity over time and/or space. It is typically detected using indicators derived from observational data such as species population counts. Some events or trends with negative impacts for economies and human societies can technically increase biodiversity (e.g. invasive species) but this report uses biodiversity loss as a catch-all term.

We define **biodiversity-related risk** as a financial or economic risk related to biodiversity loss. By **nature-related financial risk**, we mean a financial or economic risk posed by any natural process, including climate, weather and biodiversity loss, or a combination of these and other natural phenomena.

Megadiverse countries are those that house greater than 60 per cent of the world's biodiversity, including a large number of endemic species and the associated indigenous knowledge (Mittermeier et al., 1997). The 17 megadiverse countries include Australia, Brazil, China, Colombia, Democratic Republic of Congo, Ecuador, India, Indonesia, Madagascar, Malaysia, Mexico, Papua New Guinea, Peru, Philippines, South Africa, United States of America and Venezuela.

An **ecosystem** is defined by the Cambridge dictionary as "all the living things in an area and the way they affect each other and the environment". **Ecosystem functions** are "the physical, biogeochemical, and ecological components, processes, and outputs of ecosystems that are driven by multiple controls, such as abiotic and climatic factors, ecosystem structure, biodiversity, human disturbance, and land management" (Duncan et al., 2015). These functions largely depend on ecosystem condition and quality.

Ecosystem functions often serve to define a particular ecosystem and are the foundation for the capacity of an ecosystem to provide **ecosystem services** (de Groot et al., 2002). These can be broadly defined as a range of material and non-material benefits that humans, directly and indirectly, obtain from nature and that sustain and fulfil human life (Millennium Ecosystem Assessment, 2005), also described as "nature's benefit to people" in the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) conceptual framework (Díaz et al., 2015).

The term **tipping point** commonly refers to a critical threshold at which a tiny perturbation can qualitatively alter the state or development of a system (Lenton et al., 2008). In the context of biodiversity and ecosystem health, tipping points can be understood as leading to "abrupt and possibly irreversible shifts between alternative ecosystem states, potentially incurring high societal costs", (Dakos et al., 2019). They can occur naturally but are commonly discussed in the context of human-mediated climate change or biodiversity loss.

Nature is a more contested term, meaning "different things to different people in different places" (Ginn and Demeritt, 2008). It is defined by the Cambridge Dictionary as "all the animals, plants, rocks, etc. in the world and all the features, forces, and processes that happen or exist independently of people, such as the weather, the sea, mountains, the production of young animals or plants, and growth".

A **nature-positive** global economy is defined as one where economic activity enhances "the resilience of our planet and societies to halt and reverse nature loss" (World Economic Forum, 2021). [See also Box 3.]

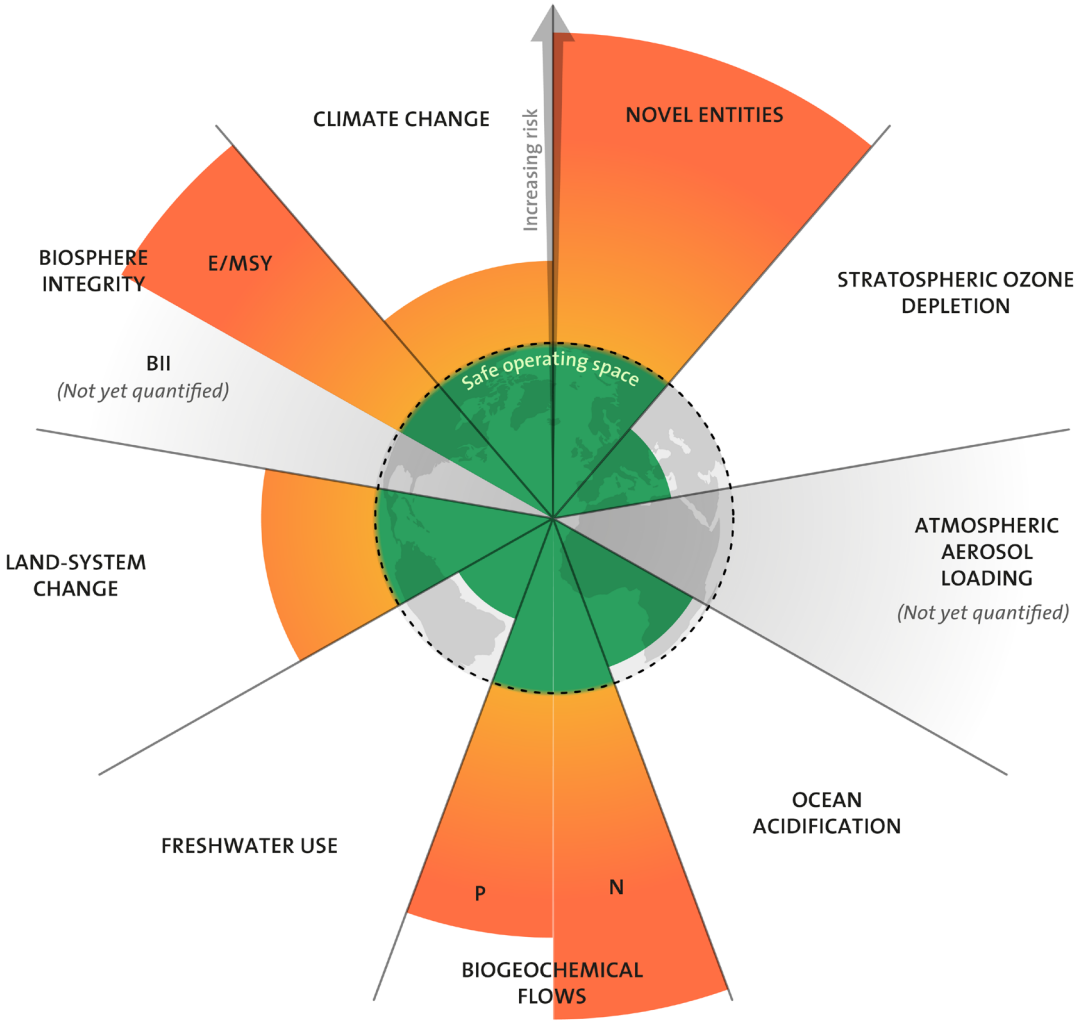
Natural capital is defined as the stock of renewable and non-renewable resources (e.g. plants, animals, air, water, soils, minerals) that combine to yield a flow of benefits to people.

The **biosphere** is that part of the Earth in which life exists (Hutchinson, 1970).

Biosphere integrity is one of nine **planetary boundaries** [see Figure 1], relating to nine processes that regulate the stability and resilience of the Earth system. The other eight are climate change, novel entities (such as plastic pollution), stratospheric ozone depletion, atmospheric aerosol loading, ocean acidification, biogeochemical flows, freshwater use and land system change. Crossing the quantitative boundaries increases the risk of large-scale abrupt or irreversible environmental change (Stockholm Resilience Centre, 2022).

and other new types of engineered materials or organisms, e.g. plastics) and land-use change (closely related to biodiversity, as discussed further below) have been crossed, putting planetary processes at risk (Steffen et al., 2015; Persson et al., 2022); see Figure 1. In addition, cascading effects could trigger tipping points where damage to global biodiversity and ecosystem function becomes irreversible[1] (Lenton et al., 2019).

Figure 1. Planetary boundaries



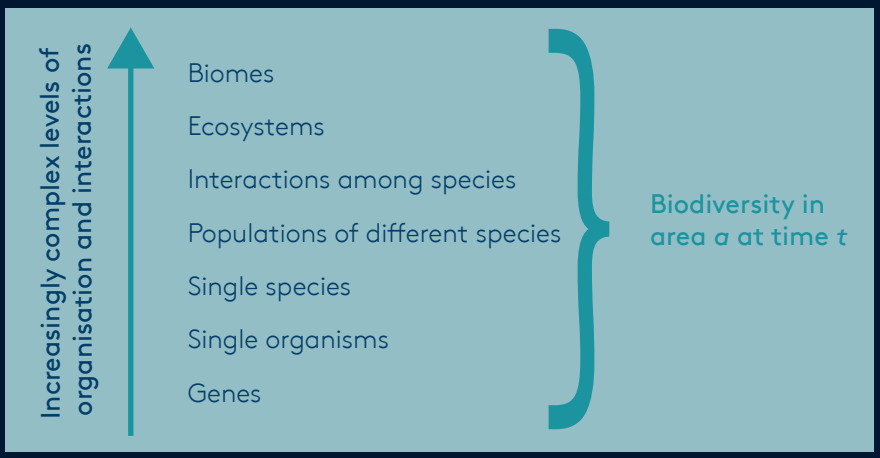
Notes: *P = phosphorous, N = nitrogen; BII = Biodiversity Intactness Index; E/MSY = extinctions per million species per year.* ***Source:*** *Designed by Azote for Stockholm Resilience Centre, based on analysis in Persson et al., 2022 and Steffen et al., 2015.*

1 This does not mean that all biodiversity losses are irreversible. In fact, several examples show that species can recover in specific cases (e.g. Moskowitz, 2008; Thompson, 2020). However, at the global scale, scientific evidence shows that biodiversity is declining much faster than ecosystems and species can recover, and that pursuing current trends could increasingly lead to irreversible losses or to recovery processes that could take up to millions of years (e.g. Neubauer et al., 2021).

Box 2 | Biodiversity in more detail

Biodiversity, "the variability among living organisms of all sources", as defined in Box 1 (CBD, 2006), is a general term that becomes increasingly complex from the level of genes to ecosystems. Any measure of 'biodiversity' should always be given in the context of where it was measured in space and in time, since biological processes are highly dynamic. For example, the number of species that exist on Earth today differs from the number that existed a million years ago, due to natural evolutionary dynamics. Biodiversity is therefore in a constant state of flux, and human impacts on biodiversity must be measured against a baseline or against a 'natural' rate of change (Leclère et al., 2020).

The interactions between the different hierarchies of biodiversity are particularly important in the context of climate change. For example, many trees that store and sequester carbon may also require pollinating insects to reproduce successfully, and many need animals to consume their fruits and disperse their seeds. A forest with no animals (e.g. because of over-hunting) or fewer pollinators (e.g. because of pesticides) can continue to store and sequester carbon for a time, but it will no longer be a 'functional' forest ecosystem. Eventually, the number of older, dying trees might outnumber new trees, leading the forest to become a carbon source instead of a carbon sink. More broadly, forest loss over large scales can contribute to climate warming and drying through the disruption of ecological processes such as the water cycle (Mantyka-Pringle et al., 2011).



The spatial distribution of any species is always limited, and every species has a 'range', the maximum of which would be global distribution. Temporal biodiversity dynamics such as speciation rates and population cycles are complex and can operate over timescales from minutes or hours during cell-division to millennia for the lifespan of some individual trees. Space also interacts with time to dictate the realised range (geographical distribution) of a species. For example, when a new water body created by geological phenomena or human activity causes an existing population to be divided into two isolated populations, this can lead to the evolution of new, independent species over million-year timescales.

'Biodiversity' should therefore be considered an aggregated, catch-all term for the planet's living diversity. Measuring biodiversity change [see Box 6] is only possible by using clearly defined biological units (e.g. number of species) that are counted (or estimated) in a defined area at a given time. These counts or estimates can then be compared with a reference level to evaluate change.

IPBES has identified five primary drivers of biodiversity loss, which are, in decreasing order of magnitude at the global scale: land- and sea-use change, overexploitation of organisms, climate change, pollution and invasive alien species (IPBES, 2019). Some indicators suggest that species extinction rates could accelerate significantly in the 21st century (WWF, 2018; IPBES, 2019; International Union for Conservation of Nature [IUCN], 2020). However, the rates at which biodiversity responds to these drivers can be difficult to predict, and there are often lags between the timing of threats (such as human-mediated habitat loss) and biodiversity responses that can be in the order of decades or more (Watts et al., 2020).

Land degradation is by far the biggest driver of nature loss. IPBES (2018) defines land degradation as any "processes that drive the decline of biodiversity, ecosystem functions or ecosystem services". Croplands and grazing lands cover more than one-third of the Earth's surface (Food and Agriculture Organization of the United Nations [FAO], 2020), with 33 per cent of croplands dedicated to producing animal feed (FAO, 2012). Almost three-quarters (71.4 per cent) of tropical deforestation is caused by unsustainable commodity production (Richards et al., 2020).

Pesticides and herbicides used to increase agricultural productivity have been shown to build up within the environment, creating unintended effects on decomposition, nutrient cycling and non-target species. Land-based pollution such as agricultural run-off and sediments from soil erosion can drive a decline in the diversity, size and structural complexity of freshwater and marine ecosystems (Chagnon et al., 2015; Global Coral Reef Monitoring Network [GCRMN], 2021). Similarly, overgrazing, tillage and unsuitable agricultural practices accelerate soil erosion and decrease the biodiversity present within soil micro-habitats. Soil biodiversity plays a fundamental role in supporting and enhancing provisioning services, such as food, water quality, species conservation, ecosystem-supporting services such as carbon and nutrient cycling, and soil structure formation (FAO et al., 2020).

Deforestation is a particular concern, given that 80 per cent of land-based species live in forests (WWF, 2021). Direct drivers of deforestation include agricultural expansion, extraction industries and human settlement-related activities such as transport, urbanisation and other infrastructure projects. Investments in the extraction and infrastructure necessary to achieve climate commitments and the Sustainable Development Goals (SDGs) suggest substantial future threats to land, including forests, and Indigenous and local people's rights. This is particularly so given that resource extraction and infrastructure are mutually reinforcing and enable agricultural expansion and population migration (Bebbington et al., 2018). Linear infrastructure such as roads, railways, pipelines, canals and fences can have significant negative impacts on mobile and migratory species by fragmenting their habitat, isolating populations, preventing access to essential resources such as foraging and water, and causing direct injuries and mortality (UNEP and CMS, 2019).

Indirect drivers of biodiversity loss include production and consumption patterns and associated trade and financial flows that enable or amplify direct drivers (IPBES, 2019). Economic, financial and trade systems are key indirect drivers of biodiversity loss: economic activities and technological developments at the root of land degradation, overexploitation, pollution and climate change must be financed. More broadly, human and natural systems are linked by a range of feedback loops (Liu et al., 2007). Market economies thus regularly generate new externalities, leading to regulatory systems being overrun by externalities (Kapp, 1950; Oman and Svartzman, 2021), notably biodiversity loss. Figure 2 below presents an overview of drivers of and responses to deforestation.

Figure 2. Drivers of and responses to deforestation

Source: Adapted from Pacheco et al., 2021

1.3. The economic effects of biodiversity loss

Biodiversity loss has chronic as well as acute economic effects. An example of chronic effects would be the decline in pollinator species numbers and diversity, driven by habitat loss and fragmentation, environmental pollution including pesticide use, and climate change. This in turn could drive down crop yields, or increase the costs of manual pollination through high labour material inputs (Wurz et al., 2021). Greater economic analysis is required to better understand these costs and the impact they may have on food prices (IPBES, 2016).

Acute effects include pests wiping out significant parts of a harvest or rapid, large-scale pollution events like the Deepwater Horizon oil spill, which can devastate ecosystems and livelihoods such as fishing that rely on natural resources. Trade networks, habitat degradation and climate change can introduce or facilitate the arrival of invasive alien species. Invasive species can cause local biodiversity loss (e.g. by out-competing native species), resulting in altered ecosystem functionality and weakened ecosystem resilience. For example, invasive insect species alone are estimated to cost a minimum of US$70.0 billion per year globally, while associated health costs from health care and productivity loss exceed US$6.9 billion per year (Bradshaw et al., 2016). Another example is disease spreading as a consequence of reduced ecosystem resistance, and increased contact between people, wildlife and novel pathogens (e.g. through land-use change), potentially leading to pandemics.

Effects can be both chronic and acute, such as the disruption to micro-climates and the hydrological cycle caused by deforestation. For example, land-use change in the Amazon biome could affect local rainfall patterns, tipping the rainforest from a stable state into an open savannah (Staal et al., 2020).

Box 3 | Towards a nature-positive future in the UK

Global trends in biodiversity loss have been mirrored in the UK. According to the Natural History Museum's Biodiversity Intactness Index, the UK has lost around half of its native wildlife since the Industrial Revolution and has the lowest level of native wildlife remaining in the G7 (Natural History Museum, 2021). More recently, stock of the UK's natural capital has fallen over the decade from 2010. According to the Office for National Statistics, both the monetary flows and asset value of total UK natural capital have declined since that year, with the value of the UK's aggregate stock of natural capital around 10 per cent lower in 2018 than in 2010 (Office for National Statistics [ONS], 2020).

In 2019 the Government commissioned Sir Partha Dasgupta to lead an independent global review on the economics of biodiversity and the resultant report, The Economics of Biodiversity: The Dasgupta Review, was published in February 2021 (Dasgupta, 2021). It presented an economic framework grounded in ecology and earth sciences to understand the sustainability of humanity's engagements with nature. It asserted that biodiversity loss reduces nature's productivity, resilience and adaptability, and thereby the provision of ecosystem services upon which all economic activities depend. Continued global trends in biodiversity loss could therefore have significant economic and financial consequences for companies and financial firms.

The Review proposed three broad and interlinked global transitions to sustainably engage with nature:

(i) Humanity needs to reduce its aggregate demands on nature and increase nature's aggregate supply.

(ii) Economic measures of success need to be improved; 'inclusive wealth' is the appropriate main measure of sustainable economic prosperity.

(iii) Effective institutions and system-wide changes are required to enable persistent, widespread sustainable engagement with nature at a global scale and across generations. The global financial system and education system have particularly critical roles in enabling persistent change.

In response to the Dasgupta Review, the UK Government committed to a delivering a "nature-positive" future, in which it would improve the state of the environment and ensure that economic and financial decision-making is geared towards doing so (HM Treasury, 2021a). It defines nature-positive as "reversing the current decline of biodiversity so that ecosystem restoration is underway and species are increasing in abundance and fewer are threatened with extinction" (Natural England et al., 2021). To this end, the Government pledged to designate at least 30 per cent of the UK's land and ocean as protected by 2030 and legislate for a framework for setting new legally-binding environmental targets, including an introduction of a new target on species abundance for 2030.

Recent research has shown that exposure to degraded land can impact the value of listed companies in the food supply chain in Brazil, with healthy soil being the differentiating factor between negative and positive market value (University of Cambridge Institute for Sustainability Leadership [CISL], 2022). By using stress-test scenarios, researchers found that the market value of farmers operating largely on degrading land declined by 13 per cent following extreme weather, while those on healthy soils increased by 6 per cent. Small-scale (local) companies with exposure to degrading land were found to be most vulnerable to soil degradation: small packaged-food companies connected to degrading land have suffered a negative impact on valuation of up to 45 per cent. There are also spillover impacts on companies along the supply chain, such as fertiliser suppliers. Furthermore, increased purchasing costs, caused by the need to cover supply shortfalls using increasingly expensive spot markets, cannot be passed on to consumers without risking loss of market share to rivals not connected to degrading land. Increased capital costs could mean that farmers may even reach an economic tipping point: such tipping points have occurred before, with large farming companies divesting of land in the Bahia and Piaui regions of Brazil due to the unpredictability of harvests (CISL, 2022).

Biodiversity loss also has potentially system-wide impacts. Many impacts caused by biodiversity loss are local but with increasing global connections local impacts can be felt across long distances (IPBES, 2019). However, there are a number of globally important ecosystems such as the Amazon Rainforest and coastal ecosystems within the Coral Triangle reef system whose collapse would have systemic impacts. Problems with the delivery of one ecosystem service can disrupt the delivery of many ecosystem services or cause large-scale disruption on its own. Such a transition would impact global supply chains and likely have serious climate implications (Global Food Security programme, 2017).

While low- and lower-middle-income countries could be particularly hard-hit by the disruption of ecosystem services (Johnson et al., 2021), sectoral effects, such as declines in agricultural production or diminishing water resources, cascading impacts and second-round effects could also impact high-income countries. For instance, while a sector such as agriculture might make only a small contribution to GDP in high-income countries, even its partial collapse would have profound social implications, disproportionate to their monetary costs.

The scientific community also finds that biodiversity loss could lead to an increase in pandemics (IPBES, 2020), and those could have massive economic impacts. While there is uncertainty about its precise origins, the COVID-19 pandemic is a possible example of how biodiversity loss and degraded ecosystems can have systemic economic, financial and social impacts (see Box 4).

Reversing biodiversity loss could also lead to positive economic outcomes compared with a business-as-usual scenario. For example, the Inter-American Development Bank has estimated that policies to prevent the Amazon reaching a tipping point that would see it convert to savannah, including reducing deforestation, investing in climate-adapted agriculture, and improving fire management, would generate approximately US$339.3 billion in additional wealth (Bannerjee et al., 2021). As with climate change and other environmental threats, inaction is as much of a choice, albeit with its own risks, as a decision to act.

Biodiversity loss also has implications for equity and social justice. Indigenous peoples make up just 5 per cent of the global population, yet own, occupy or make use of a quarter of the world's land area. Furthermore, they safeguard around 80 per cent of the world's remaining biodiversity and 17 per cent of forest carbon (World Bank, 2021a;

Garnett et al., 2018). Meanwhile, low-income populations are more likely than their high-income counterparts to directly depend on ecosystem services provided by natural systems (Martínez-Alier, 2002). Ecosystem degradation, including land degradation, negatively impacts people's vulnerability to extreme events, access to resources and small-scale food production and agricultural sustainability, with negative impacts on both the urban and rural poor who are directly reliant on environmental resources (IPBES, 2019). Excessive consumption and use of resources by wealthy populations are also causes of biodiversity loss (Warlenius et al., 2015). As governments design strategies to tackle biodiversity loss, these will need to be inclusive of people at all levels of income, to ensure a just transition (International Labour Organization [ILO], 2015).

Box 4 | Biodiversity loss and pandemic risk

While there is much uncertainty about the origins of the COVID-19 pandemic, experts from IPBES and others argue that it should serve as a warning that failing to reverse biodiversity loss could lead to a new "era of pandemics" (IPBES, 2020). By February 2022 the COVID-19 pandemic had caused 436 million infections and at least 5.9 million deaths (World Health Organization, 2022). It has also had significant economic and financial impacts, and has illustrated some of the risks that societies, economies and financial systems could face in the near future, partly due to biodiversity loss (ibid.).

Over 70 per cent of emerging infectious diseases have their sources in animals, domestic or wild (World Bank, 2020.) The risk of the emergence of zoonotic disease is associated with land-use change owing to the growing human pressure on natural habitats, particularly deforestation and forest fragmentation in forested tropical regions and where wildlife biodiversity is high (Allen et al., 2017; Platto et al., 2021).

Growing demand for animal protein has led to agricultural and aquacultural expansion. These have contributed to the conversion of natural habitats while altering wildlife population dynamics, bringing humans and livestock into closer proximity to wildlife (Jones et al., 2013). Zoonotic infectious diseases are also associated with wildlife use and consumption of meat from wildlife species that constitute primary hosts (WWF Global Science, 2020).

As shown by the COVID-19 pandemic and acknowledging the uncertainty related to its origin, pandemic crises can affect the real economy with incredible speed and scale, with impacts such as economic recession and rising unemployment (Billio and Varotto, 2020). In 2020, global GDP declined by 6.7 per cent as a result of COVID-19. The World Bank estimates that the pandemic pushed 97 million people into extreme poverty globally in 2020, and low-income countries and countries in sub-Saharan Africa may have seen further increases in poverty rates in 2021 (Mahler et al., 2021). Even as the world's largest economies are recovering in 2022, new virus mutations and fear of new waves of infection make the global economic outlook highly uncertain, while major supply-side disruptions continue.

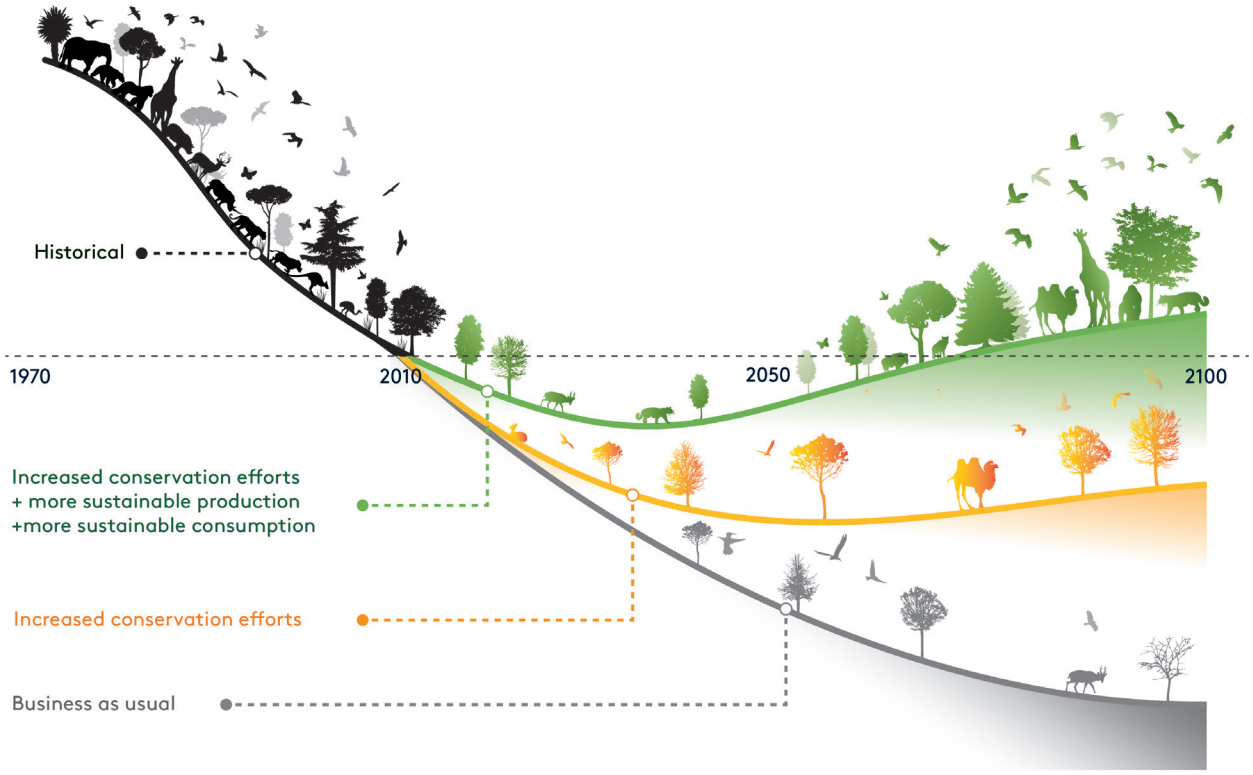
The associated costs of efforts to prevent pandemics (e.g. reducing deforestation, livestock production and the wildlife trade) are estimated to be substantially lower than the economic, social and mortality costs of responding to zoonotic infectious diseases once they have emerged. Spending of around US$260 billion over 10 years would substantially reduce the risks of another pandemic on the scale of the COVID-19 outbreak (Dobson et al., 2020), which is just a small fraction of the estimated costs of the pandemic to the world economy, which have run into the trillions. Moreover, spending linked to wildlife protection and forest conservation would contribute to the fight against climate change and the cutting of carbon dioxide emissions.

Source: This box is derived from Abdelli and Pacheco, 2021.

A systematic understanding of the economic importance of biodiversity requires an assessment of the unique role of natural capital as the fundamental enabler of economic activity. Standard economic models of production assume substitutability between labour, capital and land/nature. However, the regulating services provided by biodiversity and ecosystem services that underpin all economic production are mainly not substitutable, as outlined in the *Final Report of the Independent Review on the Economics of Biodiversity* (known as the Dasgupta Review) (Dasgupta, 2021). That review presented an economic growth model that incorporates the linkages between the functioning of ecosystems, the economic activity that they enable, and the impacts on those ecosystems of such economic activity. This 'bounded global economy model' (BGEM) treats natural capital as a stock of resources and as a flow of extracted provisioning services, with the latter being only very partially substitutable by labour and human-made capital. (See Box 3 for more on the Dasgupta Review's recommendations.)

Assessing the interactions between biodiversity and the economy also calls for acknowledging the considerable complexity and uncertainty at stake. Natural systems and processes are subject to complex, non-linear dynamics and potentially irreversible changes when tipping points are crossed (Kedward et al., 2020; Lenton et al., 2008, 2013). In addition, the complexity of ecosystems makes it difficult to aggregate different aspects of biodiversity under a common unit of measurement, such as CO_2-equivalent (Svartzman et al., 2021).

Figure 3. Bending the curve on biodiversity loss



Source: International Institute for Applied Systems Analysis (IIASA), 2020 (Credit: Adam Islaam)

Box 5 | The Global Biodiversity Framework

Developments at the international policy level, specifically around the Convention on Biological Diversity (CBD), could give biodiversity protection a boost similar to that delivered to the climate agenda by the Paris Agreement in 2015. The CBD is a multilateral and legally binding treaty, drawn up in 1992 at the Earth Summit in Rio de Janeiro and ratified since by 196 parties. It has three main goals: the conservation of biological diversity; the sustainable use of its components; and the fair and equitable sharing of benefits arising from genetic resources.

At the 15th Conference of the Parties to the CBD (COP15), which was initiated virtually in October 2021 (COP15-1) and will be continued in-person in Kunming, China in 2022 (COP15-2), governments are expected to reach an agreement on a post-2020 Global Biodiversity Framework. The framework aims to set in motion an economic transition that puts biodiversity on a path to recovery by 2030, and builds towards a vision of 'living in harmony with nature' by 2050 (see Figure 3 for illustration of this). It will be a successor to the Aichi Biodiversity Targets, agreed in 2010, and it is likely, as was the case with the Paris Agreement for climate, to spur policy responses around the world to protect biodiversity.

It is intended that the Framework will tackle the five drivers of biodiversity loss: land- and sea-use change, climate change, pollution, overexploitation and invasive alien species. Four main goals consisting of 21 targets have already been outlined and will be finalised in Kunming, focusing on three priority areas: reducing threats to biodiversity, meeting people's needs through sustainable use and benefit sharing, and tools for implementation and mainstreaming.

Specific targets are likely to include ensuring that 30 per cent of the Earth's land and sea areas are conserved, managing agriculture, aquaculture and forestry sustainably, and making sure that all financial flows are aligned with the Framework and that all businesses assess and report their dependencies and impacts on biodiversity. Redirecting and reforming incentives harmful to biodiversity in a just and equitable way is set to be another target, along with increasing both public and private financial resources for biodiversity.

By analysing the proposed targets up for discussion at COP15, it is possible to identify potential sources of transition risk to the financial sector. Target 3, for example, looks to ensure that at least 30 per cent of the land and sea area globally, especially areas of particular importance for biodiversity and its contributions to people, are conserved by 2030. Target 7 aims to reduce by at least half the volume of nutrients lost to the environment, reduce pesticide use by at least two-thirds, and eliminate the discharge of unmanaged plastic waste into the environment by that date. Target 10 seeks to ensure that all areas under agriculture, aquaculture and forestry are managed in line with the conservation and sustainable use of biodiversity. If adopted at COP15, these targets will affect firms' operations, and thus impact the financial institutions that lend to, invest in or insure these firms.

Once adopted, the Framework will be translated into policies and regulations at the regional and national levels and will have direct consequences on the operations of companies and financial entities. Target 14, for example, will require ensuring that all financial flows are aligned with biodiversity values, and Target 15 will require all businesses to manage their risks, impacts and dependencies and to report on them.

The finance sector will need to play a key role in supporting the delivery of the goals and targets of the framework, while policies intended to protect biodiversity will have impacts on the global economy and on the financial system. For these reasons, the outcomes of the talks in Kunming are of direct interest to central banks and financial supervisors (Secretariat of the CBD et al., 2021a).

Source: This box is derived from Almeida et al. (2021).

This complexity makes it challenging to estimate the specific contribution of biodiversity to economic production and the specific economic impacts of biodiversity loss. Monetary valuations of ecosystem services struggle to provide meaningful estimates of the impacts of ecological tipping points (Kedward et al., 2020) and should therefore be assessed cautiously (Norgaard, 2010). Moreover, monetary valuations of ecosystem services are not exempt from ethical considerations, such as the fact that poor communities that often directly depend on ecosystem services provided by natural systems are less able to place a high monetary value on them (Martínez-Alier, 2002). These issues are at least partially acknowledged by several scholars who make such monetary valuations, who argue that the usefulness of the valuations lies in their ability to raise awareness rather than as decision-making tools (e.g. Costanza et al., 2014).

Estimating the monetary and other values of ecosystem services is important but reversing biodiversity loss will require a whole range of efforts that go beyond pricing mechanisms. These include ad hoc regulations and quantity-based policies, among others. For instance, the introduction of policies to increase the area of protected land and marine reserves will impact economic actors seeking to unsustainably exploit natural resources in newly protected areas. More than 70 countries are pushing for the Convention on Biological Diversity's Global Biodiversity Framework (see Box 5) to commit governments to formally protect 30 per cent of the world's land and ocean areas by 2030, up from 15 per cent of land and 7 per cent of ocean at present (High Ambition Coalition for Nature and People, 2019).

Similarly, the European Commission is acting to ban timber imports from unsustainable or illegal sources through regulation rather than pricing mechanisms (European Commission, 2021a). Real economy reforms that target particular sectors such as agriculture will also be required, as well as policy reforms – to address perverse subsidies, for example (OECD, 2020, 2021). Assessing the economic implications of such measures will be difficult: a policy or social response to biodiversity loss (or several such responses) can impact many sectors in different ways (van Toor, 2021).

More broadly, the urgent and structural transformations needed to deliver a biodiversity- and nature-positive global economy could come with significant macroeconomic and microeconomic challenges. Challenges could include the need for measurement methods beyond GDP. It is also increasingly argued that infinite growth in GDP may not be compatible with a nature-positive global economy (e.g. Albagli and Vial, 2021; Dasgupta, 2021; European Environment Agency, 2021; Keyßer and Lenzen, 2021). For instance, as stressed by the European Environment Agency (2021), it is unclear whether GDP growth can be completely decoupled from environmental impacts, and decoupling is especially challenging in a global system in which gains in some regions can be offset in others. Acknowledging these challenges (and the very diverse positions that exist in their regard) should not undermine the need for an ecological transition, but rather serve to better assess the potential roadblocks and related financial risks that central banks could face.

While there is no doubt that significant conceptual and methodological challenges exist in assessing the monetary value of biodiversity and ecosystem services and the potential macroeconomic implications of certain transition paths, the scientific consensus is clear: biodiversity loss could have systemic economic and financial consequences if "transformative changes" to our social, economic and financial systems are not urgently undertaken to reverse current trends (IPBES, 2019).

1.4. Extending the case from climate: the climate–biodiversity nexus

Biodiversity loss is not the first environmental source of economic and financial risk to be considered by central banks and financial supervisors. In its 2018 progress report, the NGFS stated that "climate-related risks are a source of financial risk. It is therefore within the mandates of central banks and supervisors to ensure the financial system is resilient to these risks" (NGFS, 2018). Since then, central banks and financial supervisors have made great progress in the assessment of such risks. This includes their consideration in a range of micro- and macroprudential policies (see Chapter 4), as well as through the development of climate scenarios that can be used for the purpose of financial stability assessment (NGFS, 2021b). Some of the challenges related to the approaches and methodologies used for such scenarios (e.g. time scale, nature and severity of the shocks, second-round effects) are also relevant for the understanding of biodiversity-related financial risk.

There are several characteristics of climate change that are similar to biodiversity loss in terms of likely impacts on economies and financial systems. These impacts will be far-reaching, affecting all parts of the economy and all types of economic agent, from households to sovereign entities. They are likely to be subject to tipping points and be non-linear in nature. Many are likely to be irreversible. Although both sets of risks are foreseeable, the time horizons and future pathways of both are uncertain. The magnitude and nature of future impacts will depend on the types of action taken by governments, businesses, financial market participants and households in the near term (NGFS, 2019).

Biodiversity loss also exhibits differences to climate change, however. For example, in terms of prevention, there is a clearer narrative on climate change mitigation, focused on reducing carbon emissions regardless of where in the world they are produced. Biodiversity is multidimensional and cannot be reduced to a single metric. There is often a lack of understanding of some elements of biodiversity and their interrelationships. For example, the presence of a diverse and functioning plant community can encourage infiltration of water into the soil, recharging ground and surface water, anchoring the soil, reducing erosion and aiding flood protection. These interactions between plant biodiversity and sustainable land-use might not be well understood by non-specialists. Awareness of climate change among policymakers is considerably more advanced compared with their knowledge of biodiversity loss, particularly regarding mitigation, and the monitoring, data, methodologies and tools to address climate change are more mature than their equivalents for biodiversity loss.

While biodiversity loss poses several risks in its own right, these risks and their impacts are closely related to climate change, presenting synergies and opportunities for mutually-reinforcing responses. Activities such as fossil fuel consumption and land-use change increase greenhouse gas emissions, resulting in climate change. In turn, climate change is one of the main drivers impacting biodiversity by altering species ranges, species abundances and ecological communities, restructuring trophic food webs and altering ecosystem functions (IPCC, 2019). Simultaneously, destruction of natural ecosystems is contributing to greenhouse gas emissions (Pörtner et al, 2021). In turn, biodiversity loss exacerbates climate change through degrading carbon storage, releasing carbon emissions and altering natural infrastructure crucial for climate resilience. Between 2000 and 2009, land degradation was responsible for annual global emissions of 3.6–4.4 billion tonnes of CO_2, the main processes being deforestation and forest degradation and drying or burning of peatland (IPBES, 2018). Deforestation releases about 10 per cent of all annual anthropogenic greenhouse gas emissions. Moreover, land-use change is a driver of both climate change and biodiversity loss.

As climate change is a key driver of biodiversity loss, actions by central banks and financial supervisors to respond to climate risks in the financial system should have positive co-benefits for ecosystem health. Equally, measures to protect and restore biodiversity typically provide mitigation and adaptation co-benefits related to climate change. For example, if the conversion of natural terrestrial ecosystems were halted and degraded ecosystems restored as set out within the Aichi Biodiversity Targets agreed in 2010, an estimated 0.4 to 3.8 billion metric tonnes of carbon would have been absorbed per year, contributing to carbon sequestration from the atmosphere (CBD, 2015a).

Beyond capturing and storing carbon, biodiversity is critical in terms of supporting adaptation and resilience to climate change, including preventing or reducing disaster risk. Ecosystems such as wetlands, forests and coastal systems can reduce physical risks by providing protective barriers or buffers in the face of extreme weather events like storms, wildfires, landslides or floods (CBD, 2015b). Mangrove forests provide at least US$65 billion in flood protection, and safeguard 15 million people against flooding per year (Menéndez et al., 2020). The essential goods provided by these ecosystems, such as food, fibre, medicine and construction materials, strengthen community resilience to disasters (ibid.). The importance of climate adaptation was highlighted at the COP26 climate summit: the Glasgow Climate Pact commits to mobilising US$40 billion per year by 2025 in adaptation funding (UNFCCC, 2021a).

There is also potential, however, for negative trade-offs to happen. Some strategies for mitigating climate change could have negative impacts on biodiversity. Poorly planned tree planting (such as exotic species and monocultures) to capture carbon dioxide emissions (Di Sacco et al., 2021), mining for materials needed to develop renewable energy and battery storage technology, and altering natural environments to build renewable energy infrastructure or plant crops for biofuel feedstock, can harm biodiversity (Pörtner et al., 2021). Destruction of megadiverse ecosystems such as tropical rainforests, particularly in emerging market and developing economies (EMDEs), to facilitate these types of economic activities could trigger tipping points. Action to tackle climate change and build a net-zero emission economy needs to be placed in the wider context of sustainable development to avoid threats to biodiversity, for example from poorly designed programmes for bioenergy or large-scale net-zero infrastructure that does not make provision for ecosystem health. Moreover, the carbon budget available to limit global warming to 1.5°C could be lower than expected when accounting for some of these issues (Keyßer and Lenzen, 2021).

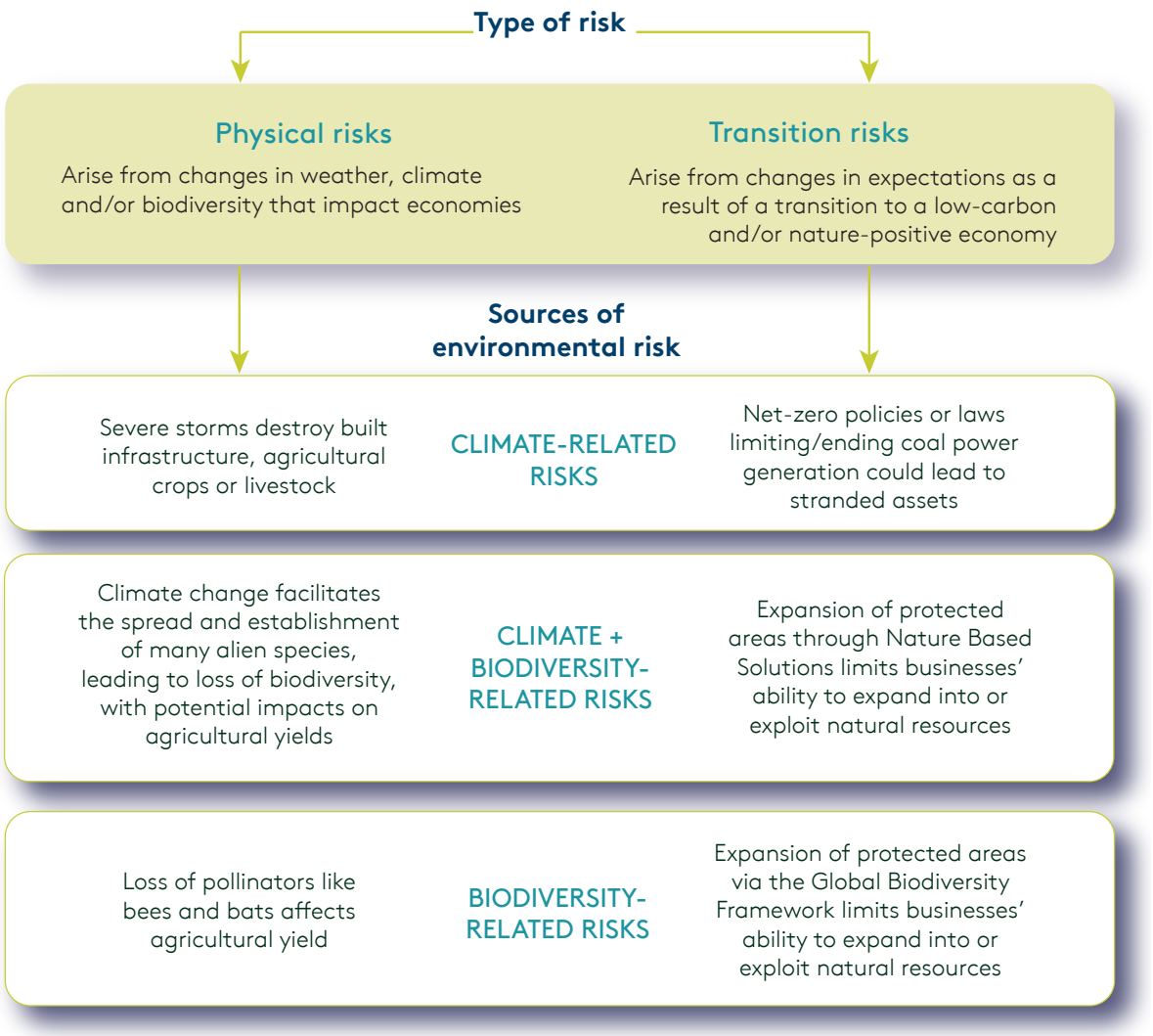
The complex linkages between biodiversity loss and climate change are not yet well understood, particularly in the design of scenarios for financial stability assessments. Improving this understanding could reduce the work required of financial policymakers to incorporate the consideration of biodiversity loss into their existing responsibilities. In addition, it could help policymakers understand the extent to which addressing climate change could deliver positive biodiversity outcomes, and vice versa. Figure 4 below sets out some example interactions.

Such interactions extend beyond the climate–biodiversity nexus, with major implications for the Earth system and thus for financial stability. The Earth system is regulated by interactions among the Earth's compartments – the biosphere, atmosphere, hydrosphere, cryosphere and lithosphere. Feedback mechanisms include links between forest cover, the carbon and water cycles, and biogeochemical cycles. These feedback mechanisms can have major impacts on the Earth system's functioning and physicochemical characteristics (Boutaud and Gondran, 2020). The biosphere affects the functioning of the hydrological, carbon and nitrogen cycles, in particular.

For example, nitrogen fixing plants within an ecosystem can help reduce the need for artificial fertilisers. Nitrogen run-off costs billions of dollars annually in clean-up to purify contaminated drinking water, remove toxins from harmful algal blooms, and restoring impaired water bodies and ecosystems (Katz, 2020).

The replenishment and maintenance of the share of oxygen in the atmosphere that makes complex life possible depend on the interaction of the biosphere, the long-term carbon cycle, and the phosphorus cycle (Lenton, 2016; Lovelock, 1995; Langmuir and Broecker, 2012; Kump et al., 2009). Human systems are now often the main drivers of change in the Earth system (IGBP, 2021). Interactions among the Earth's compartments and between natural and human systems (e.g. the global economy) could destabilise the Earth system, impacting global financial stability, notably by triggering a catastrophic global cascade of tipping points (Lenton et al., 2019).

Figure 4. Examples of interactions between biodiversity- and climate-related financial risks



Source: Adapted from Almeida (2021)

The interactions between climate-related and biodiversity-related financial risks call for a comprehensive approach, as captured, for instance, by the term 'nature-related financial risks', which encompasses different environmental issues.

1.5. Greening the financial system: biodiversity and financial stability

There is an increasing international policy focus on the role of the financial system in contributing to, stopping and reversing biodiversity loss. At the G7 meeting of June 2021, leaders adopted the G7 2030 Nature Compact, which included the commitment to reverse biodiversity loss by 2030 (G7 presidency, 2021). In October 2021, the UN Human Rights Council passed Resolution 48/13, recognising for the first time that having a clean, healthy and sustainable environment is a human right, calling on UN Member States to cooperate to implement this right (United Nations General Assembly, 2021). Later that month, at the opening of COP15 of the Convention on Biological Diversity, governments agreed the Kunming Declaration, which states a need to "transform economic and financial systems" and "align all financial flows in support of the conservation and sustainable use of biodiversity" (CBD, 2021b). The 2021 G20 Leaders' Summit also committed to "strengthen actions to halt and reverse biodiversity loss by 2030" and endorsed the Roadmap from the Sustainable Finance Working Group, which highlighted the importance of integrating nature and biodiversity (G20 SFWG, 2021). The Glasgow Climate Pact recognised the interlinked crisis of climate change and biodiversity loss (UNFCCC, 2021a), while the Glasgow Leaders' Declaration on Forests and Land Use committed the 141 signatory governments to halt and reverse forest loss and land degradation by 2030 and align financial flows to that end (HM Cabinet Office, 2021).

As with climate change, governments have the primary responsibility for addressing biodiversity loss and addressing the drivers that contribute to it. They are responsible for introducing policies to discourage activities that harm biodiversity, to remove subsidies that incentivise nature loss and other environmental harms, to provide incentives, subsidies or programmes to preserve and restore ecological systems, and to ensure that economic actors are properly regulated in order to limit damage to biodiversity. Specifically, the Convention on Biological Diversity calls on each of its Parties to prepare a National Biodiversity Strategy and Action Plan (under Article 6a) that establishes specific activities and targets for achieving the objectives of the Convention. The Kunming Declaration and a greater focus on biodiversity in international fora such as the G20 and the G7 are likely to encourage national and sub-national policy formulation, much as the Paris Agreement has done for climate policy.

The private sector, including financial institutions, is anticipating a greater focus on biodiversity, driven by regulation, investor concerns and changing customer preferences. Seventy-five financial institutions, managing €12 trillion in assets, have signed the Finance for Biodiversity pledge, committing to take "ambitious action on biodiversity" (Finance for Biodiversity, 2021). Investors with US$8.7 trillion in assets committed at COP26 in Glasgow to eliminating agricultural commodity-driven deforestation risks in their investment and lending portfolios by 2025 (UNFCCC, 2021b). The China Banking Association, supervised by the China Banking and Insurance Regulatory Commission, issued in October 2021 a joint statement on behalf of more than 50 banks, calling for action to protect biodiversity, including developing strategies, mitigating negative impacts, supporting nature-positive projects and enhancing biodiversity-related disclosure (China Banking Association, 2021).

Leading investors, companies and service providers have come together to form the Taskforce on Nature-related Financial Disclosures (TNFD), which aims to deliver a risk management and disclosure framework for organisations to report and act on nature-related risks (TNFD, 2021). Banks and investors are exploring real-world examples that demonstrate how nature-related financial risks can be financially material (CISL, 2021a). However, the private sector's stated attention to biodiversity has so far led to limited investments and often unknown biodiversity impact. It is estimated that only 3 per cent of proceeds from the issuance of green bonds has been allocated to sustainable land-use projects (Global Landscapes Forum, 2020), while very few investment products employ screening against negative impacts on biodiversity (Dempsey et al., 2021).

In the context of managing transition risks, central banks and financial supervisors can have an important role in ensuring that the private financial sector is aligned with emerging government policy on biodiversity. The focus for central banks and supervisors should be twofold: first, to protect the financial system and financial stability from physical risks related to their dependency on biodiversity; and second, to ensure that the transition risks linked to the negative impacts of financial flows on biodiversity are addressed in line with emerging government policy, market norms and social expectations. Central banks and financial supervisors need to ensure that financial institutions do not endogenously contribute to biodiversity-related financial risks. Such a task remains firmly within central banks and supervisors' mandates and some operations must be adjusted to address the nature of ecological challenges such as biodiversity.

The growing range of central bank and supervisory responses are included in Chapters 2 and 4.

The NGFS-INSPIRE Study Group's Vision Paper and Interim Report explored why and how central banks and financial supervisors could seek to understand how the economic impacts of biodiversity loss could in turn impact financial stability, while recognising the methodological challenges discussed above.

Specifically, the Interim Report made four initial recommendations for central banks and financial supervisors, namely that they could:

- Begin building the skills, capacities, tools and cooperation to address biodiversity-related economic and financial risks;
- Assess the dependencies and impacts of their financial institutions on ecosystem services and biodiversity;
- Become more familiar with existing biodiversity–economy models and develop ad hoc methodological approaches that better capture the risk of impacts cascading through economic and financial actors; and
- Signal to the financial institutions that they supervise, other economic actors and policymakers the importance of understanding, managing and disclosing the risks arising from their dependencies and impacts on biodiversity.

This Final Report further explores each of the issues raised in these first two publications, while providing central banks and financial supervisors with further options, recommendations and avenues for future research.

- Chapter 2 provides a theoretical framework to assess and understand exposures to, and dependencies and impacts on, biodiversity. It then reviews the evidence base, including evidence and case studies of exposures.

- Chapter 3 discusses the considerations relating to forward-looking assessments of biodiversity-related risk, with a focus on the development of scenarios tailored to financial stability assessments but that could also be used for macroeconomic forecasting and monetary policy.
- Chapter 4 examines other issues of concern to central bankers and financial supervisors regarding biodiversity, given the partly endogenous nature of these risks.
- Chapter 5 moves on to options for actions that central bankers and financial supervisors can take in light of all these elements.
- Chapter 6 concludes with recommendations from the Study Group for next steps.

2. Understanding existing financial system exposures to biodiversity-related risks

The degradation of ecosystems is leading to risks for financial institutions and the financial system. A growing number of studies have sought to understand, measure and model how these biodiversity-related risks flow into the economy and to financial actors. This chapter presents a conceptual framework to understand these risks, including their origins and transmission channels.

2.1. A conceptual framework for the transmission of biodiversity-related financial risk

Physical and transition biodiversity-related financial risks

Biodiversity-related financial risks are typically categorised as either physical or transition risks. This follows, among others, the categorisation developed by the Task Force on Climate-related Financial Disclosures (TCFD), which divides climate risk into exposures to the physical impacts of climate change and those related to the transition to a lower-carbon economy (policy, technology, market and reputational risks). In this view, litigation and reputational risks can be considered as a subset of both physical and transition risks (NGFS, 2021a), although some approaches consider them as a separate category (e.g. Takahashi, 2021; CISL, 2021b).

Physical sources of risk include the degradation of ecosystem services on which economic actors depend. These risks can be chronic (e.g. a gradual reduction in the diversity of pollinator species resulting in reduced crop yields, or increasing costs of manual pollination) or acute (e.g. pests wiping out significant parts of a harvest because of the disappearance of natural predators, or disease spreading as a consequence of reduced natural resistance, potentially leading to pandemics), or both (e.g. disruption to microclimates and the hydrological cycle caused by deforestation). Transition risks result from the misalignment between the impacts on biodiversity associated with financial institutions' portfolios and developments aimed at reducing or reversing the damage to biodiversity and ecosystems. These include government measures, technological breakthroughs, litigation and changing consumer preferences.

Transmission of biodiversity-related shocks to the financial system

Biodiversity loss can translate into physical or transition risks for financial institutions. Physical risks (e.g. land use change, invasive species, climate change) can negatively impact business operations, thus affecting profitability and the ability to repay lenders. This results in market and credit risks for financial institutions. Similarly, transition risks (e.g. changes in policy, technology or consumer preferences), can also affect business operations and profitability, particularly for companies whose processes have a negative impact on biodiversity. These risks can threaten individual financial institutions, and potentially aggregate into systemic financial exposures, warranting the attention of central banks and financial supervisors (see Figure 5).

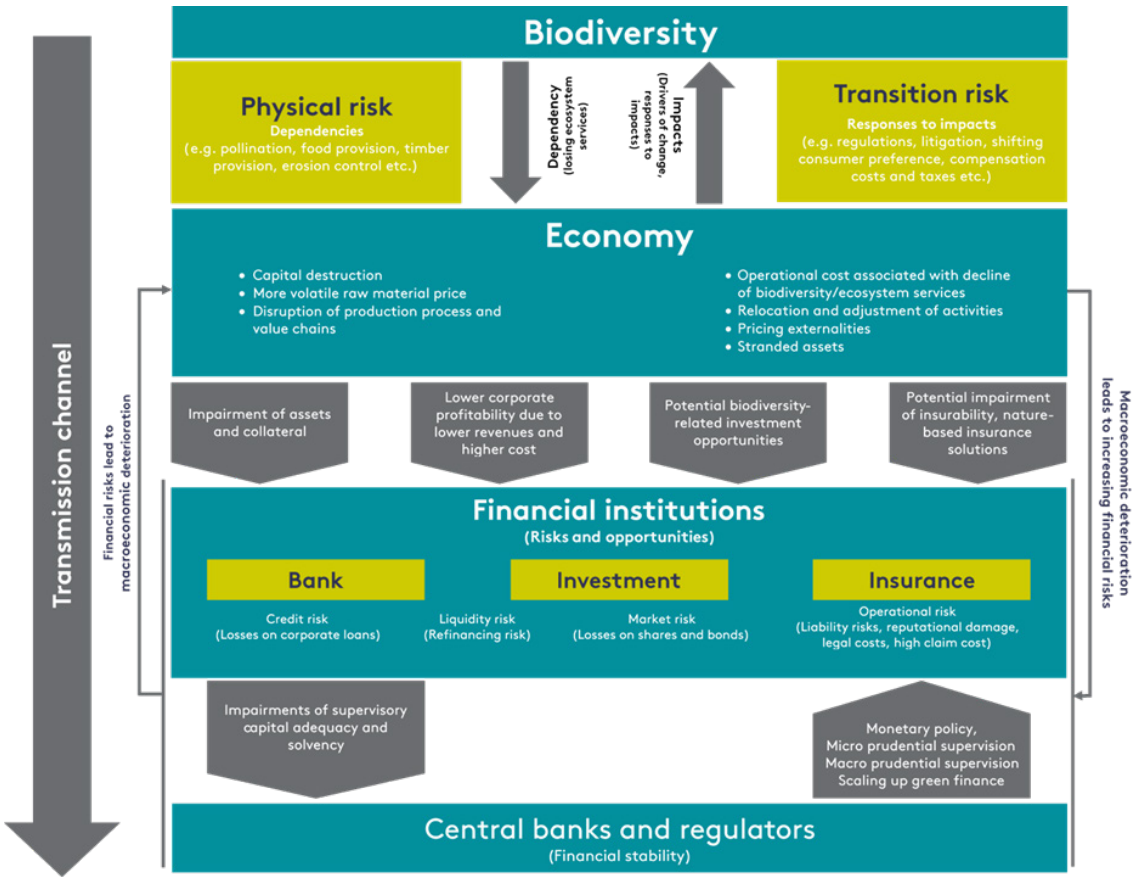
To understand how biodiversity-related financial risks can be assessed, it is important to understand the mechanisms that link an initial physical or transition shock (or longer-term trend) to a possible financial impact. The initial perturbation might be a change in biodiversity conditions (physical shock), or a change in policy, market

demand or technology related to biodiversity (transition shock). This could be an abrupt shock (e.g. a pandemic or a sudden ban of harmful business practices) or a longer-term trend (e.g. gradually decreasing agricultural yields or incremental regulations of certain activities), a single perturbation or numerous ones, and be either local, regional or global. It might impact a specific element of an ecosystem or the economic system or might trigger chain reactions (Chenet, 2022).

These shocks can then affect economic agents such as households, companies (including financial ones), national and sub-national entities and so on, whose operations and prospects are disrupted directly or indirectly, e.g. via supply chains. For instance, specific losses of ecosystem services, the introduction of policies designed to protect biodiversity, or changes in consumption patterns, can impact the availability of natural resources (affecting volume, quality, price), and/or the operations of economic agents (raw materials sourcing, commuting and travel capacity and conditions, labour and health conditions, and so on).

These shocks also impact economic agents through macroeconomic variables. Biodiversity-related shocks and their transmission channels can impact a country's exchange rates and debt sustainability, global commodity prices, GDP growth prospects and more. While it may not be easy to follow the propagation of a shock at the micro

Figure 5. Biodiversity, the economy and the financial system



Source: NGFS-INSPIRE (2021 a, b)

scale, it becomes even more challenging to do so at the macro scale, especially in isolating other factors from biodiversity-related changes (Chenet, 2022).

Once exposed to a shock, economic actors react differently to changes, on a spectrum from total immobility to fully adaptive. The capacity to adapt can be intrinsic or behavioural. For example, if the availability of a raw material is interrupted, some firms will be able to switch to alternative suppliers or inputs, and some will not. This depends on factors external to the exposed agent, such as the type of activity concerned or geographical location, but also on agent-specific characteristics, such as cash availability, business model or management agility. The previous steps can then be translated into concrete economic outcomes relevant for each agent (such as firms' revenues and expenditure, sovereigns' borrowing costs, households' purchasing power, and so on), which can then be aggregated up to sector or regional level while accounting for feedback loops.

Lastly, by assessing financial institutions' exposures to such activities, it is possible to assess how these impacts could translate into specific financial risks such as credit or market risk. For instance: if firms' default probabilities are impacted, this could translate into an increase in credit risks for the financial institutions exposed to them; if the market value of some sectors are impacted by a physical or transition shock, this could translate into market risks; a large physical shock such as a pandemic could lead many firms to claim higher than expected insurance claim pay-outs, thereby creating an underwriting risk for insurers and reinsurers.

Moreover, physical and transition sources of risk could reinforce each other, and multiple contagion channels could appear between different financial risks (which could generate, for instance, liquidity risks), with potential feedback loops to the real economy. Some sectors may be particularly exposed to a mix of physical and transition risks. For example, agriculture is both a high dependency and a high impact industry due to its potential impacts on biodiversity through its use of land area. Agricultural practices have environmental impacts that affect many ecosystem services, including water quality, pollination, nutrient cycling, soil retention, and carbon sequestration (Dale and Polasky, 2007). In turn, changes to the availability of ecosystem services, such as pollination, soil quality and water regulation, affect agricultural productivity (UNEP-WCMC, 2022).

Estimating impacts at each step of the transmission chain presents its own difficulties and obstacles. Combining the inherent complexity of each single phenomenon and associated compound dynamics with the multiplicity of possible events and reactions, through direct and indirect effects, makes assessing and modelling the transmission of biodiversity-related risk extremely complex. As a result, a cautious and humble approach is needed to analysing the results of any biodiversity-related risk assessment exercise (van Toor et al., 2020; Svartzman et al., 2021).

However, the complexity and uncertainty at stake at each step of the transmission of the shocks does not mean that it is irrelevant to undertake any analysis of biodiversity-related financial risks. A number of empirical studies conducted by central banks and others have shown that considerable insight can be gained from such assessments, as discussed below, while other developments, such as scenario analysis (see Chapter 3) and other approaches (see Chapter 4) can also inform the range of actions that central banks can take to address such risks.

The endogeneity of biodiversity-related financial risks

Much as with climate change, economic and financial agents are not only exposed to external biodiversity-related physical and transition shocks: they can also exert a high impact on nature and natural systems, and therefore endogenously contribute to the risks they need to manage. For instance, activities with a strong negative impact on biodiversity could be misaligned with future regulations and therefore be impacted by those regulations. However, the contribution and exposure to risk is not necessarily symmetrical for an individual firm or agent: some sectors such as chemicals may not be the most significantly and directly exposed to physical risks but their overall high impact on biodiversity could increase physical risk for the system as a whole (Kedward et al., 2021b).

Given this endogeneity of risk, it is important to assess jointly how financial institutions not only face risks from environmental threats (financial materiality triggered by physical or transition risks) but also contribute to the build-up of such risks through the activities that they finance, with various complex feedback loops between them. Hence it is critical for financial institutions, central banks and policymakers to understand and manage channels of financial impact upon nature as part of a comprehensive risk management strategy. Currently, existing private financial flows adversely affecting the biosphere outstrip those that enhance natural capital and therefore, as Dasgupta puts it, "there is a need to identify and reduce financial flows that directly harm and deplete natural assets" (Dasgupta, 2021).

Deutz et al. (2020) estimate a biodiversity financing deficit of between US$598 billion and $824 billion per year. Further, planetary boundaries related to biodiversity integrity, biochemical flows and synthetic chemicals have been crossed. This potentially puts the stability of the Earth system at risk (with corresponding implications for financial stability). As such, there could be a strong case for acting directly on financial flows that harm and deplete natural assets (Steffen et al., 2015; Persson et al., 2022). Such an approach, which focuses on the risks towards the Earth system, independently of financial materiality, corresponds to a 'double materiality' approach that some jurisdictions (e.g. the European Union) support. At the very least, there is an urgent need to consistently measure and report financial flows that adversely affect the biosphere.

Financial institutions should not be seen as the sole responsible agents for all these impacts, but it is important to acknowledge that they are enablers of economic activity. The way in which financial capital is governed and allocated plays a role in determining the extent of human demands on nature and the ensuing risks for economic and financial institutions. For instance, there is evidence of the role of banks in extending credit to promote extensive agricultural business models, resulting in detrimental effects on biodiversity (Kedward and Ryan-Collins, 2022; Van der Weijden et al., 2021; Portfolio. Earth, 2021; Global Witness, 2021; Ripoll-Bosch and Schoenmaker, 2021).

Alternative agricultural production models exist. An obvious example is organic farming, and other agricultural models are being proposed that could benefit biodiversity and the environment and meet other societal demands, such as circular agriculture (Muscat et al., 2020), agroecological approaches (Wezel et al., 2009), nature-inclusive farming (Runhaar, 2017) and agroforestry (Nerlich et al., 2013). In short, how the financial sector funds the agricultural sector and, in particular, large-scale, mechanised agricultural business models, has significant implications for biodiversity loss and ensuing financial risks, as well as for social issues and development pathways, particularly in EMDEs.

Box 6 | How is biodiversity change measured in practice?

Biodiversity at all levels is measured using a wide variety of techniques and methods, ranging from genetic sequencing, to direct and indirect observations (e.g. counts) of organisms in their natural habitats, to measuring and quantifying organism 'traits' – or biological characteristics – in the lab. When discussing 'biodiversity loss' this usually refers to an average decline in the numbers of organisms or species in a given space at time t relative to a baseline. Biodiversity change is typically measured through the 'Essential Biodiversity Variables' (EBVs), which are defined as "the derived measurements required to study, report, and manage biodiversity change, focusing on status and trends in elements of biodiversity" (Pereira et al., 2013).

There are three significant challenges to measuring directional changes in biodiversity caused by human activities. The first is that 'baseline' data on the abundance and distribution of species are often rare. In Europe and North America, there are good, systematically collected data for a number of species or species groups going back at least 30 years. Well-known examples include surveys of breeding birds in the UK (Harris et al., 2021) and in the USA (Sauer et al., 2017). However, such detailed, long-term observational data are rare in most regions.

The second challenge is technical: not all species are currently known (Mora et al., 2011) and it is possible that not all living species would be detected, recorded and individually identified at any given moment in time. Even for well-known species groups like mammals, it is technically and logistically challenging to estimate their distribution or count their populations because they often live in remote, inaccessible locations or because they are difficult to detect. However, technological progress is constantly being made to improve monitoring, detection and data collection. For now, to address this challenge, whole 'ecosystem models' (such as the Madingley model, 2022) can be used to predict biodiversity under different scenarios of environmental change and human pressure, but there are still challenges in their application.

The third challenge is that individual species can respond in different ways to ecosystem change, leading to winners and losers. Some species can benefit from change, for example birds that thrive in farmland habitats can benefit from deforestation, while forest specialists will lose out. Biodiversity losses are therefore often given in the context of broad 'habitat' types, such as 'forest biodiversity' or 'marine biodiversity'.

The challenges and opportunities around measuring biodiversity and monitoring change are being addressed by the Group on Earth Observations (https://geobon.org), which is a global network of biodiversity scientists that aims to "improve the acquisition, coordination and delivery of biodiversity observations [data] and related services to users including decision-makers and the scientific community". The network provides a rich resource that can be accessed by financial decision-makers to inform their understanding and use of biodiversity data and indicators.

What next for measuring biodiversity loss?

Although there are challenges to measuring biodiversity and detecting change, there is a consensus that biodiversity is declining at unprecedented rates globally. Perfect observational data are not required to detect these changes, but financial policymakers could consider contributing to improving national biodiversity monitoring capacity. Improved data can be used to better understand and mitigate the risks posed to financial services by biodiversity loss.

2.2. Emerging methodologies to assess potential risk exposure

Given that biodiversity-related financial risk is an emerging area of concern for researchers and practitioners, the related analytical frameworks, models, methodologies, data and evidence needed to assess the risks involved are in their infancy, too. However, new approaches, tools and datasets are being developed to better understand financial institutions' impacts and dependencies on biodiversity. While most available methodologies focus on impacts, the ENCORE framework, which has been utilised by various central banks, is able to provide measures for dependencies on biodiversity as well.

The positive or negative impacts of economic activities on biodiversity can be measured via a biodiversity footprint. The biodiversity footprint can refer either to actual changes in biodiversity associated with the activities over time, or to the potential impact based on the contribution of an economic activity to drivers of biodiversity loss or biodiversity gain. For a financial institution, the biodiversity footprint can provide a measure of the impact of its operations (e.g. impacts resulting from land use or energy use by banks' operations) and the economic activities it finances (e.g. in the form of loans or investments). Most existing approaches focus on the latter, as those impacts on biodiversity would generally be much larger.

Table 1 summarises the ENCORE approach and six other ways to measure biodiversity (for more information, see Appendix 3). The approaches featured are identified based on the following three criteria: i) relevant to, and are currently explored or used by, the financial sector, ii) include all the main drivers of biodiversity loss, and iii) are scientifically robust.

Table 1. Biodiversity measurement approaches for financial institutions

Approaches	Summary description	Methodological details
Exploring Natural Capital Opportunities, Risks and Exposure (ENCORE)	A database that enables users to visualise how the economy potentially depends on and impacts nature and how environmental change creates risks for businesses.	For dependencies (impacts) on ecosystem services, literature reviews were carried out for each ecosystem service class (impact drivers) and production process combination using Web of Science, Google and key document searches, with standardised search terms, and targeted website searches, including leading companies in the sector and industry initiatives. Expert interviews were also conducted with sector specialists to validate information for some dependencies (impacts) or fill gaps for some sectors and production processes that are not available in literature.

Cont. p30

Approaches	Summary description	Methodological details
Corporate biodiversity footprint (CBF)	Assesses the annual impact of companies, financial institutions and sovereign entities on global and local biodiversity.	CBF covers the impact of the four environmental pressures (land use, climate change, air pollution and water pollution) on species and habitats along the whole value chain of the assessed company, its processes and its industrial and consumer products or purchases. Each environmental pressure is translated into a quantified impact on either terrestrial (using the GLOBIO model) or freshwater ecotoxicity, expressed in km² of Mean Species Abundance (MSA). Results are then aggregated to calculate the annual biodiversity impact of the assessed company. The metric is expressed as an impact in absolute terms at company level (km² MSA) and in relative terms (ratio based on a financial indicator km². MSA/m€ or a physical metric km². MSA/tons).
Biodiversity footprint financial institutions (BFFI)	Provides a biodiversity footprint of the economic activities in which a financial institution invests.	BFFI measures the biodiversity footprint in four steps: 1. Creates an overview of the economic activities in which the financial institution invests. 2. Assesses the environmental impact of the economic activities of the company or projects in which the financial institution invests. 3. Applies the ReCiPe model to calculate the environmental pressures [see Table notes]. 4. Conducts qualitative analysis to guide the interpretation and the use of the results.
Global Biodiversity Score for Financial Institutions (GBSFI)	Provides an overall and synthetic vision of the biodiversity footprint of economic activities.	GBSFI measures the biodiversity footprint in two steps: 1. Identifies the pressures caused by economic activities on biodiversity. 2. Estimates the impacts of these pressures on ecosystems, using the GLOBIO model, which is based on pressure-impact relationships [see Table notes].
Biodiversity Impact Analysis (BIA)	An integrated biodiversity impact database using the GBSFI methodology, enabling firms to calculate the biodiversity impacts of underlying assets.	Assesses the biodiversity impacts for underlying assets by combining Carbon4 Finance's financial and carbon data (available at the company level) and GBSFI's impact factors.

Approaches	Summary description	Methodological details
Species Threat Abatement and Restoration metrics (STAR)	Measures the contribution that investments can make to reducing species extinction risk, through abating threats and by restoring habitat.	STAR consists of a global map of species extinction risk scores mapped by 5 x 5 km squares. For each square, the contribution of each threat to the score is given. Users can overlay polygons (corporate footprint, project sites, commodity production zones) on the STAR map to compare values, add up total potential contributions, or assess options for management based on addressing the threats in each polygon.
Comprehensive Accounting in Respect of Ecology (CARE)	Aims to reconcile biophysical and monetary accounts by assessing the costs of preserving natural capitals rather than by assessing the economic value of natural capital.	Starting from the view that revealing the economic value of nature is not sufficient to trigger the transformative changes needed to protect biodiversity and from the observation that accounting systems are socially-constructed norms with profound economic implications, Feger et al. (2021) suggest the use of the CARE model (for the business level). This model defines 'capital' as an 'entity' (material or non-material, human or natural), e.g. a forest, a river or biodiversity, employed and consumed by a firm in its business model, the existence of which is independent of the firm's activity (including its utility/productivity), and recognised as having to be preserved for its own sake (including because it is not substitutable). The CARE model then applies the costs of conserving (preventing or restoring) different forms of natural capital over time to the firm's balance sheet and income statement. The CARE model is to be used in conjunction with the Ecosystem-Centric Management Accounting framework (at the level of the collective management of ecosystems). This enables the assessment of a firm's impacts and contributions to natural capital preservation objectives relative to other business/stakeholders' activities affecting the same ecosystem in diverse governance contexts.

Notes: *The Global Biodiversity Model for Policy Support (GLOBIO) is hosted and maintained by PBL Netherlands Environmental Assessment Agency and is updated in collaboration with various international organisations. GLOBIO calculates local terrestrial biodiversity intactness, expressed by the mean species abundance (MSA) indicator, as a function of six human pressures: land use, road disturbance, fragmentation, hunting, atmospheric nitrogen deposition and climate change. The core of the model consists of quantitative pressure-impact relationships that have been established based on extensive terrestrial biodiversity databases. (See https://www.globio.info/what-is-globio.) ReCiPe is a method for the life cycle impact assessment; the primary objective of which is to transform the long list of life cycle inventory results into a limited number of indicator scores. (See https://pre-sustainability.com/articles/recipe/.) Appendix 3 provides a detailed comparative analysis of these measurement approaches. Appendix 4 explains the mean species abundance indicator.*

Sources: *Lammerant et al., 2019, 2021; and Finance for Biodiversity Pledge, 2021.*

A major challenge to measuring any impact on biodiversity is that it is often difficult to measure biodiversity itself, and to identify baselines from which to measure change. Sources of biodiversity data for monitoring and detecting directional change in populations and species diversity can come from national or regional databases (like eurobirdportal.org), from targeted survey efforts or from remote sensors including satellites and remotely deployed 'camera traps'. These sensors can be used to systematically survey wildlife. In combination with artificial intelligence technologies, sensors and other incoming technologies will improve the availability, precision and accuracy of biodiversity data for impact evaluation and measuring directional change, but financial professionals should be aware that uncertainties remain around collecting accurate data in many regions of the world.

It is likely that no single approach will comprehensively capture all dependencies and impacts on biodiversity. Different objectives, applications and required associated levels of detail will necessitate different measurement approaches. The dynamic interactions between the natural environment and economic and financial activities also means financial institutions should not routinely apply the measurement approaches over time, as factors such as the composition of biodiversity pressures may change. A fundamental point is that there are many interdependencies between human and natural systems, only some of which are known or, possibly, are only knowable ex-ante (IPBES, 2019; Pottier, 2017).

2.3. The growing evidence base on biodiversity-related financial risks

Over recent years, a number of country-level case studies have been carried out by central banks and other stakeholders to assess the dependencies and impacts of these countries' financial systems on biodiversity. We summarise some of these below. In addition, there has been analysis of the accumulation by central banks of exposures resulting from unconventional monetary policy, and the sector-level exposure of the insurance industry, as outlined following the country case studies.

The Netherlands

De Nederlandsche Bank (DNB) was the first central bank to attempt to quantify the extent to which the financial institutions it oversees are exposed to risks from the loss of biodiversity (van Toor et al., 2020).

Exposure to physical risk

The DNB analysis sought to illustrate how the financial sector is exposed to physical risks from biodiversity loss. It examined the extent to which the Dutch financial sector is exposed to ecosystem services indirectly, through the activities of the firms it finances. It applied the ENCORE database described in Table 1 to financial institutions' holdings of loans, shares and bonds.

It found that 36 per cent of the investments of Dutch financial institutions are highly or very highly dependent on one or more ecosystem services. Thus it concludes that for €510 billion of the €1,400 billion of investments analysed, "the loss of ecosystem services would lead to substantial disruption of business process and financial losses". It found the highest dependence on ecosystems that provide groundwater and surface water. The study likely underestimates the extent of disruption and financial loss as it only considered "first-order dependencies" and did not capture dependencies in supply chains.

The study specifically examined exposure to the disappearance of animal pollination, estimating exposure at €28 billion. An estimated 5–8 per cent of global crop production,

worth an annual US$235–577 billion worldwide, depends on animal pollination. The DNB identified 271 product groups that contain 55 pollination-dependent crops. It then determined the importance of those product groups to the various economic sectors, before calculating the extent of lending to, and investment in, sectors with products that are dependent on pollination.

Exposure to transition risk

The study also offered an estimation for the biodiversity footprint of the Dutch financial sector, stemming from the activities of the 8,000 companies worldwide in which the sector invests. Expressing this footprint as the loss of species and populations in ecosystems compared with a pristine situation, the DNB found that the Dutch financial sector's biodiversity footprint is comparable with the loss of 58,000 km² of pristine nature, equivalent to an area 1.7 times the size of the Netherlands itself. This biodiversity footprint is used in the study as an indicator for transition risk, where a disproportionately large footprint can serve as an indicator of increased risk.

The study also examined transition risk in the context of financial institutions' financing of activities in biodiversity hotspots. Financial institutions will face transition risks should governments seek to protect these areas, reducing or halting impactful economic activities. To link these protected and valuable areas to financial exposure, the DNB used a dataset from market intelligence provider Four Twenty Seven containing 932,359 business locations of 1,846 major companies. For each company, each business location was assessed against four criteria: protected area; valuable area in a scenario where 24 per cent of land area is protected; valuable area in a scenario where 30 per cent of land area is protected; and non-protected and non-valuable area. It found that, in a scenario where protected areas are increased from around 15 per cent to 24 per cent of land and inland waters, financial institutions face exposures of €15 billion. If that area were to increase to 30 per cent, the exposure would rise to €28 billion.

As an additional transition risk assessment, the study examined the financial sector's exposure to efforts to reduce nitrogen emissions in the Netherlands. It found a total of €81 billion in loans from the three largest Dutch banks to companies that emit nitrogen.

The report also examined the exposure of financial institutions to reputational risks from environmental controversies. Using the environmental controversy database maintained by financial data provider MSCI, it found that at the end of 2019 the Dutch financial sector had provided a total of €96 billion in financing to companies involved in 414 environmental controversies. Businesses involved in very severe incidents had received €4.7 billion of this total.

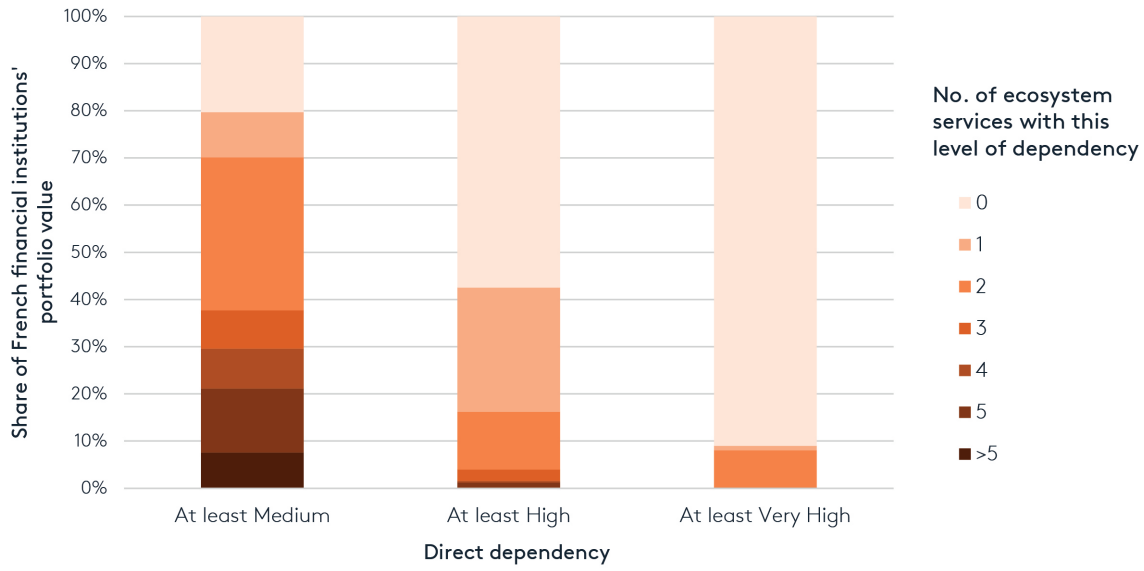
France

In August 2021 the Banque de France published an assessment of the dependencies and impacts on ecosystem services of the securities held by French financial institutions. Following the work of DNB, it considered the exposure of French financial institutions, mainly investment funds, insurance companies and banks (Svartzman et al., 2021).

Exposure to physical risk

The analysis found that 42 per cent of the total value of securities held by French financial institutions were issued by companies that are highly or very highly dependent on at least one ecosystem service (Figure 6). Nine per cent were issued by companies with a very high direct dependency on at least one ecosystem service, and 21 per cent were issued by companies with a combined dependency of at least 'Medium' on five or more ecosystem services. Portfolio companies are particularly dependent on ecosystem services related

Figure 6. Dependence of French financial institutions' portfolios on ecosystem services



Source: Svartzman et al., 2021

to water supply (surface water and groundwater) and on certain maintenance and regulation services (erosion control, flood protection and climate regulation).

When supplier dependencies along the upstream value chain are also included, all the firms that issued the securities in the portfolio become at least slightly dependent on all ecosystem services (while some were not *directly* dependent on these ecosystem services).

Exposure to transition risk

The analysis also assessed the impacts (or footprint) on terrestrial biodiversity of these financial institutions through the activities of the companies whose securities they hold. It used the Global Biodiversity Score (GBS) developed by CDC Biodiversité (2020) and its translation to a database developed by Carbon4Finance (BIA-GBS). This tool first converts a company's turnover by region and production sector into pressures on biodiversity (in terms of climate change or land use, for example), then into an impact expressed in a single metric, the MSA.km². An impact of 1 MSA.km² can be interpreted as having the same effect on biodiversity as transforming 1km² of pristine ecosystem into a completely artificial surface (e.g. a car park).[2]

The study estimated that, through the companies financed, French financial institutions' equity and bond portfolios had an accumulated terrestrial biodiversity footprint at end-2019 comparable to the loss of at least 130,000 km² of pristine nature. This corresponds to the complete artificialisation of 24 per cent of the surface area of metropolitan France (i.e. the area of France which is geographically in Europe). Land use is the main factor of biodiversity pressure accounting for these results. Various economic sectors contribute to this footprint, including chemicals and gas production, manufacturing of dairy products and food products processing. Their impact stems primarily from scope 3 (upstream) dependencies, with relatively little impact from scope 1 (direct) dependencies.

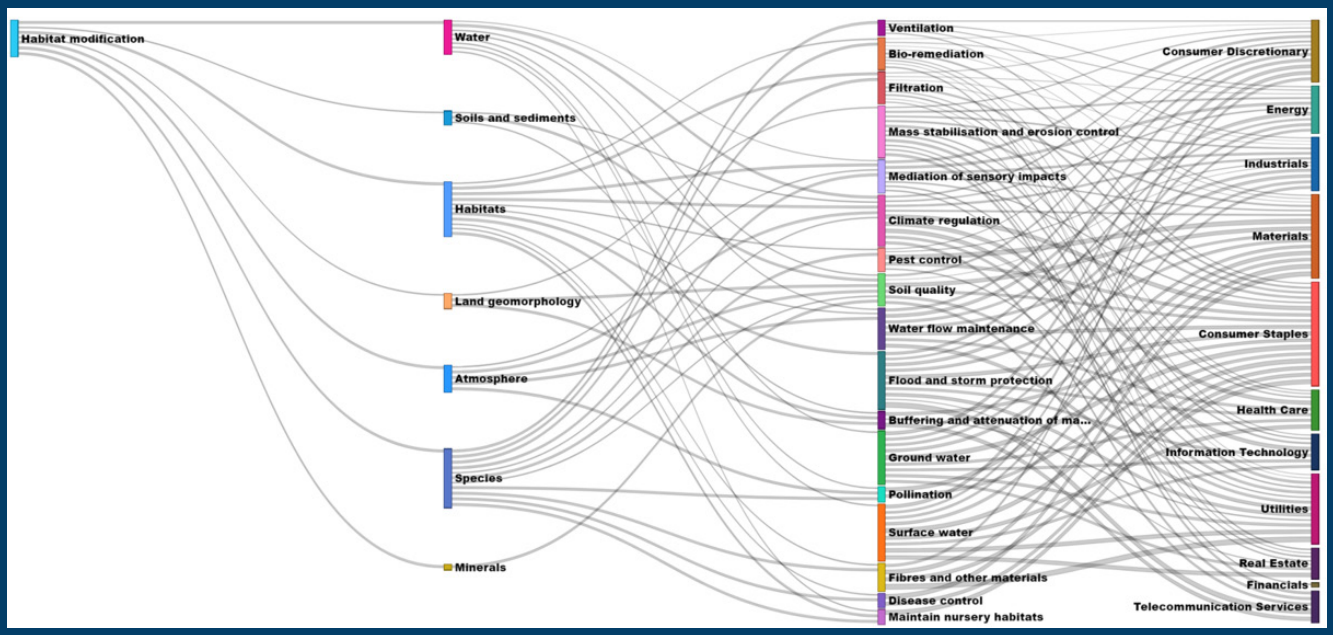
2. See Appendix 4 for explanation of Mean Species Abundance/MSA.

Box 7 | Using ENCORE to link habitat modification and economic activities

ENCORE – the Exploring Natural Capital Opportunities, Risks and Exposure database – can be used to assess the dependency of a whole financial system to ecosystem services (see case studies below) or to explore specific issues. For instance, the UN Environment Programme World Conservation Monitoring Centre used ENCORE to establish links between habitat modification* and production processes via natural capital assets and ecosystem services. With the influence, importance and materiality ratings included in ENCORE, it derived how material a specific ecosystem service is to a sector, how important a particular asset is for the provision of an ecosystem service, and how much habitat modification influences an asset (UNEP-WCMC, 2022).

The exercise first mapped the impact of habitat modification to seven of the eight natural capital assets in the ENCORE database, and from there to 17 ecosystem services (see Figure 7). It then examined the extent of dependency of economic sectors on those services. The exercise identified subindustries, which were accorded at least one habitat modification high risk rating. Given that most subindustries depend on more than one ecosystem service, the process can be used to discover which are most exposed to habitat modification (see Figure 8, next page) (ibid.).

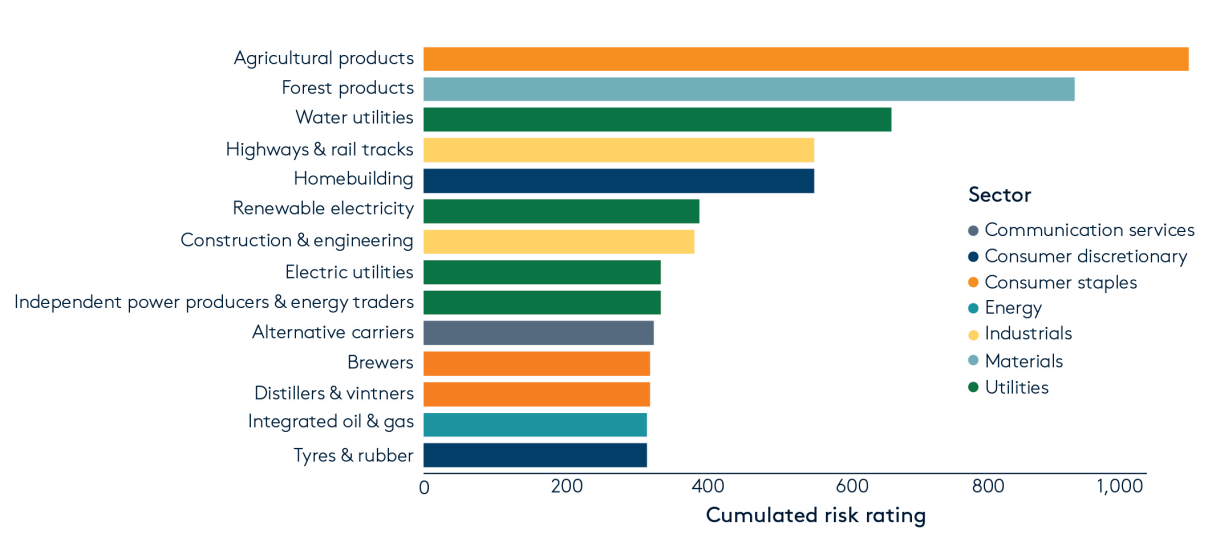
Figure 7. Linking natural capital assets and ecosystem services impacted by habitat modification, and the sectors that depend on these services



Source: UNEP-WCMC, 2022

**Under a business-as-usual scenario, the world is projected to lose about 46 million hectares of natural land cover between 2021 and 2030. This will impact ecosystem services, with implications for agricultural yields and industries dependent on timber, among other sectors (World Bank, 2021). Agricultural expansion – the most widespread form of land use change – has converted over one-third of terrestrial land surface for crops or livestock, causing loss and fragmentation of habitats (Stehfest et al., 2019).*

Figure 8. Ranking of industry sectors that have the highest habitat modification cumulated risk ratings



Source: Adapted from UNEP-WCMC, 2022

While ENCORE provides useful insights, it is important to keep in mind that it only provides specific insights into the assessment of dependencies. It does not include cultural ecosystem services or nutrition (Wong et al., 2021).

In addition to the cumulative (or static) impact, the portfolio of securities, through the constituent companies, had an additional annual (or dynamic) terrestrial biodiversity impact comparable to the loss of 4,800 km² of pristine nature. This corresponds to the complete artificialisation of an area 48 times greater than that of Paris. These results are primarily attributable to the pressure exerted by climate change on biodiversity with various sectors contributing to this footprint, including chemicals production and oil refining.

Brazil

The first assessment of financial sector exposure to the loss of biodiversity in a biodiversity-rich developing country was carried out by the World Bank, analysing Brazil's banking sector. In its study, published in August 2021, the World Bank noted that Brazil is one of the most biologically diverse countries in the world, hosting 15–20 per cent of the world's biodiversity, and that biodiversity is threatened by climate change and deforestation. It also noted the potentially key role local banks play in Brazil's economy, accounting for two-thirds of total financial system assets (Calice et al., 2021).

Exposure to physical risk

The authors set out to explore how and to what extent Brazilian banks are exposed to the loss of biodiversity through their lending to non-financial companies. It used the ENCORE database, linking the 21 ecosystem services to Brazil's economic sectors and from there determining bank credit exposures to those sectors, using data from Banco Central do Brasil. The authors found that 46 per cent of Brazilian banks' non-financial corporate loan portfolio is concentrated in sectors highly or very highly dependent on one or more ecosystem services. This figure represents 20 per cent of banks' total credit portfolio.

The study found that a collapse in ecosystem services could increase the cumulative long-term rate of corporate non-performing loans by 9 percentage points. This assessment was based on an estimate of the effects of a collapse in ecosystem services on Brazil's GDP, and a macroeconomic modelling of the historical sensitivity of Brazilian banks' asset quality to macroeconomic conditions.

Exposure to transition risk

The analysis also describes the extent to which Brazilian banks finance companies that potentially operate in protected areas and priority areas for biodiversity conservation. This analysis begins with a mapping of bank loan exposure to the municipal level. Those geographical exposures are merged with data from the World Database on Protected Areas and the Brazilian Ministry of Environment to identify banking sector loans to companies in protected or priority areas. Brazilian banks have an outstanding loan exposure of BRL 254 billion, or 15 per cent of their corporate portfolio, to firms potentially operating in protected areas. This exposure could increase to BRL 437 billion (or 25 per cent of the corporate credit portfolio) should conservation efforts be increased, and to BRL 664 billion (38 per cent), should all priority areas become protected.

Malaysia[3]

Bank Negara Malaysia has collaborated with the World Bank to explore nature-related financial risks in Malaysia (World Bank and Bank Negara Malaysia, 2022). Malaysia is one of the world's most megadiverse countries, and many of its economic activities are supported by nature and its ecosystem services. The study used the ENCORE database to explore potential physical risks faced by the banking sector through its sectoral lending portfolio. It also extended the use of ENCORE to estimate transition risks arising from loans to sectors that drive impacts on nature.

Exposure to physical risk

The study found that 54 per cent of the commercial loan portfolio analysed is channelled to sectors that depend to a high extent on ecosystem services. Dependencies on ecosystem services that stand out are surface water (29 per cent), climate regulation such as carbon storage (26 per cent), and flood and storm protection (16 per cent).

Exposure to transition risk

It also found that banks are exposed to transition risks through the funding of sectors that strongly impact nature, particularly via greenhouse emissions, water use and terrestrial ecosystem use. Eighty-seven per cent of the commercial loan portfolio analysed is channelled to sectors that highly or very highly impact various natural assets and ecosystem services. Among all impact drivers, the ones individually impacted the most[4] are greenhouse gas emissions (61 per cent), water use (56 per cent), and terrestrial ecosystem use (43 per cent).

Implications for developing scenarios

The study also explored a set of nature-related events with a range of adverse physical and transition risk scenarios that could affect Malaysian banks. Similar to the CISL (2021b) scenario classification, the study categorised scenarios according to types of risk, driver

3. This section is derived from World Bank and Bank Negara Malaysia, 2022.
4. The impacts considered here are classified as high or very high impacts. An impact is different to an impact driver. Impacts are "changes in the quantity or quality of natural capital that occurs as a consequence of an impact driver. A single impact driver may be associated with multiple impacts" (Natural Capital Coalition, 2016).

of risk, and sectors, natural assets and ecosystem services where the risk scenario would originate. Based on ENCORE and interviews with stakeholders, the study identified 21 possible nature-related physical risk scenarios and seven transition risk scenarios. These scenarios capture the current banking exposure should there be adverse events that could affect a combination of ecosystem services, and thereby a multitude of economic sectors.

Scenarios with the highest banking sector exposure are scenarios that affect a wide range of sectors due to continued high resource use, pollution, and urban sprawl (44 per cent of the Malaysian banking sector lending portfolio), sudden and unexpected climate policy introduction (38 per cent), and ecosystem service deterioration due to continued high rates of deforestation (30 per cent).

The study provides initial insights into nature-related risks for the Malaysian banking sector. Further research is necessary to enable more refined exposure estimates from the ENCORE tool. The development of a comprehensive set of scenarios, and a better understanding of the likelihood and severity of impacts from adverse scenarios to economic and financial loss, would also improve the assessment of nature-related financial risks.

Mexico[5]

Prompted by its participation in the NGFS-INSPIRE Study Group, Banco de México undertook an analysis to estimate the dependency of Mexico's banking system to ecosystem services and study its exposure and possible economic losses related to biodiversity loss (Martínez-Jaramillo and Montanez-Enriquez, 2021). Mexico is one of the world's most megadiverse countries, but it faces severe consequences from biodiversity loss for its economy, financial system and for the wellbeing of its population.

Exposure to physical risk

The analysis begins with an overview of the relationship between Mexico's natural capital and its economy. Following the approach first used by van Toor et al. (2020), Svartzman et al. (2021) and Calice et al. (2021), the authors used the ENCORE database to link ecosystem services to subindustries.

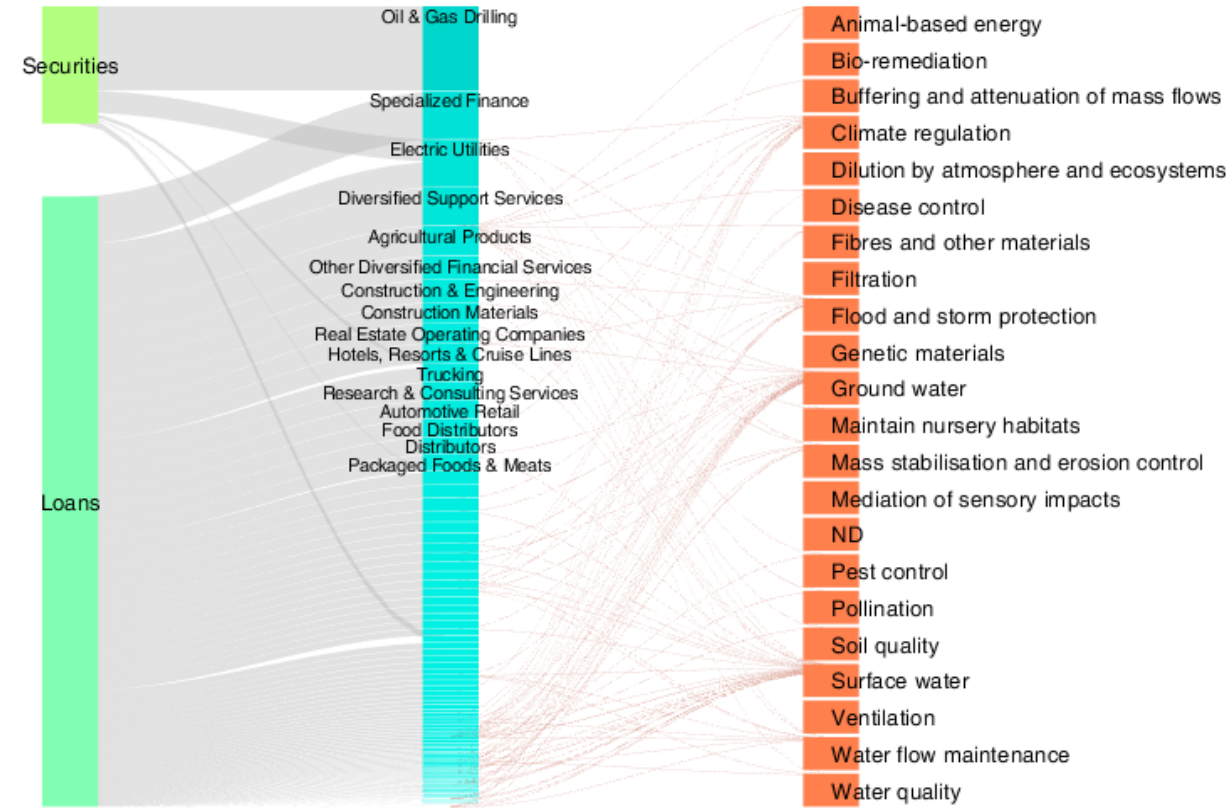
It then proceeds to estimate the exposure of the banking system to these industry sectors. The authors derived this exposure from Banco de México's credit registry, a monthly regulatory report of all outstanding commercial credits at the individual loan level, which includes the economic sector of the loan recipient, and the daily regulatory report of all securities held at the security issuance level. Ideally, the analysis would also have included exposures from banks' equity holdings; however, this information was hard to obtain, and these holdings do not represent a significant source of exposure.

The largest sectoral exposures, besides specialised finance, are to oil and gas drilling, electric utilities, diversified support services and agricultural products (see Figure 9). The industries with the largest number of dependencies on ecosystem services are agricultural products (15 services) and forestry production (12 services). The services on which most sectors rely are surface water (28 subindustries); ground water (24 subindustries); climate regulation (15 subindustries); and flood and storm protection (11 subindustries).

More than one-third (36.5 per cent) of banking sector lending is to subindustries that are highly or very highly dependent on one or more ecosystem services (see Figure 10). These exposures can be considered a proxy for physical risk. Fifty-nine of the 100 subindustries are not significantly dependent on any ecosystem service.

5. This section is derived from Martinez-Jaramillo and Montanez-Enriquez, 2021.

Figure 9. Exposures and eco-systemic dependencies of the Mexican banking sector



Source: Martínez-Jaramillo and Montanez-Enriquez, 2021

Figure 10. Amount and number of subindustries with high (H) or very high (VH) dependence on ecosystem services

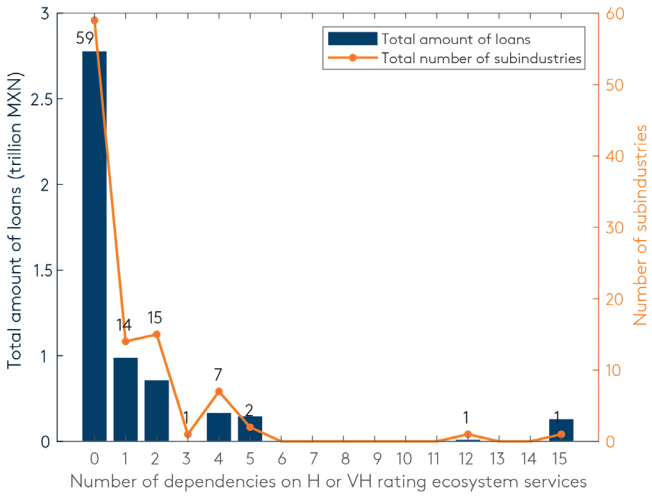
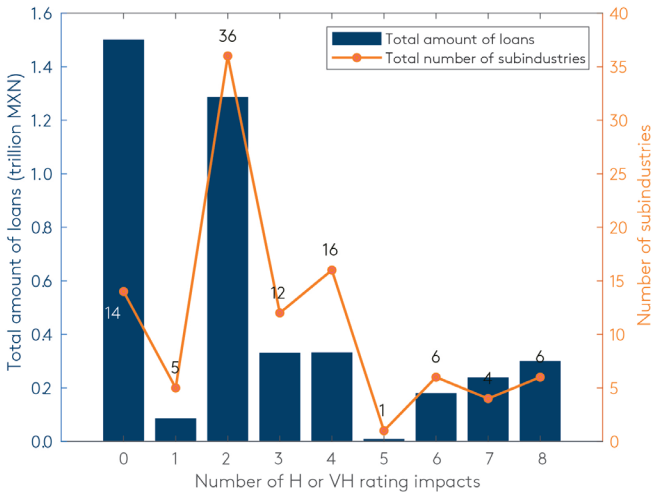


Figure 11. Investment amount and number of subindustries impacting ecosystems



Source: Adapted from Martínez-Jaramillo and Montanez-Enriquez, 2021

Exposure to transition risk

Meanwhile, 64.9 per cent of bank lending is to sectors that have a high or very high impact on one or more ecosystem services (see Figure 11). Compared with dependencies, only 14 subindustries have little or no impact on ecosystem services.

Future avenues

Banco de México considers this analysis to represent just the first step to uncovering the links between biodiversity loss and the financial system. Additional work is needed to incorporate the exposures of other financial intermediaries, such as pension funds, insurance companies and other institutional investors. Once a complete picture of exposures is formed, more comprehensive exercises could be undertaken, such as investigating the amplification effects that the financial system could have on shocks from the dislocation of important ecosystems in Mexico. Further work is also needed on forward-looking scenarios of environmental degradation, similar to current work being done on climate change.

Central bank exposure and impact through monetary policy operations[6]

The operations that central banks use to implement monetary policy expose them to biodiversity-related risks. Central banks implement monetary policy through two main types of operation: credit operations and asset purchases. Both expose their balance sheets to biodiversity risk. Credit operations indirectly expose central banks to biodiversity risk through the exposure of the financial institutions they lend to and, if some of them default, through the exposure of the collateral that they hold from them. Asset purchases, both domestic and foreign, directly expose central banks to biodiversity risk through the assets they own in their monetary policy portfolios. As with climate risk (BCBS, 2021), biodiversity risk materialises within traditional risk categories: credit, market, liquidity and operational risks.

Monetary policy operations also have an indirect impact on biodiversity loss or conservation. When an asset is bought by central banks or accepted by them as collateral, its price increases. This gives an incentive for financial institutions to issue such assets in larger quantities and to provide funding to the corresponding firms at a lower price. Similarly, the conditions that central banks set to access their credit operations can impact the distribution of credit in the economy, and thus which firms get bank funding. By choosing which assets they purchase, which ones they accept as collateral and which loans give access to targeted credit operations, central banks incidentally select which economic activities they indirectly support with better funding conditions. This can translate into indirectly supporting economic activities that are detrimental to biodiversity and thus exacerbate biodiversity loss. It can, however, also potentially support economic activities that maintain or restore biodiversity. Using the ENCORE framework, Kedward et al. (2021a) find that 40 per cent of the Eurosystem's Corporate Sector Purchase Programme (CSPP) portfolio is invested in sectors that are highly or very highly dependent on ecosystem services (a result similar to those found by van Toor et al. [2020] and Svartzman et al. [2021] when assessing the dependency score of the Dutch and French financial systems).

6. This section is derived from Monnin, 2022.

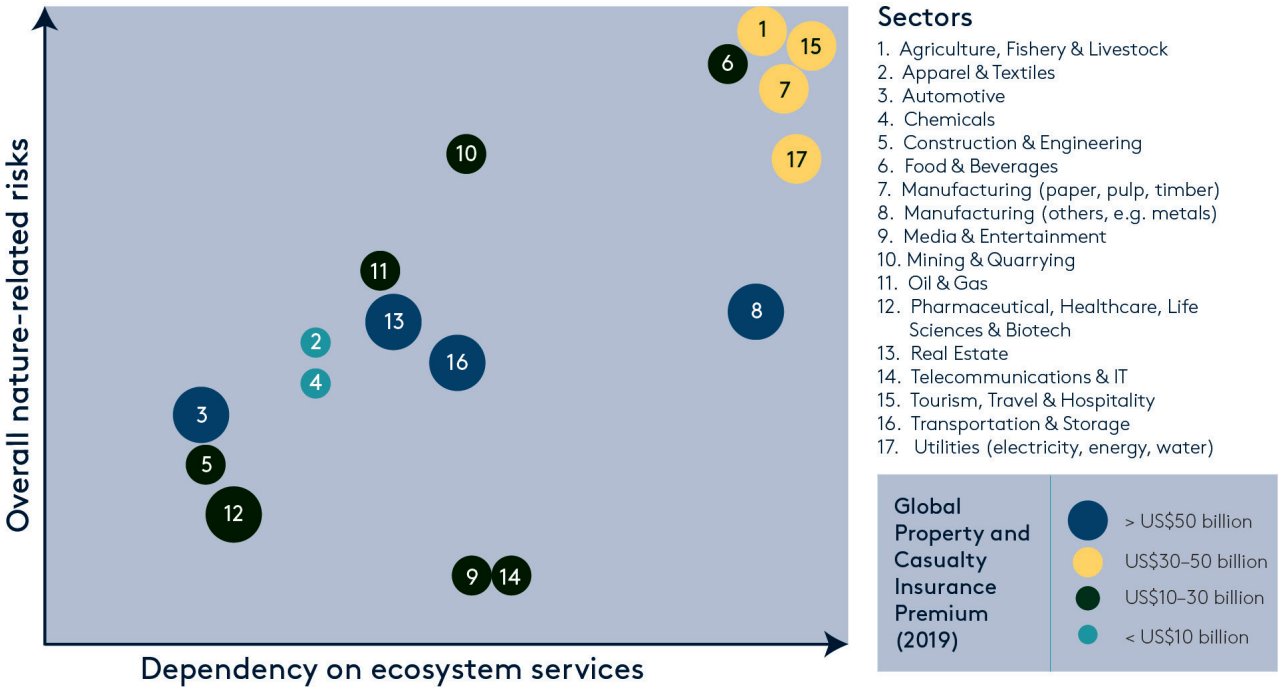
Insurance sector exposure[7]

Given its role in managing risk across the real economy, the insurance sector faces indirect exposure to biodiversity risk. There is a growing consensus among insurance industry experts that nature-related underwriting and investing risks can be financially material to the industry (Retsa et al., 2020). However, most [re]insurers do not currently assess these risks in their underwriting and investing businesses because of several barriers, namely lack of data and information, including relevant methodologies; lack of regulatory/supervisory guidance or requirements; lack of technical capacity and skills; lack of mandate or buy-in from executive management or company boards; and a lack of awareness of nature-related risks.

A recent global survey of the insurance industry conducted by the UNDP Sustainable Insurance Forum (SIF) found that the current level of understanding of nature-related risks is lower than related risks such as climate change and natural hazard risks. Nonetheless, given that nature has been declining globally at rates unprecedented in human history, the global insurance sector is beginning to take a more holistic view of nature-related risks, expanding beyond climate and natural hazard exposures.

The transmission of nature-related risks (physical and transition) into financial risks for the insurance sector occurs through the propagation of nature-related risks via clients/policyholders or investees of insurance companies. The underwriting and investment activities of the insurance sector are predominantly concentrated in 17 economic sectors that are dependent on nature to varying degrees. Based on expert consultations and qualitative research, a directional estimate of the overall risks, including both physical and transition risks, is presented in Figure 12 with regard to the dependency of each business or economic sector on nature.

Figure 12. Directional estimate of overall nature-related risks for economic sectors



Source: Adapted from UNDP SIF, 2021

7. This section is derived from UNDP SIF, 2021.

The analysis suggests that seven economic sectors, accounting for about 10 per cent of global property and casualty insurance premiums, could be exposed to significant disruption as nature-related risks become more severe.[8] Such disruption is unlikely to be evenly spread among firms and geographies because of firm- and geography-specific characteristics. The next eight economic sectors, contributing to approximately 77 per cent of insurance premiums, could experience moderate disruption. When global health insurance premiums are also considered, more than 90 per cent of global non-life insurance premiums depend on economic sectors that are at high or moderate risk from nature loss. Only two economic sectors (media and entertainment, and telecommunications and IT) are currently within 'safe' limits.[9] The same sectors also constitute a significant portion of the global insurance sector's investment portfolio.

It is also important to examine these economic sectors' geographical exposure to nature-related risks. It is likely that some sectors might face greater overall nature-related risks if both the dependency of those sectors on nature and the corresponding level of nature loss are very high in a particular geography in which the sectors or their supply chains are located.

8. These are: Agriculture, Fishery and Livestock; Food and Beverage; Manufacturing (paper, pulp, timber); Tourism, Travel and Hospitality; Utilities; Mining and Quarrying; and Oil and Gas.
9. For a deeper discussion, see UNDP SIF (2021).

3. Understanding future biodiversity-related risks

Building on the growing evidence of biodiversity-related risks based on mostly static impacts and dependencies, questions and challenges arise for central banks and financial supervisors in understanding and addressing these risks with a dynamic, or forward-looking, perspective. This chapter considers some of the issues around building biodiversity scenarios, and considerations for price stability and sovereign risk.

Biodiversity loss, like climate change, poses novel sources of risk to economies and financial systems. The theoretical framework, emerging methodologies and case studies discussed in the previous chapter provide insights into the current state of knowledge around the transmission of biodiversity-related risks into financial systems. A number of additional considerations and challenges surround these risks. The consequences of both climate change and biodiversity loss, and the transitions required to address them, have only begun to emerge; the future is unlikely to resemble the past. Therefore, central banks and financial supervisors will need to take dynamic and forward-looking approaches to understanding the risks involved.

3.1. Scenario analysis: dynamic approaches to assessing the sources, transmission channels and materialisation of risks[10]

For climate change, scenario analysis has emerged as a tool for providing forward-looking insights. There is now a consensus that the financial risks from climate change cannot be assessed solely with past data. This is because, depending on actions taken, there are fundamentally different future outcomes. To navigate these various future pathways and to understand associated future financial risks and economic costs, central banks and financial regulators have utilised scenario analysis. Scenario analysis is likely also to be valuable in understanding biodiversity-related impacts on the economy, including those on prices and financial stability.

Defining the narrative of a biodiversity-related scenario

Building on the static assessments explored in Chapter 2, scenario analysis provides a promising tool for central banks and financial supervisors to dynamically stress-test financial institutions and systems against specific biodiversity-related financial shocks. By simulating the effects of past crises, stress-testing has helped regulators assess the resilience of financial institutions to economic or financial shocks. However, in the case of entirely new sources of future risks, such as those related to climate change or biodiversity loss, backward-looking stress-tests are unhelpful. To address climate-related risks that could materialise in the future, central banks and academics developed new types of stress-tests using forward-looking scenarios to assess the impact of potential physical and transition shocks on financial stability.

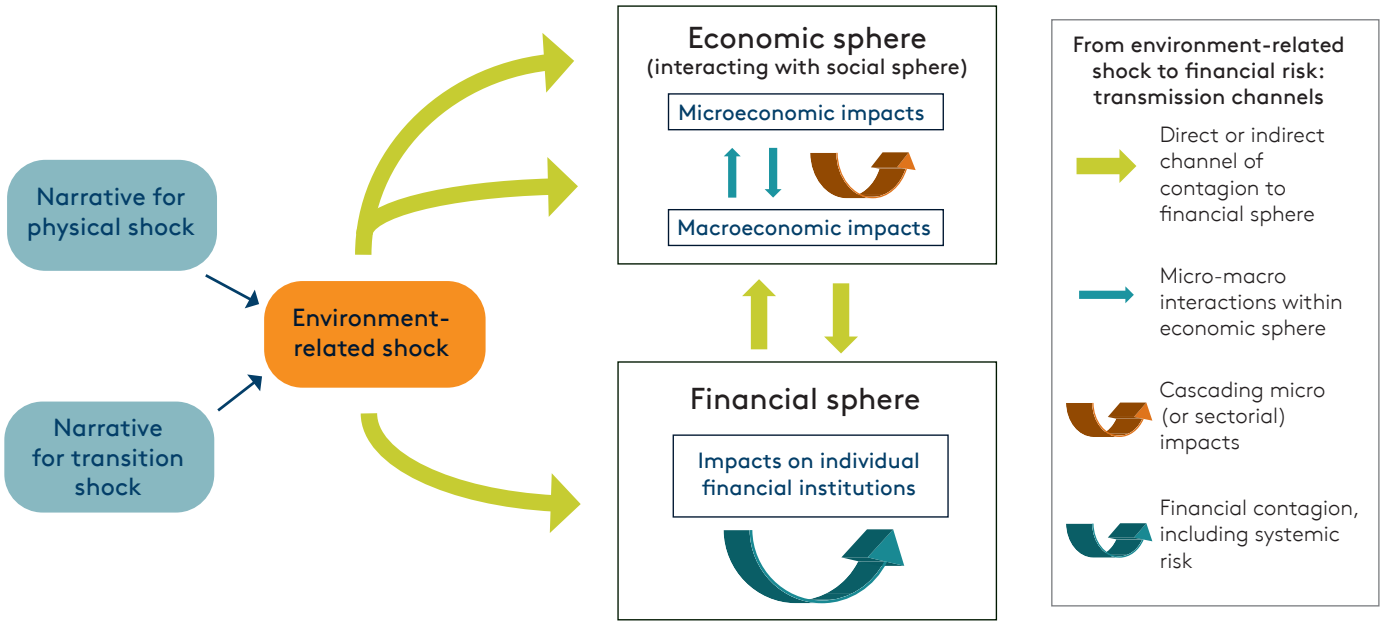
Some of the lessons learnt in developing climate scenarios for stress-testing could be applied to biodiversity-related risks. To create an environment-related stress-test (e.g. for climate or biodiversity), three theoretical steps are proposed: (1) the elaboration of a narrative of shock; (2) the modelling of its micro and/or macroeconomic consequences; (3) the modelling of its impact on financial institutions. These steps are outlined below, drawing from examples used to develop climate scenarios.

10. This section is derived from Salin and Svartzman, 2021.

- **The first step is to define the narrative regarding the specific shock that could occur.** An example of a climate-related physical shock is rising CO_2 emissions (initial shock) leading to rising global temperatures and impacts on prices and productivity. Meanwhile, climate-related transition shocks could arise in the form of the introduction of specific policies aimed at reducing carbon emissions or changes in technologies or consumer preferences (Vermeulen, 2018).
- **The second step is to model consequences at the micro- and macroeconomic levels.** Microeconomic exposures include exposures of individual firms or households to localised climate shocks such as floods or cyclones, or increased costs in response to changing policies or consumer preferences. Macroeconomic exposures include impacts on inflation, GDP, unemployment, or long-term interest rates in response to changing policies such as the introduction of a carbon tax (NGFS, 2021b; Vermeulen et al., 2018) or to physical climate shocks like severe weather events.
- **The third step consists of incorporating macrofinancial variables from steps 1 and 2 into financial models to assess the impact of shocks on financial institutions.** This would enable the assessment of the resilience of individual financial institutions and the global financial system to the specific shock and its transmission. These steps are summarised in Figure 13 (see Appendix 5 for a detailed description).

While the design of climate- and biodiversity-related risks share some characteristics, there are unique challenges in constructing a biodiversity scenario analysis. For transition shocks, a key challenge is the lack of specific biodiversity targets or metrics comparable to those for climate change, such as the 1.5°C (or 2°C) threshold and CO_2-equivalent. For physical risks, these challenges include: the uncertainties and non-linearities in terms of biodiversity-related risks, which makes consistent and comprehensive scenarios on the future evolution of ecosystems difficult to build; the multiplicity of pathways; and the lack of biodiversity equivalents of the Representative Concentration Pathways (RCPs) used in physical climate risk scenarios.

Figure 13. An environmental stress-test: mapping the key relationships



Source: Adapted from Salin and Svartzman, 2021

A further challenge for developing biodiversity scenarios is the determination of an appropriate time horizon, as biodiversity impacts may materialise sooner than those of climate change. Physical impacts are likely to materialise relatively soon (Johnson et al., 2021), while most biodiversity policies aim for transformative impacts by 2050, with intermediary targets coming into effect by 2030, thus justifying the consideration of short- to medium-term horizons for biodiversity scenarios.

Potential ways forward – narrative approaches

To develop narratives for transition shocks, a list of existing and announced biodiversity policies could provide a starting point (what Jacquetin [2021] calls an "enumerative approach"). For example, De Nederlandsche Bank assesses the potential financial impacts in a scenario whereby 24 per cent or 30 per cent of land globally becomes protected (van Toor et al., 2020). The current lack of an overall global biodiversity target necessitates the inclusion of several 'credible' sources of transition risks to substantiate the emergence of a risk. Creating credible narratives could also help raise awareness about the existing biodiversity targets and future policies that could lead to stranded assets. This could then improve understanding on the microeconomic and financial impacts of biodiversity loss on firm-level metrics such as non-performing loans throughout value chains (see e.g. Godin and Hadji-Lazaro, 2021).

It is vital to note, however, that biodiversity objectives and policies are very diverse, and thus may be difficult to include into economic models. This makes it challenging to develop a comprehensive and consistent scenario. To improve the scope and consistency of the model would require a thorough mapping of different transition policies that could take place and to carefully select those with the greatest potential economic and financial impacts. This approach would require granular data and an analysis of cascading impacts through value chains, both of which can be difficult, especially if the goal is to assess several shocks at the same time.

An alternative approach to constructing narratives for transition shocks involves creating hypothetical policies or transformative changes that would limit biodiversity loss and cause a severe economic shock (a "hypothetical approach", in the typology by Jacquetin [2021]). For example, this might involve imagining a scenario in which firms must pay a price for each unit of their biodiversity footprint (similar to paying a price for carbon).

While this approach would be easier than listing all existing or possible policies, there are a number of limitations. The first is that by placing a price tag on a unique metric that would apply to all sectors, it would be difficult to distinguish between production processes with different impacts on biodiversity across and within sectors (e.g. intensive versus organic farming). In addition, the credibility of such a scenario could be questioned, and its didactic dimension would be limited. Some of these shortcomings could be addressed by focusing on precise – and severe – hypothetical policies at the sectoral level. For example, a possible scenario could be the introduction of payments for land restoration to address the negative impacts of the artificialisation of soil by an economic sector. However, this approach would come at the expense of a comprehensive view.

For physical shock narratives, hypothetical narratives could be created by creating scenarios in which biodiversity tipping points are crossed, resulting in severe shocks. This is the approach adopted by the World Bank and De Nederlandsche Bank (Johnson et al., 2021; van Toor et al., 2021). One challenge that could emerge from this approach is that while current data enable a narrow focus on the deterioration of limited provisioning ecosystem services (e.g. pollination), capturing services such as erosion or disease control

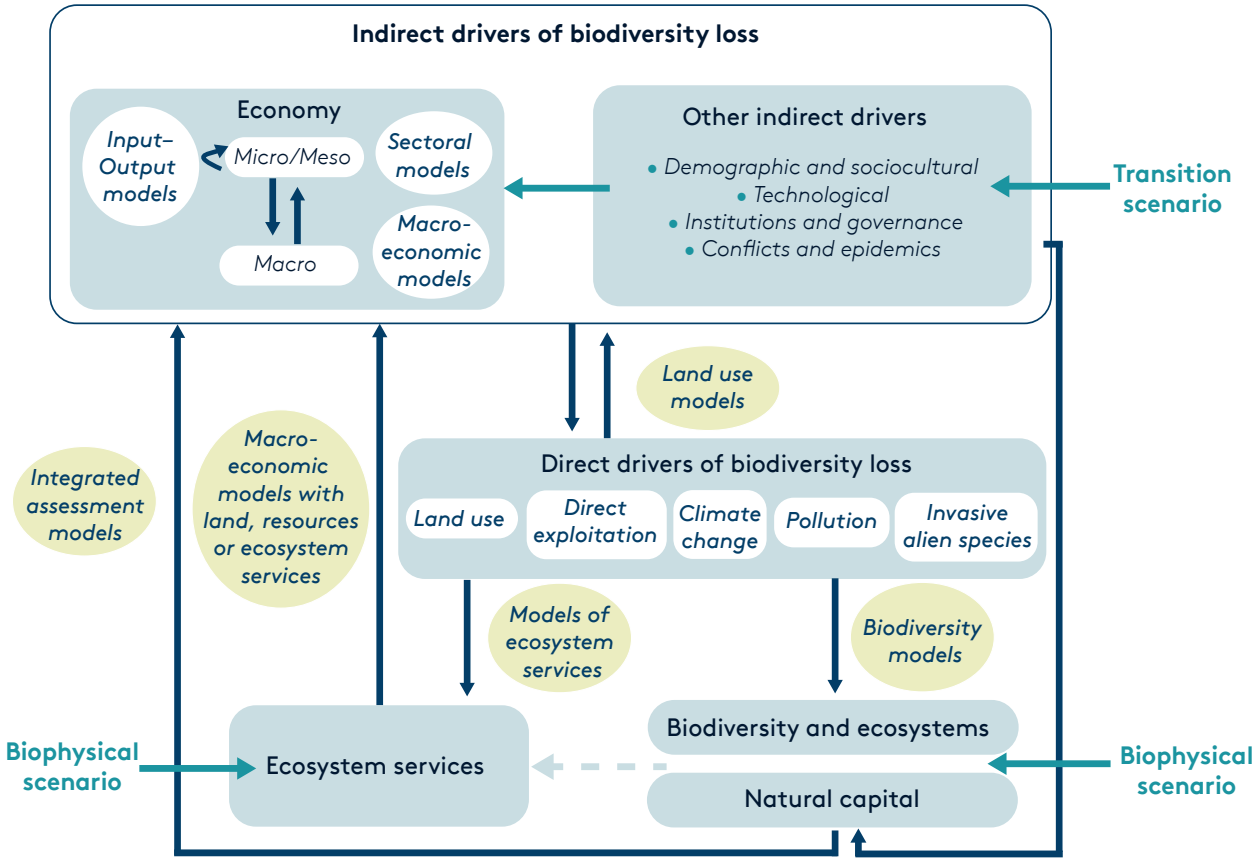
would be harder. As such, the potential impacts of these hypothetical shocks could be underestimated. Another deliberation is whether scenarios should focus on the decline of individual ecosystem services (e.g. loss of flood storm protection) or of the ecosystem that provides these services (e.g. mangroves).

Narratives for physical shocks can also be created using a 'historical approach'. For example, shocks from COVID-19 could be used to model a shock to the economy caused by a pandemic. Modelling the effect of a similar event occurring in the future would provide a credible narrative for a shock due to a zoonosis-caused pandemic because the shock has been experienced. However, this approach has its limitations given that many biodiversity-related physical risks are unprecedented within human history.

Economic modelling of the narrative

Capturing the macroeconomic and sectoral consequences of physical or transition shocks would require specific integrated models or modelling frameworks (using a combination of existing models), some of which are starting to emerge. This section provides an overview of five types of existing models: economic, land-use, economy–environment, biodiversity and ecosystem services (see Appendix 5 for a more detailed discussion of these models).

Figure 14. Modelling biodiversity–economy interactions



Source: Salin and Prudhomme, 2021

Economic models are useful in assessing the biodiversity–economy linkages. Two types of models in particular have been used to demonstrate these links:

1. **Sectoral and macroeconomic models** represent the functioning of the economy and can be useful to assess the effect of physical or transition risks on a specific sector or macroeconomic variables. As an example, Banque de France used these models to assess the economic impact of an increase in the price of carbon (i.e. a transition shock) (Allen et al., 2020).
2. **Input–output models** represent the links between the production of economic sectors with the final (consumer) demand and the intermediary demand by other economic sectors. This allows the model to be used to assess the cascading effect of policies aiming at mitigating climate change, such as the stranding of carbon assets (Cahen-Fourot et al., 2021; Godin and Hadji-Lazaro, 2021).

Land-use models can provide insights into the relationship between biodiversity and the economy, particular as land-use change is one of the biggest drivers of biodiversity loss. Land-use models can be used to explore potential future impacts on biodiversity and ecosystem services and evaluate potential trade-offs between different demands for land use (e.g. for food, resources, energy, climate change mitigation and biodiversity conservation) (van Soesbergen, 2016). There are various types of land-use model, including land-use modules in integrated assessment models (IAMs), economic-based land-use models (unrelated to IAMs), and models of rules-based allocation of land uses.

Environment–economy models allow for a better understanding of the economic impact/cost on biodiversity. The two types of environment–economy models are:

1. **Integrated models,** which include nature in the production function and a feedback loop of the impact of the economy on nature. The bounded economy model proposed by Dasgupta (2021) is an example of an integrated model.
2. **Macroeconomic models that include 'natural capital'** (or 'ecosystem services') in the production function but exclude any feedback loop from the economy to the environment.

The final two models, of biodiversity and of ecosystem services, can also be valuable in understanding the implications of biodiversity loss on the economy and financial system.

- **Biodiversity models** translate direct drivers of biodiversity loss (such as land use) into impacts on biodiversity, which are expressed with different types of metrics depending on the model.
- **Models of ecosystem services** translate the state of ecosystems (e.g. the type of land use or the stock of fish) into spatially explicit ecosystem service flows for human populations (e.g. pollination or fish provision), which can be expressed in biophysical or economic terms.

While these models are useful in their own right, they can also be combined to assess the possible consequences of specific scenarios for the economy or for ecosystems and biodiversity. For example, two or more of these could be combined to better understand the economic impact of a physical or transition shock, through constructing an integrated view of the dependencies and impacts of the economy on biodiversity and assessing the impact of policies to address biodiversity loss.

These models can help central banks and supervisors gain some insight into the ways in which biodiversity-related shocks can impact the economy and financial system (and vice versa), but these models are not without their limitations or application challenges. The models are not able to provide high levels of certainty of future events. This is compounded by the complexities surrounding biodiversity, including the existence of irreversible tipping points that alter the biosphere, the absence of clear biodiversity targets (and direction of future policy) to model transition shocks, and the lack of granular data. A challenge in adapting economic models to suit biodiversity indicators and metrics is that it requires a specific skill-set that may be outside the capabilities of central banks and supervisors. Capacity-building and upskilling could address this challenge, and help central bankers incorporate biodiversity into their macroeconomic assessments. A further challenge is that future scenarios may need to consider the interplays between climate and biodiversity, given the synergies of these environmental systems. This could be an avenue for future research.

3.2. Other dynamic considerations and challenges

In addition to the topics discussed above, integrating biodiversity-related issues into central banks' analytical frameworks will also call for the further exploration of specific issues, a selection of which are introduced below.

Integrated biodiversity and climate change scenarios

Given the interactions between climate change and biodiversity loss discussed above and the considerable work that has already gone into climate scenarios, there is a strong case for taking an integrated approach to scenario construction. The first step could be to incorporate aspects related to biodiversity into existing climate transition scenarios, such as how additional constraints on land use for biodiversity protection could make climate risk mitigation more or less difficult. However, independent biodiversity scenarios could also be developed, as most biodiversity loss is due to causes other than climate change, requiring specific policies beyond those designed to promote decarbonisation.

Biodiversity loss and price stability

Research into and evidence of the relationship between biodiversity loss and price stability is currently limited. However, parallels can already be drawn with the emerging research and evidence on the relationship between climate change and price stability.

Over a short time horizon, extreme environment-related events could have a significant impact on the aggregate economy and inflation. For example, disruptions in ecosystem services (e.g. a decline in pollinator species, or a decline or alteration of soil microbiota) could affect global food and other commodity production, potentially causing commodity price inflation. More generally, the degradation of other capital assets (physical or human) due to physical shocks arising from biodiversity loss could reduce aggregate supply, while responses by governments to nature-related events (e.g. fiscal support) could increase aggregate demand, and increase debt or add to fiscal pressure. The net effect of environment-related physical shocks on aggregate demand and supply would determine their impact on short-run inflation dynamics. These effects could be compounded if extreme environment-related events occur simultaneously in different regions or affect multiple parts of global supply chains.

Over a longer time horizon, gradual losses in biodiversity would reduce the potential level and growth rate of an economy. Biodiversity loss results in direct reductions in

the stock of natural capital and therefore the aggregate supply of an economy. In turn, reductions in natural capital could also have implications for other forms of capital. For example, zoonotic diseases or food system instability could have implications for labour productivity caused by diminished physical or cognitive performance of workers. A change in aggregate supply because of biodiversity loss would therefore have implications for supply chains, and therefore for inflation.

Responses made to mitigate biodiversity loss could also have potential effects on inflation dynamics. For example, the introduction by governments of pricing and/or quantity-based policies could potentially precipitate large and long-lasting impacts on relative prices. Technological advances could also affect prices, for example as productivity improvements in terms of more 'biodiversity enhancing' efficient use of natural capital (e.g. increased agricultural yields through agroforestry practice) lead to lower prices of certain goods. Changes in consumer sentiment or social norms in relation to biodiversity loss could alter purchasing decisions of certain goods and services (e.g. boycotts or substitution), altering relative prices, and potentially causing inflation.

The tools at central banks' disposal to deal with biodiversity-related shocks are limited. For instance, it has been noted that environment-related supply shocks often pose a dilemma for central banks, forcing them to choose between stabilising inflation or economic activity (Cœuré, 2018). This highlights the importance of coordination among different government agencies in addressing such impacts (Bolton et al., 2020), as discussed further in Chapters 4 and 5.

Biodiversity loss and sovereign risks

Biodiversity-related risks can also have implications for sovereign debt, the world's largest asset class (Pinzón and Robins, 2020). The impact of degrading biodiversity will depend on the structure of an economy, and on the synchronisation or asymmetry of biodiversity-related shocks across countries. Economies that depend to a larger extent directly on the productivity of natural resources (e.g. agriculture, fisheries, forestry) will likely be most impacted as their productive capacity declines.

Countries that are dependent on the production or export of goods with a negative impact on biodiversity (e.g. palm oil or beef production responsible for deforestation) may see their fiscal income or balance of payments negatively affected by a transition aiming at reversing biodiversity loss. An example of the former is the EU's proposal for legislation requiring companies to demonstrate that their products do not contribute to deforestation through their supply chains (European Commission, 2021a). Such a measure could also have significant impacts on importing countries. For instance, it could increase the price of commodities in the EU and create a source of transition risk for exporting countries.

On the physical risk side, the degradation of ecosystems can also trigger a collapse of ecosystem services that will in turn affect public finances and thus debt sustainability. Investors therefore may begin to charge a risk premium for debt issued by sovereigns that are degrading their natural capital. A higher interest burden will increase credit risk and raise interest rates further, potentially setting off a vicious circle. As a nation's natural capital declines, the need for additional food imports adds negative pressure on the current account balance and external debt position. These pressures will be more acute for developing countries where natural capital often accounts for a greater proportion of their wealth than richer countries, and where levels of indebtedness have increased as a result of the COVID-19 pandemic. However, they could also impact developed countries through different cascading effects.

Box 8 | Estimating the implications of ecosystem service collapse on sovereign debt sustainability and credit ratings

Agarwala et al. (2022) have developed a model* that uses a random, forest classification machine-learning technique to estimate the credit rating implications for 26 sovereigns in the case of a partial collapse of ecosystem services (see Figure 15, next page). While some countries would see little or no impact, some face prospects of significant downgrades. A partial collapse of ecosystem services would most directly impact the creditworthiness of lower-rated sovereigns in emerging and developing countries.

Kraemer and Volz (2022) argue that by not considering biodiversity, debt sustainability assessments (DSAs) used by bodies such as the IMF potentially miss a significant economic and financial risk. This could lead to a partial view of debt sustainability, erroneous policy recommendations and an increasing risk of avoidable debt crises. The IMF has started to incorporate climate risks into its key surveillance and monitoring exercises. It has also begun to explicitly reflect biodiversity risk in some economic assessments, notably for the Solomon Islands, but that remains an isolated example.

Integrating biodiversity risk into DSAs is not without its challenges. Like climate change, risks of biodiversity loss are non-linear, and tipping points are hard to predict. Moreover, the analysis is at times complicated by a need for reliable data to quantify environmental risks, given that DSAs are fundamentally quantitative models. Building on experiences with climate risk analysis, the most promising approach to incorporating biodiversity into DSAs is therefore via scenario analysis and biodiversity risk stress-tests (see section 3.1, above).

Scenario building is a crucial first step in integrating biodiversity risk into DSAs, but existing estimates of GDP impacts can also be fed into DSA models. Kraemer and Volz (2022) used GDP estimates for a partial ecosystem collapse from Johnson et al. (2021) to conduct a DSA for a number of countries, including Indonesia, assuming a biodiversity shock impacting from 2025. It finds that Indonesia's debt-to-GDP ratio rises to 65 per cent without increases of interest rates on government debt and to 65.4 per cent with an interest rate reaction. This compares with a debt ratio of 51.9 per cent under the baseline scenario. This partial nature collapse would be more damaging than the COVID-19 pandemic to Indonesia's debt sustainability. Although the timing of such a calamitous event cannot be predicted with any precision, this illustrates the importance of including such 'green swan' events in the standard scenarios regularly applied by the IMF.

**The modelling approach is split into two steps. In step 1, a random forest model is developed to process macroeconomic data for a range of countries and their associated credit ratings. This random forest model is able to make predictions about credit ratings with new data with high accuracy. In step 2, the macroeconomic data is adjusted for changes in GDP, as predicted by Johnson et al. (2021), under a scenario of a rapid partial collapse of ecosystem services (including the production of forestry and fisheries products, pollination and other services directly provided by nature) by 2030, following the crossing of tipping points. The model developed in step 1 is then used to predict the ratings change, given the new data.*

Figure 15. Rating changes in the event of partial nature collapse (in notches)

Source: *Agarwala et al. (2022)*

Conversely, those countries effectively protecting or even enhancing their biological assets could in principle see their creditworthiness improved, because losses elsewhere make their conserved natural assets globally scarcer and thus potentially more valuable. However, the potential need for significant near-term public outlays to deliver longer-term benefits to natural capital and improved resilience may lead to downward pressure on credit ratings and debt sustainability, given the short-term focus of many sovereign debt investors and rating agencies.

Neither credit rating agencies nor international financial institutions such as the International Monetary Fund (IMF) are adequately incorporating biodiversity-related risks into their assessments. Sovereign risk assessments that omit biodiversity and environment-related risks are incomplete, leading to mispriced risk and reducing the relevance and reliability of sovereign credit ratings. However, initial efforts to incorporate biodiversity and nature-related risks into sovereign ratings have proved insightful (see Box 8 above).

4. Critical challenges to the financial system in responding to biodiversity loss

Addressing risks related to biodiversity loss will require action across the financial system. Priority areas such as the development of biodiversity-related financial disclosure standards, conservation finance, market conduct, prevention of environmental crime, and international financial flows, may not fall directly within the mandates of central banks and supervisors. However, they should consider their relevance as they address biodiversity-related financial risks. This chapter provides an overview of these areas and offers potential suggestions for where central banks and supervisors can engage on these subjects.

4.1. Incorporating biodiversity into disclosure[11]

While disclosure on its own cannot result in a shift to a biodiversity-positive economy, it is a necessary and foundational condition for financial markets to price in biodiversity impacts and dependencies and act on them. To the extent that biodiversity loss is a systemic financial risk, the poor quality of biodiversity-related financial disclosures may have significant implications for financial markets and authorities. Securities regulators' objectives of fostering investor protection and the promotion of fair, efficient and transparent markets cannot be achieved in the absence of comparable and comprehensive disclosure of biodiversity-related financial information by issuers. Prudential authorities need high quality, reliable, granular reporting on biodiversity-related financial risk in order to supervise the safety and soundness of financial intermediaries and monitor the stability of the financial system.

Capital providers and other market participants, such as companies offering research, ratings and data products and services, need comparable, consistent and reliable biodiversity-related disclosures to support risk pricing, capital allocation and stewardship activities. Capital providers integrate such biodiversity-related financial information into the analysis of enterprise value creation and creditworthiness. Investors, both institutional and retail, may also need biodiversity-related disclosures at the level of the investment fund product, to ensure alignment with their preferences regarding risk appetite and biodiversity impacts. Finally, financial institutions may be expected by their shareholders and financial authorities to disclose biodiversity-related financial information that spans their entire portfolio.

Research into sustainability disclosures conducted by the International Organization of Securities Commissions (IOSCO), among others, found a number of shortcomings, risks and challenges to current practice, which appear particularly serious in the case of biodiversity:

- **Biodiversity-related disclosures are of an even poorer quality and quantity than disclosures on climate and other better understood sustainability topics, such as water risk and labour issues.** Regarding sustainability reporting in general, IOSCO found issues with regard to, among other shortcomings: the completeness, consistency and comparability of disclosures, with variations across and within jurisdictions, by company size and sector; a lack of consensus on how to define

11 This section is derived from Stampe, 2021.

sustainability matters; limited quantitative information and details on impacts on financial performance; selective reporting by companies against different standards and frameworks; and marked differences in the scope and quality of assurance affecting the reliability of disclosures (IOSCO, 2021b). Some reporting entities may already include biodiversity-related elements in their sustainability disclosures but most do not. For example, more than 10,000 companies report using the Global Reporting Initiative (GRI) standards but just over 2,000 of them use the GRI biodiversity standard (GRI 304) (GRI, 2021). Of the almost 10,000 companies that disclosed through CDP in 2020, only 687 companies disclosed through the CDP forests programme (CDP, 2020; 2021). KPMG reviewed sustainability reporting from 5,200 companies in 52 countries and jurisdictions and found that less than 25 per cent of large companies at risk from biodiversity loss report on the topic (KPMG, 2020).

- **Shortcomings in biodiversity-related disclosures by companies flow through to environmental, social and governance (ESG) ratings and data products, risking misallocation of capital and greenwashing.** The use of ESG ratings and data in the investment and fund creation process is pervasive, especially in the fast-growing sustainable index fund space. IOSCO conducted a fact-finding investigation into ESG ratings and data providers that revealed weaknesses such as insufficient transparency around rating methodologies, and information gaps due to uneven coverage across industries and geographical areas; building on this, IOSCO has recommended that regulators consider focusing more attention on their use and providers of these products (IOSCO, 2021a). Biodiversity loss is a relatively new subject matter compared with carbon emissions, with no global consensus on indicators, measurement methodologies or metrics (see below). In addition, many biodiversity hotspots are located in emerging market and developing economy (EMDE) jurisdictions that may have less robust disclosure regimes and lower coverage by ESG ratings and data providers compared with developed countries. It is therefore even more unclear whether and how comprehensively biodiversity loss is measured and reflected in ESG ratings and data products.

- **The current state of investment product-level disclosures relating to sustainability factors creates additional challenges to managing biodiversity-related financial risks and allocating capital to biodiversity-positive opportunities.** IOSCO found examples of different types and severity of greenwashing and mis-selling across over 20 member jurisdictions. It has recommended that securities regulators and/or policymakers consider adequate regulatory requirements to improve product-level disclosures so investors can better understand sustainability-related products and material sustainability-related risks for all products (IOSCO, 2021b). More discussion of challenges related specifically to conservation finance can be found in Section 4.2.

The challenge now is to increase and enhance biodiversity-related disclosures, considering both the specificities of the topic, which calls for its own set of indicators, measurement methodologies and metrics, and developments underway to address the issues that sustainability disclosures encounter more generally, including to avoid further fragmentation of the disclosure landscape. A common approach across financial authorities within and across jurisdictions is critical to the ability of the global financial system to robustly incorporate biodiversity factors into risk pricing and capital allocation. The global nature of supply chains that act as biodiversity risk transmission channels also calls for consistency across jurisdictions.

To avoid further fragmentation, the IFRS Foundation recently established the International Sustainability Standards Board (ISSB) to create a global baseline for sustainability disclosure standards. The ISSB standards will improve the global

consistency, comparability and reliability of reporting, and will likely include biodiversity in the Foundation's workplan for the medium term, although climate will be the first thematic standard to be issued. The ISSB plans to issue the IFRS Sustainability Disclosure Standards, starting with a climate disclosure standard in 2022 that leverages the recommendations of the Task Force on Climate-related Financial Disclosures (TCFD), alongside a General Requirements standard. Before standards for other specific sustainability topics are created, issuers can use the General Requirements standard to provide material sustainability-related information, including biodiversity supplemented by topical reference materials from other standard-setting bodies. These would include:

- The application guidance for biodiversity-related disclosures published in November 2021 by the Climate Disclosure Standards Board (CDSB), whose technical standards and frameworks were consolidated into the ISSB in January 2022.
- The Value Reporting Foundation's (VRF) SASB Industry Standards, which cover 77 industries and which include biodiversity-related issues such as ecological impacts and pollution (via air quality, wastewater and waste management), with VRF resources to be consolidated into the ISSB before June 2022.
- The European Financial Reporting Advisory Group's (EFRAG) draft biodiversity standard, to be co-constructed with the Global Reporting Initiative and published in June 2022 (see below).
- The Global Reporting Initiative's biodiversity standard, which is already used by issuers and is being updated in alignment with EFRAG before the end of 2022.

The main features of these intended standards are as follows:

- The IFRS Sustainability Disclosure Standards are designed to enhance linkages between financial statements (via connectivity between the ISSB and IFRS International Accounting Standards Board [IASB]) and sustainability-related financial information. Connectivity with financial statements will encourage issuers to perform robust assessments of the impact of biodiversity loss on their financial performance and position. This increases issuers' understanding of their dependencies on ecosystem services that are currently not reflected in financial statements.
- The dynamic materiality approach of the ISSB will allow for issues to become incorporated into disclosures as they become material to enterprise value creation over the short, medium and long term. This will pave the way for future incorporation of biodiversity information into the enterprise value creation threshold, as the materiality of various biodiversity impacts is likely to increase over time, in line with changes in policy, science, stakeholder preferences and technology. As issuers begin reporting on biodiversity impacts through a multi-stakeholder lens, capital providers can factor this information into scenario analysis to assess potential future transition risks to their portfolios. For example, the 2021 Inevitable Policy Response (IPR) scenarios include policies forecast to end deforestation in major tropical forest countries by 2030 (Principles for Responsible Investment [PRI], 2021). At the COP26 climate summit, more than 100 world leaders representing over 85 per cent of global forests committed to ending and reversing deforestation and land degradation by 2030 (HM Cabinet Office, 2021), potentially resulting in the materialisation of this policy forecast.

International fora are supportive of the imminent publication of the IFRS Sustainability Disclosure Standards. Subject to its endorsement of the ISSB standard, IOSCO will encourage its 130 members to consider adopting the ISSB standards when setting sustainability-related disclosure requirements. The support expressed for the ISSB by the International Association of Insurance Supervisors (IAIS) and the Basel Committee for Banking Supervision (BCBS) is a promising start to enhance the regulatory application of the ISSB across the wider financial ecosystem (IAIS, 2021; Bank for International Settlements [BIS], 2021).

The common approach will facilitate and reinforce the consideration of biodiversity risks and opportunities by equity, bond, insurance and loan markets, allowing the finance sector to contribute to a nature-positive outcome. It is also aligned with the recommendation of the Financial Stability Board that coordination on climate-related disclosures among financial authorities at the jurisdiction level and across jurisdictions is critical to accelerating progress on a global adoption of international reporting standards based on the TCFD Recommendations. This recommendation would also apply to biodiversity-related financial disclosures. In November 2021, G20 leaders endorsed the G20 Sustainable Finance Roadmap, produced by the G20 Sustainable Finance Working Group. The Group welcomed the establishment of the ISSB, and stated that "the ISSB should over time extend coverage from its initial focus on climate-related information to include other sustainability-related topics such as nature, biodiversity and social issues" (G20 Sustainable Finance Working Group, 2021). This statement represents, for the first time, a G20-level policy consensus that sustainability reporting should include biodiversity-related information.

Some jurisdictions have already taken steps towards mandatory, biodiversity-related disclosures that have come into force in the short term and cover both biodiversity-related risks and impacts. For example:

- **France became the first country to introduce mandatory reporting for biodiversity, under Article 29 of its 2019 Energy Climate Law.** In May 2021, a decree implementing Article 29 requires financial investors to disclose biodiversity- and climate-related risks and impacts starting in 2022 (with full scope as of 2023), using the concept of double materiality. With regard to environmental materiality, financial institutions will have to disclose their strategy to align with long-term biodiversity goals, including a measure of their compliance with the objectives of the Convention on Biological Diversity, an analysis of their contribution to reducing the impacts and pressures listed by IPBES, and a mention of the use of a biodiversity footprint indicator. On financial materiality, financial investors will have to disclose information on how they consider ESG factors in risk management, explicitly including physical, transition and liability risks related to biodiversity loss, as well as dependencies and impacts. However, for now, the decree does not define the methodology of indicators (Ministère de L'Économie, des Finances et de la Relance, 2021).

- **The EU has also taken a mandatory approach to biodiversity reporting, with its proposed Corporate Sustainability Reporting Directive (CSRD).** The directive will extend mandatory corporate sustainability disclosure requirements to all large and/or listed companies, numbering almost 50,000. According to the proposed directive, the mandatory sustainability reporting standards developed by the EFRAG will cover all six environmental objectives defined by the EU Taxonomy Regulation, including biodiversity and ecosystems (European Commission, 2021b). In addition, Article 8 of this Regulation requires entities in scope to report the alignment of their revenues, operational expenditures and capital expenditures (in the case of financial institutions, assets or underwriting premiums) with the Taxonomy. In 2022,

the European Commission will publish a delegated act covering activities with a substantial contribution to biodiversity and ecosystems, along with three other environmental objectives not already covered by the existing climate delegated act (European Commission, 2021c). (See Box 9.)

What remains to be resolved is the lack of consensus around an agreed set of biodiversity indicators, measurement methodologies and metrics that can be incorporated into the standards and requirements mentioned above. Private sector-led initiatives are underway that can help develop biodiversity risk and impact measurement methodologies and metrics and bridge data gaps. The following are of particular note:

- The **Taskforce on Nature-related Financial Disclosures (TNFD)** is developing a reporting and risk management framework that aggregates the best tools and materials to assess and manage nature-related risks and opportunities arising from impacts and dependencies on nature. It released a beta version of its Nature-Related Risk & Opportunity Management and Disclosure Framework in March 2022 (TNFD, 2022). The TNFD does not intend to develop a disclosure standard per se, but rather to contribute its technical outputs to advance the development of a common set of accounting metrics and indicators to support comparable and consistent biodiversity-related financial disclosures. It comprises representatives from financial institutions, corporates and market service providers, supported by a multi-stakeholder forum with over 250 members, including public financial institutions and central banks, and by knowledge partners, including CDP, the Global Reporting Initiative, the SASB Standards Research Team, and the NGFS.

- The **Finance for Biodiversity Pledge** has completed a public consultation on biodiversity issues, metrics and measurement tools to guide biodiversity measurement approaches by financial institutions. The Biodiversity Pledge is stated as an important reference by the Working Group on Biodiversity under the Sustainable Finance Platform set up by De Nederlandsche Bank, the Dutch Financial Markets Authority, Dutch Government ministries and financial industry associations.

- The **Natural Capital Finance Alliance (NCFA)** has been developing tools to assess impacts and dependencies on nature (e.g. NCFA created ENCORE), risk and impact measurement methodologies and metrics, target-setting and biodiversity criteria for financing policies, and so on.

- The **Science Based Targets Network (SBTN)** is a multi-stakeholder network of more than 45 organisations that is building on the momentum of the Science Based Targets initiative (SBTi) to develop methods and resources for science-based targets for nature. SBTi has issued guidance for the finance sector to set science-based targets for reductions in greenhouse gas emissions to accompany guidance for corporates. SBTi is currently consulting on its guidance on Science-Based Net-Zero Target Setting for Financial Institutions, which includes principles, definitions, metrics, portfolio alignment and target formulation considerations. The insights gained from net-zero guidance for climate could prove useful for future work on biodiversity-related targets.

Close collaboration between these initiatives and others is expected to leverage resources and avoid duplication of efforts, to accelerate the resolution of this critical outstanding gap. It will also be necessary for companies and other organisations to publish 'nature transition plans', analogous to the climate transition plans the TCFD recommends that companies produce.

Box 9 | The EU's sustainable finance taxonomy and its application to biodiversity

Rising awareness among financial policymakers about climate change and the need to limit global warming has encouraged the development of green taxonomies.

Taxonomies make it easier to identify sustainable investment opportunities, assess the sustainability profile of financial instruments and products, create a common understanding among investors, financial institutions and companies on the definition of a 'sustainable asset', improve transparency regarding an economic activity's contribution to specific [environmental or social] policy goals, and encourage capital to flow towards economic activities that align with those goals.

For example, the EU has been developing its sustainable finance taxonomy since 2018. The taxonomy aims to identify which economic activities are aligned with six environmental objectives: climate change mitigation, climate change adaptation, the sustainable use and protection of water and marine resources, the transition to a circular economy, pollution prevention and control, and the protection and restoration of biodiversity and ecosystems. The latter objective and the one related to water and marine resources explicitly relate to supporting positive outcomes for biodiversity, while other objectives may also have an impact on the drivers of biodiversity loss, in particular pollution and climate change.

Biodiversity preservation and restoration are integrated into the EU Taxonomy in two ways:

- First, via the "do no significant harm" principle: an economic activity may meet taxonomy requirements if it contributes substantially to one or more of the environmental objectives while not being detrimental to the others. In the context of achieving biodiversity objectives this entails not harming the good environmental status of marine waters, the good condition and resilience of ecosystems, or the conservation status of habitats and species.
- Second, via the substantial contribution to the two biodiversity-related objectives of the taxonomy.

The first part of the EU taxonomy, adopted in December 2021, covers the economic activities of approximately 40 per cent of the companies listed in the EU, in sectors responsible for nearly 80 per cent of direct greenhouse gas emissions. However, at this stage, the EU taxonomy only identifies activities with a significant contribution to the two climate objectives. Hence, the identification of economic activities has mainly relied upon the identification of carbon-intensive activities, rather than addressing biodiversity loss, which is only covered via the application of the "do no significant harm" principle.

The European Commission is expected to define the list of activities and applicable technical screening criteria for the remaining four objectives in 2022. Designing technical screening criteria in the case of biodiversity may prove particularly difficult as no single indicator captures and normalises the various types of impacts of economic activities on biodiversity and ecosystems. Moreover, in terms of application, it is difficult to assess biodiversity outcomes with regard to alignment to the taxonomy, as this would rely particularly on qualitative analysis and expert judgement, rather than concrete quantitative measurements.

Source: Derived from Gardes, 2022.

4.2. Conservation finance

The propagation of biodiversity-related risks throughout economies and financial systems raises questions for central bankers and financial supervisors regarding operational elements of those financial systems. These include the promotion of financial flows to support biodiversity. The Kunming Declaration calls for parties to "[w]ork with ministries of finance and economy [to] align all financial flows in support of the conservation and sustainable use of biodiversity" (CBD, 2021a).

One avenue through which to support these financial flows is to promote specialist financing that promotes positive outcomes for biodiversity, and that seeks to close the 'conservation finance gap'. Researchers have estimated that in 2019 spending on biodiversity conservation reached between US$124 billion and US$143 billion (Deutz et al., 2020). Adequately protecting biodiversity would require annual spending of between US$722 billion and US$967 billion, leaving a biodiversity financing gap of between US$598 billion and US$824 billion per year. Closing this gap, Deutz et al. (2020) suggest, would involve reducing subsidies harmful to the environment and increasing government spending to protect biodiversity, but they also see an important role for instruments such as biodiversity offsets, green financial products and nature-based carbon markets.

Evidence from the performance of private sector financial products that aim to positively impact biodiversity over the last 30 years suggest they face three issues (Dempsey et al., 2021):

- **First, the lack of rigorous, consistent and transparent science-based metrics and monitoring mean that investments in these products do not necessarily deliver biodiversity outcomes.** Biodiversity is a complex, interconnected and non-fungible quality of particular ecosystems, subject to ongoing scientific measurement debates (Mace et al., 2018). Biodiversity gains and losses are challenging to measure without multiple baselines and high levels of monitoring, which can be logistically and technically challenging. Financial products often rely on measuring a single ecosystem service or species, while a lack of transparency can allow asset managers to decide what constitutes biodiversity impact, using proprietary ratings tools and metrics that are difficult or impossible to evaluate (Dempsey et al., 2021).

- **Second, investments remain small and difficult to scale.** Low rates of return, high risk, long timelines and high transaction costs have tended to hinder investment and scalability, with few projects demonstrating that they are scalable above US$5 million. Mobilising and scaling up private finance towards biodiversity protection is challenging because many biodiversity-positive outcomes do not create revenue. Furthermore, financial products rarely address the drivers of biodiversity loss as identified by IPBES. There is little evidence that return-generating biodiversity conservation will deliver large amounts of new funding to biodiversity (Dempsey et al., 2021).

- **Third, the geographical distribution of investment does not always match areas with high biodiversity.** For-profit biodiversity finance is often geographically constrained, with the majority of investment occurring in the Global North. The geographical distribution of investment does not correspond with areas of high biodiversity. One exception is the forest carbon market, where, in 2019, 86 per cent of forest carbon credits came from Indonesia, Peru, Kenya, Brazil, the US, Guatemala, Zimbabwe and Ethiopia (Maguire et al., 2021). However, there are questions over the extent to which forest carbon offsets have delivered biodiversity gains (Dempsey et al., 2021).

Focusing on creating new financial products or investment opportunities (or attempting to scale-up existing conservation finance products) risks distracting from the role of the financial system in creating biodiversity-related financial risks. An example of this is the rise of agricultural land as an 'alternative' financial asset class over the past 20 years. A land area roughly the size of Spain was subject to large-scale land acquisitions by non-domestic investors for agricultural purposes between 2000 and 2010, much of it located in the Global South, and especially on the African continent (Anseeuw et al., 2012). Empirical studies have linked such transactions by financial actors to increased commercial pressure on land in high-biodiversity-value tropical biomes, associated with both land intensification and extensification (including deforestation) (Kedward and Ryan-Collins, 2022).

Evidence suggests that standard financial practices in the management of agricultural land, such as maximising agricultural land productivity, realising capital gains and achieving scale, are systemically associated with land-use change and intensive agricultural practices that drive biodiversity loss and degradation (ibid.). This example shows that biodiversity-related financial risks are to a certain extent endogenous, given that direct drivers of biodiversity loss can be exacerbated by dynamics originating from within the financial system itself. Policymakers may need to focus on institutional structures, incentives and market practices that affect capital allocation beyond direct pricing mechanisms. Resolving these entrenched dynamics may well require institutional and structural reforms that are unlikely to occur without significant policy interventions (ibid.).

A focus on the avoidance of harm by the financial sector could help to limit the sector's negative impacts on biodiversity. Some industrial sectors such as mining, energy and manufacturing are using a framework known as the 'mitigation hierarchy' to guide their activities towards limiting negative impacts on biodiversity (Arlidge et al., 2018). While the hierarchy does allow offsetting as a last resort, it also involves always taking into account a counterfactual of 'no development' when predicting and preventing negative impacts on biodiversity prior to development. Research suggests that the conservation benefits of avoiding impacts are likely to outweigh those of more uncertain remediation and offsetting measures once damage has occurred (Dempsey and Suarez, 2016; Lindenmayer et al., 2017; Watson et al., 2016; Kedward and Ryan-Collins, 2022).

Disincentivising biodiversity-negative investment could be a more effective way to address biodiversity risks than attempting to make biodiversity conservation investable. For instance, policymakers could encourage financial institutions to prioritise the reduction of their portfolio exposures to activities that harm biodiversity before resorting to the use of offset-type instruments (Kedward and Ryan-Collins, 2022). Moreover, identifying activities that promote biodiversity protection (a positive impact taxonomy) and those that do meet minimum thresholds regarding biodiversity (a negative impact taxonomy, or one that requires activities to 'do no significant harm') could help to align financial flows with biodiversity protection (Dempsey et al., 2021). In addition, real economy reform and the removal of perverse subsidies and other support will be needed to help disincentivise investments that harm biodiversity.

4.3. Market conduct and environmental crime

Activities associated with biodiversity loss may not only generate financial risk: they can also be illegal, generating litigation risk. Biodiversity is adversely impacted by global environmental crimes such as the trafficking of natural resources and wildlife. Environmental crime is among the top five most profitable global criminal enterprises (May, 2017), generating US$281 billion annually (Financial Action Task Force [FATF],

2021), with proceeds financing criminal, militia and terrorist groups (Nellemann et al., 2014). These crimes have devastating impacts on livelihoods, economic development, safety, security, wellbeing and health (TRAFFIC, 2020; Banks et al., 2008). Impacts are particularly acute in poorer, biodiversity-rich countries facing poor governance and corruption, both of which enable illegal natural resource extraction and drive biodiversity loss (Dasgupta, 2021).

The ability to exploit wildlife and land for large financial gains amplifies land-use change and puts further pressure on biodiversity loss. The illegal wildlife trade is valued at up to US$23 billion (May, 2017), and threatens the existence of animal species, with cascading effects on the Earth's biosphere, climate, biodiversity and vegetation (Estes et al., 2011). Illegal logging is valued at up to US$157 billion annually (May, 2017), and contributes to deforestation, climate change and rural poverty (UN Office on Drugs and Crime [UNODC], 2010). While wildlife trafficking exterminates species one at a time, causing deterioration of ecosystems over time, deforestation eliminates entire ecosystems quickly (ibid.), potentially causing irreversible impacts in a short timeframe.

The scale of environmental crimes is too large to occur without widespread financial crime and corruption (TRAFFIC, 2020). Tax havens, for example, have been implicated in connection with illegal, unreported and unregulated fishing, as well as deforestation in the Amazon basin (Galaz et al., 2018). Financial transactions related to environmental crime sometimes occur via financing trade with falsified details (TRAFFIC, 2020) and through legitimate banking and online payments platforms (Nelleman, 2018). The involvement of third parties in the shipment process and the availability of a licit trade (e.g. timber) makes it easy for the perpetrators to conceal origins and deceive buyers (UNODC, 2010) so that it is difficult to isolate and trace these transactions. However, advances in technology such as satellite imagery and blockchain could help overcome this challenge.

In addition to driving biodiversity loss, these illicit financial flows threaten economic development. These outflows deprive countries of resources that could be used to finance public services required for economic development such as security, justice, education and health (Nellemann et al., 2014) and limit capital available for private investment. Illicit financial flows, including from environmental crimes, can also drain foreign exchange reserves, affect asset prices, lower tax receipts and distort competition (IMF, 2021). These activities could expose banks to various forms of risk that undermines their business, including reputational and legal risks (Fundanga, 2003).

The cross-border nature of financial flows relating to environmental crimes, as well as their global impacts, make this an international concern. In June 2021 the G7 Finance Ministers acknowledged the severity of environmental crime and agreed to implement measures to tackle illicit financial flows stemming from environmental crimes (HM Treasury, 2021b). While it is well-understood that protecting these natural resources is a global responsibility requiring international coordination, constrained resources impair monitoring and enforcement.

The responsibility of financial supervisors for ensuring good financial conduct brings some elements of biodiversity risk under their aegis in this regard. Depending on their mandate, central banks and financial supervisors may have the responsibility to ensure compliance to legislation regarding anti-money laundering (AML) and countering the financing of terrorism, market integrity and/or consumer protection. Those that do not have such explicit functions can still work in partnership with law enforcement agencies and other stakeholders to identify risks relevant to their mandates. As part of prudential supervision, they can integrate these considerations when assessing, for

example, operational risk related to non-compliance, as well as risk management and governance arrangements.

In the short term, increased supply chain transparency would allow financial institutions to accurately price risk (Finance for Biodiversity, 2022). A number of financial institutions already track occurrences of environmental crime in their financial value chains, to adhere to compliance requirements and avoid reputational and litigation risks. This could be further encouraged. A risk framework such as AML would help financial institutions to avoid mispricing the exposure of their investments and make better-informed financing decisions. It would also prepare financial institutions to avoid potential sources of transition risk if new laws to curb environmental crimes were introduced. For example, in the United States, the Lacey Act bans trafficking of illegal forest or animal products across US state lines or international borders.

Central banks and financial supervisors can play an important role in ensuring that financial institutions are not complicit in biodiversity-related crime (e.g. illegal wildlife trade, illegal deforestation, illegal fishing). Tax havens and other forms of tax evasion could be addressed for their roles in supporting economic activities linked to illegal environmental action (Galaz et al., 2018). Addressing financial crime of this nature may include working with non-traditional partners such as environmental crime investigators and protection agencies, strengthening operational capacity to detect and pursue financial investigations into these crimes, and implementing existing AML standards that are relevant (Finance for Biodiversity, 2022), including to strengthen customer due diligence (FATF, 2021).

4.4. Geographical dimensions: international linkages and spillovers

Like climate change, the causes and implications of biodiversity loss do not respect national borders. While many impacts of biodiversity loss tend to be localised, there are a number of international dimensions to the challenges faced by central banks and financial supervisors in addressing the consequences of biodiversity loss. These include the existence of systemically important biomes, the contribution of international financial flows to biodiversity loss and protection, and the transmission of biodiversity risk through supply chains.

A number of biomes have been identified as critically important for global climate stability, notably the Amazon Rainforest and the boreal forests of North America and Eurasia (Steffen et al., 2015). The resilience of these biomes is affected by both climatic and non-climatic anthropogenic drivers, such as deforestation driven by economic activities and their associated financing (Galaz et al., 2018). The systemic importance of these biomes suggests that their resilience, and their vulnerability to tipping points, need to be factored in by policymakers around the world, as well as those directly responsible for them.

Many of the companies involved in the potentially unsustainable exploitation of these biomes are recipients of investment from international investors. It is possible to trace substantial ownership of these companies to these investors. Galaz et al. (2018) follow five steps to do so: identifying the main drivers of land-use change in each biome; identifying the most important industrial sectors in each biome associated with those drivers; identifying the largest companies in each sector by market share; analysing the ownership of selected strategic companies; and identification of the prevalent shareholders. Their research shows **substantial ownership of key companies in these biomes by a small number of large passive investment managers.** These collectively hold more than 10 per cent of the stock of two of the eight most important companies

in the Amazon biome, two out of 16 in Canada's boreal forests, and three out of five in Russia's boreal forests (ibid.).

This kind of research illustrates the importance of a relatively small number of financial actors to the resilience or otherwise of key biomes. On one hand, it exposes potential concentrations of biodiversity-related financial risks. On the other, it suggests that these actors could wield considerable influence in ensuring that the companies they own in these critical biomes take steps towards sustainable use.

Biodiversity risk from the degradation of these biomes, and of other biodiversity hotspots, is transmitted along supply chains that often stretch around the world. Wiedmann et al. (2015), for example, propose an indicator called the "material footprint", defined as "the global allocation of used raw material extraction to the final demand of an economy" with the goal of signalling a country's responsibility – in terms of consumer responsibility – for "impacts associated with raw material extractions worldwide". International trade, the authors observe, relies on the extraction, processing and transporting of raw materials, pushing biodiversity loss further. A result that Wiedmann et al. highlight is the elevated proportion of global raw materials that goes to the sustenance of exports; according to the authors, two-fifths of all global raw materials are "extracted and used just to enable exports of goods and services to other countries".

Biodiversity loss in many commodity-dependent EMDEs is driven by international trade. A study of species on the International Union for Conservation of Nature's threatened Red List, which analysed the supply chains of more than 15,000 commodities produced in 187 countries, found that 30 per cent of global species threats are due to international trade (Lenzen et al., 2012). Biodiversity-rich EMDEs such as Indonesia, Malaysia, the Philippines and Sri Lanka are effectively exporting their biodiversity footprints, while developed countries are importers through their consumption (Fitch, 2020).

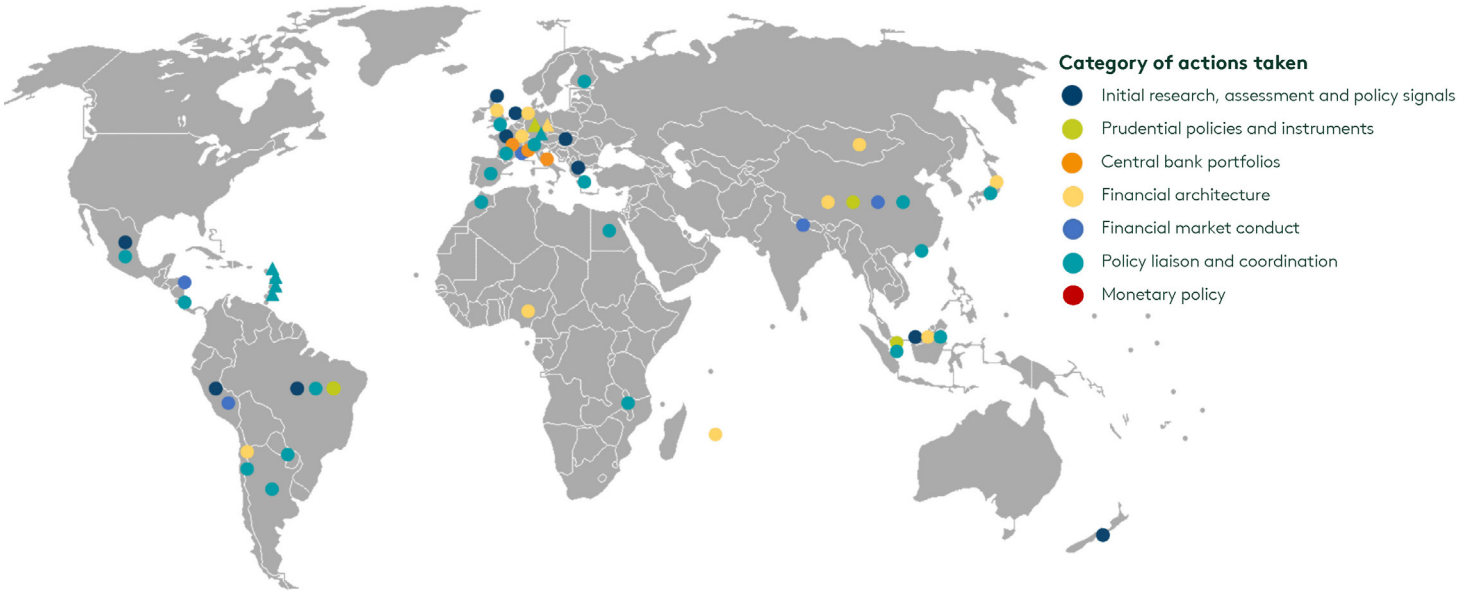
5. Options for central banks and financial supervisors to address biodiversity loss

An increasing number of central banks, supervisors and other financial policy agencies are beginning to consider biodiversity loss in their operational frameworks, within their different mandates and remits. While only a few tools have been developed and tested, a broad range of potential options is emerging in theory and practice, as this chapter outlines.

5.1. Current central bank efforts on biodiversity

As seen in Chapters 2, 3 and 4, and based on the growing evidence of the materiality of biodiversity-related financial risk, central banks and supervisors are already taking first steps to address biodiversity loss, related risks and the potential financial stability implications. In this chapter, we present some more examples. A geographical overview is provided in Figure 16. Box 10 illustrates some of these examples and Box 11 highlights the particular challenges for emerging markets.

Figure 16. High-level summary of biodiversity-related actions taken by central banks and financial supervisors



Source: Kunesch et al. (2021)

Box 10 | Central bank actions in China, Brazil, the UK and Morocco

While there is a growing awareness about the materiality of biodiversity-related financial risks among central banks and financial supervisors, the central banks of China, Brazil, the UK and Morocco – among others – have already begun to act.

In **China,** where pressures on biodiversity are driven primarily by food production, the central bank and financial supervisors have started to take action to green the financial system, with biodiversity as one of the priorities. In 2016, seven Chinese government bodies* jointly issued *Guidance for Establishing the Green Financial System*, to encourage private capital to invest in green industries and accelerate the green transformation of China's economy (Ministry of Ecology and Environment of the People's Republic of China, 2016).

China has developed a comprehensive system of green finance taxonomies, including guideline catalogues and statistical systems that guide green industries and green financial products (green credit and green bonds), respectively. These taxonomies explicitly support biodiversity conservation activities (including reforestation projects, preservation of national parks and world heritage sites, development of ecological function areas, ecological restoration projects, sustainable agrobusiness, and protection of fishery resources) with green finance.

In **Brazil**, the most biodiverse country in the world, biodiversity loss is driven by land-use change, particularly for cash crops, animal proteins and biofuels. The central bank has taken proactive steps to reduce these pressures through:

- Strengthening existing prudential regulation on environmental risk by improving the applicable requirements and the definition of social risk and environmental risk and including the definition of climate-related risk in financial institutions' management structures; requiring that financial institutions establish a social, environmental and climate responsibility policy; and establishing disclosure rules for social, environmental and climate-related risk management by financial institutions.
- Ensuring that financial institutions perform screening for the provision of rural credit and preclude lending to projects that overlap protected or embargoed areas, and Indigenous or 'quilombola' lands (settlements originally founded as a refuge by fugitive slaves or their descendants), among other restrictions.

In **the UK**, where the UK government is pursuing a 'nature-positive' future in response to the findings in the Dasgupta Review, the Bank of England is exploring ways to support this public policy goal (HM Treasury, 2021a). The Bank is in the early stages of examining the potential relevance of nature-related financial risks for UK financial stability. As set out in the Bank's response to the 2021 updates to the Financial Policy Committee (FPC)'s remit and recommendations, it is exploring the potential relevance of other environmental risks (beyond climate change) to the FPC's primary objective. The work will consider whether environmental risks beyond those related directly to climate change can create financial risks that, left unaddressed, could pose a threat to UK financial stability. This will take into account evidence from existing literature and will draw on collaborative efforts with other central banks and regulators through the NGFS and the Sustainable Insurance Forum (Bank of England, 2021).

In **Morocco**, where the economy is highly dependent on marine and terrestrial biodiversity, the degradation of natural ecosystems risks dramatically reducing cereal yields, livestock production and fish stocks. The central bank recognises the material risks posed by pressures on biodiversity and the impact these risks could have on the financial sector: by financing clients operating in biodiversity-dependent economic sectors, financial institutions are exposed to the risk of financial losses due to the degradation of natural ecosystems and the implementation of policies for the transition to environmental sustainability. Bank Al-Maghrib is cognisant of these risks and is exploring ways to better understand the linkages and impacts of biodiversity loss on the banking sector, financial stability, and the wider Moroccan economy.

** These include the central bank, the People's Bank of China; financial regulators – the China Securities Regulatory Commission and the China Banking and Insurance Regulatory Commission; and broader public policy agencies – the Ministry of Finance of the People's Republic of China, the National Development and Reform Commission, and the Ministry of Ecology and Environment of the People's Republic of China.*

Sources: Bai et al., 2021; Mouhaouri, 2021b; Arduini et al., 2021; Viegas, 2021.

Box 11 | Emerging markets and biodiversity risk

Eighty-five per cent of biodiversity hotspots are situated in emerging market and developing economies (EMDEs), which make up 15 out of the 17 megadiverse countries globally. These countries are therefore highly vulnerable to biodiversity loss – especially if governments consider the protection of biodiversity as a trade-off to achieving economic growth and development. This vulnerability and the threat of a loss of crucial ecosystem services makes it imperative to increase the understanding of how biodiversity loss could affect financial and economic stability in the EMDE context.

Central banks and financial supervisors in EMDEs also face unique economic and financial challenges and financial markets and market forces tend to be less prevalent in these countries.

- First, underdeveloped capital markets could lead to greater financial risks posed by biodiversity loss due to credit concentration (particularly in natural-resource-based economies) and greater exposure to market volatility. This in turn could lead to cascading impacts on the economy through adjustments in prices. However, given the lower levels of financial development in EMDEs, financial stability implications could be less pronounced there than in developed countries.
- Second, resource and capacity constraints may limit the focus on efforts related to environmental issues.
- Third, loss of biodiversity (particularly through forest-clearing activities) could lead to immediate local impacts such as flooding or severe air pollution that could result in disruptions in the economy and may require competing central bank expertise/resources to address.
- Finally, financial systems are sometimes marred by prevalent market failures and institutional imperfections, and influenced by controls and intervention, as well as by uncompetitive banking systems, artificially low interest rates and the administrative allocation of resources.

However, EMDE central banks and financial supervisors may already have mandates that provide space for assessing biodiversity-related financial risks. To cope with the myriad of challenges they face, EMDE central bank mandates often extend beyond primary price and financial stability objectives. Central banks and supervisors are also responsible for achieving secondary objectives that support public policy priorities such as financial inclusion, consumer protection and broader economic development, and that provide advisory support to the government's fiscal, economic and financial plans. Through supporting wider public policy priorities, EMDE central banks could be regarded as implicitly having biodiversity conservation objectives in their mandates and could be tasked with incentivising the reallocation of financial flows into sustainable sectors of the economy, including biodiversity conservation.

Moreover, it will be important that financial system efforts to address biodiversity loss and build a biodiversity-positive economy are delivered through a just transition so that they generate positive impacts for jobs, livelihoods and development. Equally, it is important that EMDEs are not penalised by the incorporation of biodiversity risks in key international financial frameworks and fora, nor by the inclusion of these risks in, for example, credit ratings.

As a result, central banks in EMDEs have an important role to play in assessing and understanding biodiversity-related financial risks, and avenues for action. There are already examples of this in practice, as described in previous sections of this chapter.

Source: Derived from Mouhaouri, 2021a.

5.2. Options for central banks, supervisors and other actors

Building on the evidence base presented in Chapter 2 and the challenges outlined in Chapter 3, a number of policy options for central banks, supervisors and other financial policy institutions to act on biodiversity loss are beginning to emerge. These are derived from the emerging practice summarised above, actions already underway or under discussion to address climate-related risk, and ideas from the Study Group input papers. The list of options (summarised in Table 2 and detailed beneath) intends to be as comprehensive as possible and therefore does not reflect the circumstances of different mandates, remits, choices or stages of financial and economic development. Some of the options discussed would be considered outside of the remit of some central banks and supervisors, while being part of the core policy frameworks of others.

Table 2. Summary of options for central banks, supervisors and other actors for acting on biodiversity loss

i) Initial research, assessment and policy signals	• Financial and economic stability assessments • Market outreach • Strategy formulation • Capacity-building
ii) Contributing to the financial architecture	• Classification, standards and taxonomies • Disclosure standards and supervisory reporting • Indicators, metrics, dashboards and tools
iii) Prudential policies and instruments	• Scenarios and stress-testing • Microprudential • Macroprudential
iv) Financial market conduct	• Addressing greenwashing • Addressing financial crime
v) Macroeconomic analysis and monetary policy	• Price stability integration • Calibrating monetary operation
vi) Central bank non-monetary policy portfolios	• Non-monetary policy portfolio management
vii) Policy liaison and coordination	• Policy liaison and coordination • International cooperation

i) Initial research, assessment and policy signals

Initial efforts need to focus on creating the empirical evidence base and foundations for policy options on biodiversity loss and conservation. Collaboration with ministries and agencies in charge of the environment and natural resources, NGOs and interdisciplinary academic researchers, including ecologists, will be needed to better understand the main drivers of biodiversity loss and conservation. Conditional on the outcomes of initial assessments and research, concret policy options could then be explored.

First and foremost, it is essential to create the evidence base by conducting *financial and economic stability assessments* and undertaking internal research to investigate the risks of biodiversity loss. More specifically, assessing the biodiversity-related impacts and dependencies of the economy and the financial sector, as well as the identification of priority drivers of biodiversity loss and financial risk, are key enabling steps. Meanwhile, financial institutions could also be encouraged to conduct biodiversity impact and risk assessments of their investment, lending and insurance underwriting activities. System-wide and individual assessments can reinforce each other along the way, by providing initial empirical findings and helping to identify methodologies and metrics.

A strengthening of awareness could be achieved through *market outreach*, where central banks and financial supervisors engage with financial firms to communicate the implications of biodiversity loss to the financial system. Furthermore, financial sector consultations on the implications of biodiversity loss and related risks could be conducted. In this context, collaboration with other relevant stakeholders will be important to jointly identify measurement approaches for financial risks and trends, and to agree on the biodiversity risks that are most financially material to financial institutions. Central banks and supervisors could play an active role in allocating resources to create greater awareness and build capacity in the financial sector by elevating the skills and tools needed to identify, monitor and manage the relevant risks.

Green finance *strategies* and agendas of central banks and supervisors could be reassessed in order to explore the implications of incorporating biodiversity loss. Policy strategies, remits and mission statements could be clarified concerning the role of the authorities in addressing biodiversity risk, with the aim of connecting biodiversity loss to climate frameworks and strategies. There would also be particular implications for those CBD signatory countries with national biodiversity targets, some of which have been signed into national law.

Central banks and supervisors could strengthen their own *capacity-building* efforts by creating programmes to enhance the understanding, assessment and addressing of biodiversity loss-related impacts and dependencies. Internal evaluation and monitoring capacity could be expanded through technical workshops. Furthermore, programmes could aim to support the assessment and mitigation of economic and financial risks arising from biodiversity loss and, where mandates permit, mitigation of the effects of financial sector activity on biodiversity loss. Advanced and EMDE central banks and supervisors would have different capacity-building requirements, which could be addressed through international coordination and knowledge-sharing.

In practice, initial assessments and signalling have been areas where many central banks and supervisors have started to take the first substantial steps towards a better understanding of biodiversity loss:

- **Banco de México** has published a report that discusses risk management practices that recognise biodiversity loss, environmental and social negative externalities and risks (Banco de México and UNEP, 2020). Banco de México also partnered with the Center for Latin American Monetary Studies (CEMLA) to host in December 2021 'Biodiversity and Environmental Challenges for the Financial System', a three-day public conference that explored financial risks and challenges associated with preserving and restoring biodiversity (CEMLA, 2021).

- **Banco Central do Brasil** has adopted a new regulation on risk management and social, environmental and climate responsibility, which redefines environmental risk to include the destruction of biodiversity (BCB, 2021).

- **De Nederlandsche Bank** (van Toor et al., 2020), **Banque de France** (Svartzman et al., 2021), **Banco Central do Brasil** (Calice et al., 2021), **Banco de México** and **Bank Negara Malaysia** have conducted financial and economic stability assessments.

- The **Bank of England** is considering whether environmental risks beyond those related directly to climate change can create financial risks that, left unaddressed, could pose a threat to UK financial stability (HM Treasury, 2021c, 2021d).

- The **Magyar Nemzeti Bank** has received an updated remit to support the Hungarian government's economic policy and its policy related to environmental sustainability, using instruments at its disposal. It is one of the first European central banks to acquire a 'green mandate' (MNB, 2021).

- The **Reserve Bank of New Zealand** has published a report that acknowledges and discusses the implications of nature and natural capital in the Te Ao Maori (Maori worldview) for its operations, where humans are not seen as superior to nature but rather as existing within it (RBNZ and BERL, 2021).

- The **Bank of Albania**'s Medium-term Development Strategy establishes that the Bank will develop models dedicated to investigating and interpreting the effects of shocks, risks and trends from 'environmental and ecological developments' in the Albanian economy. The objective is to use these models as a platform for analyses and forecasts to endorse decision-making (Bank of Albania, 2021).

- **Superintendencia de Banca, Seguros y Administradoras Privadas de Fondos de Pensiones Peru**'s Regulation for the Management of Social and Environmental Risk requires firms to identify training and dissemination needs for an adequate management of social and environmental risk (SBS, 2015).

ii) Contributing to the financial architecture

A second foundational step is to refine and expand the critical underlying financial frameworks and architecture (including standards, taxonomies, disclosure frameworks and metrics) to enable the mobilisation of financing for biodiversity protection, and to help assess and address the risks arising from biodiversity loss. This work would benefit from engagement and cooperation with a broad range of stakeholders and experts, including ecologists and researchers from other relevant natural sciences.

Including biodiversity protection in *classifications, standards and taxonomies of economic activities* would be a key step in ensuring that sustainable finance activities support biodiversity-positive investments and avoid investments that are harmful to biodiversity, thereby reducing future financial risks arising from biodiversity losses. Central banks and supervisors may either lead or support these efforts, depending on the jurisdiction.

Where central banks or supervisors are responsible for developing these standards (e.g. use of proceeds, verification, and reporting requirements for sustainable loans and bonds) and taxonomies (that provide a list of qualified activities for sustainable finance instruments), they can explore how to include biodiversity and ecosystems in the design principles of taxonomies.

In this context, it would be essential to define terms such as 'biodiversity-positive' and 'biodiversity-harmful' activities through an interdisciplinary consultation process that included scientists and conservation experts. Furthermore, central banks and supervisors could play a leading role in developing risk-based classifications for biodiversity loss-relevant sectors and assets to enable the calibration of various prudential and monetary instruments.

Another critical step is to promote the inclusion of biodiversity in *disclosures* and *supervisory reporting*, with the aim of gathering sufficient data and creating a basis for biodiversity impact and risk assessment, such as stress-testing and scenario analysis, giving due consideration to consistency within and across jurisdictions and in international value chains (Stampe, 2021). Interested central banks and supervisors, as well as the NGFS, could engage with the International Sustainability Standards Board on this topic. Non-financial corporations and financial institutions could be encouraged or required to disclose the impacts of their activities (including production of goods and services, investments, underwriting, and so on) on biodiversity. It could also be important to encourage the integration of biodiversity loss and conservation considerations into financial institutions' business decisions for investments, lending and insurance underwriting (biodiversity/nature integration as part of ESG integration).

Central banks and supervisors can help to create consensus on definitions, metrics, measurement methodologies and target formulation by joining private sector-led initiatives such as the TNFD Forum, Finance for Biodiversity Pledge[12] and Science Based Targets Network. This could enable disclosure as a key instrument for a smooth transition to sustainable economies. Furthermore, the development of a global and harmonised corporate biodiversity accounting standard and reporting framework will be critical to success. Central banks could consider contributing to this effort, where mandates permit. The prospects of aligning investment policies with conservation cost accounting rather than fair value accounting could be explored.

Defining and developing the relevant *indicators and metrics* and *bridging the data gaps* are further key steps for building a financial architecture that addresses biodiversity loss. The suitability of specified measurement approaches in different contexts should be assessed to ensure that tools, indicators and metrics are credible and transparent and can be subject to rigorous peer review by independent third parties (e.g. academics and IPBES), avoiding, for example, proprietary metrics that cannot be subjected to independent peer review by such interdisciplinary scientists and experts. Statistical departments of central banks and supervisory authorities could collect data and develop indicators for biodiversity risk. These could ultimately inform the creation of dashboards of biodiversity metrics to assess the state of biodiversity risks, both in terms of dependencies and impacts (Braunschweig et al., 2021). However, given the urgency of the challenge there could also be a rationale to act on the available biodiversity data even if incomplete and imperfect, to avoid the potentially large and irreversible economic and financial costs of biodiversity loss.

12. The Finance for Biodiversity Pledge has two requests for the post-2020 Global Biodiversity Framework (GBF): the GBF should ensure that the alignment of financial flows is not only an implementing mechanism but also a policy aim for both government action and financial market actors, which is crucial to reducing negative impacts on biodiversity and to incentivising positive impacts; and when the GBF references 'financial flows', it should clearly define these as both public and private financial flows and ensure this definition is also reflected in relevant goals and targets.

In practice, this is another area where some central banks and supervisors have started to take first steps:

- **De Nederlandsche Bank**'s Sustainable Finance Platform has established a Biodiversity Working Group, which offers practical tools and examples of good practice for investing in conserving and restoring biodiversity and combatting deforestation (Sustainable Finance Platform, 2020).
- The **People's Bank of China** has included biodiversity in its Green Loan Taxonomy and Green Bond Taxonomy, offers support for biodiversity-friendly projects, incentivised via low-cost funding, and has encouraged local governments to provide interest subsidies and guarantees for such projects (PBC, 2021).
- **Bank Negara Malaysia** explicitly links climate and biodiversity in its Climate Change and Principle-based Taxonomy, which is intended to help financial institutions categorise economic activities by their impact on climate and environmental objectives. This includes assessing whether an economic activity protects healthy ecosystems and biodiversity (BNM, 2019, 2021).
- The **Bank of Mauritius**'s guide for the Issue of Sustainable Bonds includes projects/assets to sustainable land use (forestry and agriculture), biodiversity and increased resilience of marine and coastal ecosystems (BOM, 2021).
- The **Central Bank of Nigeria**'s Sustainable Banking Principles outlines processes to avoid, reduce and mitigate biodiversity loss (CBN, 2012).
- **Mongolbank**'s Green Taxonomy Framework sets out "Sustainable agriculture, land use, forestry, biodiversity conservation and eco-tourism" as one of seven categories for sustainable activities (Mongolian Sustainable Finance Association et al., 2019).
- The **Bank of England, Banque de France, European Central Bank, Financial Services Agency of Japan** and **Banco de México** are part of the TNFD Forum that supports the work of the Taskforce by 'crowding-in' access to a global, multi-disciplinary pool of technical expertise and practical market experience.
- The three **European Supervisory Authorities**, in charge of banking (EBA), insurance and pensions (EIOPA) and capital markets (ESMA), are part of the **EU Platform on Sustainable Finance**, which is advising the European Commission on defining the EU Taxonomy, which includes protection and restoration of biodiversity and ecosystems as one objective. The European Central Bank and the NGFS also attend the Platform as observers (European Commission, 2021b).
- **Banco Central de Chile**'s Statistics Division contributes to the Natural Capital Committee through identifying concrete ways to measure Chile's natural capital and the information needs to achieve it, taking into account its experience in the preparation of National Accounts (BCDC, 2021).

iii) Prudential policies and instruments

Building on the first two steps of (i) strengthening the initial assessment to create the evidence base and (ii) building the financial architecture, central banks and financial supervisors can also explore the prudential implications of biodiversity loss and how to incorporate the institutional and systemic risks into prudential regimes. The disclosure aspect of this discussion is somewhat overlapping with the point raised in (ii) above, but focuses more on implementation than on the development of disclosure frameworks.

Microprudential frameworks could also be assessed with regard to the possibility of more explicitly including biodiversity loss under the Basel pillars of banking supervision and equivalent standards of insurance supervision. First, the evidence base would have to be created; this should be comprised of qualitative as well as, where possible, quantitative insights. Supervisors could encourage or mandate financial institutions (including insurance companies [UNDP SIF, 2021]) to analyse and disclose biodiversity-related risks, including physical and transition risks as well as the impact of their investments and underwriting activities on biodiversity. Prudential supervisors will need to see biodiversity and nature transition plans from regulated firms to evaluate how financial institutions are managing transition risks. Supervisory expectations on how financial institutions address biodiversity risks (building on the development of metrics, standards and taxonomies) could be developed and, where applicable, link biodiversity loss-related risks explicitly to wider environmental and social risk management frameworks. Finally, depending on the mandates and prudential frameworks in different jurisdictions, as well as on empirically or qualitatively establishing a biodiversity risk differential, biodiversity risks could be included in relevant microprudential instruments (e.g. capital or liquidity requirements).

On the *macroprudential* side, building on a thorough understanding of the interconnectedness and risk of contagion in the financial system, and of systemic risk and financial instability implications of biodiversity loss, the inclusion of biodiversity risks in relevant macroprudential instruments could be considered (e.g. systemic risk buffers). Further research should be conducted on how policy tools can be used to reduce and avoid the financing of business activities that are driving biodiversity loss, especially those linked to ecological tipping points in critical biomes, the loss of which would lead to catastrophic macro-financial impacts.

As discussed in greater detail in Section 3.1, *scenario analysis and stress-testing* can play a key role in building an understanding of future biodiversity risk (Salin and Svartzman, 2021). First, the role of biodiversity loss in the existing NGFS Climate Scenarios could be explored to assess needs for additional new scenarios, as opposed to augmenting the existing set. For example, climate scenarios could omit the aspects of biodiversity risks that are not directly related to climate change, such as soil degradation by chemical pesticides or catastrophic outcomes in the event of the collapse of thermohaline circulation. However, the existing NGFS scenarios may already include significant implicit biodiversity loss embedded in large-scale negative- or low-emissions technologies, such as biomass with carbon capture and storage. Making these assumptions and outcomes more transparent could be useful. Also, other implications of deep decarbonisation for sustainable development, such as food prices and availability, may be important and could be elucidated. It could be an option to work with the Principles for Responsible Investment (PRI) Inevitable Policy Response, which includes deforestation-related policy changes in its forecasts. Central banks and supervisors could consider conducting system-level scenario analysis on biodiversity loss, while financial institutions could also be encouraged or required to conduct their own scenario analysis and stress-testing for biodiversity risks as part of risk management (within their internal capital adequacy assessment processes [ICAAP] or own risk and solvency assessments [ORSA]).

In practice, and while the options for including biodiversity loss in scenario analysis are being investigated, central banks and supervisors have started to explore prudential options and expectations:

- The **Monetary Authority of Singapore** has published Environmental Risk Management Guidelines that sets out its supervisory expectations for governance, risk management and disclosure of environmental risks, including loss of biodiversity (MAS, 2020).

- The **European Banking Authority**'s ESG Risk Management and Supervision Report provides recommendations on how ESG factors and ESG risks, including biodiversity loss, could be included in regulatory and supervisory frameworks (EBA, 2021).
- The **European Central Bank** published a guide on climate-related and environment risks that identifies biodiversity loss as a source of environmental risk and sets out supervisory expectations relating to risk management and disclosure (ECB, 2020).

iv) Financial market conduct

Several policy options are available to central banks and financial supervisors to ensure that market participants are responding to biodiversity loss with integrity. Such options may interplay with those discussed above, especially with regard to financial architecture including disclosures (see iii above), and prudential policies and instruments (see iii above), given the financial risks that inadequate financial conduct may induce.

On *addressing greenwashing*, clear, transparent, credible criteria for a biodiversity dimension of ESG ratings and sustainable financial products – partially building on taxonomies and disclosure requirements, for example – could be established to raise awareness of biodiversity-related risks among companies and financial institutions, especially regarding the issues with transparency and credibility of biodiversity 'positive' and 'avoided impact claims'. Transparency could be promoted to avoid differing treatment of negative externalities (carbon emissions and habitat degradation) and of positive externalities (preservation of biodiversity and ecosystem services). Furthermore, ensuring transparent and credible data, as discussed in point (ii) above with regard to indicators and metrics, is a necessary first step for limiting greenwashing in this space and accurately determining biodiversity impact (both positive and negative).

There could also be a role in ensuring that financial structuring of nature-related financial instruments remains sound and does not introduce moral hazard into the financial market architecture. Concretely, supervisors have a role to play in assessing disclosures and claims by financial institutions and in monitoring the commitments they take.

More generally, requiring *extended due diligence* covering impacts on biodiversity is an option to prevent negative biodiversity impacts and, ultimately, help reduce the related financial risks. Environmental and social risk management (ESRM) systems developed in particular in project finance could be implemented more systematically by financial institutions (Schydlowsky, 2021), especially when their operations present risks of negative impacts (e.g. activities in biodiversity-rich areas or in sectors that might significantly affect biodiversity, possibly considering proportionality thresholds). ESRM systems are designed to encourage financial institutions and their clients take into account their impacts on the ecosystem in which they function, including on biodiversity, and imply that financial institutions monitor their clients' compliance with applicable environmental protection regulation and standards. Such an approach provides flexibility and creates an opportunity for system-wide learning and collection of information.

To address *financial crime*, which can be linked to biodiversity loss, relevant authorities would have the option of ensuring that financial institutions are not complicit in biodiversity-related crime, as discussed in Section 4.3, including through a focus on money laundering.

In practice, in line with their mandates, central banks and supervisors have taken the following steps:

- **The French Prudential Supervision and Resolution Authority** (ACPR – Banque de France) and **Financial Markets Authority** (AMF) have started assessing environmental commitments by financial institutions, with a view to monitoring and evaluating them. While focusing on climate change, their latest report addresses biodiversity (ACPR AMF, 2021) and work in this area is expected to expand, following the entry into force of mandatory disclosure requirements (see Section 4.1).

- The **People's Bank of China**, as part of its anti-money laundering/combatting the financing of terrorism responsibilities, has set up the China Anti-Money Laundering Monitoring and Analysis Center (CAMLMAC). The CAMLMAC is responsible for collecting, analysing and processing suspicious transaction information, supporting investigations into such transactions, coordinating studies of suspicious fund flows and transactions, and exchanging financial information and cooperating with overseas counterparts, including on illegal wildlife trade (TRAFFIC, 2020).

- The **Nepal Rastra Bank**'s Guideline on Environmental and Social Risk Management for Banks and Financial Institutions requires the integration of environmental and social risk management into the overall credit risk management process in order to fully inform the credit authority of these risks prior to the financing decision for individual transactions. This guide specifies that "clients need to prevent or minimize the potential for activities that negatively impact biodiversity and ecosystem services" (Nepal Rasta Bank, 2018).

- **Superintendencia de Banca, Seguros y AFP Peru**'s Social and Environmental Risk Management Framework includes the adoption of mitigation measures to protect biodiversity, including endangered species and fragile ecosystems, and measures to evaluate the impacts on Indigenous peoples and communities (SBS, 2015).

- **Comisión Nacional de Bancos y Seguros Honduras**'s Standard for the Management of Environmental and Social Risk requires banks and financial institutions to manage their environmental and social exposures to their credit operations, including biodiversity loss (CNBS, 2020).

v) Macroeconomic analysis and monetary policy

Apart from the investigation of the financial stability implications, more research is needed into the possible consequences of the loss of biodiversity and ecosystems, or the measures to reverse them, for price stability. Another area of work regards the integration of biodiversity-related considerations in work undertaken to green monetary policy operations, which could leverage existing reflections that focus on climate change and related risks.

First, central banks could assess options for the integration of the implications of biodiversity loss for *price stability*. They could incorporate biodiversity loss considerations into their macroeconomic analysis, modelling and forecasting. More evidence-based research, as well as sound methodology on calculations, metrics and impacts, is needed to assess the price stability implications of biodiversity loss and to incorporate relevant drivers into the analysis and monetary policy monitoring. This evidence will likely need to be built up from micro-level case studies.

Furthermore, central banks could reflect biodiversity risks in their *monetary policy operations*, by adopting both protective and proactive measures, depending on what

their mandate allows. Protective measures aim to mitigate the exposure of central bank balance sheets to biodiversity risk. Proactive measures aim to reduce the impact of monetary policy operations on biodiversity loss (Monnin, 2022).

To mitigate biodiversity loss and effectively reduce central banks' exposure to biodiversity risk, without impeding monetary policy effectiveness, central banks could consider adjusting interest rates in credit operations to reflect biodiversity considerations, and aligning collateral policy and asset purchases with benchmarks that reflect biodiversity considerations (Monnin, 2022).

The incorporation of the implications of biodiversity loss in monetary policy operations has not yet been implemented in practice. Nevertheless, reflections on greening such operations conducted in the context of climate change, for example within the NGFS (NGFS, 2021c), the Eurosystem (ECB, 2021b), the Bank of England (2022) and the People's Bank of China (PBC et al., 2016), may help in the consideration of other environmental issues, including biodiversity loss. Further research and the development of the underlying financial architecture (including taxonomies and metrics) will be key enabling factors. A first step that central banks could take is to assess and disclose their exposure to biodiversity risk and their impact on biodiversity loss through their refinancing operations. Given the current state of knowledge, priority could be given to activities that scientific consensus or emerging national policy consider to be harmful to biodiversity and nature. Making greater use of annual progress updates and verification of biodiversity-related commitments is vital.

vi) Central bank non-monetary policy portfolios

The management of central banks' own non-monetary policy portfolios has traditionally been an area of early sustainability-related efforts and adjustments (NGFS, 2019, 2020). In the context of biodiversity loss, incorporating the implications of biodiversity loss and conservation into responsible investment policies could be an option for central banks.

To establish a biodiversity loss and conservation-conscious approach to *non-monetary policy portfolio management*, responsible investment principles that include the conservation of or significant harm to biodiversity could be explored. The disclosure of biodiversity loss-related financial risks, impacts and dependencies related to central banks' own portfolios could be a first step. Taking into account return trade-offs and different mandates, central banks could consider aligning their own portfolios with efforts to preserve biodiversity by avoiding investing in biodiversity-negative assets, and increasing exposure to nature-based solutions or green infrastructures that are positive for nature conservation. Furthermore, ways to align portfolios with national and global biodiversity goals could be explored.

In practice, some central banks have already moved towards including biodiversity loss considerations in their portfolio management approaches:

- The **Banque de France** has started integrating biodiversity in the analysis of its own funds and pension fund portfolios' ESG performances and disclosing this in its Responsible Investment report (Banque de France, 2021).
- **Banca d'Italia**'s Responsible Investment Charter, which governs its financial portfolio and investment of foreign exchange reserves, prioritises firms that focus on the "responsible use of natural resources and their effects on ecosystems" (BdI, 2021).
- The **Swiss National Bank** excludes assets from companies that "seriously damage biodiversity through their production operations" from its holdings of corporate bonds that are part of its foreign currency reserves (SNB, 2020).

vii) Policy liaison and coordination

Central banks and supervisors could further strengthen cooperation with other national and international financial policy institutions, as well as other relevant stakeholders, to address the implications of biodiversity loss and conservation.

National *policy liaison and coordination* with governments and relevant agencies, in line with mandates, can be central to an organised and effective response to biodiversity loss. Governments can seek independent advice and assessments of the biodiversity challenge to identify the necessary real economy and financial system reforms. Collaboration with various actors in an inclusive, open way is crucial to identify research needs and to develop key financial architecture such as a biodiversity risk dashboard for metrics, a taxonomy and risk assessment methodologies and tools. In emerging market and developing economies, central banks and financial supervisors could be particularly well placed to coordinate and offer technical advice to other government agencies. In some cases, they may also play a central role in advising their respective governments on fiscal policy, and offer insights on the implications of biodiversity loss for macroeconomic analysis and budget planning.

Concerning *international cooperation*, working and collaborating with international organisations (such as the Financial Stability Board, the IMF, the Bank for International Settlements, the International Association of Insurance Supervisors, the Sustainable Insurance Forum and the NGFS) can help advance the explicit inclusion of biodiversity loss and related risks in relevant risk assessment frameworks and disclosure standards. Participation in international initiatives to address biodiversity-related financial risks as part of the implementation of the Global Biodiversity Framework can amplify national-level efforts. Enhanced collaboration with IPBES scientists and experts could ensure that macrofinancial surveillance and microprudential supervision take into account the most up-to-date ecosystem science. Smaller jurisdictions, emerging markets and developing countries could especially benefit.

In practice, early progress has been made in this regard:

- This **Joint NGFS-INSPIRE Study Group on Biodiversity and Financial Stability** has brought together 25 central banks and supervisors, as well as representatives of international financial institutions, with external researchers and experts to assess evidence and suggest practical actions.

- The **Sustainable Banking and Finance Network (SBFN)** is a voluntary community of financial sector regulatory agencies and banking associations from emerging markets committed to advancing sustainable finance. SBFN members, also including ministries of environment and natural resources, are committed to moving their financial sectors towards sustainability, with the twin goals of improved environmental and social risk management and increased capital flows to activities with positive climate, environmental including biodiversity-enhancing, and social impact (International Finance Corporation [IFC], 2021).

- The Central Bank of the Argentine Republic, the Ministry of Economy, the National Securities Commission, and the Superintendencia de Seguros de la Nación have signed an **agreement to boost sustainable finance development in Argentina**. The agreement seeks to create conditions for increasing public and private investments within the financial sector and will contribute to reaching economic, environmental and social objectives within the framework of the Sustainable Development Goals (BCRA, 2021).

- Banco Central del Paraguay, the Ministry of the Environment and Sustainable Development, the National Forestry Institute and the Sustainable Finance Board of Paraguay have formed the **Public-Private Alliance for Sustainable Finance** to collaborate, consolidate and coordinate the efforts of the public and private sectors to promote sustainable finance in Paraguay, including the role of sustainable finance in biodiversity preservation (BCP, 2021).

- In alignment with regional development strategies and initiatives, the **Eastern Caribbean Central Bank's Environmental and Social Management Framework** (2018) addresses issues related to environmental impacts, including biodiversity degradation and pollution, prior to approving credit guarantees to micro, small and medium-sized enterprises.

- The Reserve Bank of Malawi coordinates the implementation of **Malawi's Financial Inclusion and Entrepreneurship Scaling Project**. The Bank's E&S Policy and Procedures for this project strengthens the management of risks that are environmental and social in nature, including preventing the degradation of biodiversity (RBM, 2020).

- The Financial Services Agency of Japan will become an observing member in 2022 of the **Public-Private Study Group on a Nature Positive Economy,** a discussion group hosted and coordinated by the Ministry of the Environment of Japan. The group aims to study various ongoing international frameworks regarding nature, especially including the nature-related financial disclosure frameworks, metrics and data that are needed to induce more nature-positive activities, and to develop a strategy for a nature-positive economy that can be implemented by Japanese companies. Intergovernmental observing members include the Ministry of Agriculture, Forestry and Fisheries.

6. Conclusions and recommendations

The options set out in Chapter 5 provide central banks and financial supervisors with a wide suite of actions they could take to address issues around biodiversity. Depending on their mandates, resources and levels of existing experience, some options may be more immediately appropriate than others. Here, we summarise our conclusions before offering five recommendations that the Study Group considers to be applicable to central banks and financial supervisors.

6.1. Tackling biodiversity loss is part of greening the financial system and ensuring stability

The evidence and analysis gathered by the Study Group demonstrates that biodiversity loss poses a potentially significant threat to financial stability and sustainable development. Biodiversity loss is a driver of potentially global economic and financial disruptions, as well as more localised challenges to prosperity and livelihoods. This threat is tightly interlinked with other environmental risks, not least climate change, and has unique characteristics that warrant dedicated attention. The best available scientific and economic research confirms that the risks are material, with particular vulnerabilities in developing and emerging economies, and international ramifications through trade and financial flows. The understanding of the dependencies and impacts of financial assets, institutions and systems on biodiversity is evolving, but incomplete, suggesting that crystallisation of biodiversity-related financial risks may well take decision-makers by surprise. This points to the need for a prudent, forward-looking approach that enables financial practitioners as well as financial authorities to take action in the absence of perfect information to protect the vital ecosystem services that underpin economic activity.

The Study Group has also found that operational approaches to identifying and assessing biodiversity-related financial risk are emerging across the financial system. Typologies of biodiversity-related financial risk are available, identifying the transmission channels through which physical risks flow from the degradation of ecosystems as well as the transition risks for financial activities that are misaligned with a nature-positive economy. A growing number of central banks and supervisors have started to size the reliance of their financial institutions on biodiversity, with over 40 per cent of assets often highlighted. Others have started to signal that supervisory expectations regarding environmental risk management extend to biodiversity.

Looking across the landscape of linkages between biodiversity and financial dynamics, the Study Group has identified a set of opportunities and challenges: opportunities to improve the functioning and stability of the financial system by reducing biodiversity loss, as well as challenges that require individual and collective efforts to resolve. The momentum to address these is intensifying, not least through the increasing focus on strengthening national and international policy frameworks to overcome the market and institutional failures that drive biodiversity loss. Alongside this focus are growing efforts by banks, insurers, investors and capital markets to reduce their negative impacts and mobilise more capital for real economy investments to sustain ecosystems. These policy and market drivers for action are compounded by rising expectations from citizens and civil society that the sustainable management and conservation of biodiversity becomes a core competence across the financial system. These efforts are promising but remain insufficient to respond to the scale and urgency of biodiversity loss for all financial actors.

In conclusion, the Study Group believes that biodiversity loss is a source of financial risk that can be a threat to financial stability and thus falls within the mandates of central banks and financial supervisors. Much still needs to be done to measure these risks, identify the specific channels of risk transmission, and calibrate the tools that central banks and supervisors can take individually and with others to address these risks. It is also clear that inaction is a growing source of risk.

6.2. Recommendations for action

Action is needed now to halt the rapid degradation of nature and growing threat to biodiversity, and effectively address the range of biodiversity-related financial risks. The primary responsibility for confronting the biodiversity crisis rests with governments, notably to overcome the market, institutional and policy failures that are driving ecosystem decline. Actions by central banks and supervisors can play a complementary role to protect financial stability by reducing biodiversity-related financial risks and to help guide the allocation of financial resources to support nature-positive activities.

Chapter 5 presented a broad set of options covering several areas of activity from which NGFS members, observers and others can draw to address biodiversity-related financial risks and enhance the role of the financial system in protecting biodiversity. These options can be applied individually, collectively or with other stakeholders in accordance with institutional mandates.

In the rest of this section, we offer a set of focused recommendations for early action that could be adopted by central banks and supervisors on a voluntary basis. These are grouped under five categories.

Recommendation 1: Recognise biodiversity loss as a potential source of economic and financial risk and commit to developing a response strategy.

This could be conducted by central banks and supervisors, in collaboration with other stakeholders, and could include:

- *Strategies:* Incorporating biodiversity considerations within green finance and environmental risk management strategies, taking an integrated approach that highlights the linkages between biodiversity loss and climate change, the specific threats that it might pose to the safety and soundness of financial institutions, the stability of prices and the overall financial system.

- *Policy dialogue:* Engaging in dialogue with governments and other relevant stakeholders to identify the financial system dimensions of implementing national and international biodiversity goals, such as the Global Biodiversity Framework.

- International frameworks: Promoting the integration of biodiversity and the related financial risks in key international financial fora, such as the Bank for International Settlements (including Basel Committee on Banking Supervision), Financial Stability Board, Association of Insurance Supervisors, International Monetary Fund and World Bank.

- Role of the NGFS: Taking a leadership role in developing a strategy for the integration of biodiversity loss and broader nature-related factors across the NGFS research programme and all its Workstreams.

Recommendation 2: Build the skills and the capacity to analyse and address biodiversity-related financial risks.

This could be conducted by central banks and supervisors, in collaboration with other stakeholders. It should acknowledge that interactions among key factors in the regulation of the Earth system, notably biodiversity loss and climate change, can have potential implications for financial stability, and should involve developing integrated approaches to assessing biodiversity- and climate-related financial risks. This could include:

- *Capacity-building:* Developing the skills to identify, measure and manage biodiversity-related risks, including physical and transition risks, among central bank and supervisory staff as well as market participants and other stakeholders. This could involve international collaboration to establish training programmes on analysing the relationships between biodiversity and financial stability and sharing best practice to address related risks.

- *Research:* Taking part in further research to deepen the understanding of the sources of biodiversity loss, the climate–biodiversity nexus, biodiversity–finance interlinkages, modelling approaches to assess economic impacts, and reliable sources of data and metrics. This could be achieved at the national level as well as internationally via research networks, such as INSPIRE and the Global Research Alliance for Sustainable Finance and Investment. Appendix 1 presents a suggested research agenda, which seeks to close some of the knowledge gaps in this fast-evolving field.

Recommendation 3: Assess the degree to which financial systems are exposed to biodiversity loss.

This assessment could be conducted by central banks, supervisors and academics, and could include:

- *Risk assessment:* Conducting impact and dependency assessments on biodiversity at the micro level, the financial system level and at regional levels, and identifying priority drivers of biodiversity-related financial risk.

- *Scenario analysis:* Developing and then conducting biodiversity-related scenario analysis and stress-tests at the micro level, financial system level and regional levels, to analyse and quantify physical and transition risks arising from biodiversity losses. This could start with identifying and potentially amplifying the biodiversity sources of financial risk within the existing NGFS climate scenarios.

- *Metrics:* Creating a dashboard of biodiversity metrics to monitor the state of biodiversity risks, in terms of both dependencies and impacts, and establishing an appropriate institutional framework to further develop these metrics.

Recommendation 4: Explore options for supervisory actions on managing biodiversity-related risks and minimising negative impacts on ecosystems.

This could involve reviewing to what extent the existing supervisory framework and toolbox enable the specificities of biodiversity-related financial risks to be addressed, and developing supervisory expectations and assessment programmes that include the following elements:

- *Governance, risk management framework and strategy:* Encouraging and, as appropriate, requiring financial institutions to set up adequate governance and risk management arrangements, and to factor in biodiversity-related considerations to their business and risk strategies, including through specific metrics and targets.

- *Risk assessment and scenario analysis:* Encouraging and, as appropriate, requiring financial institutions to conduct environmental risk analysis that incorporates physical and transition risks arising from biodiversity loss, by using tools such as scenario analysis and stress-testing.

- *Disclosure:* Encouraging and, as appropriate, requiring financial institutions to disclose the impact of their investment, lending and insurance underwriting activities on biodiversity, as well as the result of risk assessments, governance, risk management frameworks and strategy associated with biodiversity loss. At the international level, this could be done via incorporating biodiversity-related risk metrics into the international sustainability reporting framework developed by the International Sustainability Standards Board, which might take into account existing and anticipated frameworks such as that of the Task Force on Nature-related Financial Disclosures.

- *Financial conduct:* Encouraging and, as appropriate, requiring financial institutions to integrate biodiversity-related considerations into their conduct and into the management of related financial risks, including but not limited to litigation and reputational risks. This could include paying greater consideration to market claims related to biodiversity and to environmental crime within anti-money laundering/combatting the financing of terrorism frameworks, and/or adopting environmental and social risk management systems to monitor clients' impacts on biodiversity and compliance with applicable environmental and biodiversity-related protection regulations and standards.

Recommendation 5: Devote efforts to building the necessary financial architecture for mobilising investment for a biodiversity-positive economy, including by considering how central banks' own operations should be conducted in the context of biodiversity loss.

Depending on the central banks and supervisors' mandate and choice, this could include:

- *Taxonomies:* Contributing to the development of sustainable finance taxonomies, e.g. by including economic activities that support the conservation of biodiversity (including reforestation, conservation of protected areas, and protection of fishery resources).

- *Environmental, social and governance (ESG) and green ratings:* Encouraging the establishment of a biodiversity dimension of ESG ratings and other sustainability measures for financial products, to raise awareness of impacts on, and risks stemming from, biodiversity loss among corporates and financial institutions. Specifically, agencies that rate ESG and other 'green' measures should be encouraged to expand the coverage of their indicators to include biodiversity-related information.

- *Monetary policy:* Exploring options, as appropriate, to integrate biodiversity-related considerations into monetary policy, including the impact of biodiversity loss on price stability and the conduct of monetary policy operations. Depending on the mandate, this may include mitigating central banks' own exposures to biodiversity-related financial risks or more proactively incentivising biodiversity-positive investments.

- *Non-monetary policy portfolios:* Enhance the ESG investment strategies for central bank non-monetary policy portfolios by incorporating biodiversity protection as a key consideration. Such strategies could involve excluding investments that are 'harmful' to biodiversity and increasing exposure to biodiversity-positive assets.

Appendix 1. The research agenda

Building on the challenges and ways forward outlined in this report, a number of follow-up research questions begin to emerge, a first set of which we present below that address the challenges to identify appropriate analytical frameworks, enhance scenario analysis, advance portfolio approaches, identify data challenges, and explore options for policy coordination. A comprehensive research agenda of the Study Group will be published as a separate document (NGFS and INSPIRE, forthcoming).

What are the analytical frameworks that are helpful to understand and assess nature–economy interactions?

- How can ecosystem services be valued based on the rich (but not consensual) literature on the topic?
- How can analytical frameworks represent the fact that multiple complementary or contrasting policies will likely be implemented to address biodiversity loss (and no single and simple measure such as carbon pricing exists)?
- How can nature-related impacts on prices be estimated?
- How can nature-related impacts on output be estimated?

What are the implications of biodiversity risks and the climate-biodiversity nexus for the design of scenarios?

- How should shock narratives be designed and implemented (e.g. top-down or bottom-up, over what time horizon)?
- How can the degree of interaction between biodiversity and climate scenarios be represented?
- How can different considerations for developed countries and EMDEs be integrated into scenarios?
- How can potential cascading, intersectoral impacts (physical and transition risks) be taken into account?
- How can non-linearity (especially for physical risks) be taken into account?

What are the implications of biodiversity loss for the portfolio of financial institutions and how can these be addressed?

- How can impacts and dependencies be effectively measured to enable the assessment of biodiversity-related financial risks?
- How can central banks incorporate biodiversity targets into their operations and portfolios?

What important data gaps need to be addressed to enable further assessments and what can be done to bridge them?

- What are the relevant metrics needed to evaluate risks, impacts and dependencies?
- What are the most relevant future objectives and metrics on biodiversity from a central banking and supervision point of view?
- What are useful approaches to utilise the expertise of ecologists and other biodiversity experts to develop measurements and tools used to mark investments that both harm and are positive for biodiversity?

What are the opportunities for and limitations of broader policy coordination between different policy institutions?

- How can central banks and supervisors provide an independent economic and financial assessment of the challenge to governments of addressing biodiversity loss?
- What are the implications for policy liaison in the context of market conduct and addressing activities that harm biodiversity?
- How can central banks and supervisors collaborate with other stakeholders on the conservation of biodiversity and the scaling up of biodiversity-positive investments?

Appendix 2. Research papers

Contributions from members of the NGFS-INSPIRE Biodiversity and Financial Stability Study Group

Abdelli, M. and Pacheco, P. (2021). *Tail risks: Covid-19 and the economics for pandemic prevention*. Unpublished NGFS-INSPIRE Study Group Input Paper.

Albagli, E. and Vial, J. (2021). *Biodiversity and economic growth: Something must give*. Unpublished NGFS-INSPIRE Study Group Input Paper.

Almeida, E. (2021). *Examples of interactions between biodiversity- and climate-related financial risks*. [Presentation.] Unpublished NGFS-INSPIRE Study Group Presentation.

Almeida, E., Muller, S., and Robins, N. (2021). *Global Biodiversity Framework: Implications for economy and finance*. Unpublished NGFS-INSPIRE Study Group Input Paper.

Arduini, S., Klink, C., and Texeira, G. (2021). *Biodiversity and financial stability: Brazil Case Study*. Unpublished NGFS-INSPIRE Study Group Input Paper.

Bai, Y., Ma, J., and Zhuan, M. (2021) *China case study*. Unpublished NGFS-INSPIRE Study Group Input Paper.

Braunschweig, O., Colesanti Senni, C., and Lunsford, D. (2022). *A dashboard for biodiversity metrics*. CEP Policy Brief. Council on Economic Policies, Zürich, forthcoming.

Chenet, H., (2022). *Quantifying financial impacts of biodiversity? Conceptual and theoretical frameworks, limits, and implications*. Forthcoming.

Dempsey, J., Irvine-Broque, A., Christiansen, J., and Bigger, P. (2021). *Thin and shallow: Financial instruments for biodiversity conservation and their outlook*. Unpublished NGFS-INSPIRE Study Group Input Paper.

Feger, C., Levrel, H. and Rambaud, A. (2021). *Ecological Accounting: How to organize information for biodiversity conservation decision and action at the national, business and ecosystem levels?* Working Paper, Ecological Accounting Chair and AgroParisTech, Paris.

Gardes, C. (2022). *Designing taxonomies for biodiversity*. Unpublished NGFS-INSPIRE Study Group Input Paper.

Kedward, K. and Ryan-Collins, J. (2022). *From financial risk to financial harm: exploring the agri-finance nexus and drivers of biodiversity loss*. UCL Institute for Innovation and Public Purpose (IIPP) Working Paper Series (No. WP 2022/05).

Kunesch, N., Almeida, E., and Dikau, S. (2021). *High-level summary of biodiversity-related actions taken by central banks and financial supervisors*. Unpublished NGFS-INSPIRE Study Group Input Paper.

Martínez-Jaramillo, S. and Montañez-Enríquez, R. (2021). *Dependencies and impact of the Mexican banking sector on ecosystem services*. Unpublished NGFS-INSPIRE Study Group Input Paper.

Monnin, P. (2022). *Monetary policy operations and biodiversity loss*. CEP Policy Brief. Council on Economic Policies, Zürich, forthcoming.

Mouhaouri, N. (2021a) *Biodiversity and Financial Stability: Considerations for Emerging Market Central Banks*. Unpublished NGFS-INSPIRE Study Group Input Paper.

Mouhaouri, N. (2021b) *Biodiversity and Financial Stability: Bank Al-Maghribi Case Study*. Unpublished NGFS-INSPIRE Study Group Input Paper.

Ripoll-Bosch, R. and Schoenmaker, D. (2021). *Impact of finance on biodiversity: How agricultural business models get financed and promoted*. Working Paper, Erasmus Platform of Sustainable Value Creation.

Salin, M. (2021). *Mean species abundance explained*. Unpublished (independent) NGFS-INSPIRE Study Group Input Paper.

Salin, M. and Prudhomme, R. (2021). *Modelling biodiversity-related scenarios: A review of existing models*. Unpublished (independent) NGFS-INSPIRE Study Group Input Paper.

Salin, M. and Svartzman, R., with the contribution of Alogoskoufis, S., Boirard, A., Cartellier, F., Dees, S., Gayle, D., Payerols, C. and Schets, E. (2021). *Biodiversity-related scenarios for financial stability assessments: Challenges and potential ways forward*. Unpublished (independent) working paper/NGFS-INSPIRE presentation.

Schydlowsky, D. (2021). *Designing Bank Regulation to Support Biodiversity: Proceeding by Phases*. Unpublished NGFS-INSPIRE Study Group Input Paper.

Stampe, J. (2021) *Implications for disclosure and reporting: The role for central banks and supervisors*. Unpublished NGFS-INSPIRE Study Group Input Paper.

Takahashi, S. (2021) *A review of the relevant reports on the risk categories of biodiversity*. Unpublished NGFS-INSPIRE Study Group Input Paper.

van Toor, J. (2021). *Can biodiversity loss lead to systemic risks?* DNB Internal Note. Unpublished NGFS-INSPIRE Study Group Input Paper.

UN Environment Programme World Conservation Monitoring Centre [UNEP-WCMC] (2022). *Land use change, ecosystem services and the economy*. UNEP-WCMC, forthcoming.

UNDP Sustainable Insurance Forum (SIF) (2021). *SIF scoping study: Nature related risks in the global insurance sector*. United Nations Development Programme, New York.

University of Cambridge Institute for Sustainability Leadership [CISL]. (2022). *Assessing nature-related financial risks: upcoming use cases from financial institutions*. Cambridge: University of Cambridge Institute for Sustainability Leadership.

Viegas, T. (2021). *UK Case Study*. Unpublished NGFS-INSPIRE Study Group Input Paper.

Volz, U., Agarwala, M., Burke, M., Klusak, P., and Kraemer, M. (2021). *The Impact of Biodiversity Loss on Sovereign Credit*. Unpublished NGFS-INSPIRE Study Group Input Paper.

Whytock, R. C. (2022). *Biodiversity: what is it and how do we measure it? Key concepts for financial policymakers*. Unpublished NGFS-INSPIRE Study Group Input Paper.

Wong, E., Au, R., Lau, N., Leung, F., Wu, G., and Yuen, W. (2021). *Broad review paper on "measuring impacts of the financial system on biodiversity loss"*. Unpublished NGFS-INSPIRE Study Group Input Paper.

World Bank and Bank Negara Malaysia. (2022). *An Exploration of Nature-Related Financial Risks*. Kuala Lumpur. World Bank.

Appendix 3. Comparative analysis of methodologies to assess risk exposure

Approach	Focus area	Biodiversity pressure	Metrics	Data/ information required	Major strengths	Key weaknesses/ limitations	Accessibility
Corporate biodiversity footprint (CBF)	Portfolio, sector, index level, company and project/ site level	Land use change, climate change and pollution	Mean Species Abundance (MSA) and aggregate index	Level of biodiversity pressures, best reported directly by companies or estimated using consumption and production data together with input/output tables	Mature, scientifically robust, supported by stakeholders, transparent, scalable, granular and comparable	Marine biodiversity and ecosystem fragmentation not yet factored in; positive impact still under development; impact of invasive species and resource consumption to be developed	Available on commercial basis, external expertise required with training, low cost of hiring and time investment
Biodiversity footprint financial institutions (BFFI)	Balance sheet, portfolio, sector, index level, company and project /site level	Land/sea use change, direct exploitation, climate change, pollution and invasive species	Potentially Disappeared Fraction (PDF) and aggregate index	Economic activities and characteristics of projects financial institutions (FIs) invest in, background data from life cycle assessment (LCA) type database, information on biodiversity impact drivers in different sectors	Scientifically robust, transparent, scalable, granular (if data available) and supported by stakeholders	Land-use related impacts are biased to temperate regions which means that land-use related impacts will be less accurate for tropical regions; inclusion of location-specific characteristics is limited; not all drivers of biodiversity loss are covered	Open source with developer support, external expertise required with training, high cost of hiring and time investment

Approach	Focus area	Biodiversity pressure	Metrics	Data/ information required	Major strengths	Key weaknesses/ limitations	Accessibility
Global Biodiversity Score for Financial Institutions (GBSFI)	Portfolio, sector, index level, company and project/site level	Land/sea use change, direct exploitation (partial), climate change and pollution	MSA and aggregate index	Economic activities, pressures, resources and emissions data	Scientifically robust, transparent, scalable, granular (if data available), differentiates past and new impacts, comprehensive and flexible	Pressure-impact relationships in the GLOBIO model (underlying model) are biased towards the most studied species and ecosystems; marine biodiversity, invasive species and soil degradation are not factored in yet; overexploitation is factored in only partially	Available on commercial basis, external expertise required with training, high cost of hiring and time investment
Species Threat Abatement and Restoration metrics (STAR)	Portfolio, sector, index level, company and project/site level	Land/sea use change, direct exploitation, climate change, pollution and invasive species	STAR	A geospatial polygon on top of the STAR map to produce a report showing the potential reduction in species extinction risk at the site, company data on land use for assessing portfolio impacts	Global coverage, comparable, comprehensive list of species covered	Does not include information about threats to habitats, as the information is not yet available at a global scale in a comparable fashion to species	Open source with developer support, external expertise required without training, low cost of hiring in general (but could vary depending on the usage) and time investment

Approach	Focus area	Biodiversity pressure	Metrics	Data/ information required	Major strengths	Key weaknesses/ limitations	Accessibility
Biodiversity Impact Analysis (BIA)	Balance sheet, portfolio, sector, index level and company	Land/sea use change, direct exploitation (partial), climate change and pollution	MSA and aggregate index	Identification numbers for underlying companies (e.g. ISIN number) of and exposure to underlying assets of a portfolio; companies' greenhouse gas emissions data, geographical or sectoral breakdown of turnover	Easy to use, scientifically robust, comprehensive, compatible with international objectives, granular, flexible and scalable	Granularity within a sector is limited; pressure-impact relationships in the GLOBIO model (underlying model) are biased towards the most studied species and ecosystems; marine biodiversity, invasive species and soil degradation are not factored in yet; overexploitation is factored in only partially	Available on commercial basis, external expertise required with training, low cost of hiring and time investment
Exploring Natural Capital Opportunities, Risks and Exposure (ENCORE)	Portfolio, sector, company and project/site level	Land/sea use change, direct exploitation, climate change, pollution and invasive species	MSA, STAR and aggregate index	Sub-industries or production processes, approximate locations for economic activities interested in analysis	Easy to use, scientifically robust, comprehensive, can be integrated with other data sources	Some dependency and/or impact links may be missing if they are not covered by literature; does not account for future developments by industries to reduce dependencies and impacts; only the direct impact and dependences are covered; no coverage of cultural ecosystem services or nutrition under provisioning ecosystem services	Open source with developer support, external expertise required with training, low cost of hiring and time investment

Source: Wong et al., 2021

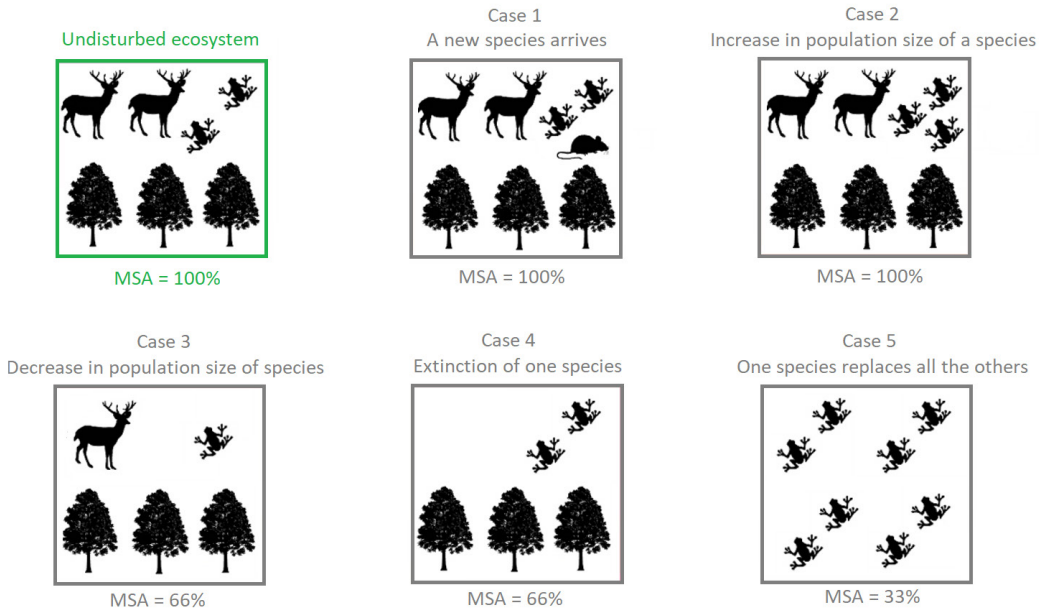
Appendix 4. Mean Species Abundance explained[13]

One of the challenges in measuring biodiversity is the difficulty of reducing complex ecosystems to a single metric. Several metrics – such as the Living Planet Index, Red List Index, Biodiversity Intactness Index and Mean Species Abundance (MSA) – have been developed to provide simplified measurements of ecosystem health.

MSA is defined as the average abundance of species (the number of individuals per species) relative to their abundance in a theoretical 'intact' ecosystem,[14] undisturbed by human activity. MSA varies between 0 and 100 per cent, where 100 per cent corresponds to the undisturbed ecosystem and 0 per cent is an ecosystem that has been completely degraded (e.g. converted into a car park). For example, the MSA of a pasture with grazing livestock might be 60 per cent, an ecosystem with intensive agriculture 10 per cent, and 5 per cent for an urbanised area (CDC Biodiversité, 2020).

Figure A1 offers an illustration of how MSA is calculated. It shows that the MSA counts only the species that were already present in the undisturbed state (Case 1: the introduction of a new species does not result in an increase in MSA) and does not take into account an increase in the abundance of a species relative to the undisturbed state (Case 2). In addition, the MSA does not necessarily reflect the extinction of a species (the MSA in Cases 3 and 4 is the same despite there being one species less in Case 4). However, the MSA does account for the initial number of species in the ecosystem (i.e. species richness), and not only for the size of the population (i.e. number of individuals) (Case 5).

Figure A1. Examples of Mean Species Abundance



Source: Salin (2021)

13. This section is derived from Salin, 2021.
14. The MSA of a given observed ecosystem is written as follows:

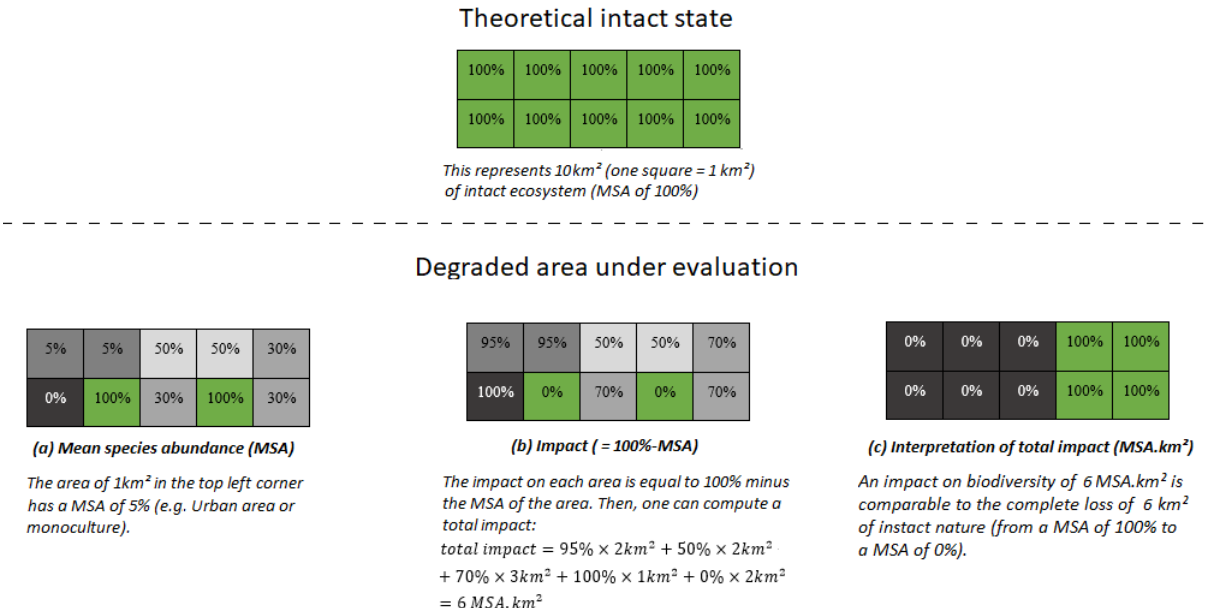
$$MSA = \frac{1}{N}\sum_{i=1}^{N} \min\left(\frac{A\,(i)}{A_0(i)}, 100\%\right)$$

Where *MSA* is the mean abundance of native species in the ecosystem, *N* is the total number of species in an undisturbed ecosystem, *A(i)* is the abundance of species i in the observed ecosystem and A_0 (*i*) is the abundance of species i in an undisturbed ecosystem.

The total biodiversity impact of a whole country, company or project can be summarised using a metric called MSA.km². It is obtained by converting the different MSA of each part of the surface area (e.g. each km²) into impacts by subtracting the observed MSA from the maximum MSA of 100 per cent (Figures A2.a and A2.b). Then, the various impacts are aggregated into a unique impact by multiplying each impact by its surface (cf. note to Figure A2.2b).

Finally, total impact can be interpreted as follows: an impact of x MSA.km² is comparable to the complete destruction (MSA of 0 per cent) of x km² of a previously intact ecosystem (MSA of 100 per cent) (Figure A2.c). This is a simplification that does not account for the location and distribution of the impacts. Indeed, from Figures A2.a and A2.c, which both show the same total impact of 6 MSA.km², we see that a total impact in MSA.km² can correspond to a multiplicity of situations in practice.

Figure A2. From MSA to MSA.km² and its interpretation



Source: Salin and Svartzman (2021)

Appendix 5. Scenario-relevant models[15]

Capturing the macroeconomic and sectoral consequences of physical or transition shocks would require specific integrated models or modelling frameworks (using a combination of existing models), some of which are starting to emerge. Below we provide a review of some of the existing models. We suggest a specific classification but we acknowledge that these models could be classified differently.

Economic models

- **Sectoral and macroeconomic models:** These models only represent the functioning of the economy and do not traditionally include any environmental aspects. They may, however, be useful if one wants to assess the effect on a specific sector or on macroeconomic variables either of a policy aiming to protect biodiversity or of a biophysical shock (e.g. a decrease in the provision of raw material like timber or fibres). For example, in the case of climate change, the Banque de France (Allen et al., 2020) uses such models to assess the economic impact of an increase in the price of carbon (i.e. a transition shock).

- **Input–output models:** just like the previous models, most input-output models were initially restricted to the economy. They represent the links between the production of economic sectors and both the final demand (by final consumer) and the demand by other economic sectors for intermediary consumption. As it makes explicit the interdependency between sectors, input-output analysis can be used to assess the cascading effect of policies aimed at mitigating climate change, such as the stranding of carbon assets in the mining and energy sectors (Cahen-Fourot et al., 2021; Godin and Hadji-Lazaro, 2021). **Some input–output models have also been extended to integrate the environment more explicitly**, by accounting both for the inputs taken from the environment and the waste products of industries (output). Hence, such environmentally extended input–output models may help estimate the impact of production or consumption on the environment (Victor, 1972), in particular on biodiversity (Bjelle et al., 2021) or ecosystem services (Cordier et al., 2011).

Land-use models

Land-use change is the main driver of change in biodiversity at the global scale. Land-use models can be used to explore potential future impacts on biodiversity and ecosystem services and evaluate potential trade-offs between different demands for land use (for food, resources, energy, to mitigate climate and reduce biodiversity loss) (van Soesbergen, 2016). There are various types of models that include land use:

- **Land-use modules in integrated assessment models (IAMs):** Such land-use modules were initially created to be associated with IAMs but can also be used separately. They are partial equilibrium models that "provide quantified estimates of future land-use patterns for given assumptions about their drivers" (Leclère et al., 2020, p. 24). Land-use components of IAMs include AIM (from the CGE integrated assessment model), GLOBIOM (from MESSAGE), IMAGE (from MAGNET) or MAgPIE (from REMIND).

- **Economic based land-use models (unrelated to IAMs):** These models allocate land uses geographically, based on the description of the economic behaviour of agents. They can be partial equilibrium models such as NLU (which can be coupled to the macroeconomic model IMACLIM [Prudhomme et al., 2020]) or models that

15 This section is derived from Salin and Prudhomme, 2021.

only depict the supply and the consequences of a supply change on demand. For example, AROPAj (Jayet et al., 2018) obtains the demand for water for irrigation with a biophysical model.

- **Models of rule-based allocation of land uses:** These models take as an input the area of land dedicated to various use at a large geographical scale (e.g. a country) and allocate it at a lower scale within this area in order to obtain detailed land-use maps. This allocation is based on statistical rules and will depend on the biophysical and demographic characteristics of the land. Example of such models include CLUEmondo (van Asselen and Verburg, 2013) or SEALS.

Biodiversity models

These models translate direct drivers of biodiversity loss (such as the type of land use) into impacts on biodiversity, expressed with different types of metrics depending on the model. Biodiversity models include AIM-B (biodiversity metric: Extent of suitable habitats, ESH), INSIGHTS (biodiversity metric: ESH), LPI-M (biodiversity metric: Living Planet Index, LPI), BILBI (biodiversity metric: Fraction of Globally Remaining Species, FGRS), cSAR_CB17 (biodiversity metric: FGRS), cSAR_US16 (biodiversity metric: FGRS), GLOBIO (biodiversity metric: Mean Species Abundance Index, MSA), PREDICTS (biodiversity metric: Biodiversity Intactness Index, BII), or LC-IMPACT (biodiversity metric: Potentially Disappeared Fraction of species, PDF).

Models of ecosystem services

These models translate the state of ecosystems (mostly depending on the type of land use, or, in some models, the stock of fish) into spatially explicit ecosystem service flows for human populations (e.g. pollination or fish provision). These flows can be expressed in biophysical or economic terms. Examples of such models include InVEST, ARIES, Ecopath with Ecosim, IMAGE 3.0 (an IAM framework containing an ecosystem services module), ESR, TESSA, Co$ting Nature or LUCI (for a detailed comparison of these models, see IPBES, 2016, chapter 5). Note that most models of ecosystem services take land use as an input, rather than the precise state of biodiversity. Indeed, IPBES (2016) notes that "models of biodiversity and ecosystem services [...] are only weakly connected to one another". The existing models that connect the state of biodiversity to a provision of ecosystem services are only restricted to specific ecosystems (e.g. the alpine pastures) or species and services (e.g. linking the abundance or richness of specific pollinators to the furniture of the pollination service).

Environment–economy models

- **Integrated models:** Such models include nature in the production function and a feedback loop of the impact of the economy on nature. We can distinguish two different types:

    - Some are more 'toy' **models that are made of a limited number of equations and adopt a cost–benefit approach** that compares the relative gains of incurring (or not incurring) some economic costs to protect the environment. Example of such modes include the 'Green DICE'-type models (Hackett and Moxnes, 2015; Bastien-Olvera and Moore, 2020) or the 'bounded economy model' proposed by Dasgupta (2021), in which nature provides ecosystem services that feed into the production function but that are themselves affected by the economy.

    - As previously mentioned, there are also some **more 'applied' and complex integrated assessment models,** which include land use modules (see above). They allow the economy to be modelled and its impacts on land use to be detailed, which then feed back to the economy due to the change in carbon storage (affecting emissions and temperature) and the change in land quality (affecting crop yields).

- **Macroeconomic models including 'natural capital'** (or 'ecosystem services', such as natural resources or land used for production), without any feedback loop from the economy to the environment. Some Computable General Equilibrium models (CGE), such as GTAP-AEZ or GCAM, introduce, for example, land or natural resources in their production functions.

The models presented here can be combined to assess the possible consequences of specific scenarios for the economy or for ecosystems and biodiversity. For example:

- **Economic impact of physical shock:** Answering the question *"What is the economic consequence of the deterioration of an ecosystem or of the ecosystem services it provides?"* can require the combination of models of ecosystem services and sectoral or macroeconomic models.

- **Economic impact of a transition shock:** To answer the question *"What is the economic consequence of the social, political, institutional or technological changes aiming at bending the curve of biodiversity loss?"*, we may need to use either a purely economic model or to combine it with a land-use model in cases where the policy aims to affect land use (e.g. regarding protected areas).

- **Integrated view:** To answer the two previous questions simultaneously (*"To what extent does the economy depends on ecosystem services and how can the economy affect these services [negatively or positively]?"*) may require an integrated modelling framework such as the one developed by Johnson et al. (2021). This framework combines a macroeconomic model that includes a land use component (GTAP-AEZ) with a model that allocates land use at a detailed geographic scale (SEALS) and a model of ecosystem services (InVEST).

- **Impact of policies on biodiversity:** *"What is the impact of the economy (or of other indirect drivers of biodiversity loss, such as changes in governance or technology) on the state of biodiversity and ecosystems?"* Providing an answer to this question may require the use of economic models combined with land-use models (or IAM land-use modules) and biodiversity models (as in Leclère et al., 2020).

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