Biodiversity and Re/insurance: An Ecosystem at Risk

Jules Chandellier, Marine Malacain

MUSĒUM NAL HIST NATURELLE

BIODIVERSITY AND RE/INSURANCE: AN ECOSYSTEM AT RISK

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Project Team – Muséum national d'Histoire naturelle, Department of Expertise
Jules Chandellier – Project Leader
Marine Malacain – Project Officer
Nirmala Séon-Massin – Director
Magali Gorce – Deputy Director
Vincent Hulin – Former Director

Scientific Advisory Board
Sara Angeli Aguiton – Research scientist CNRS, Science and technology studies and environmental sociology – Centre National de la Recherche Scientifique (CNRS)
Catherine Aubertin - Senior Research Scientist IRD, Environmental economics – Institut de recherche pour le développement & Muséum national d'Histoire naturelle
Denis Couvet – Lecturer and senior researcher, Professor in environmental conservation - Muséum national d'Histoire naturelle
Claire Gachon – Researcher, Professor in molecular plant pathology - Muséum national d'Histoire naturelle
Philippe Grandcolas – Senior Research Scientist CNRS, Head of Laboratory, Systematics and evolutionary biology – Muséum national d'Histoire naturelle, CNRS, Sorbonne Université, Ecole Pratique des Hautes Etudes and Université des Antilles
Maud Mouchet – Lecturer and researcher, Functional Ecology – Muséum national d'Histoire naturelle

Partner - SCOR Corporate Foundation for Science
Philippe Trainar, Director – SCOR Corporate Foundation for Science
Zeying Peuillet, General Secretary - SCOR Corporate Foundation for Science

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MUSÉUM NATIONAL D'HISTOIRE NATURELLE

This historic institution was created in 1635. Originally a royal garden for medicinal purposes and an educational institution, it became the Muséum national d'Histoire naturelle in 1793. At the crossroads between earth, life and human sciences, the Muséum focuses on nature and its relationship with humans. The Muséum is simultaneously a research center, a muséum and a university, creating and disseminating knowledge to a wide range of audiences (the general public, students, policymakers, private firms, NGOs, etc.). A pioneer in citizen science, the Muséum is also committed to involving visitors and partners in improving environmental awareness, through a sound scientific approach.

DEPARTMENT OF EXPERTISE – MUSÉUM NATIONAL D'HISTOIRE NATURELLE

The Muséum's Department of Expertise provides scientific support to French and international stakeholders, both public and private, in terms of developing and using the knowledge required to protect biodiversity. This activity forms an interface between research and management issues. In practice, the Muséum's Department of Expertise may be called upon to provide national nature reference databases, information and assessment protocols used for decision-making by a variety of public bodies, specific advice on major issues, and responses to private requests on a wide range of topics. All of these activities use the Muséum's scientific knowledge to help preserve our natural heritage.

SCOR CORPORATE FOUNDATION FOR SCIENCE

The SCOR Corporate Foundation for Science lends its support to different kinds of risk and (re)insurance-related projects, including university chairs, research projects, conferences and publications, within the framework of its statutes and means.

Created in 2011, the SCOR Corporate Foundation for Science forms part of the SCOR group's long-term commitment to research and the dissemination of risk-related knowledge. This commitment is an integral part of SCOR's DNA, as illustrated by the Group's tagline, "The Art & Science of Risk". Risk is, in effect, the "raw material" of reinsurance and SCOR aims to be at the cutting edge of risk expertise and research thanks to the vast network of academic institutions it works with and the support it gives to numerous disciplines, including mathematics, actuarial science, physics, chemistry, geophysics, climatology, economics and finance, among others.

FOREWORD

BRUNO DAVID, President, Muséum national d'Histoire naturelle


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Awareness of and interest in the fate of the living beings that compose the web of life that we humans are part of has been steadily rising in the past few years. Despite the fact that the COP15 of the Convention on Biological Diversity has been postponed to 2021, protecting biodiversity has never been a more burning issue. The COVID-19 pandemic was likely triggered by the deterioration of Nature's conditions. Its consequences remind us that human systems depend on their environment.

In this context of increased awareness of the urgency to protect Nature, the basic foundation that feeds and supports us in every aspect of our lives, public and private actors are increasingly motivated to take action. The Muséum national d'Histoire naturelle, leveraging 400 years of research in natural history, is proud to provide scientific support to assist them in their undertakings.

The Muséum national d'Histoire naturelle advocates for a natural history approach that sees humans and their societies as integral parts of the living world. Embracing this approach would enable companies to become more aware of the underlying interactions they have with the living environment that surrounds them.

Natural history can help companies to think about their role and responsibilities, and how they can build a clear, ethical position as actors of environmental change, at the heart of highly debated societal issues. In that respect, developing trans-sectoral and transdisciplinary partnerships that build bridges between scientific and business communities will be instrumental. Building and strengthening those bridges is in fact one of the Museum's five activities, in the form of providing expertise.

The partnership between the Muséum and the SCOR Corporate Foundation for Science that led to this report is a great illustration of how an industry leader can team up with the scientific community in order to better understand the interdependencies between biodiversity and its business activities.

Human societies themselves are ecosystems in which the elements are related and need to be mutually irrigated. Scientific research needs partnerships and funding to move forward into exploring new directions, while companies need scientific research to prepare for the future on a sound and sustainable foundation.

This partnership has proven to be a real success and lays the groundwork for many others.

Bruno DAVID
President of the Muséum national d'Histoire naturelle

DENIS KESSLER, Chairman and Chief Executive Officer, SCOR


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As a global reinsurer, SCOR aims to be at the cutting edge of risk expertise. The Group is firmly committed to pushing back the frontiers of risk-related knowledge and sharing thoughts about the current and potential emerging risks threatening societies and economies. This commitment is an integral part of SCOR's DNA, as illustrated by the company's tagline, "The Art & Science of Risk". SCOR constantly invests in the understanding of risks and actively supports risk-related scientific research, notably through its Corporate Foundation for Science.

We are proud that the SCOR Corporate Foundation for Science has partnered with the Muséum national d'Histoire naturelle (MNHN) to conduct a pioneering large-scale study on the risks related to biodiversity loss, under the aegis of the SCOR-MNHN "Biodiversity and (Re)insurance" Chair created in 2019. Founded in 1793, MNHN is one of the most renowned natural science institutions in the world.

The evidence for biodiversity loss and the accompanying loss of genetic diversity is compelling throughout the world. The growing concern over the changing variety and variability of life forms on Earth is due to both the rapid pace at which biodiversity loss is occurring, and the fact that it is primarily caused, whether directly or indirectly, by the impact of human activity. The loss of biodiversity is an extremely complex and multifaceted issue with multiple interdependencies – not least with climate change, which is increasingly contributing to the disruption of terrestrial and marine ecosystems. Identifying, understanding, assessing, tackling and addressing the associated risks is a global and shared commitment, which requires the combined efforts of both public institutions and the private sector.

The findings and conclusions of this research are key to SCOR's development of a holistic and integrated approach to managing the risks linked to biodiversity loss, and to actively contributing to the protection and preservation of the biosphere. In an ever riskier and more uncertain world, the (re)insurance industry has a leading role to play in working towards sustainable and responsible development.

Denis KESSLER
Chairman and Chief Executive Officer of SCOR

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PREFACE

Extracts from the Muséum Manifesto

"WHAT FUTURE WITHOUT NATURE?"

GROUNDING HUMANITY IN NATURE

"Natural history's key role - and no doubt the most difficult to achieve - is to contribute to raising awareness about humankind's place in nature, that is, as a species among others. Natural history not only situates humans in the history of living beings, it also implicates them in natural dynamics, including those that are underway and that contributes to evolution. It should therefore participate in considerations involving the human-nature relationship, wherein humans see themselves as determining their own evolution while they change their environment, thereby creating the very conditions that confront them with certain decisions. It is therefore important to make sure these decisions are founded. Their foundation and therefore their legitimacy are drawn from scenarios in the past, from the current state of the real world, and from rational forecasting. But it isn't just a matter of natural history: this foundation must be established equally with economic and social data. For this, the citizen-naturalist or researcher must guarantee his or her political autonomy, asserting independence, taking ethical aspects into account, denouncing studies under the influence of special interests, and supporting public funding of the research undertaken by academic institutions and organizations."

(Muséum national d'Histoire naturelle, 2017)

WHAT FUTURE FOR NATURAL HISTORY?

"At the beginning of the century, many human societies already seem ready to give in to a certain lassitude, given economic imperatives and growing demand for raw materials. Unfortunately, the very short term takes precedence in decisions for which another vision of time is vital. Little by little, protected areas are being downsized or downgraded, while the protection of endangered species remains a pious wish or the responsibility of a few courageous advocates. Can this trend be reversed by the end of the century? Perhaps, if considerable effort is made to diffuse rational, scientific knowledge of nature, as well as of the dangers certain human activities pose to it. Above all, the reasonable and ethically responsible management of quantitative limits attributed to our own species remains the key to a desirable future. It is at this price that we might eventually be able to restore, over the course of the century, a new, sustainable model of interaction, in which humans, while retaining the benefits of their own production and no doubt increasing them, will be able to reposition themselves as part of nature in a less conquering manner."

(Muséum national d'Histoire naturelle, 2017)

EXECUTIVE SUMMARY

Humans evolve in a given environment, i.e. all their activities are constrained by that environment and what it offers at any given time and place. This report investigates the interactions of one such activity, the re/insurance industry, with the ever-evolving surrounding environment in which it operates and that is characterized by biodiversity, that is the diversity of Earth's living beings.

To that end, the present report starts by providing scientific evidence on **biodiversity loss and the interactions (impacts and dependencies) with human societies.** It goes on to investigate the **risks that biodiversity loss poses to human societies** and then examines **how re/insurers are exposed to those risks, how they affect biodiversity themselves** and **what opportunities exist for them to align their agenda with biodiversity challenges.**

PART I. A SCIENTIFIC PERSPECTIVE ON BIODIVERSITY AND HUMAN SOCIETIES

MAIN FINDINGS

"Biodiversity" or **biological diversity** refers to the set of varied forms of life on Earth which constitute the **"web of life"**. It encompasses three interdependent levels of diversity, namely ecosystems, species (plants, animals, fungi, microorganisms) and genes (i.e. individuals within each species). This "web of life" provides the goods and services that are **vital to human livelihoods and societies**. These flows called **ecosystem services** or **"Nature's contributions to people" (NCPs)** can be categorized as **Regulating NCPs**, i.e. those providing the basics that support human life (e.g. Habitat creation and maintenance, Pollination and dispersal of seeds, Regulation of air quality), **Material NCPs**, i.e. those providing material goods (e.g. Energy, Food and feed) and **Non-material NCPs** i.e. those providing "spiritual inspiration and learning".

The scientific message is loud and clear, biodiversity in all its forms is degrading at an alarming and unprecedented rate, to the point where scientists consider that the **sixth mass extinction** has begun.

Humans are living beings and hence **integral parts of biodiversity**. Humans ***depend*** on the existence of ecological interactions. Individuals and companies interact with biodiversity to co-produce goods and services that are essential to the good quality of life and business. To that end, individuals and organizations make decisions and take action which have a positive or negative ***impact*** on biodiversity, depending on the type of dynamic that is engendered, namely trade-offs, synergies or substitutes. The accumulation of those decisions and action on the global level has led to a **clear dynamic in favor of the production of material NCPs at the expense of regulating and non-material NCPs**.

Through our choices as human beings and their implications, we are indeed responsible for the **five main drivers of change** in biodiversity: **changes in land and sea use, including habitat loss and degradation; species overexploitation; invasive species and disease; pollution; and climate change. Climate change and biodiversity loss** are **closely interlinked** and can be deemed **"twin crises"** in that climate change has detrimental impacts on biodiversity and biodiversity loss affects the climate-change dynamic. In that sense, **lessons learnt from the climate sphere** could be of great use to tackle the biodiversity crisis.

Biodiversity is about **interdependencies**. Changes in one of its elements initiate a **multitude of cascading effects through chains of ecological interactions**, which in turn initiate **feedback effects**. The whole process behind the loss of biodiversity is thus extremely complex to apprehend, yet the **loss dynamic is undisputed**. We are in the middle of a **vicious circle of degradation** that was initiated and is continuously fueled by harmful human activities. This unsustainable dynamic is forcing **a growing number of individuals and companies to rely on a decreasing amount of available NCPs**, with an **increasing amount of uncertainty concerning the reaction of biodiversity** to these harmful impacts and how far they are from **causing full disruption**.

The intricacies of ecological interactions and the complexity of the loss dynamic make it virtually impossible to devise an index covering all aspects of biodiversity changes, unlike the **"+2°C" mitigation target** for climate change. For that reason, the Convention on Biological Diversity (CBD) Strategic Plan for Biodiversity 20II-2020 relied on the 20 "Aichi Biodiversity Targets". The issue of setting targets will again be central at the CBD's COPI5 in Kunming in China, where the international community will gather in 202I to agree on a post-2020 Global Biodiversity Framework with a new set of targets.

Science is continuously advancing and making progress in precisely describing the state and dynamics of biodiversity loss. Yet, much remains to be studied concerning:

— **biodiversity and ecosystem services themselves**, because the vastness of biological diversity and the complex interdependencies on all levels are far from being fully mapped yet;

— **the consequences of their loss on humans**, because a great deal is still unknown about the risks and impact mechanisms on both the sectoral and macroeconomic levels;

— **the levers to mitigate such impacts and risks**, because assessing "what works" to reduce anthropic pressures on ecosystems in terms of policies, metrics and indicators is an on-going process and no harmonized framework has emerged yet.

PART II. HUMAN SOCIETIES AT RISK FROM BIODIVERSITY LOSS

MAIN FINDINGS

Environmental risks (including biodiversity-related risks) can be qualified as **"green swans"**, in reference to the commonly used "black swan" metaphor. These types of risks share **deep uncertainty, non-linear propagation, significant negative externalities and geographic magnitude**. In addition, "green swans" are characterized by a **high degree of certainty of occurrence**, an **extreme level of impact** (they pose existential threats to humans) and a **higher degree of complexity** (due to the complex chain reactions and cascading effects). The potential **irreversibility of their consequences** could also be added to the features of "green swans".

The intricacies of biodiversity and human activities, the global interdependencies of supply chains, the **cascading and feedback effects** of drivers of environmental change, the dissemination of dependencies and impacts over time and space, and the interference of political, social and economic factors all **add a layer of uncertainty as to the magnitude of biodiversity-related risk materialization**.

Individuals and organizations are exposed to biodiversity-related risks through **physical risks**, which are the material consequences of the changes in biodiversity and in the quantity and the quality of goods and services provided by nature. Individuals are threatened by increased health issues, a reduced or lack of access to resources and **increased vulnerability to extreme events**, while organizations can suffer d**isruptions in business operations** due to **commodity risks, supply-chain risks** and **material damages**.

Individuals and organization also are exposed to **transition risks**, which arise because human societies attempt to mitigate or adapt to these changes in biodiversity by transitioning to more sustainable systems. Individuals are affected through impacts on their **social and economic situation** as well as on the geopolitical context, with **forced migrations or conflicts**. Businesses are exposed to **reputation risks, market risks, regulatory and litigation risks** as well as **financial risks**.

The materialization of biodiversity-related risks depends on the combination of **exposure** and **vulnerability** of individuals and organizations. Individuals face **unequal exposure** to biodiversity-related threats depending on their location, socio-economic class, but also gender, while the exposure of a business depends on its sub-industry and production processes, given that risk materialization can transmit a**long value chains and across whole sectors**.

Financial institutions also face biodiversity-related physical and transition risks. However, because they are not directly engaged with biodiversity in their business operations, they are **less directly exposed** to environmental changes per se. Still, they are **indirectly exposed through the economic activities and individuals with which they engage**. They face a higher level of financial risks because the risks inherent to their counterparties are also transmitted onto them (via investments, loans, underwriting or advice). Consequently, they are exposed to additional **credit risks, underwriting risks, liquidity risks** and **solvency risks**.

The combination of these micro-level risks could create vulnerabilities on the **macroeconomic level, potentially destabilizing the whole economic system**, with impacts on international trade, regulations, interest rates and geopolitical stakes, as modelling exercises have already shown. These impacts would in turn have **detrimental feedback effects** on the financial system, businesses and individuals.

Underlying all these risks is the central question of **how we value and integrate biodiversity** into decision-making on the individual, corporate and national levels. **Economic valuations** show that **the value of nature's annual production exceeds that of humanity's** (i.e. the world GDP). But because the **benefits of exploiting nature are immediate**, but the **damage caused by negative externalities is more diffuse, long-term and unequally distributed**, the **causal chains** between biodiversity loss and business risks **are not yet firmly established**. The business case to protect biodiversity must still be made. Finding ways to **recognize the broader values of nature** (e.g. its intrinsic and sacred values among others) and to **integrate them in strategic and daily decision-making** would be a first step toward the **mitigation** of biodiversity-related risks.

PART III. BUILDING BRIDGES BETWEEN BIODIVERSITY AND RE/INSURERS: DEALING WITH UNCERTAINTY

MAIN FINDINGS

An insurance system is intended to **hedge against micro and macro risks** and to **build resilient societies**. Re/insurers are **underwriters**, they bear risks for other individuals and entities in exchange for a premium, ensuring stability and crisis recovery through **risk transfer**. Re/insurance companies also rank among the largest **institutional investors**, giving them substantial power over the channeling of funds in the economy. Their core expertise in **assessing, modelling, quantifying and pricing risks** and their **singular position within the economy** provide them with a **unique perspective** on the **systemic aspects** of biodiversity loss and its potential cascading effects on individuals, companies, financial institutions and economic systems.

The re/insurance business is based on two pillars, **underwriting and investing**. In the underwriting business, there are two main types of insurance policies offered to individuals and organizations, namely **Property & Casualty (P&C) insurance** (covering mainly physical damages to property, operating losses, trade credit and liabilities) and **Life & Health insurance** (providing life insurance as savings products and covering health risks such as physical injuries, disabilities, long-term care, medical expenses, critical illnesses and death). The collected premiums from the underwriting business fuel the **investing business**, which is in charge of investing in a broad range of assets to generate financial returns. A **reinsurer's business** operates essentially like that of an insurer's, except that reinsurers mainly offer coverage for insurance companies or large industrial risks. In order to provide capacity to insurers, reinsurers are **more diversified in terms of economic sectors and geography**, which is a key aspect of their business model.

For this report, we defined the concept of "risk" for a re/insurance company as **a threat which could generate financial losses if it materializes**. Re/insurers are businesses and hence exposed to **physical** and **transition risks** similar to those of other businesses. However, the **specificities** of their activities mean that they have a specific risk profile:

— There is **close to zero direct interaction between re/insurers and biodiversity**. Consequently, they suffer **very few direct physical risks**, except for the infrastructure they own (e.g. flooding of their buildings).

— That being said, they are exposed to **transition risks** similar to those of:

- Businesses: **reputation risk, market risk, regulatory and litigation risks** and **financial risks**;
- Financial institutions: **credit risk, liquidity risk, solvency risk** and **stranded-asset risk**.

— In addition, they are exposed to **transmitted risks**. Their **policyholders and investees**, as individuals and organizations, are **potentially exposed** and **vulnerable to biodiversity-related risks** which they **transfer to re/insurers**.

These biodiversity-related transmitted risks are of multiple nature, depending on the line of business:

— The **underwriting branch** is exposed to:

- **Uninsurability risks**. Biodiversity-related risks are systemic risks, difficult to measure and with high potential knock-on effects that can vastly increase maximum losses. Consequently, the standard insurance practices relying on risk diversification and pooling are ineffective and insurance companies could be unable to cover the losses in a given geographic area. Because of biodiversity loss, many currently insured risks can become **uninsurable** (or insurable, but at an unaffordable price for customers) and re/insurers could be **unable to provide solutions for emerging risks**.
- **Operational risks**. The profitability of the underwriting business relies mainly on the ability of the re/insurer to correctly price and pool the risks in order to obtain an inflow of premiums higher than outflow of claims payouts and operating expenses. Biodiversity loss could translate into:
  - **Pricing risk**. If P&C and Life & Health risks are underestimated and inaccurately priced, pricing risks arise;
  - **Claims risk**. Biodiversity loss could lead to a higher average number of claims, a higher average amount of claims and a phenomenon of geographic or sectoral concentration of claims (e.g., in the P&C case, increased infrastructure damages);
  - **Liability risk**. With evolving legislation, claims under liability policies due to harmful impacts on biodiversity could increase. The exposure would however depend on the type of liability policies underwritten by the company, as well as the development of a legal framework around biodiversity.

— The **investing branch** is exposed to risks similar to those of other financial institutions, i.e. **Credit risk, Market risk, Solvency risk** and **Liquidity risk**.

The science is clear concerning the degrading state of nature. There is no doubt that, if not addressed properly and promptly, the disruptions in Nature's contributions to people will cause an **increase in the frequency, intensity and concentration of biodiversity-related risks**, which will affect each and every level of human societies, including re/insurers. Yet, the transmission mechanisms between disruptions in ecological interactions and the materialization of risks within the highly sophisticated underwriting and investing processes are extremely complex to establish. Evidence on the causal chains is just starting to emerge.

This report specifically analyses the **case of pandemics** to **exemplify the chain reaction from biodiversity loss to materialized risks for re/insurers**.

One way to mitigate these risks is to **tackle the root causes** of this vicious circle of biodiversity degradation, i.e. halting activities that negatively **impact** biodiversity in the first place, while promoting activities that are beneficial to its conservation and restoration.

As underwriters, the mission of re/insurers is to minimize the impact of shocks for policyholders. As investors, their investment portfolio has an impact on the targeted sectors or companies, in that the investments support their development. The concept of impact is, in that sense, **at the core of a re/insurer's day-to-day business**.

All economic activities produce negative and positive **externalities** in the process of producing goods and services. By providing a **"license to operate"** to their policyholders and investees, re/insurers indirectly bear responsibility for the activities they choose to cover or invest in, and consequently for the externalities of those activities. In setting up **clear environmental criteria** in both their underwriting and investing activities, re/insurers have the power to create the right incentives for harmful activities to be reviewed and processes changed.

It is thus crucial to grasp **both the harmful and beneficial impacts** industries can have on biodiversity and to establish the right criteria to filter **both negative and positive activities**, as is already being done for climate issues. **Tools, maps and guides** exist and are continuously being developed to evaluate how and how much an activity, a company or a sector impacts the environment. Agricultural Products, Distribution, Mining, Oil & Gas Exploration & Production, and Oil & Gas Storage & Transportation in particular have been designated by recent studies as the most important sectors that financial institutions should assess if they want to mitigate their impact on biodiversity.

There are several ways re/insurers can also **rethink their practices** to mitigate their impact on biodiversity. Many international initiatives aim at setting standards and guidelines for entities wanting to engage in setting **science-based targets** to preserve biodiversity. On a more operational level, **tools and indicators are flourishing** to assess, measure and mitigate the different impacts of organizations on biodiversity. Measuring the **biodiversity footprint** of a product, a project, a portfolio or an entire entity is already possible and methods are continuously being improved. As investors, reinsurers can also aim for positive impacts through **biodiversity-positive investments**.

There is a clear and common scientific stance that **preventive action** produces better results than emergency responses. Consequently, it is better to take action against risks before they materialize because ecosystems and the services provided will very likely not be fully restorable once destroyed. The **business case for biodiversity protection** is still progressing, but we cannot afford to wait any longer. Today, there is **clear momentum** for the integration of biodiversity in business practices thanks to increased awareness and emerging methods and initiatives.

What is more, emerging risks in fact represent **opportunities** if addressed early enough. Re/insurers embracing the challenges of biodiversity loss could benefit from those opportunities, i.e.:

— ensure the **sustainability of their business in the long run** by reducing their risk exposure;

— seize **new business opportunities** by developing innovative insurance products to deal with systemic risks, supporting their customers in biodiversity risk management, providing environmental-liability insurance or developing insurance products for nature and innovative financial products;

— **enhance their reputation and leadership** through active participation in international negotiations, while potentially **redefining their social role in building a resilient society**.

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GENERAL INTRODUCTION

With climate hazards becoming more threatening with each passing year, citizens, governments and private actors alike have started factoring global warming into their day-to-day decisions. The year 2015 marked a turning point in climate action, when 196 parties adopted the Paris Agreement at the COP 21 in Paris. In step with our progression in the Anthropocene, awareness of the impacts a warmer world will have on human societies and economies is increasing.

But climate change is only part of an increasingly complex equation, given the steady development of human societies. Human activities affect nature in many more ways than just via greenhouse gases emissions. As the COVID-19 pandemic illustrates all too well, destabilized ecosystems and a degraded nature may completely disrupt human livelihoods and organizations.

Following in the footsteps of the Fifth Assessment Report by the Intergovernmental Panel on Climate Change (IPCC) in 2014, the Global Assessment Report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) in 2019 was a wake-up call. The science is clear, a biodiversity crisis is taking place and it is happening now. Humans have triggered the Earth's sixth mass extinction and will increasingly suffer from the material consequences it generates.

The international community has already started to tackle this challenge. In 2010 at the Convention on Biological Diversity (CBD) COP 10 meeting in Nagoya, the parties notably adopted the Strategic Plan for Biodiversity 2011-2020 and the Aichi Biodiversity Targets. Policies put in place and actions undertaken since have proven insufficient as most targets are still far from achieved, and 2020 was supposed to be a milestone year in the biodiversity agenda, with the establishment of a renewed post-2020 framework at the CBD COP 15 meeting in Kunming, China.

Even though international meetings have been postponed to 2021, momentum has been generated. It is time to act. Integrating biodiversity into decisions and strategies has become vital for governments, but for private businesses as well. The loss of biodiversity is an environmental issue, but it is equally a social, governance and financial issue. Biodiversity is the "web of life"; preserving it is about preserving all aspects of life on Earth and all aspects of human life and well-being in particular.

In the long run, economic health and businesses may be put at risk by the deterioration of the Earth system. Most companies are gradually integrating climate issues into their business models and those that have understood that the environment as a whole must be embedded in their strategy will be tomorrow's leaders.

Whole industries are on the brink of disruption from ecosystems collapse, not the least of which is the re/insurance industry. Underwriting and investing activities rest on the healthy condition of underlying assets and those healthy conditions are jeopardized by growing uncertainties in the face of ecosystems destabilization. The first step for re/insurers toward mitigation and adaptation to changing conditions is understanding the intricacies of the challenge, grasping exactly what the interactions are between biodiversity and their business.

This is why the SCOR Corporate Foundation for Science has turned to the Muséum national d'Histoire naturelle (MNHN) in its effort to understand the implications of biodiversity loss for its activities. This partnership reviews the scientific evidence of links between present and future human activities and biodiversity, investigates the extent to which re/insurance activities impact biodiversity, examines the risks that biodiversity loss will create for future human activities and explores the opportunities that acting in favor of biodiversity could generate.

The first part will provide **A scientific perspective on biodiversity and human societies**, the second will expand the reflection on **Human societies at risk from biodiversity loss** and the third and last part will address **Building bridges between biodiversity and re/insurers: dealing with uncertainty.**

PART I

A SCIENTIFIC PERSPECTIVE ON BIODIVERSITY AND HUMAN SOCIETIES

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A SCIENTIFIC PERSPECTIVE ON BIODIVERSITY AND HUMAN SOCIETIES

Nature is one of the simplest and also the most complex concepts that we, as humans and societies, use and refer to. Our relationship with what surrounds us might feel innate, "natural", yet it is very much linked to how and where we were raised.

Curiosity is a defining characteristic of humans, it is through the understanding, adaptation to and use of its surroundings that Homo sapiens has become what it is now. Grasping how other living and non-living entities emerge, thrive, interact and disappear has been the key factor of our survival, for we have been able to build on and advance with this comprehension.

For a few decades, multiple warnings have pointed out the alarming deterioration of the environment we live in and of which we are an integral part. The disappearance of nature's wonders is in itself a catastrophe, but it also jeopardizes that which humans have been building for their entire existence, namely our societies.

Natural history lies at the heart of the effort to understand the connections between humans and the environment, it has for decades attempted to instruct us on the value of biodiversity as "*a heritage common to all of humanity*" (Muséum national d'Histoire naturelle, 2017). It has also shown how detrimental humans can be to their own ecology.

"*Today, natural history bridges science and its applications*" (Muséum national d'Histoire naturelle, 2017) and the objective of the first part of this study is to provide the reader with a scientific perspective on biodiversity and humans. To do so, we will first review what the concepts of "nature" and "biodiversity" refer to, what is common knowledge in the scientific community on the current status of biodiversity, what we know about the relationships between biodiversity and human activities, and what still remains to be explained.

1. BIODIVERSITY, ECOSYSTEM SERVICES AND NATURE'S CONTRIBUTIONS TO PEOPLE: DEFINITIONS AND DYNAMICS

What are we talking about, when we talk about biodiversity? What is its current status and how has it been evolving for the past few decades? This first part introduces our study by answering these defining questions.

1. FROM "NATURE" TO "NATURE'S CONTRIBUTIONS TO PEOPLE"

"**Nature**" usually refers to the air, soil, water, living creatures that surround us. It would appear to be a straightforward concept that even children can easily grasp and make use of. However, nature is a complex, highly culturally-dependent and abstract notion. Providing a strict definition of what it is and what it encompasses is far from simple.

Despite the blurred frontiers of the concept and the ensuing lack of a standard definition (Ducarme & Couvet, 2020), protecting a rapidly depleting nature is a growing public concern. This study focuses on one aspect of this "changing nature" concern, which is the loss of biodiversity and ecosystem services. The following section aims to define the concepts that will be discussed at length in the present study.

Adopted in 1992, the United Nations' Convention on Biological Diversity (CBD) targets "the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of benefits arising from the use of genetic resources" (UN CBD, 1992). Article 2 of this text establishes the definition of biological diversity that is agreed upon today internationally:

> ***Biological diversity*** *means 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.*
>
> (UN CBD, 1992)

In other words, the term "**biodiversity**" refers to the "web of life" which is constituted by "*the variety of life on Earth and the natural patterns it forms*" (Secretariat of the Convention on Biological Diversity, 2000); it encompasses three levels:

— The diversity of ecosystems or living environments;
— The diversity of living forms and species - plants, animals, fungi, microorganisms;
— The diversity of individuals (or genetic diversity) within each species.

This "web of life" forms the basis of human livelihoods and societies in that it serves as their essential foundation. This idea underlies the concept of **ecosystem services**, which has been used for the past twenty years (Costanza *et al.*, 2017) to refer to the ways nature directly or indirectly contributes to and even supports human existence and wellbeing (Millennium Ecosystem Assessment, 2005). The Millennium Ecosystem Assessment published in 2005 drew interlinkages between ecosystem services and constituents of human well-being using the following terminology:

> *An **ecosystem** is a dynamic complex of plant, animal, and microorganism communities and the non-living environment interacting as a functional unit.*
>
> (Millennium Ecosystem Assessment, 2005)

and

> ***Ecosystem services** are the benefits people obtain from ecosystems. These include **provisioning services** such as food, water, timber, and fiber; **regulating services** that affect climate, floods, disease, wastes, and water quality; **cultural services** that provide recreational, aesthetic, and spiritual benefits; and **supporting services** such as soil formation, photosynthesis, and nutrient cycling.*
>
> (Millennium Ecosystem Assessment, 2005)

This idea is also embodied within the more recently constituted Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), which is "*an independent intergovernmental body established by States to strengthen the science-policy interface for biodiversity and ecosystem services*" (IPBES, 2020a).

IPBES reviewed and broadened the "ecosystem services" definition that was previously established in the Millennium Ecosystem Assessment (IPBES, 2020b), adopting a more complex and inclusive conceptual framework that embraces more diverse views and knowledge of nature. That framework relies on the **Nature's Contributions to People (NCPs)** concept, which can be defined as:

> *all the positive contributions, or benefits, and occasionally negative contributions, losses or detriments, that people obtain from nature.*
>
> (Kadykalo *et al.*, 2019)

The IPBES framework includes 18 Nature's Contributions to People (NCPs) (IPBES, 2019e):

1. **"Habitat creation and maintenance:** *The formation and continued production, by ecosystems, of ecological conditions necessary or favorable for living beings important to humans;*
2. **Pollination and dispersal of seeds:** *Facilitation by animals of movement of pollen among flowers, and dispersal of seeds, larvae, or spores of organisms beneficial or harmful to humans;*
3. **Regulation of air quality:** *Regulation (by impediment or facilitation) by ecosystems, of atmospheric gasses; filtration, fixation, degradation, or storage of pollutants;*
4. **Regulation of climate:** *Climate regulation by ecosystems (including regulation of global warming) through effects on emissions of greenhouse gases, biophysical feedbacks, biogenic volatile organic compounds, and aerosols;*
5. **Regulation of ocean acidification:** *Regulation, by photosynthetic organisms of atmospheric CO_2 concentrations and so seawater pH;*
6. **Regulation of freshwater quantity, location and timing:** *Regulation, by ecosystems, of the quantity, location and timing of the flow of surface and groundwater;*
7. **Regulation of freshwater and coastal water quality:** *Regulation -through filtration of particles, pathogens, excess nutrients, and other chemicals -by ecosystems of water quality;*
8. **Formation, protection and decontamination of soils:** *Formation and long-term maintenance of soils including sediment retention and erosion prevention, maintenance of soil fertility, and degradation or storage of pollutants;*
9. **Regulation of hazards and extreme events:** *Amelioration, by ecosystems, of the impacts of hazards; reduction of hazards; change in hazard frequency;*
10. **Regulation of organisms detrimental to humans:** *Regulation, by ecosystems or organisms, of pests, pathogens, predators, competitors, parasites, and potentially harmful organisms;*
11. **Energy:** *Production of biomass-based fuels, such as biofuel crops, animal waste, fuelwood, and agricultural residue;*
12. **Food and feed:** *Production of food from wild, managed, or domesticated organisms on land and in the ocean; production of feed;*
13. **Materials and assistance:** *Production of materials derived from organisms in cultivated or wild ecosystems and direct use of living organisms for decoration, company, transport, and labor;*
14. **Medicinal, biochemical and genetic resources:** *Production of materials derived from organisms for medicinal purposes; production of genes and genetic information;*
15. Learning and inspiration: *Opportunities for developing capabilities to prosper through education, knowledge acquisition, and inspiration for art and technological design (e.g. biomimicry);*
16. **Physical and psychological experiences:** *Opportunities for physically and psychologically beneficial activities, healing, relaxation, recreation, leisure, and aesthetic enjoyment based on close contact with nature;*
17. **Supporting identities:** *The basis for religious, spiritual, and social-cohesion experiences; sense of place, purpose, belonging, rootedness or connectedness, associated with different entities of the living world; narratives and myths, rituals and celebrations; satisfaction derived from knowing that a particular landscape, seascape, habitat or species exist;*
18. **Maintenance of options:** *Capacity of ecosystems, habitats, species or genotypes to keep human options open in order to support a later good quality of life."*

These Nature's Contributions to People (NCPs) refer to ecological services of different types, they can be qualified as either (IPBES, 2019e):

— **Regulating**, i.e. providing the basis that supports human life: NCPs 1 to 10;
— **Material**, i.e. providing material goods: NCPs 11 to 14; or
— **Non-material**, i.e. providing "spiritual inspiration and learning": NCPs 15 to 17.

N.B.: NCP 18 "Maintenance of options" comes as a fourth category in itself.

Another related concept that is used to refer to what nature provides to humans is **natural capital**:

> ***Natural capital:** The stock of renewable and non-renewable natural resources (e.g. plants, animals, air, water, soils, minerals) that combine to yield a flow of benefits to people.*
>
> (Natural Capital Coalition, 2016)

The following study will discuss at length the work by IPBES, its conceptual framework and the concept of Nature's Contributions to People (NCPs).

2. PRESENT STATE OF KNOWLEDGE ON BIODIVERSITY LOSS

Following the results of the Millennium Ecosystem Assessment published in 2005, the IPBES undertook an overall evaluation of biodiversity and ecosystem services and compiled its conclusions in its 2019 Global Assessment report. Further work has been published since, which concurs with its conclusions and it remains the reference document regarding the status of biodiversity worldwide.

Although some knowledge gaps still exist in certain areas, the IPBES report gathered the most advanced research findings at the time on this theme. The publication stressed four well-established key messages (IPBES, 2019a)[1]:

A. *"Nature and its vital contributions to people, which together embody biodiversity and ecosystem functions and services, **are deteriorating worldwide**.*

B. *Direct and indirect drivers of change **have accelerated** during the past 50 years.*

C. *Goals for conserving and sustainably using nature and achieving sustainability **cannot be met by current trajectories**, and goals for 2030 and beyond may only be achieved through **transformative changes** across economic, social, political and technological factors.*

D. *Nature can be conserved, restored and used sustainably while **other global societal goals are simultaneously met** through **urgent and concerted efforts** fostering transformative change."*

The next part will focus on reviewing the scientific evidence underlying the first of these messages, namely **the alarming and unprecedented rate at which global biodiversity and ecosystem services are degrading**. Scientific publications on biodiversity and ecosystem services all converge on the same conclusion, it is certain that biodiversity, in all its forms and meanings, is degrading. Overall, as the IPBES puts it:

> ***Much of nature has already been lost, and what remains is continuing to decline.***
>
> (IPBES, 2019d)

Research shows that the **sixth mass extinction** of biodiversity is under way and accelerating (Ceballos *et al.*, 2020). Albeit with disparities in the extent to which geographic areas and systems are affected, these degradation dynamics concern ecosystems, communities and species at large, transforming their structural conditions as much as their composition. **Scientific evidence is well-established and indicators leave no room for doubt**, they "*overwhelmingly show net declines over recent decades*" (IPBES, 2019d).

75% of the terrestrial environment, 40% of the marine environment and 50% of rivers and streams have already suffered severe deterioration (IPBES, 2019c). Only 13% of the ocean and 23% of the land on Earth can still be designated as "wilderness" (IPBES, 2019d). "Hotspots" that concentrate rare and endemic (i.e. present only in that specific region) species are crucial to global biodiversity, yet these locations have suffered the most degradation on average (IPBES, 2019d).

Wildlife populations are collapsing. In 2018, it was estimated that the biomass of humans and livestock combined weighed almost 23 times more than that of wild mammals, while the biomass of domesticated poultry was three times that of wild birds (Bar-On, Phillips and Milo, 2018). Studies suggest the total plant biomass (which today represents more than 80% of the biosphere) is less than half of what it could be without human land use (Erb *et al.*, 2017).

Indicators play an essential role in scientists' work to understand the evolution of biodiversity. The primary step before understanding our society's impact on biodiversity is to understand the status and the evolutionary path of biodiversity. Assessing the status of biodiversity will then make it possible to develop relevant strategies to take action.

The WWF, in collaboration with the Zoological Society of London (ZSL), has provided a useful indicator to illustrate the emergency. Their latest **Living Planet Index (LPI)** aggregates the average abundance of 20 811 populations of 4 392 (terrestrial, freshwater and marine) vertebrate (threatened and non-threatened) species. Using 1970 as the base year (*index value* = 1) and studying data up until 2016 (for data availability and robustness considerations), they established in 2020 that population sizes had **decreased by 68%** on average (with a 95% statistical certainty ranging from -73% to -62%) (WWF, 2020a). Figure I shows the evolution of the LPI since 1970 (index values and confidence limits). For more details on the method and indices by geographic region and habitat, refer to (WWF, 2020a).

This index is only one among a multitude of others. Biodiversity loss is about populations dwindling, but it is also about species extinction, community composition and distribution (WWF, 2020a). For that reason, **it is virtually impossible to compute an index that would cover all aspects of biodiversity changes**. By definition (as seen in Part I.I.I.), *biodiversity* is a web of living beings that are interdependent on each other and the concept of *biological diversity* covers both the diversity of species and that of individuals and ecosystems.

To grasp the extent of the problem, it is critical to understand that no single indicator could ever cover such complexity. **There is no equivalent to the "+2°C" mitigation target** that we must strive for in the context of climate change. Concerning biodiversity loss, we must integrate and combine many indices to grasp the global dynamic. This is the reasoning underlying the Aichi Biodiversity Targets that were adopted by the international community in 2010 in the framework of the Convention on Biological Diversity (CBD) Strategic Plan for Biodiversity 2011-2020 (biodiversity-related regulation and international negotiations are presented below, see Box I7). There is a great range of existing indicators. For the Aichi Biodiversity Targets alone, over 100 indicators were created to assess the targets[2]. The IPBES also published its own set of indicators corresponding to its conceptual framework[3], as well as a set of indicators to illustrate trends in ecosystem services (see Figure 7).

1. IPBES uses the following terms to describe the state of knowledge:
   - "**Well established**: comprehensive meta-analysis or other synthesis or multiple independent studies that agree.
   - **Established** but incomplete: general agreement although only a limited number of studies exist but no comprehensive synthesis and, or the studies that exist imprecisely address the question.
   - **Unresolved**: multiple independent studies exist but conclusions do not agree.
   - **Inconclusive**: limited evidence, recognising major knowledge gaps." (IPBES, 2021)
2. For further details, refer to https://www.cbd.int/doc/decisions/cop-13/cop-13-dec-28-en.pdf.
3. For further details, refer to https://www.ipbes.net/core-indicators-0.

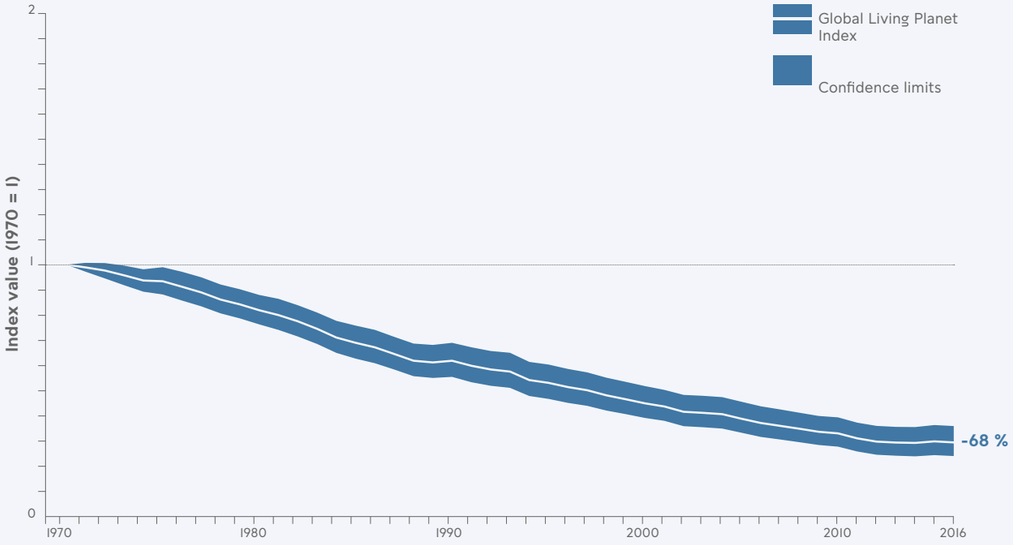


Figure I. Evolution of WWF's global Living Planet Index (index and confidence limits), 1970 – 2016. *(Source: WWF, 2020a)*

In order to simplify communication on the dynamics of biodiversity loss, a number of key indicators provide different types of information, covering different aspects of the broad spectrum of biodiversity (WWF, 2020a). The WWF report mentioned above presents some widely used indicators:

— The **Species Habitat Index** (SHI), which measures the change in habitats available to species across the world. On the basis of validated knowledge about species-habitat associations and with the help of observed (via remotely sensed monitoring) and modelled data on changes in land use, the index captures the "*losses in habitat-suitable range*" (WWF, 2020a). The SHI shows a 2% decrease in habitat available to species in 2018 compared to 2000 (see Figure 2) (WWF, 2020a). For more details on the method, refer to (WWF, 2020a).

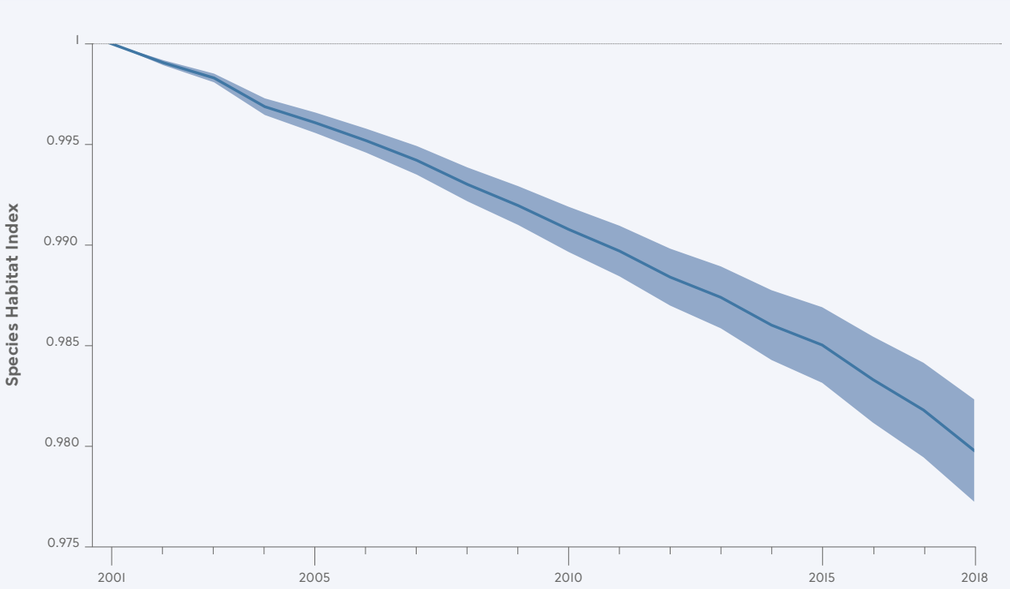


Figure 2. Evolution of the Species Habitat Index (SHI) (index and confidence limits), 2000 – 2018. *(Source: WWF, 2020a)*

Other indicators on habitat loss are equally alarming. On the E.U. level, the conservation status of more than 80% of habitats is labelled as either "Poor" or "Bad" (EEA, 2020). On the national level, in French metropolitan and overseas territories, 26% of assessed species were either extinct or under the threat of extinction in 2018 (MTES, 2018).

— **The Red List Index** is a popular indicator in that it illustrates a striking aspect of the wider reality of biodiversity loss, namely species extinction. This index measures the survival probability of species, i.e. "*the inverse of extinction risk*" (WWF, 2020a).

At an alarming pace, the collapse in populations is leading to species disappearance. The species extinction rate is "*at least tens to hundreds of times higher than it has averaged over the past 10 million years*" and no slowdown is foreseen if we pursue on the "business as usual" path (IPBES, 2019d). Today, around **one million animal and plant species are considered at threat** (IPBES, 2019d). Half a million terrestrial species can be designated as "**dead species walking**" because their habitat is deteriorating (IPBES, 2019d). Ecologically rare species in particular are under threat and over-represented in the IUCN Red List "threatened" categories (Loiseau *et al.*, 2020).

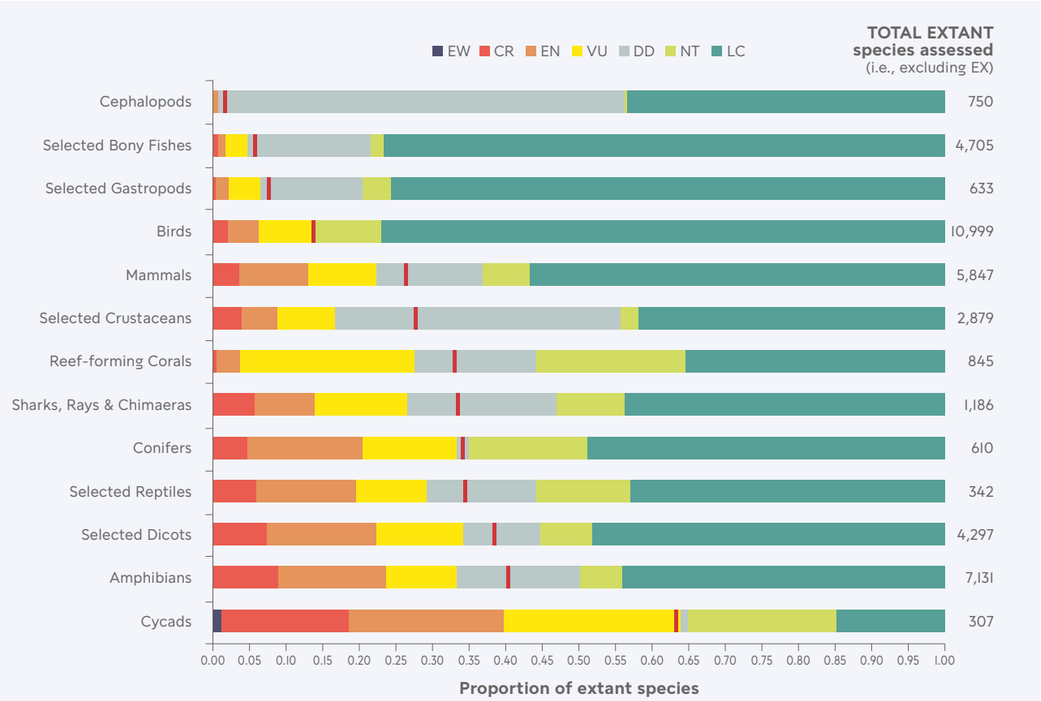


Figure 3. Proportion of species in each category of the IUCN Red List of Threatened Species (excluding Extinct species). *(Source: IUCN, 2020)*[4]

4. "*Version 2020-3 assessed in each category for the more comprehensively assessed (i.e., at least 80% of the group has been assessed) groups containing ≥150 species. Species are grouped into classes (with the exception of reef-forming corals, which includes species from classes Hydrozoa and Anthozoa), and are ordered according to the vertical red lines, which indicate the best estimate for proportion of extant species considered threatened (CR, EN, or VU). […] The numbers to the right of each bar represent the total number of extant species assessed for each group.* ***EW*** *- Extinct in the Wild,* ***CR*** *- Critically Endangered,* ***EN*** *- Endangered,* ***VU*** *- Vulnerable,* ***NT*** *- Near Threatened,* ***DD*** *- Data Deficient,* ***LC*** *- Least Concern*" (IUCN, 2020)

— The **Biodiversity Intactness Index** (BII) estimates the intactness of original terrestrial biodiversity (i.e. "*how much originally present biodiversity remains on average across the terrestrial ecological communities*" (WWF, 2020a)) within a region. The global average BII was estimated at 79% in 2014. However, the Planetary boundaries framework (see Box 2) considers 90% as the "lower safe limit" (WWF, 2020a) and the index shows worrisome trajectories in every world region (see Figure 4).

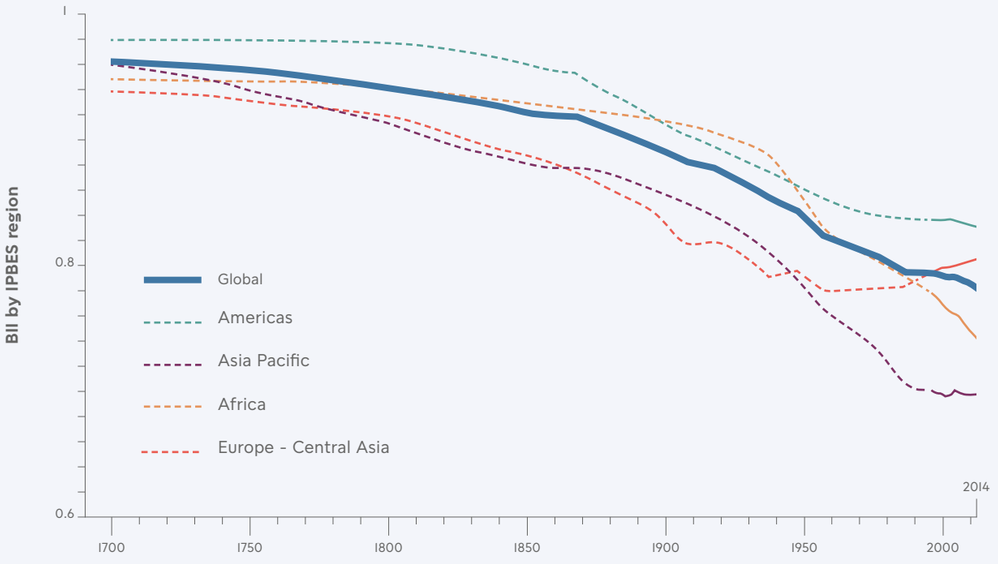


Figure 4. Evolution of the Biodiversity Intactness Index (BII) by region and globally, 1700 – 2014. *(Source: WWF, 2020a)*

However, as mentioned above, biodiversity cannot be reduced to four global indicators. Biodiversity is above all a local matter and ecosystems vary from one geographical region to another, therefore, indicators should vary too. In France, the *Observatoire national de la biodiversité* (French Observatory for Biodiversity) has developed indicators to assess the status and evolution of biodiversity. There are 50+ indicators and 16 are considered key indicators. Key indicators are chosen on the basis of four criteria:
— the indicator has a strong impact on public opinion;
— the indicator can be used to assess public policies;
— the indicator can be used from an ecosystem services perspective;
— the indicator is easily understandable for a non-expert public and is scientifically solid.

The key indicators are as follows (Naturefrance, 2021):

1. ***Presence of large predators in continental France (wolf, lynx, bear):*** presence on 8.2% of French territory in 2018;
2. ***Share of extinct or threatened species in the National Red List:*** 19% of species were extinct or threatened in France in 2020;
3. ***Citizen implication in participatory sciences related to biodiversity:*** +16% of citizen commitment in 2019;
4. ***Ecological quality of surface waters:*** 44.2% of surface waters have good or very good ecological quality;
5. ***Conservation status of natural habitats:*** 20% of remarkable ecosystems had a favorable conservation status between 2013 and 2018;
6. ***Pasture surfaces:*** -7.9% between 2000 and 2010;
7. ***Common specialist bird populations:*** -24% between 1989 and 2019;
8. ***Large trees and dead wood in forests:*** 25 million cubic meters of wood in 2020, stable;
9. ***Coral reefs:*** coral reefs were declining in 29% of observation stations in overseas France in 2017;
10. ***Protected areas in continental France:*** 1.37% is under strict protection in 2018;
11. ***Evolution of the average number of exotic invasive species per continental department:*** on average, each French department has 6 new exotic invasive species every ten years;
12. ***Date of arrival of migratory birds:*** migratory birds arrived in France 6 days earlier in 2017 than in 1989;
13. ***Consumption of phytosanitary products for agricultural purposes:*** +25% between 2016 and 2018;
14. ***Artificialization of continental territory:*** 65 758 hectares are artificialized each year;
15. ***Physico-chemical pollution of rivers in continental France:*** -12% between 1998 and 2017.

In France and elsewhere, there are certainly exceptions to this dark picture. Ecosystems in areas managed by indigenous peoples and local communities notably tend to be less impacted by these changes thanks to more sustainable practices (IPBES, 2019d).

Yet exceptions can themselves be seen as indicators of generally degrading conditions and pervasive damage. A textbook example of this is the increase in the biomass of prey fish, which can be linked to the disappearance of their predators, a disappearance which has been caused by overfishing (IPBES, 2019d).

Because ecosystem balances have been disturbed and conditions have changed, a few species have been able to expand and "invasive alien species" have been thriving and disrupting ecosystems even more (IPBES, 2019d).

These imbalances have also had impacts on the smallest of the three biodiversity levels, namely on genes. In addition to genetic diversity dwindling because of species extinction, ecosystems destabilization is causing an acceleration of evolution because species traits are rapidly changing to adapt to their transforming environment (IPBES, 2019d).

Overall, if some changes in biodiversity and ecosystem services have recently slowed or even been reversed, in part due to policies in place, others are still accelerating. In the case of forests, the deforestation rate is decreasing globally (FAO, UNEP, 2020) and the area of tree cover is actually increasing, but dynamics are very different in high and low-income countries. For example, tropical primary forests, the sites of high biodiversity, are still declining (IPBES, 2019d).

BOX 1
THE "TWIN CRISES" OF BIODIVERSITY AND CLIMATE CHANGE

According to Sir Robert Watson, Chair of the IPBES and former Chair of the IPCC:

"Successful climate action can never be at the expense of biodiversity, because stabilizing the climate is only possible over the long-term by ensuring the health and protection of biodiversity and ecosystems. This is why the scope of the four regional and the global IPBES assessments – all currently underway – include the relationships between biodiversity, ecosystem services and climate change."

Climate change and biodiversity issues are closely interlinked and can be deemed "twin crises" (Farber, 2015). Not only does climate change have detrimental impacts on biodiversity, but biodiversity loss also affects the dynamics of climate change.

— Natural ecosystems play a key role in the global carbon cycle. Thus, any change in biodiversity's ecological functioning can impact atmospheric CO_2 levels, i.e. affect climate change. Terrestrial ecosystems and oceans are the main carbon sinks. The degradation of ecosystems significantly reduces carbon sequestration and storage capacities, therefore it increases emissions of greenhouse gases and the dynamics of climate change (Secretariat of the Convention on Biological Diversity, 2009).

— Climate change in itself has detrimental effects on biodiversity and can exacerbate the four other main drivers of change in biodiversity, namely changes in land and sea use, species overexploitation, invasive species and diseases, and pollution (Secretariat of the Convention on Biological Diversity, 2009). Climate change impacts on natural ecosystems have already been observed and they are expected to have adverse and irreversible effects, even though there is still some uncertainty about the speed at which it will happen.

Climate change and biodiversity loss are interlinked in a vicious circle. What is more, solutions implemented so far to mitigate and adapt to climate change can themselves have detrimental effects on biodiversity, e.g. hydroelectric dams (mitigation), intensive reforestation practices for carbon storage (mitigation), protective infrastructure against flooding (adaptation) or pesticides against new pests (adaptation).

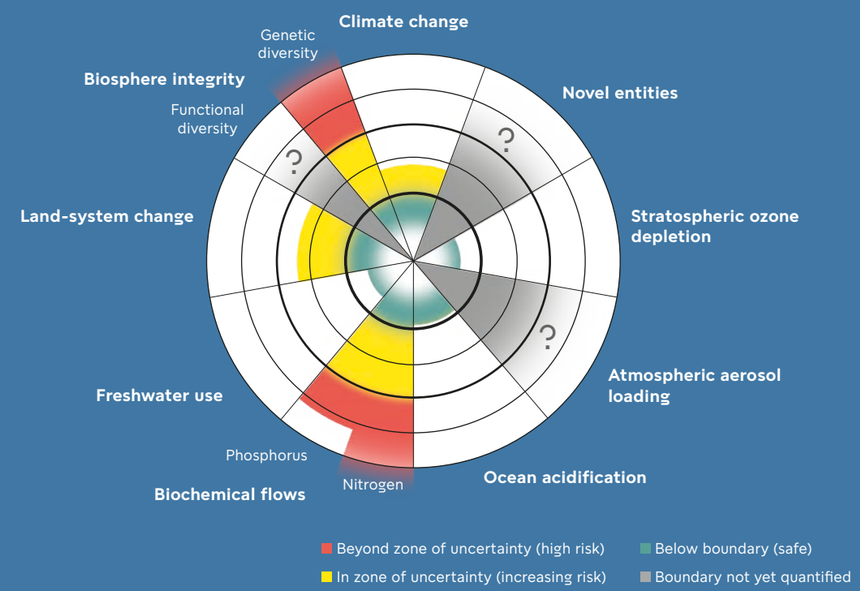
Conversely, a flourishing biodiversity can help mitigate climate change. The development of **nature-based solutions** has shown how to implement solutions against climate change while fostering biodiversity. Nature-based solutions are based on the conservation and restoration of ecosystems that help people against the adverse effects of climate change. For instance, the maintenance or restoration of mangroves protects coastal communities against flooding and coastal erosion and is a source of carbon storage.

Several biodiversity indicators concerning forests, species-extinction rates, species abundance and the intactness of biodiversity have already overrun the proposed precautionary "planetary boundaries" (IPBES, 2019d) (see Box 2) and some ecosystems are on the brink of collapse.

BOX 2
PLANETARY BOUNDARIES, A FRAMEWORK TO ASSESS THE RISKS OF DESTABILIZATION OF THE EARTH SYSTEM (Steffen *et al.*, 2015; Rockström *et al.*, 2009)

In 2015, Steffen *et al.* developed what is called the planetary boundary (PB) framework. This approach aims at defining *"a safe operating space for human societies to develop and thrive, based on our evolving understanding of the functioning and resilience of the Earth system"* (Steffen *et al.*, 2015). It establishes precautionary "safe limits" for nine processes that are fundamental to the functioning of the Earth system and that are scientifically proven to be affected by human activities, namely climate change; change in biosphere integrity; stratospheric ozone depletion; ocean acidification; biogeochemical flows; land-system change; freshwater use; atmospheric aerosol loading; introduction of novel entities (Steffen *et al.*, 2015).

The two planetary boundaries associated with climate and the biosphere integrity are considered of fundamental importance for the Earth system and seen as "core" boundaries. If one of these two limits alone were to be "substantially and persistently transgressed", it could potentially profoundly transform the Earth system (Steffen *et al.*, 2015).



Reading note. *"The green zone is the safe operating space, the yellow represents the zone of uncertainty (increasing risk), and the red is a high-risk zone. The planetary boundary itself lies at the intersection of the green and yellow zones. The control variables have been normalized for the zone of uncertainty; the center of the figure therefore does not represent values of 0 for the control variables. The control variable shown for climate change is atmospheric CO_2 concentration. Processes for which global-level boundaries cannot yet be quantified are represented by gray wedges; these are atmospheric aerosol loading, novel entities, and the functional role of biosphere integrity." (Steffen* et al., *2015)*

Figure 5. Planetary boundaries and their current status. *(Source: Steffen* et al., *2015)*

So why is biodiversity eroding and what are the causes of this transformation? **The science is straight-forward, i.e. humans play the leading role in this dynamic.** The next part will discuss the drivers of this change and make clear why the challenge of biodiversity loss is of the utmost concern for humans.

II. BIODIVERSITY AND HUMAN ACTIVITIES: A TWO-WAY RELATIONSHIP

The IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services) Global Assessment on Biodiversity and Ecosystem Services was approved and published by the IPBES Plenary in 2019. The IPBES publication, based on over 15 000 scientific papers and governmental reports, is considered an internationally acknowledged reference document in terms of biodiversity. The IPBES being an intergovernmental institution, the conceptual framework and conclusions have been approved by all 198 governments (member or observer). The following demonstration is largely based on the publication of the IPBES Global Assessment on Biodiversity and Ecosystem Services.

From the genetic diversity of algae to our financial system, what are the underlying interactions between the biological diversity of living beings and our quality of life or our way of doing business?

While the majority of species' populations which make up biodiversity are falling, the human population would not seem to be affected by the same dynamics, suggesting a unique type of interaction between humans and biodiversity.

Humans are part of biodiversity, the diversity of living beings. However, as Homo sapiens cognitive abilities developed and it formed more and more complex societies, some of these societies took a developmental path characterized by utilitarian, instrumental views of nature. That being said, whatever society they live in, humans maintain an intrinsic relationship of dependencies and impacts with biodiversity. On the one hand, our survival and development entirely rely on the existence of biodiversity, on the other, the development of human activities can have beneficial or harmful impacts on biodiversity.

Following a review of the scientific and grey literature, this section attempts to explain the underlying mechanisms of dependencies and impacts in both directions, between biodiversity and human activities.

This section will discuss the interactions presented in the conceptual framework below (see Figure 6) to depict how individuals and companies benefit from biodiversity through Nature's contributions to people (green interactions), how they impact nature (orange interactions) and eventually understand how the disruption of these ecological interactions can turn into risks.

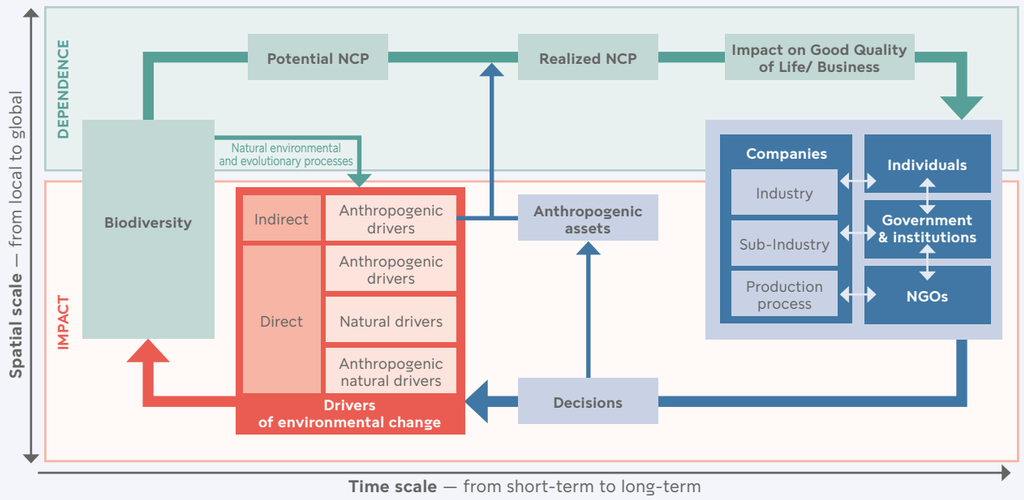


Figure 6. Conceptual framework of the interactions between biodiversity and human activities *(Adapted from the IPBES Conceptual Framework in IPBES, 2019b, Textbox I.2).* (Note. NCP = Nature's Contribution to People)

A conceptual framework determines the scope of an analysis and the central notions to be used by stakeholders (EFESE, 2020), therefore it is a biased representation of reality centered on the notions that are relevant to the particular study. This conceptual framework of interactions and biodiversity is one among others, but it attempts to provide an overview of the interactions between biodiversity and human societies, and an understanding of the underlying mechanisms of dependencies and impacts. The conceptual framework has been reworked using the IPBES conceptual framework because the objective is to provide the reader with general knowledge on biodiversity and human interactions, and the IPBES work is the most widely acknowledged to date.

BOX 3
A SHIFTING PARADIGM FROM A SPECIES TO AN ECOSYSTEM FOCUS

Even though biodiversity underpins our existence and well-being, it can also be detrimental in different manners to humans and the current pandemic is a perfect illustration of that. For a long time, humans have analyzed their interactions with biodiversity by looking at specific species, assessing from an economic point of view whether a given species was beneficial or harmful to the economy and then choosing whether or not to protect it. Thus, humans determined whether a certain species should thrive or shrink for the well-being of our societies. This was the major approach over the 20th century. Today, scientists and economists look at biodiversity from the angle of ecosystem interaction. The perspective has moved from a population approach of biodiversity with beneficial and detrimental species for human activities to **a network of complex, ecological interactions with opportunities and risks.**

Taking the COVID-19 as an example, if it were to be demonstrated that this virus has zoonotic origins (see the Case Study on Biodiversity, Pandemics and Re/insurance in Part 3.II.), the species approach would question whether pangolins or bats are harmful to human societies, whereas the interactions approach would question the influence of deforestation on the spread of zoonoses.

The ecosystem approach is thus more complex, but it embraces the concept of humans being part of a larger system of ecological in which all species play a role, rather than just being tagged as either useful or harmful to humans. Each species is no longer either useful or a pest, it is part of a larger system, i.e. the ecosystem, it participates in ecological processes and occupies a specific place in the food web (i.e. its trophic level). This contemporary view of biodiversity provides a clearer understanding of our dependencies and impacts and enables us to make more relevant decisions regarding environmental management.

Fisheries are a good example to illustrate this paradigm shift. Traditionally focused on maximizing the catch of a target species, leading to incidental mortality (90% of annual mortality in the case of white marlin) and dramatic shifts in population demographics, e.g. the famous collapse of Northern Cod off Newfoundland's coast, fisheries are starting to invert priorities, focusing on ecosystems rather than the target species. **Ecosystem-based fisheries management (EBFM)** has emerged. The basic idea of EBFM is to minimize the impacts of fisheries on the ecosystem in order to support long-term socio-economic benefits and generate knowledge on ecosystem processes. EBFM practices include spatial controls of fishing, the prohibition on capturing forage species on which other fish, birds and mammals depend, and the control of incidental catches (Pikitch *et al.*, 2004).

I. DEPENDENCIES: HOW HUMANS RELY ON BIODIVERSITY

Humans rely on biodiversity for basic life support and access to material and non-material goods for a good quality of life. By extension, businesses and other human structures also rely on biodiversity. These services are called Nature's contribution to people (NCP) by the IPBES and represent all the beneficial or harmful goods and services we receive from nature. However, understanding the connection from the genetic diversity of a given species to the fulfilment of a human life or business is a complex one, which the scientific community is still working on. This section details the steps and concepts of the anthropo-ecological process to achieve good quality of life and business provided by biodiversity.

A. FROM POTENTIAL TO REALIZED NATURE'S CONTRIBUTIONS TO PEOPLE

To understand how goods and services are produced by biodiversity, the IPBES introduced an essential distinction between potential and realized Nature's Contributions to People (NCPs) (IPBES, 2019e):

> *"**Potential NCP** is the capacity of ecosystems to provide NCP, while **realized NCP** is the actual flow of NCP that humanity receives."*

AN ILLUSTRATION VIA AGRICULTURE

In the case of agriculture, the potential Nature's Contribution to People (NCP) corresponds to the extent of agricultural land, while the realized Nature's Contribution to People (NCP) is the output of the agricultural land.

- Potential NCP: area of arable land;
- Realized NCP: weight of crops collected.

Agricultural production depends on the following NCPs:
- NCP 2: Pollination and dispersal of seeds;
- NCP 3: Regulation of air quality;
- NCP 4: Regulation of climate;
- NCP 6: Regulation of freshwater quantity, location and timing;
- NCP 7: Regulation of freshwater and coastal water quality;
- NCP 8: Formation, protection and decontamination of soils;
- NCP 9: Regulation of hazards and extreme events;
- NCP 10: Regulation of organisms detrimental to humans.

And the co-production of agricultural outputs contributes to the realization of NCP 12: Food and feed.

The transition from potential to realized NCP requires either an external intervention, a particular situation or a specific condition:

— For **material services**[5], the generation of realized NCPs depends on anthropogenic drivers and assets. For instance, fish production for food depends on the market demand for fish products (drivers) and on fishing infrastructure (assets).

— For some **regulating services**, the generation of realized NCPs will depend on environmental conditions. For instance, the regulation of air quality, besides ensuring a constant composition of air, is affected by the fact that air is polluted.

— And for some **non-material services**, the generation of realized NCPs will depend on the situation. To experience the beneficial effects of nature on mental health, humans need to experience being in a natural environment (as opposed to urban areas).

For human societies to benefit from material resources provided by biodiversity, it is necessary to have *assets* and *driving demand* (IPBES, 2019b):

Anthropogenic drivers: Direct and indirect human-induced factors that affect negatively or positively nature and the supply of NCPs, due to human requirements or preferences in their quality of life translating into the need of a certain amount of a given NCP over time, e.g. economic, demographic, technological or cultural factors.

Anthropogenic assets: Assets necessary to obtain realized NCPs from potential NCPs. It refers to the co-production of realized NCPs.

The main anthropogenic assets are (IPBES, 2019e):

— Built-up infrastructure;
— Knowledge: indigenous and local knowledge, technical and scientific knowledge, formal and non-formal education, and experience;
— Technology: physical objects and procedures;
— Financial assets;
— Institutions to mediate them;

AN ILLUSTRATION VIA AGRICULTURE

The co-production of the realized NCP 12 (agricultural output) is generated by anthropogenic drivers and is rendered possible by anthropogenic assets.

Anthropogenic assets. The production of agricultural output depends on:
- Infrastructure and machinery;
- Human capital and knowledge;
- Financial capital;
- Institutions, to mediate the three mentioned above.

Agricultural production is generated mainly by:
- Demographic drivers;
- Change in dietary patterns (rising meat diet in developing countries);
- Technological drivers.

When human assets and drivers are necessary to produce NCPs, we talk about co-production of NCPs. The notion of co-production emphasizes the interdependence between biodiversity and humans to produce goods and services required for a good quality of life (IPBES, 2019e).

To sum-up, the association of biophysical processes and ecological interactions (*potential NCP*) with human inputs (*anthropogenic assets*) driven by human needs and preferences (anthropogenic drivers), leads to the co-production of a good or service (*realized NCP*) to support basic life and the quality of life. Therefore, humans depend both on the availability of potential NCPs and their own capacity to develop the required assets to produce realized NCPs.

B. IMPACT ON THE GOOD QUALITY OF LIFE

Human quality of life relies in part on the quality and the quantity of co-produced realized NCPs and how they affect us. Good quality of life is described by the IPBES as a state of **fulfilment of human life**, thanks to the access to all necessary material and non-material dimensions of life (IPBES, 2019e). The concept of good quality of life is "*value-laden and context-dependent*" (IPBES, 2019b) from one society to another, but also within societies and among different social groups. Cultural and spiritual beliefs, socio-economic classes, geography, education and all subjective visions of a fulfilled life alter the way each individual is impacted by a given NCP (IPBES 2019b). Therefore, by including the concept of fulfilment of human life, this conceptual framework expands beyond economic value in the interaction between human societies and biodiversity, and highlights the value biodiversity brings to human life, in addition to its intrinsic value.

According to the IPBES classification, Good Quality of Life (GQL) is divided into 13 material and non-material criteria (see Table I).

Impact on Good Quality of Life		
Material	1	Food and nutritional security
	2	Water security
	3	Energy security
	4	Shelter
	5	Livelihood and income security
	6	Health
Non-material	7	Good social relations
	8	Equity
	9	Cultural identity
	10	Personal and physical security
	11	Recreation and leisure
	12	Knowledge and education
	13	Spirituality, religion
	14	Freedom of choice and action
	15	Enjoyment of natural beauty

Table I. Good quality of life criteria according to the IPBES and adapted from the Millennium Ecosystem Assessment. *(Source: IPBES, 2019b)*

The impact on the Good Quality of Life (GQL) of a certain realized NCP can be either positive or negative, e.g.:

— *Positive effect:* Pollination services for agricultural productivity;

— *Negative effect:* human-wildlife conflicts, with elephants trampling crops or mosquitoes spreading diseases;

— *Positive and negative effects:* pests feeding on plants are negative for agriculture productivity but essential for the production of biochemical compounds with high nutritional values.

Therefore, the good quality of life of an individual depends on positive impacts of realized NCPs and, at the same time, people need to cope with the negative impacts of realized NCPs.

Inequality of impacts on the good quality of life for individuals

Biodiversity provides positive and negative impacts on individuals' quality of life. However, to benefit from these positive impacts, individuals need to have access to them. The positive impact is guaranteed by the distribution of realized NCPs to people. The distribution of realized NCPs relies on the **availability, access, utilization and stability** (*these concepts have been taken from the analysis of the FAO on distribution of food in IPBES, 2019f*) of the given NCP. The IPBES has initiated research on the distribution of impacts of NCPs across different groups of users, a topic which was poorly documented to date.

There is considerable **heterogeneity of distribution of impacts on GQL**. The main identified **factors** leading to unequal distribution of NCPs are:

— Geographic location;
— Nearness of nature;
— Social-status hierarchies and power relations;
— Property and access regimes;
— Availability of anthropogenic assets needed to co-produce NCPs.

It is also essential to point out that the impact of NCPs on GQL does not necessarily have **geographical boundaries**, given that the impact does not necessarily take place where the NCP was realized. There are two main reasons for this (IPBES, 2019e):

— *Globalization and international trade:* Production areas are decorrelated from consumption areas, consequently so are co-production of NCPs and impacts on GQL. The demand for an NCP in one place can increase pressures on biodiversity in another place and have detrimental effects on other NCP co-production processes;

— *Environmental interconnections*.

AN ILLUSTRATION VIA AGRICULTURE

Agricultural output has mainly positive impacts on the good quality of life, through material and non-material impacts:
- Food and nutritional security;
- Livelihood and income security;
- Health, through a balanced diet;
- Good social relations;
- Equity;
- Cultural Identity.

However, the access to these positive impacts differs between geographic locations and populations:
- According to the geographic location of populations, the amount of arable land and the climate can vary, i.e. be more or less favorable for productive agriculture;
- Property can also hinder access of people to the benefits of agricultural outputs;
- The lack of sufficient capital or infrastructure can be detrimental to benefits from arable land.

Moreover, with globalization and demand for certain products rising in some parts of the world, the impact of agricultural output on the good quality of life can be detrimental to local populations. For instance, indigenous people in Brazil suffer from the expansion of deforestation, done in order to increase arable lands for soy crops intended to feed animals in intensive livestock farming for the populations of developed countries.

5. ***Reminder*** (see Part I.I.I.): Nature's Contributions to People (NCPs) refer to ecological services of different types. They can be either (IPBES, 2019e): **Regulating** (i.e. providing the basics that support human life: NCPs 1 to 10); **Material** (i.e. providing material goods: NCPs 11 to 14); **Non-material** (i.e. providing "spiritual inspiration and learning": NCPs 15 to 17).

C. IMPACT ON THE GOOD QUALITY OF BUSINESS

Drawing on the principle of Good Quality of Life, this section takes the same perspective and applies it to the business world. This section aims to understand how realized NCPs impact on the Good Quality of Business. *This section is an original contribution in that the IPBES publication does not address the issue from the private sector's viewpoint.*

Good quality of business is similarly described in this report as a **state of fulfilment of a company**. Where good quality of life is assimilated to good living conditions, good quality of business relates to good business conditions. This concept of good business conditions could have various interpretations depending on the industry, business model or business strategy and objective.

One of the biggest challenges when trying to understand the interdependencies and aligning business with biodiversity dynamics is the **time horizon**. For this analysis, good quality of business occurs when a company has all the resources (material, capital, human and services) needed to pursue its objective over the **long term**.

The impact of NCPs on GQB and GQL overlaps because companies are made up of individuals. The advantage of introducing GQB is to adopt another perspective, because co-production takes place on a different scale.

The same way GQL depends on people's vision of a fulfilled life, GQB will depend on the sector, the sub-industry and the production process of a given company (ENCORE, 2020).

Five main criteria have been identified as factors in the good quality of business (see Table 2).

Impact on Good Quality of Business		
Direct physical inputs	**NCPs that are a direct input into production processes**	Animal-based energy
		Fibers and other materials
		Genetic materials
		Ground water
		Surface water
Enable the production process	**NCPs that are enabling factors for all or part of the production process**	Maintain nursery habitats
		Pollination
		Soil quality
		Ventilation
		Water-flow maintenance
		Water quality
Mitigate direct impacts	**NCPs that help to mitigate direct impacts on production processes**	Bio-remediation
		Dilution by the atmosphere and ecosystems
		Filtration
		Mediation of sensory impacts
Protect from disruption	**NCPs that protect against the disruption of the production process**	Buffering and attenuation of mass flows
		Climate regulation
		Disease control
		Flood and storm protection
		Mass stabilization and erosion control
		Pest control
Good Quality of Life	**NCPs that provide good quality of life to individuals (essential when considering that companies are made up of individuals)**	Material support to individuals
		Non-material support to individuals

Table 2. Good quality of business criteria. *(Adapted from ENCORE, 2020 and IPBES, 2019e)*

The impact of NCPs on the good quality of business depends on the distribution of realized NCPS across companies, depending on different factors (see Part I.II.I. on the Impact on the good quality of life).

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AN ILLUSTRATION VIA AGRICULTURE

Agricultural output is essential for any business because it is the key to providing a good quality of life to all individuals taking part in the company.

For a farming business, the following impacts on Good Quality of Business are essential:

- Direct physical inputs (e.g. seeds, ground and surface water);
- Production process enablers (e.g. pollination, soil quality, water quality and flow maintenance);
- Mitigation of direct impacts (e.g. bioremediation to detoxify contaminants, filtration for pollutants);
- Protection from disruption (e.g. pest control to avoid crop contamination, flood and storm protection, climate regulation to avoid droughts).

For instance, the food-processing industry relies entirely on the functioning of the agricultural system, and consequently on the criteria above, to create value.

D. TRENDS

The flow of Nature's Contributions to People (NCPs) is a continuously evolving process with an undetermined number of interdependencies and a high level of complexity, given the influence of external factors. In order to better understand this flow and its evolution, it is essential to observe the trends.

The IPBES has studied the evolution of potential NCPs, realized NCPs and the impact on Good Quality of Life over 50 years from 1968 to 2018 (see Figure 7).

	NCP		Output		Impact
	Indicator	Indicator	Indicator	Indicator
1 Habitat creation and maintenance	Extend of suitable habitat			
	Biodiversity intactness index			
2 Pollination and seed dispersal	Pollinator diversity	Abundance of managed and wild pollinators		Health associated with intake of pollinator dependent foods
	Natural habitat in agriculture	Pollen deposition		
3 Air quality regulation	Retention and prevented emissions of air pollutants by ecosystems	Reduced concentrations of PM2.5		Avoided morbidity and premature mortality from air pollution
				Avoided costs from air pollution
4 Climate regulation	Prevented emissions and uptake of greenhouse gases by ecosystems	Reduced concentrations of greenhouse gases in the atmosphere		Reduction in climate related costs
5 Ocean acidification regulation	Land and ocean carbon sinks	Reduced ocean acidification		Seafood availability due to ocean acidification (e.g. shellfish)
		Extent of marine calcification		Benefits from corals reefs (e.g. ecotourism, food)
6 Freshwater quantity regulation	Ecosystem impact on air-surface-ground water partitioning	Water availability		Water available for people relative to demand
7 Freshwater quality regulation	Extent of ecosystems that filter or add constituent components to water	Reduced concentration of pollutants in water		Reduced incidence of water borne disease
				Avoided water treatment costs
8 Soil regulation	Soil organic carbon	Soil quality		Soil quality impact on crop production
9 Natural hazard regulation	Ability of ecosystems to absorb and buffer hazards	Reduced incidence and severity of hazards		Reduced morbidity and premature mortality due to natural hazards
				Reduced property loss due to natural hazards
10 Pest regulation	Natural habitat in agriculture	Reduced food spoilage		Reduced net farm income loss from pests and diseases
	Diversity of competent hosts of vector-borne diseases	Reduced risk of disease transmission		Reduced incidence of infectious diseases
11 Energy	Extent of agricultural land	Energy content of bioenergy crops		Revenue from bioenergy production
	Extent of forested land	Production of fuelwood		Energy security from bio-energy and fuelwood
12 Food and feed	Extent of agricultural land	Food produced (kcal)		Reduced hunger
		Food quality (nutrients)		
	Marine stocks	Seafood produced (kcal)		Reduced malnutrition
13 Materials	Extent of agricultural land	Agriculture-based materials produced (tons)		Employment in materials production
	Extent of forested land	Timber production (m3)		Revenue from forestry
14 Medicinal biochemical, and genetic resources	Fraction of species known to be medicinal	Natural medicinal products and manufactured bio-derived medicines		Improved health from natural medicines or bio-derived medicines
	Phylogenetic diversity	Gene bank accession and available genetic resources		
15 Learning	Proximity of people and nature	Ideas and products mimicking or inspired by nature		Economic value of bio-inspired production
	Diversity of life from which to learn			
16 Experience	Area of natural and traditional landscapes and seascapes	Visitation rates to natural terrestrial, coastal, and marine areas		Increased awareness, care, mental health, cultural security, life satisfaction - urban
		Daily exposure natural terrestrial, coastal and marine areas		Increased awareness, care, mental health, cultural security, life satisfaction - rural and ILPC
17 Supporting identities	Stability of land use and land cover	Identity value - urban		Increased awareness, care, mental health, cultural security, life satisfaction - urban
		Identity value - rural and ILPC		Increased awareness, care, mental health, cultural security, life satisfaction - rural and ILPC
18 Options	Species richness			
	Phylogenetic diversity			

Figure 7. Global trends in potential NCPs, realized NCPs (corresponding to outputs in the table) and impacts on the good quality of life. *(Source: IPBES, 2019e)*

The IPBES provides evidence and the level of certainty (see Part I.I.2., Footnote I) for each of these global trends. For further details, refer to IPBES, 2019e, Table 2.3.4 p.45.

Potential NCPs (IPBES, 2019e)

Overall, the potential of 3 out of 4 material NCPs (Energy, Food, Materials) has been partially increasing over the past 50 years, through human-dominated land uses and extractive activities (increasing extensive agricultural land, mining territories and urban areas), at the expense of all other potential regulatory NCPs (10), material NCPs (Medicinal, Biochemical and genetic resources) and non-material NCPs (4).

Realized NCPs (IPBES, 2019e)

The co-production of realized material NCPs (Energy, Food, Materials) is globally increasing at an unsustainable rate. For instance, fish catches have exceeded population-replacement rates for many species. According to the FAO, the percentage of fish stocks harvested at an unsustainable biological level increased from 10% in 1974 to 33% in 2015 (FAO, 2018). At the same time, almost all regulatory and non-material NCPs have endured a decline that is mainly correlated to the loss of potential NCPs, e.g. the decline in pollination is mainly due to the loss of habitat for wild pollinators.

Impact of NCPs on Good Quality of Life and Business

Impacts of the increase or decrease of potential and realized NCPs on the good quality of life and business are less directly correlated because of social, economic and political factors which can counterbalance or interfere in these trends. Also, human-made substitutes can offset the decline in NCP impacts. Still, between 1968 and 2018, only 3 (Energy, Food, Materials) out of 18 NCPs have increased their positive impact on the good quality of life and business.

The overall trend of increasing material NCPs at the expense of regulating NCPs is compensated by non-sustainable, anthropogenic alternatives, e.g. abandoning less productive agricultural land and deforesting to create new agricultural land, using non-renewable materials (phosphates and oil) to make fertilizers and pesticides. This anthropogenic intervention only postpones the reality of decreasing regulating services, without proposing a sustainable alternative.

AN ILLUSTRATION VIA AGRICULTURE

Potential NCPs

Agricultural land has increased over the past 50 years and will continue to increase under the current scenarios. However, the adoption of intensive agricultural practices has had many trade-offs, which are now impacting potential NCPs for agricultural production in the future. Agricultural productivity has declined in 23% of terrestrial areas (IPBES, 2019e).

Realized NCPs

Given that agricultural land is increasing and technology is providing better yields, global food production is also increasing. It now meets global caloric needs. Crop production is projected to increase by 50 to 100% by 2050 to meet future demand under current population and diet trends. However, from a local point of view, some regions in the world are facing increasing tension on food supplies due to climate change. (IPBES, 2019f)

Impact on Good Quality of Life

Despite increasing global food production, the agricultural system fails to provide diversified and healthy diets. Malnutrition has been increasing since 1970, resulting notably in obesity. And inequalities in the distribution of positive impacts are still increasing (IPBES, 2019e):

- The prevalence of anemia among women of reproductive age, which has significant health and development consequences for both women and their children, is rising.
- The unequal distribution of food leaves 800 million people suffering from hunger and malnutrition.
- Climate change is expected to drive local tensions on food supplies in the driest regions of the globe, leading to major famine, wars and migrations.

To sum-up, there is a clear dynamic benefitting material NCPs to the detriment of regulating NCPs. **This dynamic is unsustainable in the long run** for two main reasons. **First**, because the increase in material NCPs takes place at the expense of regulatory and non-material NCPs on which they rely, initiating a vicious circle. **Secondly**, because of the complex interdependencies between NCPs and the high level of reliance of material NCPs on non-renewable resources or on non-sustainable practices.

2. IMPACTS: HOW HUMANS DRIVE BIODIVERSITY LOSS

Part I.I.2. depicted the depletion of biodiversity with plunging indicators, from populations to species and habitats. This raises the question as to the causes of this decline and the responsibility of human activities in this trend.

Professor Josef Settele, co-chair and co-author of the IPBES Global Assessment, warns that:

> *Ecosystems, species, wild populations, local varieties and breeds of domesticated plants and animals are shrinking, deteriorating or vanishing. The essential, interconnected web of life on Earth is getting smaller and increasingly frayed. This loss is a direct result of human activity and constitutes a direct threat to human well-being in all regions of the world.*
> (UN, 2019)

There is indeed a scientific consensus on human responsibility in the current environmental depletion dynamic occurring at an unprecedented rate in human history. According to Sir Robert Watson, IPBES Chair (UN, 2019):

> *We are eroding the very foundations of our economies, livelihoods, food security, health and quality of life worldwide.*

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A. DRIVERS OF ENVIRONMENTAL CHANGE

> *Drivers of environmental change: natural or anthropogenic pressures on biodiversity, ecosystems and their ability to provide goods and services.*
> (ENCORE, 2020)

Commonly, **five main drivers of change are acknowledged** (WWF, 2020a):

1. **Changes in land and sea use, including habitat loss and degradation;**
2. **Species overexploitation;**
3. **Invasive species and disease;**
4. **Pollution;**
5. **Climate change.**

Researchers have focused on identifying the sources of decline in biodiversity, drawing up a typology of the main drivers of environmental change. These drivers have been divided into direct and indirect drivers. Among the direct drivers, there are natural, anthropogenic and natural-anthropogenic drivers. As for the indirect drivers, these are 100% anthropogenic.

Natural drivers. These drivers are caused by natural phenomena over which neither people nor companies have any initial influence. The only possible anthropogenic action is mitigation and prevention or adaptation (IPBES, 2019b). For example, volcano eruptions are natural and not subject to human influence. They can be drivers of biodiversity loss and in fact they were one of the main drivers during the last mass extinction of biodiversity.

Anthropogenic drivers. These drivers are human made. It is essential to understand their consequences, trade-offs and potential synergies to avoid negative impacts on future use of potential NCPs. Here, GQL and GQB are at stake (IPBES, 2019b). For example, deforestation for agricultural purposes eradicates natural habitats and thus leads to biodiversity loss, because of a lack of habitat and resources to breed future generations.

Natural-anthropogenic drivers. These drivers find their root in human action, but their consequences are natural. There is an ecological process transforming an anthropogenic driver into a natural driver with impacts on the environment (IPBES, 2019b). For example, hurricanes can devastate coral reefs, mangroves and other natural habitats for biodiversity, as well as living populations. Hurricanes are not directly created by human activities, however, human activities are responsible for climate change, which is responsible for the increased frequency and intensity of hurricanes. Therefore, through carbon-intensive activities, human influence on hurricanes can in turn impact on biodiversity.

Direct drivers	Natural	Extreme events	Droughts
			Flooding
			Landslides
			Storms
			Volcanoes
			Wildfires
		Natural changes	Population changes
	Anthropogenic	Pollution	Emissions, disposal, spills, noise, others
		Land/sea use change: - Transformations - Intensity changes	Habitat modification
			Industrial or domestic activities
			Industrial or domestic construction
			Intensive agriculture and aquaculture
			Water abstraction
			Human movement
		Direct disturbance, exploitation and extraction (of components of nature)	Human modification of genetic material
			Overfishing
			Overharvesting
			Overhunting
	Natural-Anthropogenic	Manifestation of climate change	Weather conditions
			Ocean currents and circulation
			Ocean acidification
			Sea-level rise
			Sea-surface temperature
		Invasive alien species	Pests (harmful plants or animals)
			Disease outbreaks, zoonosis, pathogens, microbes
Indirect drivers	Anthropogenic	Institutions (formal and informal)	
		Economic drivers	Patterns of supply
			Patterns of production
			Patterns of consumption
		Demographic drivers	
		Technological drivers	
		Governance drivers	
		Conflicts and wars	
		Sociocultural and socio-psychological drivers (values, beliefs, norms, education)	
		Health problems	

Table 3. Typology of drivers of environmental change. *(Sources: IPBES, 2019c; ENCORE, 2020)*

It is essential to bear in mind that **all forms of biodiversity, as well as the related NCPs, are interdependent and that a pressure on one will have harmful or beneficial effects on others**. These drivers of environmental change can have impacts on different NCPs, depending on the type of driver. However, they usually do not have a single impact, but a **multitude of cascading effects through a chain of ecological interactions**. The impacts of drivers of environmental change therefore alter the natural functioning and essential interdependencies of NCPs, resulting in a decline of potential NCPs and, as a consequence, in harmful impacts on the good quality of life and business. The degradation of biodiversity and disruption of ecosystem services today has a delayed impact on our future use of biodiversity.

Therefore, understanding the emergence of drivers of environmental change and their origin is essential to assess our future ability to continue to benefit from NCPs and to act in order to ensure future positive impact on GQL and GQB.

AN ILLUSTRATION VIA AGRICULTURE

Agricultural activities are a prime driver of environmental change, for example through the following direct drivers:

- Land-use and land-use change: agroecosystems cover approximately 40% of land today (IPBES, 2019c);
- Pollution: agriculture is responsible for 25% of global greenhouse gases emissions, mainly due to land clearing, crop production and fertilization (IPBES, 2019c).

The increasing impact of these direct drivers is generated by the following indirect drivers:

- Demographic growth;
- Dietary habits, especially increasingly meat-based diets in developing countries.

However, it should be noted that agricultural activities are diverse, ranging from large monocultures and intensive livestock farming with the most high-impact drivers to agroecological practices and organic agriculture with the least impacts.

B. THE CONSEQUENCES OF HUMAN ACTIVITIES

Individuals and companies interact with biodiversity to co-produce goods and services essential to their good quality of life and business. To do so, individuals and companies make decisions, sometimes directly (e.g. agricultural production) or indirectly impacting nature (e.g. smartphone production). In both cases, the implementation of these decisions will have a positive or negative impact on biodiversity at the end of the value chain, where there is contact between humans and biodiversity.

Depending on the decisions made on how to co-produce goods and services, individuals and companies can generate three types of dynamics, namely *trade-offs*, *synergies* and *substitutes*.

Trade-offs correspond to a situation where an increase in a given realized NCP or GQL is associated with a decrease or loss of populations, ecosystem degradation, and thus, fewer NCPs (IPBES 2019e). Trade-offs are also often referred to as **negative externalities**. The drivers of change presented in the last sections are the results of trade-off decisions.

Synergies, on the contrary, correspond to situations where the increase of a given NCP leads to the increase of another, i.e. a win-win situation (IPBES 2019e). Synergies are often referred to as **positive externalities**.

Substitutes occur when an NCP is replaced through human-made processes, e.g. the production of quality drinking water can be achieved through ecosystem filters or through water-treatment facilities. Substitutes can affect the way NCPs impact on GQL (IPBES 2019d).

Understanding these three options when making a decision, particularly decisions that would appear to have no link with biodiversity, helps in assessing one's impact on the good quality of life and good quality of business in the future. It also helps in understanding the limits of managing and predicting environmental interactions.

AN ILLUSTRATION VIA AGRICULTURE

Trade-offs

Today, in agriculture as we know it, the co-production of agricultural outputs has negative consequences on potential NCPs and on biodiversity. Agriculture is one of the largest causes of biodiversity loss through land-use change, it contributes to 25% of global GHG emissions and is one of the largest sources of pollutants (IPBES, 2019f). The rise in intensive agricultural practices has occurred at the cost of many regulating NCPs. These intensive practices, especially the use of fertilizers, have undermined the capacity of nature to regenerate soil quality by improving soil biodiversity and enhancing soil organic carbon, which is necessary to soil health and crop productivity. Agricultural production has been increased at the expense of habitat creation for species, carbon sequestration through deforestation, water quality and other NCPs, which will undermine potential NCPs for future uses. Intensive agriculture promotes monoculture, which undermines crop biological diversity and thus resilience to pests.

Synergies

However, it has been proven that synergies exist. Studies have found that diversified food production systems with fewer chemical inputs contribute to higher biodiversity, improved soil and water quality, reduced impacts on climate, enhanced nutritional values and more diversified diets (IPBES, 2019e). Moreover, analyses have proven that meeting global food demand is achievable through sustainable agriculture. "*Recent scenario analyses have shown that globally enough food could be produced for everyone in 2050 on existing agricultural land, while halting deforestation and protecting 17% of the world's terrestrial habitats if we shifted towards more sustainable diets, reduced food waste and closed yield gaps*" (IPBES, 2019f).

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Trade-offs and synergies also need to be understood from a spatial and temporal perspective. Decisions made at a given time and place can have consequences in the future and far across the world, especially in such an interconnected world. Demand for products in one part of the world will impose pressures on ecosystems on the other side of the world. Also, ecological interactions can flow across time and space, and an action on an ecosystem can have impacts downwind, for air quality, downstream for water, or across territories for migratory species, for instance.

When discussing the interactions of human activities with biodiversity, there are two main barriers to the integration of biodiversity which institutions have to date failed to overcome in developing a sustainable approach to biodiversity:

— **Tragedy of the commons.** When common interest is not sufficient to overcome the pursuit of personal interests. The tragedy of the commons can be easily illustrated with environmental issues, such as climate change, deforestation or fishing. For example, the climate is a public good and there is a common interest of governments to limit climate change, however they would also all prefer to see other countries bear the costs, leading to a free-rider problem and a lack of commitment in international agreements (Combes, 2016).

— **Tragedy of the horizon.** Short-termism is another hindrance when tackling long-term environmental issues such as biodiversity loss. Financial actors expect short-term financial returns. The long-term depletion of ecosystems is not taken into account and the damage is not perceptible within the average time span of financial analyses, i.e. 3 to 5 years. Even though the lead time for the consequences of biodiversity loss is shortening given increasing human pressures on ecosystems, the materialization of such risks greatly exceeds the time horizon of financial actors and is therefore ignored. This is easily illustrated by the continuous investment flowing to unsustainable, but financially profitable activities such as fossil fuels (Dasgupta, 2020).

In conjunction with the tragedy of the commons, this tragedy of the horizon highlights an institutional failure and a critical role for governments and regulators to "*compensate for the inability of markets to react in the face of potentially catastrophic losses related to tipping points*" (Dasgupta, 2020).

To sum-up, the complexity of integrating trade-offs and synergies in the consequences of corporate or public decisions relies on an understanding of the interdependencies between NCPs as well as the temporality of these connections and the spatial implications of the impacts. In addition, it is essential to bear in mind the demonstrated pattern of increases in material NCPs at the expense of regulatory NCPs due to human management of ecosystems.

III. RESEARCH PERSPECTIVES ON BIODIVERSITY AND HUMAN ACTIVITIES

Science is continuously advancing and making progress in precisely describing the state and dynamics of biodiversity loss. A number of facts have been firmly established regarding the alarming tendencies and the causal links with human activities, as seen above.

If the state of knowledge is continuously advancing, much remains yet to be studied concerning the loss of biodiversity and ecosystem services, the consequences for humans and the levers to mitigate the impacts and risks.

1. ON THE LOSS OF BIODIVERSITY AND ECOSYSTEM SERVICES

The vastness of biological diversity requires far more research and mapping, it is estimated that 8 to 12 million species remain unknown (INPN, 2020). Among existing species, approximately 86% of terrestrial species and 91% of marine species must still be described (IPBES, 2019a). Some taxonomic groups (e.g. terrestrial mammals and birds) are far more studied than others and this skews our overall perception of the status of biodiversity. There are also geographic imbalances. Setting up observatory systems and maintaining them over time is quite difficult in some areas and we lack data (on environments, taxa, their status and dynamics) for some world regions.

Grasping how whole ecosystems function is highly complex. Beyond data and loss quantification per se, we also lack an understanding of interrelationships and interdependencies. Populations dwindling, migrating or disappearing will not immediately translate into ecosystem collapse, there will be time delays before cascading effects materialize and it is extremely difficult to predict such outcomes given the uncertainties in the behavior of living beings.

2. ON BIODIVERSITY AND HUMAN INTERACTIONS

Scientific research needs to advance on biological and ecosystem questions, but it also needs to go further concerning the interactions and interdependencies between biodiversity and humans. Data is lacking in this respect and the scientific literature is growing, but still sparse.

For instance, more study is being put into the effects of agricultural development on biodiversity and what the introduction and expansion of agroecology could entail. But the potential risks facing other economic sectors and their impacts on biodiversity have undergone very little empirical testing.

When it comes to the financial industry, the mechanisms at work are still unclear and evidence is largely missing (Busch, Timo *et al.*, 2019). These micro-level risks could materialize on different space and time scales, and computing how they will combine on the macro level will be yet another step in understanding the scope of the challenge ahead. We need to pursue studies on the potential occurrence of systemic risks (WWF, 2019a) and continue the work on the ramifications of biodiversity loss for economies and societies.

One way to do so is first to build upon the growing work on climate change-related risks and impacts. These two challenges share deep connections (Farber, 2015) and lessons learnt from the climate sphere could be of great use in the biodiversity field. For the financial industry for instance, the framework and recommendations put forward by the Task Force on Climate-related Financial Disclosures could constitute building blocks for further integration and disclosure of loss-related risks for NCPs (WWF, 2019a).

An approach that is mainstreaming in the climate field and that is progressively gaining ground in the biodiversity field as well is modelling. Models are increasingly being used to provide insights into what could happen in the future under diverse scenarios, taking into account socio-economic factors. Adopting different approaches, e.g. bottom-up and top-down, from ecosystem services to humans or from anthropic pressures to biodiversity, can indeed help in better understanding and framing the problem.

Multiple entities are working in that direction. Within the Sixth Framework Programme of the European Commission, the ALARM (Assessing LArge-scale environmental Risks for biodiversity with tested Methods) integrated project gathered scientists from 68 research institutions to devise and test protocols under different scenarios (Spangenberg *et al.*, 2012). A consortium of more than 40 universities and non-profit organizations gathered in 2017 to launch the *Bending the Curve* initiative (WWF, 2020a), which led to the publication of an article using a panel of land-use and biodiversity models to evaluate the possibility of reversing the terrestrial biodiversity loss that is being caused by habitat conversion (Leclere *et al.*, 2020). Most recently, the article by Powers and Jetz titled "Global habitat loss and extinction risk of terrestrial vertebrates under future land-use-change scenarios" (see Powers & Jetz, 2019) published in *Nature Climate Change*, received much attention from the scientific community.

Back in 2016, IPBES published a *Methodological Assessment Report on Scenarios and Models of Biodiversity and Ecosystem services* to review the existing literature on this theme and guide the use of models and scenarios (IPBES, 2016).

3. ON THE LEVERS TO MITIGATE BIODIVERSITY LOSS

The purpose of these types of analyses is to inform policy-making and the work by the CBD on the future framework and objectives to be agreed upon on the international level. However, given that ecosystems are multifactorial, highly complex and uncertain, i.e. unpredictable systems, it is of the utmost importance to bear in mind that these modelling methods can provide helpful decision-support tools, but they cannot be seen as stock answers and need to be applied with care (IPBES, 2016).

Aside from modelling, in the run-up to COP15 of the CBD, a great deal of research work is focusing on past and present trajectories to assess policy actions and promote those that work in order to reduce anthropic pressures on ecosystems. For instance, research shows that protected areas are key factors in halting biodiversity loss (Geldmann *et al.*, 2019) and that they could, in the maritime domain more particularly, create benefits in multiple and even distant places.

Concerning economic agents, metrics and indicators are increasingly being used and developed to evaluate impacts and dependencies on biodiversity. In the past few years, many methods have emerged, for example tools to calculate biodiversity footprints (Berger *et al.*, 2018). The E.U. Business & Biodiversity Platform in partnership with UNEP-WCMC has been mapping and assessing these different approaches (Lammerant *et al.*, 2019; OECD, 2019). But this work is on-going and far from achieved. Much remains to be done on the question and no harmonized framework has emerged yet.

To sum-up, the IPBES Global Assessment Report synthetized the knowledge gaps in eight areas (IPBES, 2019a):

- *"Data, inventories and monitoring on nature and the drivers of change;*
- *Gaps on biomes and units of analysis;*
- *Taxonomic gaps;*
- *NCP-related gaps;*
- *Links between nature, nature's contributions to people and drivers with respect to targets and goals;*
- *Integrated scenarios and modelling studies;*
- *Potential policy approaches;*
- *Indigenous peoples and local communities"*

These categories show broadly the direction being taken by scientists in the fields of biodiversity, biodiversity and human interactions, and actions undertaken to mitigate the losses. The *Fondation pour la recherche sur la biodiversité* (FRB), which hosts the Scientific Secretariat of the IPBES French National Committee, recently reviewed research projects being undertaken by French researchers in these fields (Cazaux-Debat, Hallosserie *et al.*, 2020).

PART I. KEY TAKE-AWAYS

Biodiversity refers to the "web of life" on Earth and encompasses three levels: **ecosystems, species, and individuals**. Humans are part of this web of life.

Nature directly or indirectly contributes to and supports human existence and wellbeing. This is what the concepts of ***ecosystem services*** and ***Nature's contributions to people*** (NCPs) reflect. The conceptual framework designed and used by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) is based on 18 NCPs.

The IPBES 2019 Global Assessment Report is the current reference document on scientific knowledge concerning biodiversity. Its main message, which more recent work has been confirming since, is that **nature is deteriorating worldwide, at all levels** (from individuals to ecosystems), **at an unprecedented and alarming pace**. We are currently witnessing the **sixth mass extinction of biodiversity**.

The **interactions** between biodiversity and human activities are **two-way streets**.

— Humans **depend** on realized Nature's contributions to people (NCPs) for a good quality of life and good quality of business, yet the dynamics of change of these NCPs is currently **unsustainable**.

— Humans also have **impacts** on biodiversity through the decisions they make, triggering either **trade-offs, synergies or substitutes**. Today, humans are responsible for the **five main drivers of change** in biodiversity: **Changes in land and sea use, Species overexploitation, Invasive species and disease**, **Pollution** and **Climate change**.

Through cascading and feedback effects, the vicious circle of harmful **impacts and dependencies** between humans and biodiversity loss **jeopardizes the future availability of Nature's contributions to people** and hence **our very conditions of existence**.

Biodiversity and climate change are **twin crises** that need to be addressed concurrently. The "**planetary boundaries**" that are associated with these two crises are the "core" boundaries, meaning that the consequences of one of these crises alone could irreversibly change the Earth system.

Science is continuously progressing in describing the state and dynamics of biodiversity loss, and the interactions with humans. Yet, **considerable knowledge gaps remain** in our understanding of biodiversity, biodiversity and human interactions, and actions undertaken to mitigate the losses.

PART II

HUMAN SOCIETIES AT RISK FROM BIODIVERSITY LOSS

Important notice. The following analyses and reflections on biodiversity and human societies are based on a Western understanding of social and corporate organizations.

1. FEATURES OF BIODIVERSITY-RELATED RISKS

To understand biodiversity-related risks, how they are approached and managed today, it is crucial to have a clear understanding of their key features, which separates them from other emerging or more usual risks. Even though this report is focused on biodiversity, the features of the risks presented can be broadly labelled as nature-related risks, including biodiversity and climate change.

The first part of this report highlighted two interactions and one dynamic: First, our societies, from individuals to all types of organizations, are **dependent** on biodiversity for their existence and well-being. Second, through their decisions and actions, individuals and organizations have the power to positively **impact** (through synergies) or negatively impact (through trade-offs) ecological interactions. Finally, during the last century, the unprecedented demographic and economic growth of human societies has **increasingly put pressure on biodiversity by overexploiting Nature's Contributions to People**, providing material goods at the expense of other regulatory and non-material services, leading to **a steep decline in biodiversity** in terms of ecosystems, populations and species, with scientists sounding alarms about the oncoming planetary boundaries.

This vicious circle of harmful human activities on biodiversity combined with the cascading effects between ecological interdependencies is forcing **a growing number of individuals and companies to rely on a decreasing amount of available Nature's Contributions to People**, with an increasing amount of uncertainty about the reaction of biodiversity to these harmful impacts and how far they are from causing **full disruption**.

The full extent of the biodiversity-loss challenge is not yet fully grasped by the scientific community. There are still knowledge gaps (see Part I.III.) in understanding how ecological interactions will adapt to disruption and where biodiversity-related threats will arise, their evolution in the future and how they will materialize into risks. Some specific industries or situations have been or are being studied, e.g. agriculture and health (by the IPBES or the FAO), financial institutions (by the Natural Capital Finance Alliance (NCFA)) and global economic impact scenarios (by the WWF, among others).

This section aims at understanding how biodiversity loss could arise as a threat for human societies as we know them today, on four different scales of social organizations, namely **individuals, companies, financial institutions** and **the whole economic system**. We will first propose a definition of the main features of biodiversity-related risks, then present a typology of different biodiversity-related risks on the four levels of human societies mentioned above. This analysis is based on current observations of the consequences of biodiversity loss and the limited number of projections that have been made.

I. CORE CHARACTERISTICS OF BIODIVERSITY-RELATED RISKS

When studying risks in general, animals play a central role, especially swans. In addition to "**white swans**", referring to relatively certain and predictable risks, e.g. car accidents, "**black swans**" are now famous for representing **risk linked to high uncertainty**, such as terrorist attacks. The main features of black swans are as follows:

— They are unexpected and uncommon;
— They have high-magnitude impacts;
— They are unpredictable and can be explained only afterwards.

A new color of swan has been added by the financial community to refer to an emerging type of risks, namely **environmental risks represented by "green swans"**. "Black swans" and "green swans" share some features, they are both **characterized by deep uncertainty, non-linear propagation and significant negative externalities**. However, three specific features of green swans initiated the creation of a separate category (Bank for International Settlements, 2020):

— There is a high degree of certainty they will occur. "*That is, there is certainty about the need for ambitious actions despite prevailing uncertainty regarding the timing and nature of impacts*" (Bank for International Settlements, 2020);
— The level of impacts is more serious than other systemic crises, because they pose existential threats to humans;
— Their complexity is greater than other swans, due to their "*complex chain reactions and cascading effects*" (Bank for International Settlements, 2020).

According to the Dasgupta report (the latest independent global review on the economics of biodiversity, commissioned in 2019 by the United Kingdom HM Treasury and led by Professor Sir Partha Dasgupta), the irreversibility of their consequences is a further factor.

2. BIODIVERSITY-RELATED RISKS AND HUMAN SOCIETIES

Biodiversity-related risks for human organizations arise from the "*change in available stock or condition of natural capital*", i.e. the flow of ecosystem services and the "societal responses" to these changes in goods and services provided by nature (Dasgupta, 2020). The changes in the condition of ecosystems and their capacity to produce goods and services impact individuals but also organizations, and are identified as **physical risks**.

The societal reaction to these changes includes "*regulation and pricing of externalities, technological changes, evolving social norms and consumer preferences, and the threat of legal liabilities and litigation*" (Dasgupta, 2020) thus impacting the quality of life and businesses, and are identified as **transition risks**.

In other words, individuals and organizations are exposed to **two different types of biodiversity-related risks**:

— ***Physical risks*** due to direct exposition and consequences of biodiversity loss and ecosystem degradation or disruptions;

— ***Transition risks*** due to the consequences of the collective response to the threats or materialization of physical risks.

Biodiversity-related risks can be diverse in terms of geographic occurrence, intensity, frequency and time period (Dasgupta, 2020).

As most biodiversity-related threats for individuals, businesses and financial institutions arise from their dependence on biodiversity, it is important to keep in mind this feedback dynamic of human and biodiversity interactions, as shown in Figure 8.

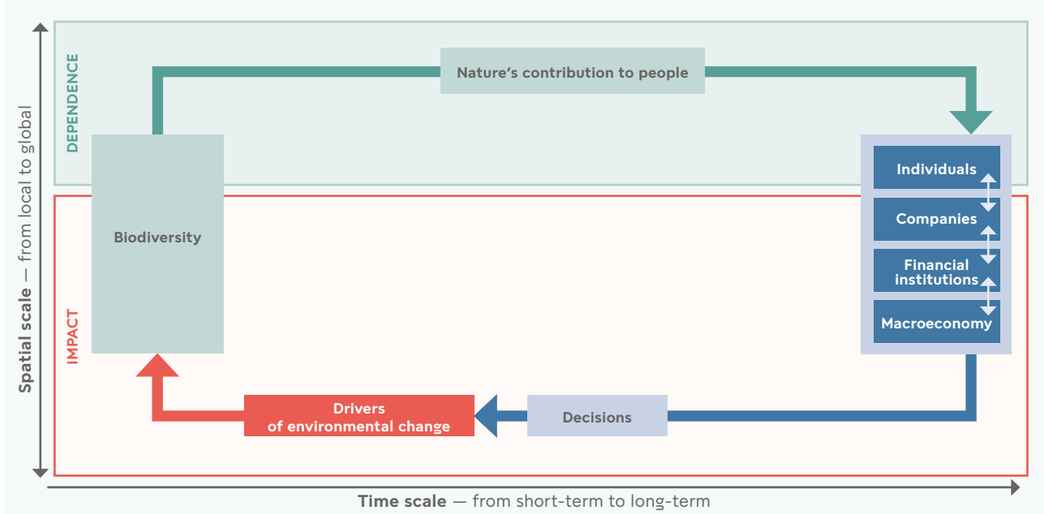


Figure 8. Simplified conceptual framework focusing on the feedback effect of risks. *(Source: author, based on IPBES 2019e; IPBES 2019f, WWF, 2019a; NGFS, 2020; OECD, 2019)*

In the following analyses, the concepts of feedback and cascading effects are used to describe the material consequences of biodiversity loss on individuals, the private and public sector and the economy as a whole. These concepts are defined here as follows:

Cascading effect: effects cascading from one actor to the other through the value chain or through an industry, or several industries;

Feedback effect: when the effect worsens the initial cause in a vicious circle.

After having defined what the main features of biodiversity-related risks are, we will now look into what it entails on the four levels of human societies, namely individuals, businesses, financial institutions and the economic system.

II. INDIVIDUALS

Rising threats related to losses of biodiversity and ecosystem services are the most tangible on the scale of the individual. Biodiversity loss poses threats to individuals on two different levels, directly with physical constraints or the lack of access to natural resources (**physical risks**), but also indirectly with threats to their socio-economic situation and security (**transition risks**) (see Table 4).

Risks for Individuals		
Physical risks	**Health**	Rising health issues
		Proliferation of diseases, rise of vector-borne diseases, of zoonoses, with potential pandemics
		Negative impacts on human physical and mental health and well being
		Loss of treatment options for the future
		Premature death due to health issues
		Dietary issues
	Access to resources	Shortage or lack of access to basic life-supporting resources
		Shortage or lack of access to other resources
	Vulnerability to extreme events	Increasing physical injuries/deaths
		Property damages
Transition risks	**Societal**	Social inequalities
		Rising poverty
		Social unrest
		Loss of cultural identity
	Economic	Decrease in livelihood and income security, especially nature-based income (related to resources or derived products, tourism, payment for environmental services, small-scale agriculture, aquaculture)
		Depletion of household assets
	Geopolitical	Conflicts, uprisings
		Migration

Table 4. Biodiversity-related emerging threats for individuals *(Adapted from WEF, 2020a; iPBES, 2019; OECD, 2019).*

The following paragraphs present three examples to illustrate threats to people in the fields of "Health", "Conflicts" and "Coral reefs". These are just examples, hence a non-exhaustive list of the channels through which individuals can be affected by biodiversity loss.

HEALTH (based on IPBES, 2019e)

According to the IPBES, Nature's contributions to people can impact individuals' health through diet, environmental exposure, communicable diseases, hazard risk, psychological health and natural and biochemical compounds for medicines.

— **Diet.** Food production and a multitude of other supporting NCPs are key to providing humans with a healthy diet. Even though global food systems produce enough calories to feed the world population today, many still suffer from dietary health issues. Diet-related diseases are the first cause of premature mortality around the world and non-communicable diseases such as diabetes or cardio-vascular illness produce as many deaths as starvation. While poorer countries are facing diseases caused by undernutrition, wealthier countries are seeing a rise in obesity. Biodiversity factors linked to the global food supply are essential to provide healthy diets, as well as for the resilience of the global food system.

— **Environmental exposure.** Deteriorating environmental quality is a source of health issues for humans, such as the rise in air and water pollution. The decline in NCPs related to the regulation of air and water quality combined with anthropogenic sources of pollution exponentially increase the risk of health impacts.

— **Communicable diseases.** Nature can be the source of communicable diseases and contagion risks for human societies. The loss of habitats increases the risk of proximity with pathogen-host species and consequently contagion to humans, or the creation of environments conducive to vectors. Therefore, the loss of ecosystems and the overlap of vector and human habitats creates an increasing risk of the spread of communicable diseases, e.g. Ebola following deforestation by humans (see the Case Study on Biodiversity, Pandemics and Re/insurance in Part 3.II) (see Box 4).

BOX 4
ILLUSTRATING THE CAUSAL CHAIN FROM BIODIVERSITY LOSS TO INCREASED HUMAN HEALTH RISKS: THE CASE OF INDIAN VULTURES

In the late 1990's, observers reported that the populations of three vulture species were rapidly declining in India. Between 1992 and 2007, they declined by almost 100 %[6]. This was unprecedented, in terms of both the rapidity of the decline and its geographic scale (Markandya *et al.*, 2008). According to Richard Cuthbert, a biologist at the United Kingdom's Royal Society for the Protection of Birds, "*In a single decade* [Indian Gyps vultures] *have undergone the most rapid population collapse of any animal in recorded history.*" (Smithsonian Magazine, 2007).

In 2003, researchers found that this hecatomb that spanned the whole Indian subcontinent was not due to a virus, as was feared at one point (Smithsonian Magazine, 2007). It had one major (if not sole) cause, i.e. vultures were poisoned by diclofenac, a non-steroidal anti-inflammatory drug that was extensively administered to livestock in the region (Markandya *et al.*, 2008). The drug was widely used by herders due to its high effectiveness in speeding cows' recovery from pain, inflammation and fever (Smithsonian Magazine, 2007). Carcasses constitute the primary source of food for vultures and consuming livestock that had been treated with diclofenac shortly before death directly exposed them to a drug that is fatal to them (Markandya *et al.*, 2008).

Not only was this population collapse an ecological disaster, it had tremendous repercussions on inhabitants of the region from a health, socio-economic and cultural perspective. As scavengers, vultures provide essential ecosystem services in disposing of animal remains. With the decline in the number of vultures, the amount of uneaten livestock carcasses surged (Markandya *et al.*, 2008).

The decaying corpses pose direct health problems by constituting breeding grounds for the development of pathogenic bacteria, contributing to air, soil and water pollution, and consequently causing the transmission and propagation of infectious diseases (such as tuberculosis or anthrax). But the increase in uneaten livestock carcasses is also thought to have induced an increase in other scavenger populations, namely rats, feral cats and, most importantly, dogs (Markandya *et al.*, 2008); mammals for which diclofenac is not lethal (Smithsonian Magazine, 2007).

In step with the disappearance of the vultures, dog populations increased substantially. It is estimated that their numbers rose from 21.8 to 29 million between 1992 and 2003, while the number of vultures fell from 10 million to approximately 72 600 (Markandya *et al.*, 2008).

At the time, India had the world's highest death toll from rabies and two thirds of the deaths were caused by dog bites (Smithsonian Magazine, 2007). Research has established that the consequences of vulture decline on human health in terms of rabies was significant. Over the 1992-2006 period, the total impact on health due to the collapse of the vulture populations in India was estimated at 1.046 trillion INR (that is, approximately 34 billion USD) (Markandya *et al.*, 2008).

By a similar mechanism, the increase in rat populations also made public officials at the time fear a raise in the probability of bubonic plague and other outbreaks of rodent-transmitted diseases affecting humans (Smithsonian Magazine, 2007).

This case is a clear illustration of how human activities are direct drivers of biodiversity loss, how the decline in the population of one species can translate into destabilized ecosystems on a regional level and how this destabilization can have direct, tangible and measurable impacts on human health. The causal chain from biodiversity loss to increased human health risks is tangible. And the message is loud and clear that to mitigate such health risks, we must act at the beginning of the cascade by modifying human activities that are deleterious to biodiversity.

— **Hazard risk**. As already observed and documented with climate change, environmental change can result in hazard risk and increasing human exposure to heat waves, extreme storms and wildfires among others. Biodiversity can help reduce these risks by buffering the impacts or providing protection against these extreme events. Through the regulation of extreme events, biodiversity can reduce the impacts of ocean flooding and storms as well as heat waves and heat exposure, especially in urban areas.

— **Psychological health**. Exposure to the natural environment is thought to have a positive effect on psychological well-being, even though scientific findings are still inconclusive regarding the extent of this effect (see Box 5).

6. The decline varied depending on the species. "*The estimated decline during the period 1992–2007 is 96.8 (LBV* [Long-billed vulture: Gyps indicus]) *to 99.9 (OWBV* [Oriental white-backed vulture: *Gyps bengalensis*]) *percent.*" (Markandya *et al.*, 2008)

BOX 5
BIODIVERSITY AND MENTAL HEALTH

According to the World Health Organization and the Secretariat of the Convention on Biological Diversity (CBD), "*the connections between biodiversity, mental health and physical activity are particularly relevant in the context of a shifting global burden of disease, in which noncommunicable diseases (NCDs) are the most rapidly rising challenge to global public health.*" (WHO & Secretariat of the CBD, 2015). In fact, as the world becomes ever more urbanized and humans ever more sedentary, a significant share of the world population suffers from NCDs such as cardiovascular diseases, chronic respiratory diseases, diabetes type 2 and mental health disorders (WHO & Secretariat of the CBD, 2015; WHO, 2021).

It is well established that "*observing nature and participating in physical activity in green spaces play an important role in positively influencing human health and well-being*" (Pretty *et al.*, 2011). "Green exercise" has been proven to induce significantly improved self-esteem and mood (Pretty *et al.*, 2011) while "nature experiences" (e.g. vigorous outdoor activities, but also walking and hiking, birdwatching or "forest bathing") could have significant positive physiological impacts (e.g. on the heart rate and blood pressure) (Pretty *et al.*, 2011; Park *et al.*, 2009; EFESE, 2018; MTE, 2020b; Bratman *et al.*, 2019), to say nothing of the health benefits from exposure to the sun in terms of vitamin D absorption (Pretty *et al.*, 2011) and from the opportunities for social engagement and interaction that going outside provides (Pretty *et al.*, 2011). (For more details on the body of evidence, refer to Bratman *et al.*, 2019 as well as the U.K. National Ecosystem Assessment: Technical Report, Chapter 23: Health Values from Ecosystems (Pretty *et al.*, 2011).)

Research work has shown that interaction with nature provides cognitive benefits as well as emotional and existential benefits (American Psychological Association, 2020). Studies have associated exposition to and contacts with nature with improved sleep and with reduced depression, anxiety and stress (Fondation pour la Recherche sur la Biodiversité, 2018; Bratman *et al.*, 2019; American Psychological Association, 2020). In parallel, "nature-deficit disorder" is considered a new developmental disorder in children who are less and less in contact with the natural world and increasingly exposed to electronics (Fondation pour la Recherche sur la Biodiversité, 2018).

However, the research in this field is ongoing and the evidence needs to be filled out. Most studies establish correlations between contacts with nature and increased human health and well-being (Bratman *et al.*, 2019), but more evidence is needed on the causal relationships. Moreover, the existing literature focuses primarily on the "quantity" rather than the "quality" of nature (Van den Berg *et al.*, 2015) and does not address biodiversity per se (Marselle *et al.*, 2019). To date, the one systematic review of the literature which specifically investigated the health and well-being effects of biodiversity found no clear pattern of results (Marselle *et al.*, 2019). Researchers are calling for more interdisciplinary studies that would include more detailed characteristics of nature and more diversified population subgroups (Van den Berg *et al.*, 2015; Marselle *et al.*, 2019; Bratman *et al.*, 2019).

From a very different yet complementary angle, another field of research is increasingly shedding light on the connection between biodiversity and human health, namely microbiology. When discussing biodiversity loss, one tends to immediately think and focus on the extinction of iconic species, but this is the tree that hides the forest of alarming signals regarding the vast process of biodiversity loss (see Part I.I.I). And a similar bias arises when dealing with the health aspects of biodiversity. One tends to forget that biodiversity is not only the nature outside of us, but it also refers to the genetic diversity of individuals and is composed of the diversity *within* them.

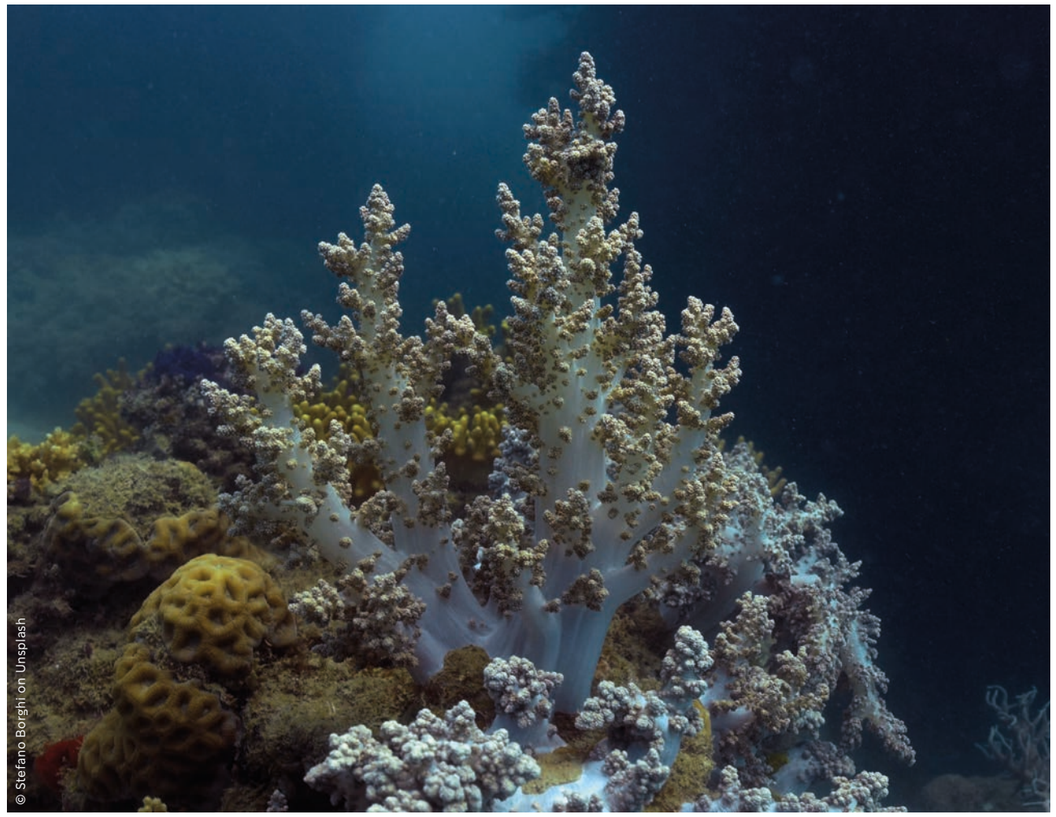
A wide variety of microorganisms (e.g. bacteria, viruses or fungi) live inside the human body, notably in the gut. The links between the gut microbiota and the brain in humans are being actively investigated by researchers and the concept of bidirectional signaling is emerging (Du Toit, 2019). Associations have already been scientifically established between the presence of specific bacteria in the human gut microbiota and the mental health of individuals (notably with regards to depression) (Valles-Colomer, M. *et al.*, 2019; Du Toit, 2019). This is yet another aspect to be considered when looking into the repercussions of biodiversity loss on human mental health.

— **Natural and biochemical compounds for medicines**. Biodiversity is a primary resource for many medicinal products, both traditional and modern. Antibiotics, cancer-fighting drugs and other medicines such as aspirin are derived from nature. Even though modern medicines are dominated by synthetization, nature continues to be the main source of new medicines, e.g. new antibiotics for antimicrobial resistance.

Biodiversity loss can also have detrimental effects on the scale of society, hitting each and every individual within a society.

CONFLICTS

Shortages of natural resources, especially food and water, can be a source of geopolitical and social tensions. The loss of biodiversity and ecosystem services is expected to increase these situations, mainly through acute extreme events such as droughts. In Africa, droughts are known to be a source of increased violence, up to and including major worldwide conflicts such as the Syrian civil war (WEF, 2020b).



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CORAL REEFS AND THREATS TO PEOPLE

The decrease in coral reefs around the world represents a major threat for people living in coastal areas. In terms of access to resources, coral reefs support the development of fisheries (coral reefs host more than a quarter of all fish species). Concerning vulnerability, coral reefs are a critical protection against coastal erosion, especially in the case of extreme events, such as storms, and they can protect against flooding. Coral reefs are also a major source of income for coastal populations thanks to tourism. Therefore, a single ecosystem can support access to basic resources, protect from extreme events and support economic development for individuals living nearby (WEF, 2020b). Similar examples could be developed for other types of ecosystems, such as mangroves, wetlands, etc.

People are not equally vulnerable to these threats. Vulnerability depends on the exposure of each individual and on his capacity to protect himself or to adapt. The exposure to biodiversity-related threats can vary across regions, but also across socio-economic classes and even gender. And the ability to adapt depends on the available financial capital of each individual, among other factors. Therefore, increasing biodiversity threats is a cause of worsening social and economic inequalities around the world.

— **Gender inequality** increases through biodiversity loss because women and children have a role in managing biological and natural resources, consequently, they have greater exposure to biodiversity. Increasing gender inequality is a threat to economic development (WEF, 2020b).

— **Poorer populations** have greater exposure to the loss of biodiversity and ecosystem services because poorer populations tend to live in rural areas, depend highly on nature-based incomes and have less access to technologies and the means to mitigate biodiversity loss. As such, they face higher direct impacts from biodiversity loss, worsening the dynamic of global poverty and threatening social and economic development.

To sum-up, on the scale of individuals, the loss of biodiversity and ecosystem services has both direct and indirect impacts. The exposure to these threats depends on many factors such as the geographic location, the level of development of the country, the availability of individual protection mechanisms such as insurance coverage, but also gender and culture. However, in all cases, the increase of biodiversity loss will have detrimental effects on social, economic and gender equality, thus affecting economic development.

III. BUSINESSES

For many years, climate change has dominated in the minds of regulators and companies, at the expense of the loss of biodiversity and ecosystem services. However, since the IPBES Global Assessment report in 2019 and the announcement of 2020 as the year of biodiversity, the topic has become increasingly present in corporate agendas and initiatives are flourishing in the corporate world, such as the Act4Nature program. In the past few years, a multitude of grey and scientific literature has emerged on the exposure of businesses to biodiversity-related threats and how they materialize. Depending on the industry, the research has made more or less progress.

The WWF's new nature-related risks framework (see WWF, 2019a) provides a new perspective on how to look at the increasing threats linked to biodiversity loss (see Box 6). The following section will use the concepts of this framework to depict these threats.

BOX 6
WWF'S FRAMEWORK ON NATURE-RELATED RISKS FOR BUSINESS

The WWF's Nature of Risk report (see WWF, 2019a) provides a new perspective on the emergence of nature risks for businesses by developing the *threat*, *exposure* and *vulnerability* concepts. A given company will face consequences from biodiversity loss if there is a threat to which the company is exposed and vulnerable.

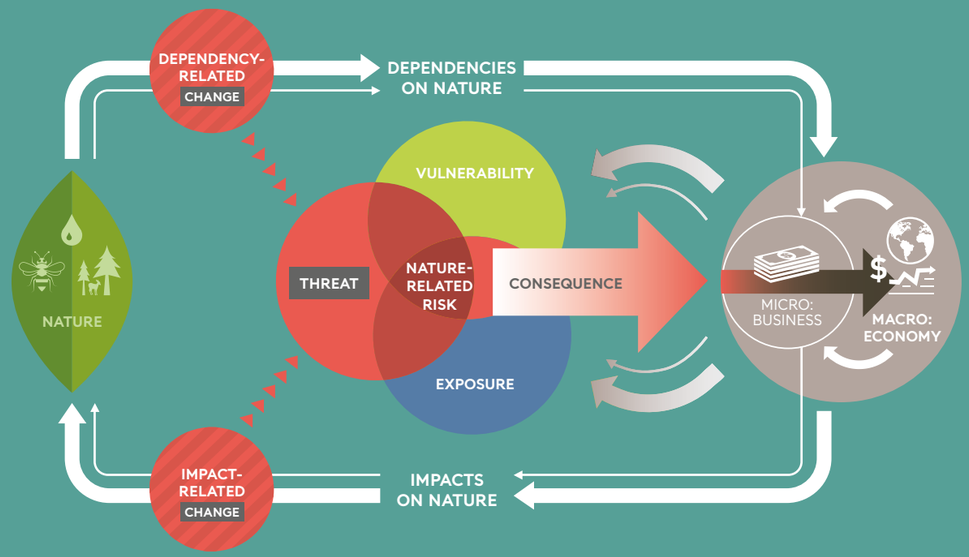


Figure 9. Nature-related risk to business/economy framework. *(Source: WWF, 2019a)*

Threat: "the result of an event or change in the business's operating conditions that may jeopardize business value or profitability." (WWF, 2019a)

Consequences: "to businesses and other actors occur only if threats or risks are not managed. Consequences affect a business's cash flow and profitability by disrupting its operations directly or affecting its costs, sales, and/or cost of capital (i.e., credit rating, equity value)." (WWF, 2019a)

Risk: "refers to a probabilistic concern with the consequences to business of a threat arising from a change." (WWF, 2019a)

Exposure: "the presence of a company's operations in places and settings that could be adversely affected by a threat. For a business, determinants of exposure include factors like the business's sector and industry (the practices of these, and proximity to consumers and regulators), the geographic spread of their value chain (with implications for their legal jurisdictions and their socio-political contexts of operation), and finally their (degree of) reliance on ecosystem services or natural capital. Exposure is the sum of "elements at risk" to any given threat occurring within a business's operating conditions." (WWF, 2019a)

Vulnerability: "the propensity or predisposition of a business to be adversely affected by threats in its operating conditions. For a business, determinants of vulnerability include size, expendable capital (or cash on hand), risk management practices along the value chain, risk awareness (including definitions of materiality), degree of operational and managerial resilience, value chain and/or product diversification, and influence on the market/within the sector (including pricing power and brand value). A business's vulnerability can mediate both threats and exposure." (WWF, 2019a)

Similar to individuals and as seen in Part 2.I., businesses face physical and transition risks.

Physical risks

Direct risks are physical risks which relate to the direct consequences of biodiversity loss and NCP disruption on business operations. A physical risk can be **acute** (short-term), i.e. related to a single extreme event, e.g. a storm or a surge of an infectious disease, or it can be **chronic** (long-term), for example in the form of changes in ecological interactions within ecosystems degrading its capacity to provide goods or services in the same quantity or quality, e.g. soil quality for agriculture (Dasgupta, 2020). If physical risks occur, there may be ***operational consequences* corresponding to how a risk becomes material for a business**. Usually a biodiversity-related risk, if not prevented or mitigated, can lead to a cascade of operational consequences and turn into financial consequences.

For instance, the depletion of soil quality or of wild pollinators can be considered chronic risks whereas pandemics or extreme climatic events associated with biodiversity loss are acute risks.

Relying on ENCORE's typology of business dependencies on biodiversity, we can define physical risks, which arise from the disruption of those dependencies (see Table 5).

Businesses risks				Operational consequences
Physical risks	Commodity risk	Lack of inputs for the production process	Scarcity of raw materials (lower quantity, higher costs)	Disruption of business operations, labor shortage, increased exposure to indirect risks
			Lower quality of resources	
			Loss of resources (biodiversity loss and species richness)	
	Supply chain risk	Lack of enabling factors for production processes	Reduced productivity /output of land resources	
			Availability, reliability and security of regulating NCPs	
			Disturbances of natural assets (pollution)	
		Lack of direct impact mitigation	Disruption of NCPs due to direct harmful impact of production processes on biodiversity	
	Vulnerability risk	Lack of protection from disruption	Material damages from acute events	Disruption of business operations, damages to infrastructure, labor shortage, increased exposure to indirect risks

Table 5. Biodiversity-related emerging physical threats for businesses. *(Adapted from WEF 2020b; OECD 2019; WWF 2019; ACCA, 2014; ENCORE, 2020)*

BOX 7
AN ILLUSTRATION OF THE MATERIALIZATION OF DIRECT OR PHYSICAL RISKS

PG&E and wildfire liabilities

The case of the utility company PG&E, which filed for bankruptcy in January 2019, is thought to be one of the first climate change-related bankruptcies. The company's trial should result in a $13.5 billion settlement to help wildfire victims and resolve the bankruptcy. The company was facing legal charges for wildfires liabilities. These wildfires induced by sparks from the utility's infrastructure in California were caused by a lack of vegetation control and climate change, because dry vegetation is more prone to wildfires (WWF, 2019a; Powermag, 2019).

The cosmetic market and forests

The €200 billion worldwide cosmetic market is threatened by the degradation of forests. The commodities frequently used for cosmetic products such as shea butter (shea tree) and argan oil (argan tree) are increasingly exposed to deforestation, pollinator loss and parasites threatening the long-term supply security for businesses (WEF, 2020b).

Transition risks

Indirect risks are also referred to as transition risks and relate to risks arising from the shifts to a sustainable economy with lower harmful impacts on biodiversity. Transition risks include **regulatory policies, technological innovations, shifts in market preferences** and **can occur over the long-term or as abrupt disruptions** (Dasgupta, 2020). These risks emerge from the inability of a company to adapt to a new environment.

There are four types of indirect risks (see Table 6).

Businesses risks				Operational consequences
Transition risks	Reputational risks	Brand value decrease due to public awareness of harmful impact on biodiversity		Loss of customers, negative press coverage, divestment of stakeholders, new sourcing and/or production process requirements, increasing regulatory risks
	Market risks	Shifting market demand due to: Changes in customer preferences for lower impact goods and services Changes in purchaser requirements		Loss of customers, new sourcing and/or production process requirements
	Regulatory and litigation risks	New regulations and legal restrictions to address biodiversity loss impact business operating conditions, such as restrictions, compensations, standards, licensing and permitting procedures or moratoriums		The rise of litigation risks with increasing lawsuits from parties suffering from biodiversity-related loss and damages, higher legal costs, threats to business value with for instance the rise of stranded assets, threats of operating license loss
	Financial risks	Increasing requirements and costs to access financial services	Credit risk	Higher cost of capital or lending requirements
			Market risk	Depreciated business value
			Underwriting risk	Higher costs of insurance

Table 6. Biodiversity-related emerging transition threats for business. *(Adapted from WEF 2020b; OECD 2019; WWF 2019; ACCA, 2014; ENCORE, 2020)*

The complexity of identifying biodiversity-related risks comes from the complexity of the dependence of businesses on biodiversity in combination of political and economic factors.

Not all companies are equal in the face of biodiversity-related risks and direct and indirect risks vary from one business to another according to the sector, the sub-industry and the production process. Moreover, biodiversity-related risks can be passed on horizontally (through the industry) or vertically (through the supply chain) to other businesses (WWF, 2019a).

As awareness of biodiversity loss and concerns about the uncertainty of its consequences rise, **transition risks tend to arise earlier than physical risks**. There are more examples of companies suffering from transition risks than from physical risks (see Box 8).

BOX 8
AN ILLUSTRATION OF THE MATERIALIZATION OF TRANSITION RISKS

Infinito Gold

In 2012, a Canadian gold-mining company, Infinito Gold, lost its license to operate in a mine in Costa Rica. This refusal was based on environmental concerns, including potential detrimental impacts on agriculture and biodiversity. Following the ruling by the Costa Rican government, the company's share price dropped by 50% (ACCA, 2014).

BP oil spill

In 2010, the tragically famous oil spill in the Gulf of Mexico impacted the company in terms of both operational and legal costs. BP has since paid $3.5 billion in clean-up costs and $7.8 billion in litigation and claims (ACCA, 2014).

Greenpeace & KitKat

In 2010, the Greenpeace NGO launched an awareness campaign against the presence of palm oil, linked to Indonesian rainforest deforestation, in Nestle's KitKat products. Nestle's stock fell by 4% (Dasgupta, 2020).

To sum-up, biodiversity-related risks for businesses can have a multitude of origins, affect business operating conditions in various forms and, if not anticipated or mitigated, materialize into serious operational and financial consequences. What is more, the impacts of biodiversity-related risks are not necessarily limited to a given company, but can also spread to vertical and horizontal partners, depending on their exposure and vulnerability.

IV. FINANCIAL INSTITUTIONS

In 2019, Busch *et al.* conducted the first comprehensive literature review of how nature risks become financial risks (see Busch, Timo *et al.*, 2019). This paper highlights the growing concern and interest of financial institutions in biodiversity loss as well as the lack of empirical evidence on the impacts of nature risk on the financial industry.

In this report, we chose to separate financial institutions from other companies because the biodiversity-related risks to which they are exposed are different from the ones facing other businesses, due to the nature of their business and their specific position within the industry value chain.

Financial institutions are **less directly exposed** to environmental changes, **however they are not less sensitive to the effects of these changes** because they rely on businesses which must directly cope with these environmental dynamics. Most companies rely on the financial industry's services for diverse needs, including investments, loans, financial advice and insurance. Therefore, **the financial industry is indirectly related to nature through the economic activities with which they engage**. The biodiversity-related risks for financial institutions materialize when a company is exposed to a biodiversity-related risk and is also vulnerable to the risk, i.e. when the question arises as to whether the company has the ability or not to adapt to the risk.

Therefore, **as lenders, investors, insurers or advisors, financial companies face biodiversity-related risks as well** (see Table 7). This analysis is focused on the asset side of financial institutions.

Financial institutions		
Physical risks	**Credit risk**	Risk of increasing default rates for businesses due to natural capital depletion and decrease in outputs
		Risk of revaluation of debt-servicing capacity and collateral depreciation
		Risk of increasing insurance claims
	Market Risk	Risk of investment devaluation: repricing of equities, fixed income, commodities
		Depreciation of assets
	Operational risk	Infrastructure damages due to exposition to extreme events
Transition risks	**Reputation risks**	*See business risks*
	Regulatory legal risks	Legal fees for breaching legal frameworks
		Loss of investment opportunities
	Credit risk	Investee losses due to sanctions or taxes related to negative impacts on biodiversity
		Stranded assets
		Higher cost of capital, more stringent lending requirements with new environmental standards
	Market risk	Market shifts due to actions to address biodiversity loss, asset repricing
		Loss of investment opportunities due to biodiversity criteria in investment strategies
	Underwriting risk	Increased insured losses
		Increased insurance gap
	Operational risk	Loss resulting from inadequate or failed internal processes, people and systems or from external events. (This definition includes legal risk, but excludes strategic and reputational risk for the Basel Committee on Banking Supervision (BCBS))
	Liquidity risk	Increased demand for liquidity in case of acute nature-related events
	Solvency risk	Refinancing risk due to new solvency capital requirements in case of chronic nature-related risks

Table 7. Biodiversity-related emerging threats for financial institutions. *(Adapted from NGFS, 2020; OECD, 2019; BCBS, 2011; Dasgupta, 2020, Table 17)*

Financial institutions are thus very sensitive to the exposure and vulnerability of their customers and financial products to nature-related risks (DNB, 2020).

— **Exposure of customers to physical risks may** turn into credit and market risks, through business disruption or decreasing business value, companies then struggling to generate profit and payback debts;

— **Exposure of customers to transition risks**:
- Reputation or market risks for companies having negative impacts on biodiversity can translate into a higher probability of default on loans and write-offs of investments, consequently turning into credit and market risks.
- Regulatory risks can increase operational risk for the financial party due to liability claims and reputational damages.

Across the financial industry, the exposure to biodiversity-related risks differs from one sector to another. Busch *et al.* studied four main financial sectors, representative of the available research to date (Busch, Timo *et al.*, 2019):

— **The real estate market** is the most at risk due to the rise in extreme events and hazards, increasing market and liquidity risks (drop in property prices);

— **Stock market performance** could also be hit when markets react to the materialization of biodiversity-related risks such as oil spills, pollution and diseases. Moreover, some correlations have been observed between harmful impacts on biodiversity and decreased cash flow. Some companies are legally obligated to compensate for their pollution and investors will, at some point, tend to implement environmental criteria in their portfolios;

— **The banking** system has not been studied enough yet, with only one paper examined in the study (Castellani & Cincinelli, 2015);

— **The insurance sector** will be developed in Part 3 of the present study.

As a global consequence of financial risks and as the financial industry experienced during the last crisis, the systemic aspects of biodiversity-related risks could spread across the financial industry and worsen an economic downturn, leading to a macro financial risk (DNB, 2020) (see Box 9).

BOX 9
FROM FINANCE TO BIODIVERSITY: THE "INDEBTED TO NATURE" REPORT (DNB, 2020)

In June 2020, the Dutch National Bank and the Netherlands Environmental Assessment Agency (PBL) teamed up to assess the Dutch financial sector's exposure to biodiversity-related risks and published a ground-breaking report titled "Indebted to Nature". This report is the first of its kind within the financial sector, acknowledging both dependencies and impacts of financial activities in terms of biodiversity. Thanks to a set of tools, they were able to assess the exposure of the Dutch financial sector to physical, reputational and regulatory risks.

First, through an in-depth review of Dutch financial institutions' dependencies on ecosystem services, using the ENCORE tool, the Dutch National Bank was able to produce an overview of the exposure, ranging from the different types of financial institution to the associated financial assets, the ad hoc business processes and the ecosystem services supporting them.

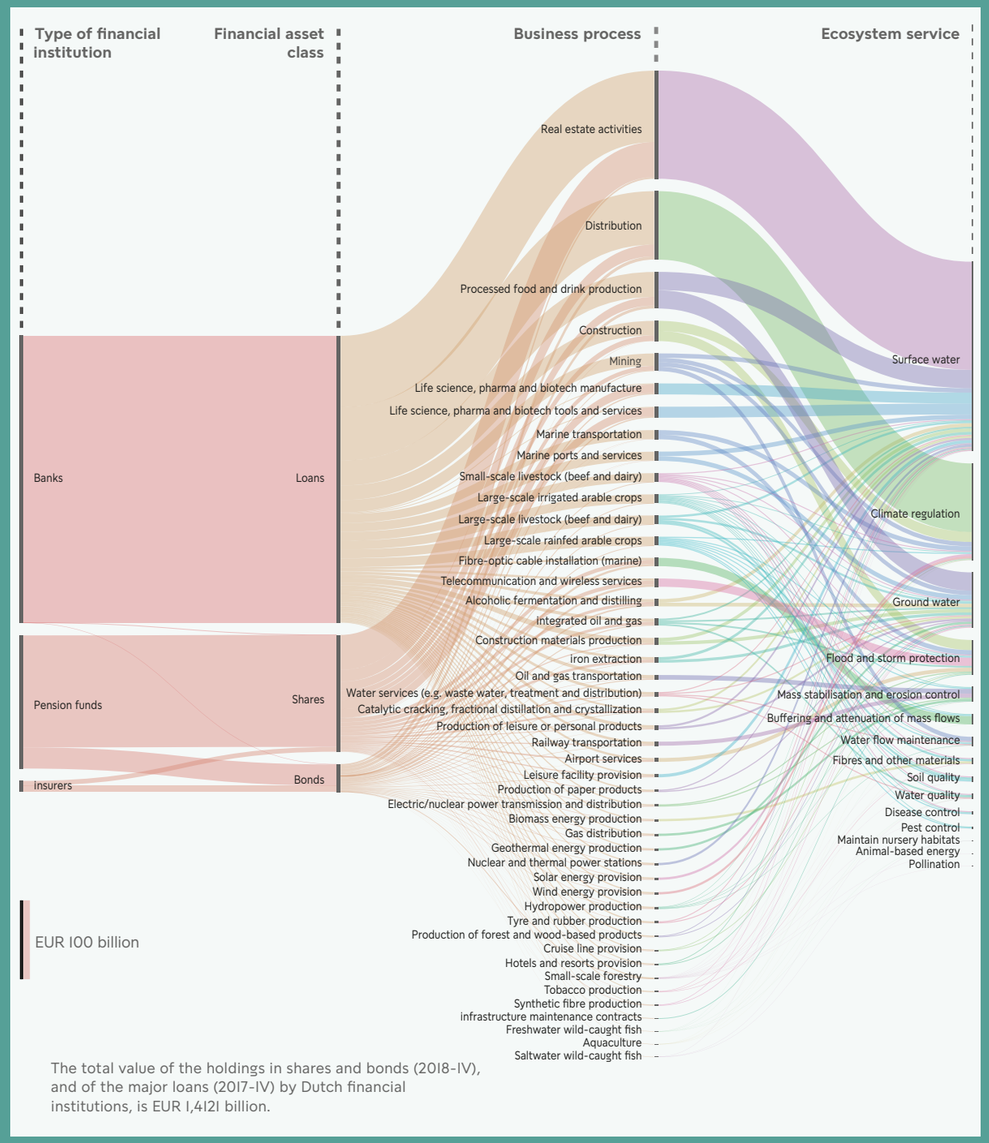


Figure 10. Financial system dependencies to ecosystem services: a value chain. *(Source: DNB, 2020)*

Then, the Dutch National Bank was able to quantitatively assess the Dutch financial sector's exposition to biodiversity.

Physical risk

"Dutch financial institutions have provided worldwide EUR 510 billion in finance to companies that are highly or very highly dependent on one or more ecosystem services. One of these ecosystem services is animal pollination. The financial sector is exposed to the amount of EUR 28 billion to products that depend on pollination." (DNB, 2020)

Reputational risk

"The Dutch financial sector has worldwide EUR 96 billion of investments in, or loans to, companies involved in environmental controversies with negative consequences for ecosystem services or biodiversity. There is additional exposure of EUR 97 billion to businesses with a heightened reputational risk resulting from products or activities related to deforestation." (DNB, 2020)

Regulatory risk

"The transition to less nitrogen-intensive business models can lead to transition risks for the EUR 81 billion in loans that the three large Dutch banks have made to sectors with nitrogen-emitting activities." (DNB, 2020)

"Financial institutions have exposure of EUR 28 billion to companies operating in areas that are protected or that might come under protection." (DNB, 2020)

V. THE ECONOMIC SYSTEM

As seen in the last three sections, all the elements that make up economic systems are exposed to biodiversity-related risks. Consequently, the global economic system is most likely exposed as well.

I. AN ECONOMIST'S APPROACH TO BIODIVERSITY BY VALUING ECOSYSTEM SERVICES

Similar to other fields of study, economists are becoming increasingly aware of the necessity to integrate nature into models and ways of thinking (see Box 10).

Since the 1990s, scientists have undertaken an **economic valuation of ecosystem services**. Thanks to the emerging methods of economic valuation of goods and services which are not priced by markets because they are public goods, individuals, businesses and governments can estimate in monetary terms how much they benefit from nature.

BOX 10
THE ECONOMICS OF BIODIVERSITY, THE LATEST ASSESSMENT (Dasgupta, 2020)

The latest report on biodiversity economics, ***The Economics of Biodiversity: The Dasgupta Review*** (Dasgupta, 2020) draws up a global analysis on the causes of the barriers to integrate biodiversity within our economic system and to face its loss.

Humans are part of biodiversity. However, Western industrialized societies have failed to understand it. Whereas the finitude of Nature is acknowledged, the development of Western societies is based on an unbounded conception of economic growth, betting on their ingenuity and institutions to eventually break free from the finitude of the Earth. The world's prime economic indicator, GDP, is a flow. It excludes the natural stock that basically sustains this flow. GDP does not account for the depreciation, i.e. the decline in quantity and quality, of the finite stock of natural assets on which the flows rely.

The demand for natural assets has been driven by demographic growth, the quantity and quality of individual demands, and our efficiency in converting Nature and in returning waste to it. Today, the extraction rate exceeds the regenerative rate of Nature, leading ecosystems to depreciate because **demand exceeds supply**. The unsustainable development of our economies drives ecosystems toward **points of no return, also called tipping points**, which if reached could entail dramatic consequences for our economies and well-being. However, this economic dynamic has trapped us in a paradox where only economic growth is able to provide the necessary funds to reduce our footprint.

Three specific features of Nature, namely *mobility, silence and invisibility*, made it difficult for markets to assess the use we make of Nature's goods and services. Markets have failed to reflect the value of Nature within our economic frameworks, leading to an overconsumption of natural resources, a distortion in prices leading to underinvestment in natural assets, focusing attention on valuable assets (produced capital) and producing increasing quantities of negative externalities. Natural goods and services often lack a market price because they are free for users. When they are traded on a market, there is a gap between the market price and the shadow price, i.e. their true value to society. Markets have failed, but institutions have also failed to frame human activities within ecological realities and to restrict market distortions in order to balance externalities. Institutions and markets have failed to value and protect Nature, the public good we all depend on.

To balance the equation, shape a sustainable form of growth and account for externalities, the report presents three necessary transitions:

— **ensure that our demand does not exceed supply**, focusing primarily on food production, shifting consumption patterns through prices and behavioral norms to align global supply chains with environmental objectives, accelerating the demographic transition, **while increasing Nature's supply** by conserving and restoring ecosystems while keeping in mind that conservation is less costly than restoring a degraded ecosystem, fostering quantity restrictions over pricing mechanisms, expanding protected areas and developing nature-based solutions;

— **transform our economic indicators** by developing an inclusive measure of wealth to integrate the well-being of current and future generations, especially through natural capital accounting;

— and **transform our institutions and systems, notably finance and education**, by ensuring fair access to information on ecosystem management, fostering supra-national institutional arrangements to limit excess demand from governments on ecosystems, encouraging the global financial institutions to shift financial flows, account for dependencies and impacts, and measure and disclose nature-related risks, enabling individuals to connect to Nature and empowering citizens to demand changes thanks to educational environmental programs.

Considering the supporting vital functions of nature, no impartial or all-inclusive price can be attributed to nature. However, a price can be calculated for the protection and degradation of nature. Since the publication of the 2007 Stern report (see Stern, 2007) on the effects of global warming on the world economy, **the cost of inaction** has become a prevalent topic.

It has been estimated that **the economic value of goods and services provided by nature exceeds the economic value of human annual production**. However, the wealth provided by biodiversity and its services is never included in calculations on our economic system. Human societies benefit freely from the goods and services of the most productive machine on Earth, Mother Nature.

Since 1997 and the publication in the scientific magazine Nature of "The value of the world's ecosystem services and natural capital" (see Costanza *et al.*, 1997), awareness of the value of nature and its services provided to human societies has been increasing. These "free" goods and services have no market value and are not included in economic valuations and indicators such as GDP. Since the beginning of the 21st century, initiatives have been undertaken to calculate an economic value for natural capital, for example the Economics of Ecosystems and Biodiversity initiative in 2010 encouraged by the CBD administration.

There are several advantages to allocating a monetary valuation to ecosystem services. It makes it possible to compare different services and human-made substitutes, it ensures better understanding of the phenomena and enhances consideration on the part of decision makers.

Some ecosystem services and goods provided by nature have already been given an economic value, especially material NCPs, such as commodities, and even some non-material NCPs such as the recreational aspects of nature, for instance by estimating nature tourism revenues. However, a majority of ecosystem services are not traded in markets and thus lack a monetary value. Economists have developed several methods to give them an accurate value. There are three main types of economic valuation:

— **revealed-preference methods**: value based on observed choices by people;

— **stated-preference methods**: value based on responses to survey questions;

— **cost-based methods**: value based on the estimation of costs to replace a given NCP.

In order to regulate the use, trade or the pressures of human activities on biodiversity, some institutions have also given an indirect monetary value, either through taxes, e.g. a carbon tax, or through market establishment. For climate change, the UNFCCC has implemented carbon credits and, for biodiversity, the CBD has created rights on genetic resources.

Assigning an economic value to ecosystem services acknowledges the value provided by biodiversity and justifies, in part, its protection. In its 2019 "Biodiversity: Finance and the economic and business case for action" report, the OECD (see OECD, 2019)

gathered a sample of economic valuations of ecosystem services, making clear the degree to which biodiversity underpins the global economy. **In 2011, the total economic value of these services was estimated to amount to USD 125-140 trillion**, i.e. over one and a half times the world's GDP that same year (Costanza *et al.*, 2014). Table 8 provides examples of the estimated annual value of certain goods and services.

Scale	Good or service	Estimated annual value
Global	Seagrass nutrient cycling	USD 1.9 trillion
Global	Annual market value of animal pollinated crops	USD 235-577 billion
Global	First sale value of fisheries and aquaculture	USD 362 billion
Global	Coral-reef tourism	USD 36 billion
Europe	Ecosystem services from Natura 2000 protected area network	EUR 223-314 billion
Canada	Value of commercial landings from marine and freshwater fisheries	CAD 3.4 billion
France	Recreational benefits of forest ecosystems	EUR 8.5 billion
Germany	Direct and indirect income from recreational fishing	EUR 6.4 billion
Italy	Habitat provision	EUR 13.5 billion
Japan	Water purification from tidal flats and marshes	JPY 674 billion
United Kingdom	Physical and mental-health benefits of the natural environment	GBP 2 billion
United States	Air purification from trees and forests (avoided morbidity and mortality) (see Box 11)	USD 6.8 billion

Table 8. Examples of economic valuation of ecosystem services. *(Adapted from: OECD, 2019)*

BOX 11
VALUING ECOSYSTEM SERVICES: THE EXAMPLE OF AIR PURIFICATION FROM TREES AND FORESTS IN THE U.S.

Air pollution (outdoor) is estimated to be responsible for the premature death of 4.2 million people globally in 2016 (WHO, 2018). The main pollutants considered when discussing air pollution are ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2) and particulate matter with a diameter of less than 10 microns.

The adverse health effects related to air pollution can include **cardiovascular disease, immune disorder, various cancers, chronic and acute respiratory diseases** and even **death** (WHO, 2018; WHO and CBD, 2015). Air pollution is mainly **caused by human activities** through the combustion of fossil fuels for industry, energy generation and transport, among others.

Trees interact in many ways with air pollution and naturally provide air-quality regulation services. Trees are directly responsible for elimination of air pollution by uptake through the leaves or directly by the plant surface. This capacity differs according to many parameters including the leaf area of the tree and the amount of air pollution (WHO and CBD, 2015). Through the reduction of air pollution, trees are directly linked to human health.

Nowak *et al.* (2014) valued the monetary impacts of the reduction of air pollution by trees on human health in the United States in 2010. By assessing the health incidence of air pollution eliminated by trees and attributing a monetary value to this service through estimates of healthcare expenses and productivity losses, they concluded that trees removed **17.4 million tons** of air pollution, representing **USD 6.8 billion** in human health.

The substantial benefits came from reducing human mortality (850 incidences), followed by acute respiratory symptoms (670 000 incidences), asthma exacerbation (430 000) and school days lost (200 000). Greater value was attributed to the elimination of air pollution by trees in urban areas. Despite the limitations of the study, the results provide a rough idea of the correlation between pollution elimination by trees and human health.

However, the economic-valuation approach has **significant limitations** when it comes to protecting vital ecosystem services (see Box 12) and it has been **widely criticized**. Currently, researchers are looking more into **ways to integrate natural capital into private and national accounts**, considering the **maintenance cost** of such capital rather than trying to assign a price to nature.

BOX 12
THE LIMITATIONS OF ATTEMPTS TO VALUE ECOSYSTEM SERVICES
(MUSÉUM NATIONAL D'HISTOIRE NATURELLE, 2020b; IPBES, 2019e)

It is possible to view biodiversity as an economic resource, however the protection of biodiversity is not profitable in economic terms. Our economy relies on the concepts of the market and property rights, however, benefits provided by ecosystems and biodiversity are diverse, global, common and span the long term. They do not align with market rules and it is highly complicated to create markets, contracts, property rights and transaction costs for these goods and services.

An alternative to this orthodox economic approach is to **oppose weak and strong sustainability**, two concepts developed by Robert Solow and John Hartwick. Proponents of weak sustainability, the conventional idea, state that financial capital can substitute natural capital, e.g. deforestation can be justified if it provides society with economic value equal to that of the forest. **Strong sustainability**, on the contrary, defends the notion that **financial capital cannot substitute natural capital**. This approach is supported by the concept of conservation and the cost of maintaining ecological functions.

These reflections on the limitations of the economic valuation of biodiversity pave the way for considering other types of values and especially intrinsic values, in an effort not to make biodiversity fit our economic system, but on the contrary to consider our society and economy as part of nature.

The preamble of the Convention on Biological Diversity, ratified by the 168 Parties, declares in its opening sentences that all Parties recognize the "*intrinsic value of biological diversity and of the ecological, genetic, social, economic, scientific, educational, cultural, recreational and aesthetic values of biological diversity and its components*" (UN CBD, 1992). All these values attributed to biodiversity make it an issue far more important than its simple economic value.

Indeed, the value of biodiversity can be seen from several perspectives going beyond the idea of biodiversity as an enabling asset or capital good. The value of biodiversity can be split into different categories (Dasgupta, 2020):

— **The intrinsic value**, the value beyond the fact that biodiversity means or brings something to us;

— **The existence value**, the value that lies in the fact that biodiversity exists, expressed by our motivation to protect biodiversity;

— **The use value**, the value that lies in the making of goods and services on which we rely;

— **The amenity value**, the value of biodiversity as an enjoyment;

— The value of biodiversity as a **direct contribution to human health**.

In France, in 2013, the Senate approved the recognition of the concept of "**ecological prejudice**" in the Civil Code of law, accepting the intrinsic value of nature. This concept was incorporated in the French Law on Biodiversity voted in 2016. It had been used for the first time in 2012 against the oil company Total regarding the Erika oil spill of 1999.

In several cases, Nature has been considered a legal entity. In 2008, the Ecuadorian government deemed Mother Earth (Pachamama) a legal entity and in India, the Ganges has the same legal rights as any citizen (Gellers, 2020).

2. THE GLOBAL ECONOMIC SYSTEM AT RISK

According to the World Economic Forum's 2020 Global Risk Landscape report, for the first time since 2011, "Biodiversity loss" reappears in the top five Global Risks in terms of likelihood and impact, respectively in the fourth and third positions (WEF, 2020a). It should be mentioned that all top five global **risks in terms of likelihood are environmental risks**.

As seen in the previous three parts, our economy is embedded in nature. Risks are increasing on all microeconomic levels and consequently on the macroeconomic level as well. By threatening human health and security, businesses' value creation and financial institutions' stability, risks related to biodiversity loss put the global economy at risk.

Biodiversity loss is a **potential source of business disruption and financial instability**. At the macroeconomic level, biodiversity loss could also **cause wide-ranging changes in the way the current economy is organized** through (NGFS, 2020):

— Capital depreciation;
— Shifts in investment flows;
— Productivity changes depending on the geographic location;
— Shifts in prices (from structural changes and supply shocks);
— Labor-market frictions;
— Socio-economic changes with rising inequalities and poverty, changing consumption patterns and demand, increasing migrations and conflicts;
— International trade changes with new power balances, depending on the availability and disruption of NCPs in some places, and changes in trade agreements, e.g. France's opposition to the E.U.-Mercosur trade agreements over deforestation concerns (Actu Environnement, 2019).

All these factors could have global impacts on the structural organization of the financial system, companies and individuals.

Going beyond valuations of nature, scientists today are trying to integrate nature in all its aspects in decision-making (on the public and private levels). Modelling, as seen in Part I.III. is increasingly used to try to account for the complexity of the challenge and build comprehensive scenarios (see Box 13).

BOX 13
MODELLING THE GLOBAL ECONOMIC IMPACT OF LOSS OF BIODIVERSITY AND ECOSYSTEM SERVICES, AN ILLUSTRATION WITH THE "GLOBAL FUTURES" PROJECT

As part of the research perspectives mentioned above, initiatives aiming at modelling impacts of biodiversity loss on our society are flourishing. The WWF, GTAP and the Natural Capital Project have led a co-initiative called **Global Futures** focusing on economic scenarios (see WWF, 2020b).

Tools: linking two existing models, the *Integrated Valuation of Ecosystem Services and Tradeoffs* (InVEST) model from the Natural Capital Project and the *Global Trade Analysis Project* (GTAP) Computable General Equilibrium (CGE) model from Purdue University.

Objective: to assess the potential global, national and sectoral economic impacts of environmental change, under a range of alternative scenarios, using metrics that resonate with political-economy audiences (e.g. how it will affect GDP, trade, production and prices).

Scenarios, based on the IPBES Shared Socioeconomic Pathways (SSP)

1. **Business-as-Usual.** *"Continued increase fossil-fuel usage to support energy intensive lifestyles. High levels of market competition and integration of global markets through trade. Global population peaks in the middle of the 21st century and then declines. Land use change is widespread and untargeted and climate change is an extreme problem."*

2. **Sustainable Pathway.** *"Widespread shift to more sustainable practices at the national level within global environmental boundaries. Common-good resources are effectively managed. Widespread recognition of the costs of climate change lead to effective global mitigation. Land-use change (e.g. from development and agricultural expansion) is more effectively managed, but it is not targeted to specific locations to enhance ecosystem services or biodiversity."*

3. **Global Conservation.** *"In addition to international coordination on climate change and land use (as per the SP scenario), society also implements more transformational policies to protect nature by targeting land-use change to avoid areas that are high in biodiversity and provide important benefits to people through ecosystem services."*

Ecosystem services model included (based on the sufficient availability of data and academic literature):

1. Pollination
2. Coastal protection
3. Water yield
4. Forestry production
5. Marine fisheries
6. Carbon storage

Results

Ecosystem service	Business-as-Usual	Sustainable Pathway	Global Conservation
Pollination	-0.021	0.016	0.058
Coastal protection	-0.457	-0.188	-0.188
Water yield	-0.026	-0.024	-0.019
Forestry productivity	-0.011	0.005	0.012
Fish productivity	0.024	0.024	0.080
Carbon storage	-0.179	-0.014	0.072
All ecosystem services	***-0.670***	***-0.180***	***0.016***

Table 9. Annual percentage change in global GDP due to changes in all ecosystem services under the scenarios. *(Source: WWF, 2020b)*

Ecosystem service	Business-as-Usual	Sustainable Pathway	Global Conservation
Pollination	-15,310	11,789	41,727
Coastal protection	-326,854	-134,169	-134,169
Water yield	-18,617	-16,995	-13,565
Forestry productivity	-7,519	3,856	8,418
Fish productivity	17,083	17,079	57,337
Carbon storage	-127,679	-10,120	51,570
All ecosystem services	***-478,895***	***-128,560***	***11,319***

Table 10. Annual change in GDP (USD million, 2011 baseline) due to changes in all ecosystem services under the three scenarios. *(Source: WWF, 2020b)*

	Business-as-Usual	Sustainable Pathway	Global Conservation
All ecosystem services	***-9,866,000***	***-2,646,361***	***232,923***

Table 11. Cumulative change in GDP by 2050 (USD million, 2011 baseline) due to changes in all ecosystem services under the three scenarios. *(Source: WWF, 2020b)*

Key takeaways

— The **only option** to avoid an economic downturn due to biodiversity loss is to **embrace a global conservation scenario**. Otherwise, under a business-as-usual scenario, the world economy will face an annual decrease in global GDP of 0.67 percentage points, i.e. USD 479 billion per year (base year 2011).

N.B. These estimates do not integrate the potential occurrence of major disruptions due to biodiversity loss and their catastrophic consequences for the economy (e.g. pandemics).

— Uneven distribution of economic impacts across the globe:
  • Least developed countries would be hit the hardest due to changes in prices;
  • Countries with high exposure due to large coastal areas such as the United States, the United Kingdom and Australia will have large losses under the three scenarios.

— The global conservation scenario would favor social equity by lowering the impact for low-income countries and would decrease the economic impact of coastal vulnerability combined with climate change induced sea-level rise, thanks to nature-based solutions.

— Sustainable patterns of production and land use, and economic and financial reforms to encourage nature-based decision-making are necessary to foster positive trends for the future.

PART II.
KEY TAKE-AWAYS

Biodiversity loss is certain and scientifically established. The consequences and their magnitude however remain mostly unknown. This dynamic generates risks for human societies that they must understand to ensure their survival and future well-being.

Biodiversity-related risks can be considered a separate risk category, labelled "**green swans**". They share similar features with "black swans", namely **deep uncertainty, non-linear propagation and significant negative externalities**. However, they differ with their **high degree of certitude of occurrence**, a more **significant range of impacts**, a **higher degree of complexity and potential irreversibility**.

The materialization of biodiversity-related risks depends on the **exposure** as well as the **vulnerability** of individuals and organizations. The intricacies of biodiversity and human activities, the global interdependencies of supply chains, the cascading and feedback effects of drivers of environmental change, the dissemination of dependencies and impacts over time and space, and the interference of political, social and economic factors all **add a layer of uncertainty concerning the degree of risk materialization**.

Individuals and organizations are exposed to nature-related risks through **physical risks**, which are the material consequences of the changes in biodiversity and in the quantity and the quality of goods and services provided by nature. They also are exposed through **transition risks**, which arise because human societies attempt to mitigate or adapt to these changes in biodiversity by transitioning to more sustainable systems.

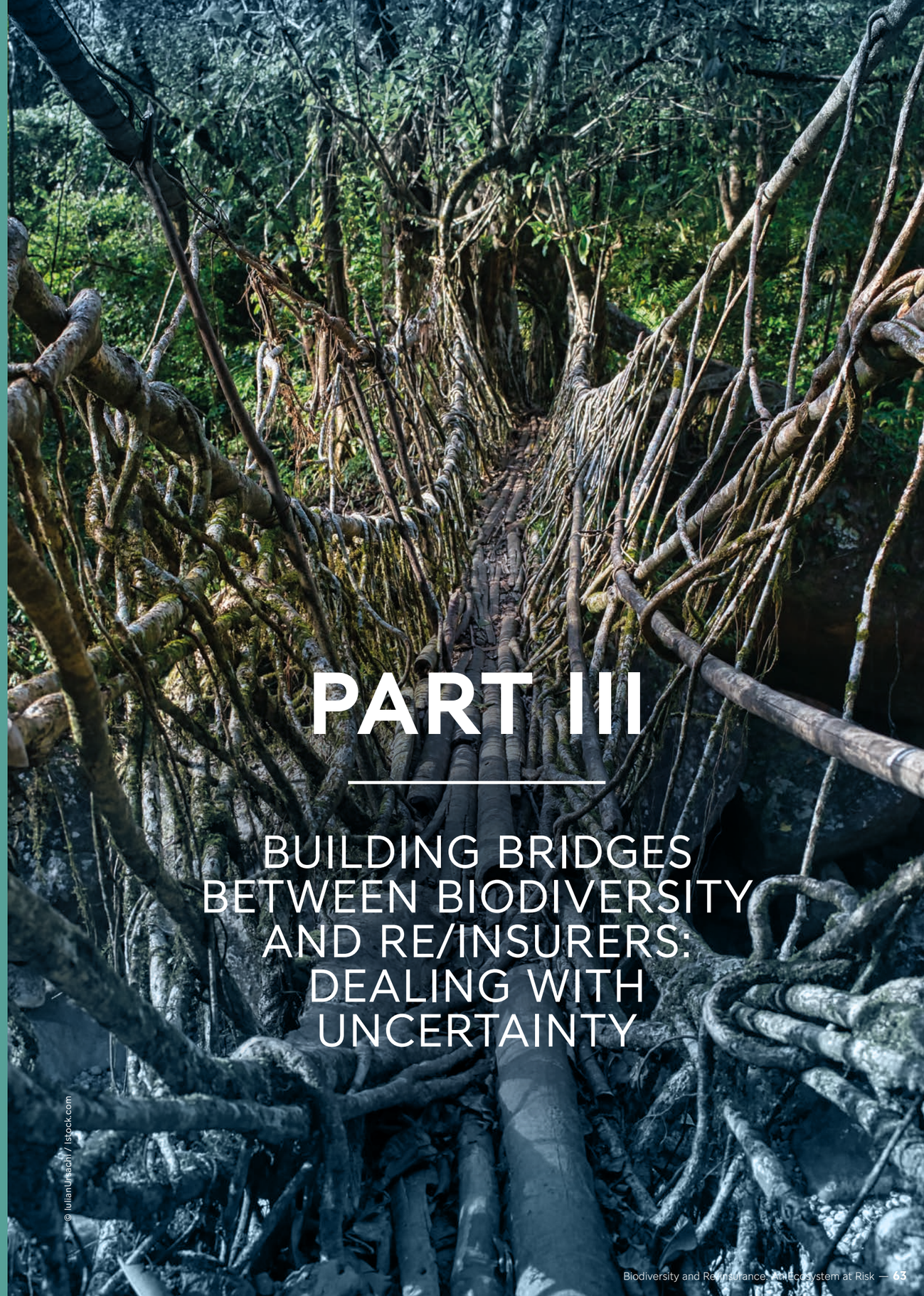
Individuals are threatened by biodiversity loss directly, through **health issues**, a **lack of access to resources** or **vulnerability to extreme events**, as well as indirectly, through effects on their social and economic situation as well as on the geopolitical context, with forced migrations or conflicts. Individuals face **unequal exposure** to biodiversity-related threats depending on their location and socio-economic class, but also gender.

Businesses face **physical risks** due to exposure to the loss of biodiversity and ecosystem services, leading to operational disruptions or damage to infrastructure. Businesses are also prone to **transition risks** if they fail to adapt to a changing environmental situation and economy, with for instance reputational or regulatory risks. Exposure depends on the sub-industry and production process. Risk materialization can be transmitted along value chains and across whole sectors.

Financial institutions, though not directly engaged with biodiversity in their business operations and hence only slightly exposed to physical risks, face biodiversity loss that could materialize into **financial risks**. Similar to any business, they face transition risks. However, they face a higher level of financial risks because the risks confronting their counterparties are also transmitted to them (via investments, loans, underwriting and advice).

On the **macroeconomic level**, biodiversity loss threatens the **stability of the economic system** with potential impacts on international trade, regulations, interest rates and geopolitical stakes, with feedback and wide-ranging effects on the financial system, the corporate level and individuals.

To foster a global approach to conservation, it is essential to understand the **limitations of economic valuation of biodiversity, i.e. the *use* value, and to recognize and include the other values of biodiversity, namely the *intrinsic* value, sacred value and *amenity* value, among others**, in decision-making processes.



PART III

BUILDING BRIDGES BETWEEN BIODIVERSITY AND RE/INSURERS: DEALING WITH UNCERTAINTY

Developed countries rely on an insurance system to cover micro and macro risks and build resilient societies. The insurance industry has been able to fulfil this role thanks to its unique knowledge and expertise in risk assessment and management. At the dawn of an unprecedented environmental crisis, how will insurers cope with new uncertainties?

The re/insurance industry has a special position within the private sector which allows it to play a crucial role in addressing biodiversity loss. Re/insurance companies stand at the heart of the economic system, at the cross-roads between individuals, companies from all economic sectors, but also between regulators and financial institutions. Their economic role as risk managers, ensuring stability and crisis recovery through risk transfer, as well as their significant financial influence through their investment portfolio give them singular leverage. Last but not least, their core expertise in assessing, modelling, quantifying and pricing risks provides them with a unique perspective on the systemic aspects of biodiversity loss and its potential cascading effects on individuals, companies, financial institutions and economic systems.

The re/insurance industry is already facing the challenge of climate change. Re/insurers are developing resilience to extreme weather events and integrating climate data into underwriting and investing practices. Biodiversity loss is an equally critical issue, however it is not yet as high up on the agenda. In the last two years, in line with the development of the Post-2020 Framework of the CBD at the COP 15, there has been growing interest and concern on the part of financial institutions for biodiversity. Recently, several reports addressing the biodiversity challenge for the re/insurance industry[7] have been published, with calls for actions. Building on the understanding of climate-change issues, re/insurers can broaden the scope of these initiatives to develop a wider approach in their risk and impact analyses and to seize opportunities (see Box 14).

This section looks at **how the re/insurance industry can integrate biodiversity loss in its planning**, first by analyzing how the industry interacts with biodiversity, what is at stake for their business, how re/insurers take part in the loss dynamic and what role they can play to reverse the current trends and find opportunities in this new reality.

BOX 14
INSURANCE AND CLIMATE CHANGE: DRAWING A PARALLEL FOR BIODIVERSITY

In the re/insurance industry, climate change has widely been acknowledged as a significant risk with, among others, flood damages likely to cost 0.3 to 5.0% of global GDP in 2100 (CRO Forum, 2019). Re/insurance companies now issue annual climate reports and modelling agencies are integrating forward-looking climate scenarios in their models to adjust premiums to a new level of uncertainty.

Re/insurance companies are assessing the carbon footprint of their investment portfolio and taking action, such as phasing out coal. They may also adopt a new role of "*providing society with data that is global and structured in historical series, to contribute to the understanding of natural perils*" (SCOR, 2020a).

Biodiversity loss has been scientifically proven to be an aggravating factor of climate change and that in itself should be enough to demonstrate that re/insurers have an interest in addressing this issue. However, biodiversity loss and ecosystem disruptions could lead to **new and more intense acute and chronic risks as well as financial volatility for financial assets**. Climate change and biodiversity are intricately intertwined and their consequences on human societies and the re/insurance industry will be as well.

7. Examples are Biodiversity at risk, AXA Research Fund, 2019; Into the Wild: Integrating nature into investment strategies, WWF France, AXA, 2019; Protecting our world heritage, insuring a sustainable future, UN Environment's Principles for Sustainable Insurance Initiative and WWF, 2019; Underwriting environmental, social and governance risks in the non-life insurance business, UNEP Finance Initiative, Principles for Sustainable Insurance, 2019; Measuring And Managing Environmental Exposure, Allianz Global Corporate & Specialty, 2018.

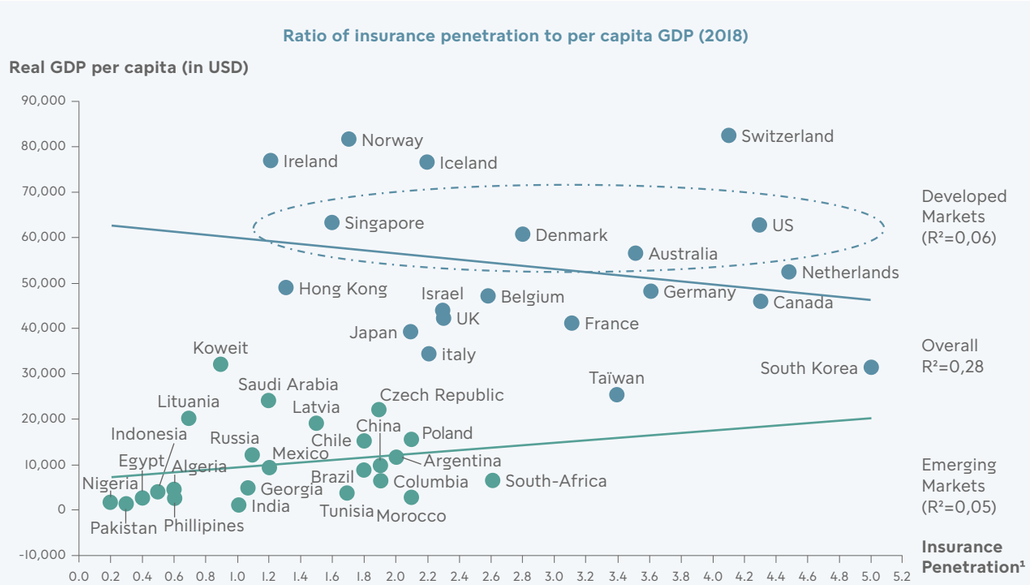
I. BIODIVERSITY, THE BACKBONE OF THE RE/INSURANCE BUSINESS

Re/insurance companies' core business consists in bearing risks for other entities in exchange for a premium. What makes re/insurers better than policyholders at managing risk that they are not even responsible for? Thanks to their risk-analysis expertise and actuarial-modelling capacities, re/insurers are able to estimate the probability of risk occurrence, i.e. the potential losses, and thus to price premiums, in order to assign risks to policyholders and minimize negative financial impacts for individuals and companies. Therefore, any new threat to individuals and companies is a concern for re/insurers and biodiversity should be one of them.

This section looks at how the re/insurance industry is organized and how biodiversity interacts with business processes.

1. THE BASICS OF THE RE/INSURANCE BUSINESS

The re/insurance business has a unique position within the economy and plays a specific role in the development of human societies. The penetration rate of insurance coverage is correlated with GDP per capita, even though disparities exist depending on legal frameworks, risk exposure and economic development (see Figure II).



Source: Sigma explorer
1. insurance penetration= Direct Non-life premiums / GDP

Figure II. Economic development and insurance penetration. *(Source: Swiss Re Institute, 2019; Swiss Re Institute, 2020)*

Similar to the work in the field of climate change, re/insurance has a major role to play in terms of mitigation and adaptation to environmental changes, according to the CRO Forum (CRO Forum, 2019). In addition to its primary objective of creating value through its underwriting and investing activities, the re/insurance industry can also theoretically create economic and social value for individuals, companies and governments especially by:

— protecting companies from physical impacts;
— providing risk-management advice;
— supporting insurability, sustaining the economy;
— providing long-term investment;
— investing in hazard models and developing emerging-risk expertise, to minimize future insurability gaps.

Re/insurance companies' revenue generation is divided into two separate businesses, namely underwriting and investing (see Figure I2).

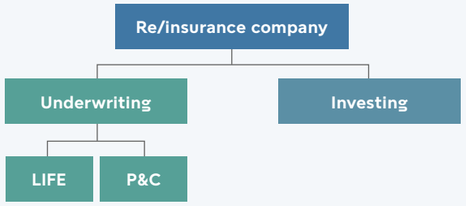


Figure I2. A re/insurance company's general business framework. *(Source: Author)*

A. UNDERWRITING

Re/insurance companies underwrite risks. The re/insurer receives a remuneration (premium) from the policyholder (the customer) for his willingness to bear the risk of a potential loss and provides a financial compensation in case the given risk materializes. Re/insurance coverage is based on a contract with a **fixed premium** beforehand. To be **insurable**, a risk needs to be future, unexpected, unintended and calculable.

Before underwriting a risk, the re/insurer needs to assess it to understand the probability of its occurrence and estimate the potential losses. The objective is to accurately price the premium required from the policyholder in exchange for the risk-taking services. This is a distinctive feature of the re/insurance industry, i.e. a **reverse production cycle**, meaning the pricing and the selling of the product take place before the re/insurer and the policyholder know exactly what the claim and the payout will be.

In order to minimize the concentration of claims payouts, re/insurers build their portfolio based on two complementary strategies, **risk diversification**, i.e. the spreading of risk across different areas and markets, and **risk pooling**, the spreading a given risk over a large number of policyholders. In the end, **the re/insurance business is based on accurate risk assessment and risk pricing**.

Simply stated, re/insurers need to cover three types of costs, claims payouts, operating expenses and shareholder remuneration (i.e. the cost of capital).

Concerning the underwriting activity per se (i.e. discounting all investing activities), the financial equilibrium depends on sufficient collected premiums to cover the costs of that specific activity (i.e. claims payouts and operating expenses). The equilibrium of the underwriting business is intrinsically linked to the capacity of the re/insurer to manage the uncertainty of risk, in order to price the premiums accurately and not to resort to extra capital (which comes at a cost).

One of the Key Performance Indicators (KPI) for the short-term underwriting business is the combined ratio:

$$Combined\ ratio = \frac{(Claims\ payouts + Operating\ Expenses)}{(Collected\ premiums)}$$

— if the combined ratio is superior to 1, then the collected premiums are less than payouts and expenses;

— if the combined ratio is inferior to 1, then the collected premiums exceed payouts and expenses.

N.B. The combined ratio includes only the relationship between premiums and payouts, excluding the capacity to cover claims with additional financial revenues and capital, and shareholder remuneration (which will be explained further in the next sections on Investing, Reinsurance and Solvency).

There are two main types of insurance policies, **Property & Casualty** and **Life & Health insurance**.

— **Property and Casualty** insurance, which is usually short term, includes four main types of risks, namely physical damages to property, operating losses, trade credit, and liabilities. Pricing methods are mainly based on historical risk patterns and underwriting experience.

— **Life and Health** insurance includes life insurance as financial-savings products (excluded from this study) and protection products, which cover risks such as physical injuries, disabilities, long-term care, medical expenses, critical illnesses and death. For the protection business, pricing methods rely on establishing accurate morbidity and mortality rates, considering the current situation and its evolution given that most contracts are long-term by nature.

B. INVESTING

The collected premiums from the underwriting business fuel the investing business of the re/insurer. Collected premiums are transferred to the investing activities of the re/insurance company to generate financial returns.

Re/insurance companies invest in a broad range of assets to diversify their investments and to optimize their return on risk-adjusted capital.

Examples of financial assets in which re/insurers invest are:

— Cash;
— Fixed income assets, mainly government and corporate bonds;
— Equity;
— Specific products:
  • Insurance-linked securities
  • Infrastructure debt or equity;
  • Real-estate debt or equity;
  • Private equity.

One key performance indicator for the investing business is the financial return of the assets.

C. REINSURANCE

A reinsurer's business operates in essentially the same manner as an insurer's, except that the policyholders of reinsurance companies are insurance companies. Reinsurers help insurers manage their risks by covering a share of their risks through reinsurance contracts.

Reinsurers also rely on an active investing activity. Some reinsurers also have specialty industry insurance for coverage of large industrial risks and/or a retail insurance coverage arm. The specificity of reinsurers compared to insurers is, among other aspects, the information they deal with when taking the decision to underwrite a certain portfolio. Reinsurers underwrite portfolios of risks coming from insurers, therefore the reinsurance underwriter typically does not have fully detailed information on each risk, but historical data on the risk profile of the portfolio via exposure databases. In order to provide capacity to insurers, reinsurers must be better diversified in terms of sectors and geography, which is a key aspect of their business model.

In the environmental field, reinsurers can play a unique role in that they take a global perspective on risk dynamics. They have acquired extensive knowledge on climate-change risks.

D. SOLVENCY

To ensure their solvency, re/insurers must hold a certain amount of capital, based on the Solvency Capital Requirement (SCR) which depends on the risks taken, in both the underwriting and investment businesses.

The SCR is regulated. For example, in the European Union, the Solvency II Directive applies. It is designed to ensure re/insurers will have the capacity to **fulfil their obligations even if premiums and additional financial revenue become insufficient to cover claims**, i.e. in case losses are significantly higher than expected. If an exceptional event such as a pandemic occurs, re/insurers must hold sufficient capital to face unexpectedly high claims.

This capital obviously comes at a cost for the re/insurer. And the higher the required SCR for existing activities, the less the re/insurer is able to accept new underwriting or risky investment positions with the same amount of capital. Thus, should the general uncertainty grow in the coming years, the SCR will increase accordingly, making the re/insurance business more capital intensive, which should be particularly true for long-term line of business.

2. MAPPING INTERACTIONS BETWEEN BIODIVERSITY AND RE/INSURANCE

In 2017, during the One Planet Summit in Paris, the CEO of AXA declared that a world 4°C warmer would not be insurable (AXA, 2017). Even though the equivalent of CO_2 levels and climate-change scenarios do not exist for biodiversity loss, this statement acknowledges the existence of underlying interactions between environmental dynamics and the insurance industry.

This section looks at the **key steps where re/insurance meets biodiversity** in the underwriting and investing processes.

Because re/insurance is a service industry, it can be difficult to understand how these companies and their activities are correlated to environmental issues. **There is always at least one intermediary between the re/insurer and biodiversity**. This is why this section will attempt to shed light on the underlying interactions that materialize through flows of information, financing or risk assessment, among others.

A. UNDERWRITING

From the rising risks depicted in Part 2 and the re/insurance business model explained in the previous section, it is possible to draw interactions.

Even though the re/insurer has no direct interaction with biodiversity and the potential consequences of its loss, **the customer is directly exposed, which could result in impacts for the re/insurance company**. This indirect interaction with biodiversity dynamics can be represented in the operations of the insurance company, as pictured in Figure I3.

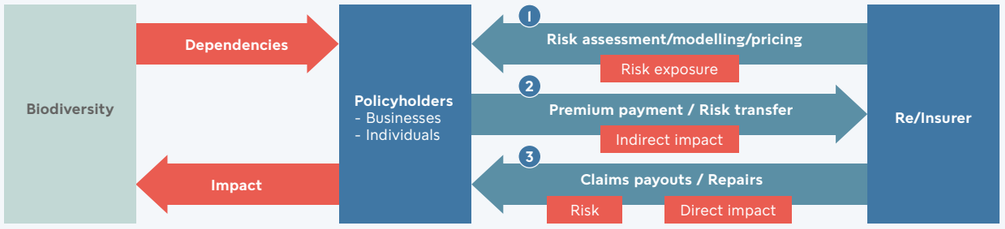


Figure I3. A simplified framework of biodiversity underwriting by re/insurers. *(Source: Author)*

N.B. For the sake of simplicity, the diagram only shows a direct flow between biodiversity and the policyholder. However, depending on the activity of the policyholder, there can be several intermediaries between the policyholder and biodiversity (see Part I.II. and Part 2).

Figure I3 shows that interactions between biodiversity and re/insurers are divided into two major dynamics. The first dynamic is between biodiversity and the policyholder, the second between the policyholder and the re/insurer. The first dynamic is described in Part 2. Individuals, Businesses, Financial Institutions of this report.

As shown in Figure I3, there are three main flows for the underwriting business, 1) risk assessment, modelling and pricing; 2) premium collection and risk transfer; and 3) claims payouts and repairs. Each of these flows exposes the re/insurer to risks linked to biodiversity or to impacts. Of course, these interactions with biodiversity are indirect and always rely on the policyholder's interaction with biodiversity in the first place.

1. **Risk assessment, modelling and pricing**. This step is key to understanding the nature of the risk arising from the exposure of the policyholder. The insurance company should be able to understand how biodiversity loss can be an aggravating source of risk and the implications for the intensity, frequency and concentration of those risks. Models are used to assess the probability of occurrence of risks covered by the insurance in order to grasp the insurers' potential exposure. Therefore, including biodiversity-loss inputs and the potential consequences for the risk profiles of individuals and companies enables re/insurers to better understand the risk exposure and impact of the policyholder. (This will be further developed in section II of this Part 3).

2. **Premium collection and risk transfer**. At this stage of the process, the insurance contract becomes effective and the policyholder transfers parts of its risks to the re/insurance company. In doing so, the re/insurer gives a "license to operate" to the policyholder, underpinning the policyholder's activity and its impact on biodiversity. (This will be further developed in section III of this Part 3).

3. **Claims payouts and repairs**. Through insurance claims payouts, the re/insurer may experience exposure to biodiversity-related damages or losses from the policyholder. On the other hand, through their commitment to repair, depending on the agreement, re/insurers can have a direct beneficial or harmful impact on biodiversity: building back with better environmental standards and less impacts on biodiversity.

As noted above, the interactions between biodiversity and re/insurers (in the underwriting business) almost always occur through the customer, the policyholder. The policyholder faces different types of risks, as seen in Part 2 of this report. Therefore, the nature of these interactions depends on the intermediary, on the policyholder, and differs between the P&C and Life branches.

N.B. The following analysis expands on the risks presented in Part 2 of this report.

For Property & Casualty (P&C) insurance (see Part 2.II. on Individuals and Part 2.III. on Businesses):

— Business operations can be affected by physical risks, especially commodity risks, supply-chain risk and vulnerability risk, as well as transition risks, for instance through modifications in regulations;

— Physical damages to goods can be increased by vulnerability risks;

— Liabilities can increase due to regulatory risks.

For Life insurance (see Part 2.II. on Individuals and more particularly the Health examples):

— Disabilities, critical illnesses and premature death can be affected by increasing health issues due to biodiversity loss, lack of access to resources, vulnerability to extreme events and living areas becoming uninhabitable. They can also be accentuated by indirect risks such as rising poverty or geopolitical tensions;

— Physical injuries can be increased because of vulnerability to extreme events.

B. INVESTING

Re/insurers are among the biggest institutional investors, investing across a wide range of financial products including almost all economic activities. Therefore, re/insurers' investment business is indirectly linked to biodiversity loss through the exposure to biodiversity of the companies in which they are invested. The risk exposure of financial institutions to biodiversity loss has been introduced in Part 2.IV. Financial Institutions and Part 2.V. The economic system.

Thus, biodiversity can be represented in the investing processes of re/insurers as pictured in Figure I4:

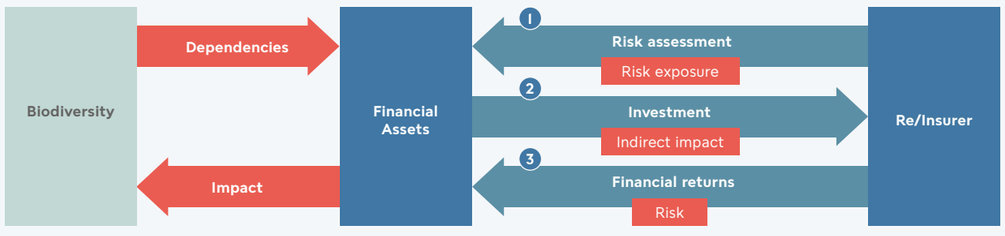


Figure I4. A simplified investing framework showing the interactions between biodiversity and re/insurers. *(Source: Author)*

As in Figure I3, the interaction of the investing business with biodiversity is divided into two main dynamics. Figure I4 shows a simplified framework with only one intermediary, i.e. financial assets. Financial assets represent the companies or projects behind these financial assets which are supported through investments.

There are three main flows included in the investing activity, risk assessment, investment and financial returns. By investing, the investor puts itself in a risk exposure position and/or in a position to have an impact on biodiversity. As for the underwriting activities, the risk and impact position of the investor depends on the interaction with biodiversity of the policyholders and investees.

1. **Risk assessment**. The investor analyses the financial product to understand its risk exposure and the potential financial return. This step is the opportunity to understand the entity's interaction with biodiversity and its possible exposure and vulnerability to biodiversity loss, which could impact the financial valuation. The exposure of the financial assets could undermine the expected financial return for the re/insurer. (This will be further developed in section II. of this Part 3.)

2. **Investment**. At this point, the investor has committed and invested his funds in the financial asset. In doing so, depending on the financial asset, the investor underpins the development of the entity behind the financial asset. Therefore, the investor indirectly supports the activity and its related impacts on biodiversity. The investor's investment choices could result in indirect responsibility for the impact of the underlying companies. (This will be further developed in section III. of this Part 3.)

3. **Financial returns**. Investors could experience biodiversity-related risk exposure and materialization if the financial returns are lower than expected. (This will be further developed in section II. of this Part 3.)

To sum-up, for both the underwriting and the investing businesses, re/insurers have within existing processes the capability to include biodiversity, similar to what is already done for climate risk. Integrating biodiversity criteria into risk-assessment analyses can raise awareness and reduce exposure to biodiversity-related risks. Assessing investee and policyholder interactions with biodiversity raises awareness about indirect impacts on biodiversity through insurance contracts or financial support. Therefore, **even though the interactions between biodiversity and the re/insurance industry are far from explicit and fully understood, they indicate in the different steps of the insurance business processes** where biodiversity could be integrated and where re/insurers can activate levers to shape and influence human activities and their impact on biodiversity.

II. RISKS: HOW BIODIVERSITY LOSS EXPOSES RE/INSURERS

Important note. *The re/insurance industry has developed expertise in understanding natural catastrophes and accrued experience in integrating climate-change dynamics. In the academic and business literature, the consequences of natural catastrophes induced by climate change have been qualified and are starting to be quantified and integrated into models. However, even though biodiversity loss has become a major global risk, the topic has not yet been taken to the qualification or to the quantification stage.*

It should be noted that there is a lack of scientific research on building a strong business analysis integrating biodiversity loss in different industries, because of a lack of modelling capacity and of inputs as discussed in Part I.III. Therefore, in this part we will limit ourselves to a conceptual analysis and focus on exploring the potential consequences of risk transmission between biodiversity loss and financial losses for the re/insurance industry. Furthermore, existing analysis for climate change will be considered to understand how environmental dynamics can affect the industry.

Similar to the consequences of climate change, biodiversity and ecosystem loss is a "leap in the unknown". Our societies are entering a new reality where the ecosystem equilibrium is buffeted and the dynamics of the services provided to human societies by nature could be disrupted. Disruption could cause an increase in terms of risk frequency, intensity and concentration. Scientists are also warning about the non-linear character of biodiversity loss and its consequences, as explained by the concept of planetary boundaries. Crossing a planetary boundary would trigger non-linear environmental changes worldwide (Rockström et al. *2009) (see Part 2.I.).*

This section looks at the **exposure of the re/insurance business to the emerging risks induced by biodiversity loss and ecosystem services disruptions**.

I. INTRODUCTION TO RISKS

How to define a "***risk***" for a re/insurance company? In the present report, we have defined it as **a threat which could generate financial losses for the re/insurer if it materializes**. As noted in Part 2.III., biodiversity-related risks for companies can be split into physical and transition risks. As seen in Part 3.I., there is virtually no direct interaction between biodiversity and a re/insurance company, nevertheless, both underwriting and investing activities deal with customers, policyholders and investees, that are themselves exposed to biodiversity risks (see Part 2.II. and Part 2.III.).

Physical biodiversity risks for re/insurers: risks arising from the consequences of the materialization of direct physical risks for the insurers. Given that re/insurance activities are services, the only physical exposure for re/insurers applies to their infrastructure.

▶ *Example:* trees play a crucial role in soil absorption and reduce the runoff of excess rainfall, therefore, deforestation increases the risks of flooding of the insurance company's offices.

Transmitted biodiversity risks for re/insurers: risks arising from the consequences of the materialization of physical and transition risks for policyholders or investees. Given that re/insurers engage with almost all economic sectors, the exposure of policyholders or investees to biodiversity-related risks is broad.

▶ *Examples:* unexpected higher claims due to business interruption or profitability decrease because of a lack of raw materials, e.g. argan trees for cosmetics, or a depleted ecosystem resulting in reduced soil productivity for agriculture; unexpectedly high property claims due to the consequences of a hurricane, following the loss of coastal protection formerly provided by mangroves or coral reefs, and the decrease of climate-regulation services.

Transition biodiversity risks for re/insurers: risks arising from the consequences of inadaptation of the re/insurance company to the transition to a low-impact economy.

▶ *Example:* degraded reputation due to investing in an environmentally controversial company.

To illustrate biodiversity-related risks for re/insurers, the following conceptual framework (Figure I5) was developed with three distinct risk categories.

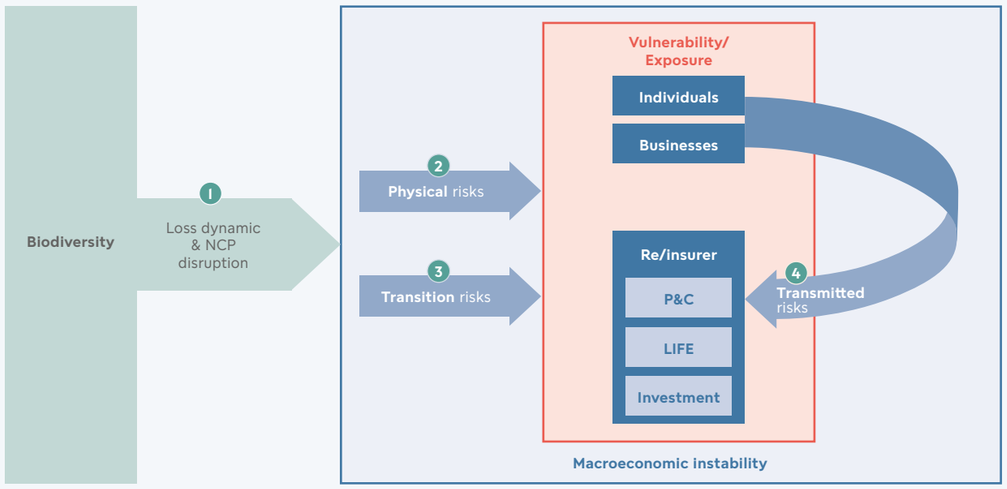


Figure I5. A framework for risk transmission. *(Source: Author)*

Part I of this report was focused on the Loss dynamic & NCP disruption (Flow I in Figure I5). Part 2 presented "direct" physical and transition risks (Flows 2 and 3) to individuals and businesses.

Underwriting and investing activities are exposed to biodiversity-loss risks despite having close to zero direct interaction with biodiversity. Re/insurers suffer from very few direct physical risks (e.g. flooding of their buildings) (Flow 2 in Figure I5), which are consequently excluded from this study[8]. However, they are exposed to transition risks (similar to "any other business") (Flow 3) and to transmitted risks (which are specific to their business) (Flow 4). **The present part will focus first on the transmitted risks (Flow 4), then will deal with transition risks (Flow 3)**.

Before entering into the complex mechanisms of underwriting and investing activities, three preliminary risks related to biodiversity loss should be mentioned:

— the most critical risk is **being unaware** of the biodiversity-loss dynamics and its potential consequences;

— a second risk is **waiting to be fully knowledgeable** about the interactions and underlying mechanisms of transmission risk before taking it into account;

— and a third risk is **waiting for this risk to become material**, meaning waiting for the actual disruption of ecosystems, before acting.

2. TRANSMITTED RISKS

What is the underlying connection between insurance and biodiversity? Compared to climate change and its consequences, for which public awareness is growing, the biodiversity-loss challenge is not as well understood and widespread within the public and corporate spheres. The scientific community is continuously progressing in its attempt to understand the complexity of ecological interactions. Modelling exercises are being developed, and understanding patterns of risk dissemination is also part of a growing body of work, in terms of the intensity, frequency and geographical concentration.

That being said, **what we know today is more than sufficient for the scientific community to warn about the certainty of rising risks for our societies**, amplified by **the uncertainty about how it will happen**. Therefore, the mechanism through which biodiversity-related risks will spread into the complex underwriting and investing processes of the insurance business is uncertain. What is certain is that, given the interdependencies between biodiversity and our societies and economies and the interconnection between the insurance system and all economic and financial sectors, **the re/insurance industry will be affected**.

Even though the risk-transmission mechanism between the disruption of ecological interactions and the highly sophisticated underwriting and investing processes is complex, it is possible to point out a few significant dynamics prevalent in the re/insurance industry and due to biodiversity loss.

Assessing the risk profile of policyholders is the cornerstone of the insurance business (as seen in Part 3.I.). Emerging risks can alter the risk profile of individuals' health, companies' operations and the stability of financial institutions (as seen in Part 2). Consequently, the materialization of biodiversity-related risks could buffet the re/insurance industry, exposing re/insurers to high financial risks.

The materialization of transmitted risks for re/insurers can consist of all types of physical and transition risks arising from biodiversity loss impacting policyholders and then turn into negative financial consequences for the re/insurer.

A. UNDERWRITING

I. Uninsurability risk

The underwriting business is at the core of any re/insurer's business, therefore the primary risk of financial loss is the incapacity to insure risks, i.e. **uninsurability**. Insurability of risks corresponds to the **availability** and **affordability** of insurance coverage for policyholders.

In 2005, Swiss Re published a paper to understand how climate change would impact the insurability of risks. Taking their criteria for insurability and applying them to the biodiversity-loss dynamics can help to understand how the industry could be exposed to underwriting risks (Herweijer *et al.*, 2009).

The set of criteria for a risk to be insurable is as follows:

— The risk needs to be measurable;
— Loss occurrences need to be independent or re/insurers need to understand and measure the correlation between loss occurrences;
— The maximum loss needs to be manageable;
— The average loss needs to be moderate;
— The moral hazard needs to be low.

So, how does biodiversity loss affect these criteria? (McKinsey, 2020; Herweijer *et al.*, 2009)

— **Measurable risk**. To date, as discussed in the research perspectives in Part I.3, biodiversity loss is only partially understood. The scientific community lacks the necessary databases, indicators and methods to be able to globally grasp biodiversity dynamics across continents.

— **Independent loss occurrence**. Similar to climate change, the consequences of biodiversity loss are positively correlated and are expected to have systemic effects across geographic and economic sectors. They are called common or systemic risks. Given the interconnection of ecological interactions, the interdependencies with human societies and the interconnection of our global economy, biodiversity-related risks do not fall under the Law of Large Numbers (Dasgupta, 2020). Re/insurers are not able to diversify these risks across individuals or companies in a given geographic sector. Because different stakeholders rely on the same natural resources and ecosystem services, their disruption could cause the aggregation of risks, thus creating interconnections between previously independent risks.

— **Manageable maximum loss**. The interconnectedness of natural systems increases the potential systemic impacts of biodiversity loss. The non-linear evolution of biodiversity loss can produce non-linear socioeconomic consequences with potential knock-on effects. These two factors increase the uncertainty surrounding maximum loss. The re/insurance industry has already experienced this phenomenon

8. This report does not analyse direct physical risks for re/insurers, even though depending on the location of offices, the risk exposure to extreme events can result in discontinuities of the insurance company's business.

for climate change and environmental risks can in turn cause significant losses for human societies. To illustrate this trend, the average, annual number of natural catastrophes in the world between 1989 and 2018 was 520, compared to 820 for 2019 alone. Moreover, we know that natural catastrophes are characterized by major, unpredictable single events leading to unprecedented financial losses. In 2020, global losses from natural disasters amounted to USD 210 billion, including record-breaking wildfires in the United States, severe floods in China and again a record-breaking number of over 30 storms during the hurricane season (Munich Re, 2021). The consequences of biodiversity losses could be responsible not only for single events, but also for entire market failures.

The very nature of biodiversity-related risks highlights **the limits of standard insurance practices**. Biodiversity-related risks are common risks, difficult to measure and with high potential knock-on effects that can vastly increase maximum losses (see Part 2.I.). Consequently, the standard insurance practices relying on diversification and pooling of risks are ineffective and insurance companies would be unable to cover the losses in a given geographic area. **Because of biodiversity loss, many risks can become either uninsurable or unaffordable for customers** (see Part 3. IV to learn how re/insurers innovate to overcome this difficulty).

The emerging biodiversity risk and threat of uninsurability can translate into operational risks for re/insurance companies through their value chain.

2. Operating risks

The profitability of the underwriting business relies mainly on the ability of the re/insurer to correctly price and pool the risks in order to obtain an inflow of premiums higher than the outflow of claims payouts. The main threat to the underwriting business is to experience an unanticipated increase of frequency, intensity and geographic concentration of claims. Three main types of risks have been identified for the underwriting P&C and Life business, namely **Low-pricing risk; Increasing-claims risk; Increasing-liability risk**.

— **Pricing risk**

Risk pricing relies on the actuarial modelling of the frequency, intensity and concentration of the occurrence of a given risk. Accurate risk pricing is key to ensuring the equilibrium of the combined ratio, thus the profitability of the company.

Biodiversity loss is a driver of change in the risk profile of individuals, assets and companies, increasing the potential risk frequency, intensity and concentration depending on the exposure of the policyholder. Re/insurers must include biodiversity-loss data in actuarial modelling to reflect this change in risk profiles.

For **Life insurance**, risk assessment is based on a given mortality rate, the evolution pattern of health risks and a health check. As seen in Part 2.II., biodiversity loss is an increasing factor in health issues. The lack of diversity in diets can cause malnutrition leading to health issues, diseases and premature deaths. It has been established that air pollution is responsible for 3.3 million premature deaths each year (IPBES, 2019e) and biodiversity loss can increase the spread of vector borne diseases, such as malaria or zika (IPBES, 2019e), with an increasing prevalence due to climate change. Harmful impacts of biodiversity loss on human health (demonstrated by scientific research, see Part 2.II. on Individuals and, more particularly, the Health examples) worsen the risk profiles of individuals in terms of their health insurance. If not taken into account by Life insurers, risk assessments and risk pricing might increasingly be underestimated, affecting the re/insurer's profitability.

The recent COVID-19 pandemic may have taken root due to excessive anthropogenic land use and biodiversity loss (IPBES, 2020c). This is a clear demonstration of the detrimental impact on individuals of biodiversity loss, showing that it can even affect the global economy and, consequently, the re/insurance industry (see the Case Study on Biodiversity, Pandemics and Re/insurance in Part 3.II.).

For **Property & Casualty insurance**, in light of the risks facing companies, the main detrimental impacts of biodiversity loss are **interruptions in business operations, operating losses** and **infrastructure damages**.

ILLUSTRATIONS

▪ Agriculture

With the increase in land use, soil productivity is declining, leading to a decrease in production quantity and quality. In parallel, the use of phytosanitary products has a harmful effect on the wild pollinators on which some crops depend, again reducing the productivity of agricultural land. In addition, the rise of extreme events, due to reduced climate regulation and the consequent disruption, can cause significant agricultural losses and infrastructure damages. All the services provided by biodiversity on which businesses rely are at risk of disruption and reductions in operating revenues.

▪ Real Estate

On coastlines, properties are already facing high risk exposure due to floods, strong storms and coastal erosion. Biodiversity, including coral reefs and mangroves, but also dunes and coastal wetlands, plays a crucial role in coastal protection. The decrease in biodiversity will increase the risk exposure of properties in the neighboring areas. Disregarding how biodiversity plays its role in climate regulation and protection against hazards, and how its decrease will affect property risk profiles could seriously undermine the accuracy of risk assessments.

Taking climate change as an example, in 1992, Hurricane Andrew was the first of a long series of highly costly natural disasters in the U.S. Insurance claims payouts amounted to USD 25 billion in 2011 and this extreme event rendered nine insurers insolvent as a result of a lack of forward-looking risk assessment, i.e. with underwriting practices based solely on historical claims patterns. Climate change is already teaching us to what extent environmental dynamics are unprecedented (Herweijer *et al.*, 2009; Insurance information institute, 2012).

BOX 15
ACTUARIAL MODELLING AND DEALING WITH UNCERTAINTY

Traditionally, the insurance industry uses historical records for actuarial modelling of future risks, relying on the principle of statistical stationarity of risks (Herweijer *et al.*, 2009). The advent of new climate patterns with an increasing occurrence of extreme weather events forced the re/insurance industry to adapt their modelling and underwriting approaches to integrate this additional component of risk to property damages, among others. Forward-looking climate scenarios have been developed and integrated into models to represent the change in patterns of weather events. Catastrophe models have existed for a long time and are developed by specialist companies, such as RMS or AIR, as well as other companies focusing exclusively on specific types of events, e.g. on floods, such as the Philippines Flood model by KatRisk, and a US Hurricane model from Columbia University, both in the open-source catastrophe model, Oasis.

The emergence of awareness concerning biodiversity loss and the potential disruption of ecosystem services adds a new layer of uncertainty to the re/insurance industry. There are three main factors of uncertainty (Muséum national d'Histoire naturelle, 2020a):

— How climate change will evolve;
— How biodiversity will react to these evolutions;
— How human societies will react to these evolutions.

These three factors of uncertainty are multiplied by the sensitive dependence on initial conditions, i.e. the butterfly effect, meaning that a small change in the initial conditions can lead to a significant difference in the resulting situation. As noted in previous sections, the scientific community is shifting from a species to an ecosystem approach, focusing on ecological interactions and their interdependencies. These phenomena are highly complex and evolve in parallel with biodiversity changes and the harmful or beneficial anthropogenic impacts.

Unfortunately, to date, the scientific and modelling community does not have the data and tools to model, forecast or to assess the probability of such events. Similar to climate change, biodiversity loss shows signs of statistical non-stationary trends and a non-linear increase in the frequency, intensity and concentration of risks may be expected. Therefore, the re/insurance industry is facing a new challenge with increasing numbers of new types of risks that do not fall into the classic framework of risk modelling, based on historical patterns and underwriters' experience.

The industry could rely on the further development of catastrophe models, however, as noted, the risks linked to biodiversity loss are not only acute, they can have chronic effects that cannot be modelled. To date, modelling the materialization of biodiversity risks remains a challenge, due to the lack of data and a clear understanding of ecological interactions (see Part I.III. on research perspectives). For the re/insurance industry, this means entering a new era of increasing uncertainty. The intense interactions between humans and biodiversity, which have degraded populations, species and ecosystem services in some places, are driving us out of the natural equilibrium in which re/insurers were able to forecast risks. This new dynamic forces re/insurers to review their risk appetite and to anticipate potentially devastating long-term risks. Today, is there any option other than limiting biodiversity loss in order to re-establish an ecological equilibrium offering a statistically stationary risk hypothesis?

Assigning an accurate price to biodiversity-related risks in order to allocate the correct premiums to each policyholder raises the question as to who should bear the price of this risk, the policyholder or those responsible for biodiversity loss? This question expands the analysis beyond the classic policyholder - re/insurer duo in the context of an anthropogenic threat with traceable responsibilities. One could imagine a taxation mechanism where those responsible for biodiversity loss would have to contribute. As we see today with the pandemic, in the most extreme situations, governments take on the role of the re/insurance industry to foster recovery and limit social and economic disasters. In the run-up to a major environmental crisis with unpredictable consequences, it is essential **to question the role of re/insurers, above and beyond creating value for shareholders**. How do re/insurers position themselves with respect to actors and potential customers who drive environmental changes or who are victims, but must still bear the costs? What is the role of the re/insurance industry in a global environmental crisis? The biodiversity issue questions the social role of private actors, including re/insurers, and how this role could increasingly complement that of the public sector.

— **Claims risk**

Insurance claims may rise from biodiversity-loss dynamics acting as a compounding driver of the frequency, intensity and concentration of existing risks. For a given risk, biodiversity loss may lead to a **higher average number of claims, a higher average amount of claims** and a phenomenon of **geographic or sectoral concentration of claims**. Re/insurers could thus experience an imbalance in their combined ratio.

The systemic effects of biodiversity loss through the interdependence of ecological interactions, human societies and economies imperil the risk-pooling principle. The lack of independence between risk occurrences would seriously affect the insurance business in terms of increasing claims. According to a publication from the Natural Capital Finance Alliance, biodiversity-related risk favors two types of potential systemic risks (NCFA, PwC, 2018):

- **Regional concentration of risk**. Even though some ecological processes are global, such as climate regulation, the majority are local, e.g. fresh water regulation or food and

feed support. Therefore, the disruption of an ecosystem and biodiversity loss would cause high risk in a given geographic zone, intensifying risk concentration and threatening the principle of risk pooling. For instance, water scarcity would hit all economic sectors and individuals in the same region.

- **Process concentration of risk**. Biodiversity loss can create systemic risks on the global level, with the disruption of ecosystem services which globally regulate environmental processes. The disruption of these services would create an increase in the global risk environment. This phenomenon is best illustrated by climate-change impacts.

— **Liability risk**

Liability risks take the form of an increase in claims under liability policies due to harmful impacts on biodiversity. Liability risks are separated from claim risks because they depend on legislation rather than on actual biodiversity loss. Liability risk arises from the exposure of policyholders to transition risks. There are two major situations in which biodiversity litigation can be initiated:

- Liability claims against damage to biodiversity, e.g. demands for restoration of a natural environment;
- Liability claims against damages and losses to people or businesses due to a harmful impact on biodiversity and ecosystems, e.g. demanding compensation for natural disasters due to deforestation.

The exposure of re/insurers to an increase in liability claims related to biodiversity depends on the type of liability policies underwritten by the company, as well as the development of a legal framework for biodiversity. This risk would primarily affect professional liability, environmental liability and directors & officers' policies (i.e. liability insurance for the consequences of decisions taken by company management).

Such risks might face a sharp increase in the coming years because the scientific community is working on enhancing our understanding of biodiversity and human interactions to limit our harmful impacts. Rising awareness will expose parties responsible for harmful impacts on biodiversity (see Box 16). This trend can already be seen for climate change, with a rise in climate-change litigation. For instance, the City of New York sued five major oil companies in January 2018 (New York Times, 2018). A rise in biodiversity litigation might cause an unexpected increase in liability claims for re/insurers.

BOX 16
ENVIRONMENTAL LIABILITY

Since 2004, the concept of environmental liability has been recognized on the European level (European Commission, 2020). In 2016 in France, the Law on Biodiversity inserted an obligation to repair environmental damages, the "**préjudice écologique**" in French, in the French Civil Code (Actu Environnement, 2016). In 2018, the International Court of Justice declared that a State must repair environmental damages caused to another State (Actu Environnement, 2018). Environmental legislation is expanding across the world, with governments, companies and individuals increasingly defending the rights of nature.

This trend is also visible within the insurance industry with the emergence of environmental-responsibility insurance policies, mainly covering events where a company causes material, physical or intangible damages to a third party. The environmental-insurance market is still not mature and coverage varies widely depending on the industry insured. The most harmful industries, thus the most at risk of liability issues, are well covered while other sectors are still too insufficiently aware of the risks.

In France, environmental-liability experts expect a sharp increase in reporting of damages caused to biodiversity, because the concept of "préjudice écologique" has been extended to all forms of interaction with the environment, not only its use, and because anyone can file a complaint. Legal costs are expected to rise and, with them, the motivation for insurance companies to assist their clients and offer new services. Given that the legal framework is still uncertain and very few legal precedents are available, the insurance market for environmental risks is constantly evolving (La Tribune de l'assurance, 2019).

The first case of environmental damage brought to court in France concerned the Parc National des Calanques, a marine reserve in the South of France where four poachers were arrested for illegally fishing 4.5 tons of fish and shellfish. In March 2020, the court sentenced them to pay 350 000 euros to repair the environmental damages (La Tribune de l'assurance, 2019).

B. INVESTING

Through their investing activities, re/insurers manage their premiums, create investment returns to grow their business by increasing the company's capacity to pay for future claims and generate benefits.

As noted in Part 3.I., re/insurance companies invest in a large array of financial products and the financial returns of the investment portfolio depend on the type and the performance of the underlying assets. The investment activities of re/insurance companies are similar to other financial institutions, therefore **the biodiversity-related financial risks for the investment arms are similar as those described in Part 2. IV. Financial Institutions**.

The investment arm of a re/insurer can invest in debt or equity linked to governments or corporates, but also to infrastructure and real estate. Biodiversity-related transmitted risks for the investing activities comprise the physical and transition risks that can impact the investees and consequently undermine the financial returns for the investor, in this case the re/insurer.

The financial valuation of these financial products is subject to volatility partly due to their exposure to physical or transition environmental risks, which depend on their geographic location, economic sector, dependencies and impacts on biodiversity. The disruption of ecosystems, with the services and goods they provide, will lead to greater volatility and uncertainty for businesses (Part 2.III. Businesses) and the financial institutions invested in them (Part 2.IV. Financial Institutions). The uncertainty for businesses can lead to adverse financial yields for financial institutions, through declines in stock prices, real-estate prices and credit defaults, but also reputational damages and regulatory changes which could impact their financial performance.

The investment activities of re/insurers are exposed to transmitted risks via the exposure of the underlying entities of the financial products they invest in. Both physical and transition risks influence the performance of financial assets:

— Re/insurers face exposure to **credit risk** due to their high level of investment in fixed income, such as corporate and government bonds or real-estate debt. The depletion of natural assets can impact investees' business operations and profitability (see Part 2. III.), increasing their risk of default. The same is true for real-estate, where cash flows can be impacted by high exposure to natural catastrophes. This can reduce the debt-servicing capacity and collateral valuation of the financial institution. Investees can also endure financial losses because of sanctions or new taxes related to environmental regulations. The cost of capital can also increase due to higher lending requirements. All these dynamics can result in a decrease in the expected financial yield for the re/insurer.

— Re/insurers also face exposure to **market risk** when changes in natural stocks impact share prices. The disruption of ecosystems can influence macroeconomic factors of growth, inflation and the overall stability of the impacted economic sectors, leading to an adverse effect on market prices and on financial returns. Market shifts can also occur due to actions taken to reduce pressure on biodiversity, whether intentional or regulated, with as a result the repricing of certain assets and loss of investment opportunities.

For countries with high economic dependence on natural assets and high exposure to biodiversity-related risks, the market price of sovereign debt may be impacted. (Dasgupta, 2020).

— Through their investing activities, re/insurers can expose themselves to **solvency risk**. European re/insurers are regulated by the Solvency II European Directive and must hold a certain amount of their own funds depending on the level of risk of their investment portfolio and underwriting positions. However, due to financial devaluations and/or default of their investees caused by ecosystem disruption and not anticipated within the Solvency Capital Requirement, re/insurers could experience a long-term decrease in financial returns that reduce their future financial flows.

— **Liquidity risks** could arise if abrupt disruptions of ecosystems services occur, requiring significant amounts of liquidity. However, contrary to banks that can be faced with large withdrawals significantly higher than their liquid assets, re/insurance companies are not exposed to such imbalances and invest essentially in liquid assets.

Mispricing of biodiversity-related risks is usually the cause of this risk exposure. **The incapacity to price nature-related risks and integrate them in the risk measurement of a financial portfolio can significantly distort the risk level of the portfolio and of the entire company**.

For the financial institution, this can lead to underestimated risk exposure with credits and investments being allocated to high-risk activities, and consequently underinvestment in low-risk activities to ensure the long-term stability of financial returns. This is a problem of risk-efficient allocation. The unaccounted biodiversity-related risks could accumulate within the financial institution that is failing its central purpose of managing risks and exposing the company to difficult situations in case of a lack of capital funds to ensure short-term liquidity and solvency over the long term in extreme cases. On the regulatory level, the mispricing of nature-related risks within financial institutions presents a serious threat to the stability of the financial system in case of disruption. If not reported as a risk exposure by financial institutions, nature-related risks cannot be accounted for within the Solvency Capital Requirements (see Part 3.I.I. on Solvency). To correctly assess the nature-related risk level of an insurance company, it is essential to take into account both the exposure and the vulnerability of the company (see Box 6).

Over the short term, transition risks will have a stronger impact on asset values than physical risks. Transition-risk impacts on financial valuations will depend on the extent of the transition in the real economy, meaning in the changes in demand and pricing. Also, financial valuations will fluctuate depending on the reaction of financial markets to the transition or to environmental regulatory measures. Furthermore, asset values can be exposed to stranding risk (CRO Forum, 2019) which will be discussed in next section on transition risks.

Over the long term, physical risk will increasingly impact financial valuations if physical damages and disruption to business models spreads across the economy (see Part 2.V. The economic system).

By affecting the value of financial assets, biodiversity risk may cause disruption to financial markets impacting reserve decisions, underwriting capacity and ultimately the solvency of the re/insurance company (IAIS, 2018) (see Part 2.IV. Financial institutions).

3. TRANSITION RISKS

Biodiversity loss creates physical risks (i.e. those associated with changes in natural stocks and flows), which translate into operational risks for businesses and re/insurers. But, as the loss dynamic worsens, awareness rises and, as society changes accordingly, all economic players, not least the re/insurance industry, are exposed to what could be deemed **transition risks** (i.e. those associated with societal response to the changes in natural stocks and flows).

Transition risks are progressively appearing and increasing because, on the one hand, the biodiversity crisis per se is worsening, and on the other, human actions are increasingly aimed at mitigating or adapting to that evolving context. These transition risks might actually materialize faster than physical risks, given that they are caused by a willingness to mitigate and adapt before the emergence of physical risks.

As mentioned above, interdependencies between biodiversity and human activities are infinitely intricate and the links between biodiversity-related risks and business risks have undergone **virtually no empirically testing yet**, whether in the academic literature or by institutional or private studies. As was the case for the previous section, the following approach will consist essentially of a theoretical, non-exhaustive attempt at pointing out the obvious. It will present **first-tier risks**, which must not hide the fact that **cascading and feedback effects** are to be expected due to both **impact and dependence relationships** between biodiversity and human activities.

As seen in Part 2.III. for businesses in general, we will explore four types of risks that re/insurers could face and that could fall under the transition-risks category, namely **reputation risks; market risks; regulatory and legal risks**; and **financial feedback risks**.

A. REPUTATION RISKS

As has been the case for climate concerns over the past few years, one can assume public attention will increasingly be drawn to worsening biodiversity issues in the near future and even more so since the COVID-19 outbreak, which has given rise to greater public interest in correlations between the status of biodiversity and health challenges (see the Case Study on Biodiversity, Pandemics and Re/insurance in Part 3.II.).

Businesses operating in biodiversity hotspots or engaging in activities detrimental to biodiversity, whether "spectacularly" (e.g. the impacts of the palm-oil industry on orang-outan habitats and survival) or "quietly" (e.g. the impacts of neonicotinoid use by the agricultural industry on bees), can suffer major reputational setbacks adversely affecting them in the long run.

These reputational difficulties can have knock-on effects on the whole value chain, including financial institutions. The re/insurance industry's business is to ensure that the activities of other agents can be carried out with limited risk. It may be said that re/insurers provide other businesses with "licenses to operate".

Financing or re/insuring controversial activities is a serious risk that the financial sector is already dealing with. The transition to a society much more aware of biodiversity challenges will add to those existing and understood risks.

A re/insurer can assess the extent to which it is exposed to reputational risks by looking at the environmental controversies confronting the entities it invests in or provides coverage to (DNB, 2020). Indicators exist to evaluate such risk. For instance, MSCI tracks and assesses the severity of what it calls **ESG Controversies**, where a controversy is defined as "*an instance or ongoing situation in which company operations and/or products allegedly have a negative environmental, social, and/or governance impact*" (MSCI, 2020).

B. MARKET RISKS

Evolving conditions on a market may generate risks for market players if they do not adapt. This is what we refer to here as market risks.

In addition to the transmitted risks it may create through inadequate pricing (as seen in the previous section on Transmitted risks), escalating biodiversity loss may also directly impact the re/insurance market via changes in the number and profile of people or entities to be covered, the nature of risks to be considered and their insurability (Herweijer *et al.*, 2009).

In a changing consumer environment, re/insurers may also face the risk of an inadequate product offering. Rising public awareness of biodiversity challenges will not only impact business reputations, it will also lead to transformations in the needs of individuals and companies.

For the re/insurance industry, this could mean increasing demand for environmental insurance. The risks faced by a non-adapting re/insurer include a product offering no longer in line with policyholders' needs and expectations, resulting in market inadequacy and client loss in the long run.

For the investment arm, the market shift in consumer preferences and the transformation of the industry to address biodiversity-loss issues could lead to asset repricing impacting the expected financial returns of re/insurers' portfolio. This shift could also represent a loss of investment opportunities due to the integration of stronger environmental criteria.

C. REGULATORY AND LITIGATION RISKS

Not only the consumer environment, but the regulatory and legal environments may be transformed as well.

Economic agents not integrating this evolving context in their playbook obviously risk falling behind and facing costly lawsuits in the future. As noted in the previous part on transmitted risks, re/insurers having invested in or covering businesses that do not comply with this evolving landscape will be affected by cascading effects. For instance, the possible expansion of protected areas worldwide will have direct impacts on businesses engaged in activities on these sites, which will in turn affect their investors and the value chain of insurers, and this example is just one possible channel.

But the re/insurance industry itself is directly subject to evolving regulations. It will increasingly be pressured to provide adequate responses to a changing environment (McKinsey & Company, 2020), pressures stemming from society as a whole. On all policy levels, biodiversity is a growing matter of concern (see Box 17).

BOX 17
BIODIVERSITY LOSS, A MATTER OF INCREASING POLICY CONCERN

On the international level, the tenth meeting of the Conference of the Parties (COP 10) to the UN Convention on Biological Diversity (CBD), held in Nagoya, Japan in 2010, marked a turning point in biodiversity negotiations. Parties notably adopted the **Strategic Plan for Biodiversity 2011-2020**, the **Aichi Biodiversity Targets** and agreed to submit **National Biodiversity Strategies and Action Plans** (NBSAPs) complying with those targets.

Fueled by the publication in 2019 of the **Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services** (IPBES) **Global Assessment Report**, there has been a powerful upswing of the biodiversity theme on the international policy agenda. The G7 conference held in 2019 in France notably addressed this issue, with the Metz Charter on Biodiversity signed by the G7 Environment Ministers. The French and Chinese Presidents also stressed the urgency of the situation in the November 2019 "Beijing Call for Biodiversity Conservation and Climate Change". More recently, on 30 September 2020, the UN Summit on Biodiversity was convened by the President of the UN General Assembly under the theme "Urgent Action on Biodiversity for Sustainable Development."

2020 was indeed supposed to be a milestone year for biodiversity on the international scene. The achievements of the plan and targets set a decade earlier were to be reviewed and a post-2020 framework, with new and more ambitious targets in a renewed framework, was to be agreed upon at the COP15 to the CBD in October 2020 in Kunming, China. The International Union for Conservation of Nature (IUCN) was also supposed to hold its **World Conservation Congress** in June in Marseille, France. These meetings have been postponed to 2021. In November 2020, 109 recommendations proposing concrete actions to be undertaken against biodiversity loss were adopted by the IUCN in the run-up to the 2021 Congress (Comité français de l'UICN, 2020).

Despite COVID-19 pandemic-related delays, enhanced international rules and regulatory levers to protect ecosystems, promote their sustainable use and act on the drivers of biodiversity loss are expected in the near future. Among those instruments, decisions to set more ambitious science-based targets, increase the size of protected areas worldwide, reform the subsidies, taxes and fines frameworks, and improve trade directives are anticipated.

Buoyed by this international momentum, **instruments and finance for biodiversity** have been on the rise lately. According to the OECD, the number of biodiversity-relevant economic incentives, notably taxes, fees and charges as well as tradable permit schemes, has been increasing worldwide (OECD, 2020a).

On the European Union level, "*preserving, protecting and improving the quality of the environment*" is included in the Treaty on the Functioning of the European Union (EUR-Lex, 2012) as an objective of the Union policy on the environment (Art. 191), a treaty which also establishes the precautionary and the "polluter pays" principles. The E.U. Directive on Environmental Liability adopted in 2004 laid down rules based on this latter principle, which means that "*a company causing environmental damage is liable for it and must take the necessary preventive or remedial action and bear all the related costs*" (EUR-Lex, 2020).

The E.U. has recently been moving biodiversity policies forward. In December 2019, the European Commission (EC) presented its new growth strategy, the **European Green Deal**, "*a roadmap for making the EU's economy sustainable*" (European Commission, 2019), in which the reversal of biodiversity loss is a significant focus. In line with that overall strategy, the Commission adopted in 2020 the **E.U. Biodiversity Strategy for 2030** and its corresponding Action plan. It also established in 2020 a **Taxonomy for sustainable activities**, in which preserving biodiversity is a goal, following its 2018 **Action plan on Financing Sustainable Growth**.

Ensuring that financial entities integrate sustainability risks into their day-to-day risk management is on the EC's agenda. It has asked for inputs from European financial supervisory authorities on this matter. European central banks and financial regulators are increasingly looking into the matter from a prudential viewpoint. They formed the Network for Greening the Financial System (NGFS) and are committing resources to measuring environmental risks and impacts on the stability of the financial system.

On the national level, several countries have already put in place regulatory levers to protect and even restore biodiversity.

Disclosure in particular is an important topic that France has been pioneering. **Article 173 of the 2015 Energy Transition for Green Growth Act** imposed extra-financial reporting requirements for institutional investors, including the re/insurance industry. It was complemented in 2017 by the transposition into French law of the **E.U. Non-Financial Reporting Directive** (MTES, MEF, AMF, ACPR, 2019) and includes items relating to measures to preserve or restore biodiversity (OREE, 2018). Article 29 of the 2019 French Law on Energy and Climate goes even further regarding transparency and reporting requirements. It is milestone toward better integration of extra-financial matters in investment decisions. Biodiversity is now explicitly covered by these extra-financial reporting requirements in French law.

Besides imposing obligations on financial institutions, France has also been advancing the biodiversity-policy agenda per se by adopting a **National strategy for biodiversity** (as requested by the CBD) and a **Biodiversity Plan** in 2018.

Increased regulation will not only put pressure on the re/insurance industry from an impact perspective (i.e. to mitigate its impacts on biodiversity loss). It will also most probably be increasingly directed toward the "dependencies" side, pushing re/insurers to adapt and develop responses to the "threat of rising uninsurability" (Herweijer *et al.*, 2009) which jeopardizes their current business model.

Litigation risks in the form of lawsuits of entities seeking to recover unlawful environmental losses from a third-party are bound to increase in parallel with the disclosure of environmental-impact assessments and the development of regulatory frameworks. Re/insurance companies are not directly targeted by these litigation risks for now (Dasgupta, 2020), because the causal chain from an environmental degradation up to the re/insurer is not yet established. But the responsibility of re/insurers could be engaged in future environmental litigation.

Engaging with policy-makers and maintaining good relationships with public authorities (Herweijer *et al.*, 2009) is essential for the re/insurance industry if it is to play a key role in a rapidly-changing world and mitigate the concrete regulatory risks that can arise.

D. FINANCIAL RISKS

In addition to transmitted financial risks stemming from the fact that the re/insurance industry insures and finances companies that are (increasingly) at risk from reductions in ecosystem services, re/insurers face different types of financial transition risks.

— Feedback financial risks

Re/insurance companies can insure and finance activities that have detrimental impacts on biodiversity (see Part 3.III. on Impacts). It follows that these businesses can participate in and even accelerate the very process of biodiversity loss and reductions in ecosystem services through which they are exposed to risks in the first place.

Engaging in activities that have negative impacts on ecosystems destabilizes business conditions and aggravates the risk environment. In the face of increased frequency of severe events due to biodiversity loss (and climate change), it is necessary to envision worsening financial risks for the whole value chain, up to and including the re/insurers.

— Liquidity risks

According to the European Central Bank (ECB), "*liquidity risk can be defined as the risk that cash resources are insufficient to meet cash needs either under current conditions or in stress scenarios. (…) Insurers can be confronted with both asset and liability liquidity risks.*" (ECB, 2009).

Aforementioned operational, reputational, financial and other risks borne by re/insurers in a biodiversity-loss context may lead to short-term cash shortfalls. In view of potential (macroeconomic and financial) systemic risks posed by the biodiversity-loss situation (see Part 2.IV. on Financial Institutions and Part 2.V. on The economic system), such risks may also cause increasing difficulties for financial institutions (including re/insurers) to obtain refinancing. However, as mentioned in Part 3.II.2.b, it should be noted that re/insurers are infrequently exposed to liquidity risks.

— Solvency risks

Re/insurance companies face solvency risks due to transmitted risks, but they can also be exposed to solvency risks due to the societal response to changes in ecosystems. In the European Union, solvency is regulated by the Solvency II Directive to ensure a minimum amount of capital depending on the investing and underwriting positions and their associated level of risk. Mispricing of nature-related risks can distort the results. Re/insurers could therefore be overexposed to nature-related risks and lack capital funds in case of changes in ecosystem services and the associated societal responses. Moreover, if correctly priced, it could appear that re/insurers are already overexposed to biodiversity-related risks, meaning they would either need a higher amount of SCR or they would need to reduce their exposure to underwriting and/or investing positions, losing some profit potential.

It should be noted however that, as the growth of the insurance business also depends on risk aversion, if uncertainty increases the demand for protection increases as well. That being said, this increase in demand could be partly or more than offset by price increases. The resulting impact on the re/insuring business and, in the end, its solvency, is therefore unclear (see also Box I9 on The insurer's dilemma).

— Stranded-asset risks

In an evolving environmental, public-opinion and regulatory context, as asset owners, re/insurers will increasingly detain **stranded assets**, which "*can no longer be developed, might face premature write-offs, downward revaluations or conversions to liabilities*" (WEF, 2020b) (see Box I8).

This increasing **stranded-asset risk** has already increased with climate change, especially in the energy and fossil-fuel sector. Stranded assets can arise from changing resource landscapes, environmental challenges, new government regulations, litigation or evolving social norms. The threat can therefore emerge from both changes in ecosystems and their societal response. Stranded assets usually correspond to assets which go against the current transition. For instance, in the fight against climate change, a number of coal plants have become stranded assets (CRO Forum, 2019). In the last few years, some assets became stranded because of a high exposure to environmental risks. For instance, in July 2020, Total announced USD 8 billion of asset impairments to remain in line with its climate ambitions (Total, 2020).

BOX I8
EXPOSURE OF THE FINANCIAL SECTOR TO STRANDED DEFORESTATION-LINKED COMMODITIES

Hosted by the World Economic Forum, the Tropical Forest Alliance (TFA) groups more than 170 entities, including companies and government entities, the civil society and local communities, engaged in supporting the implementation of private-sector commitments in favor of deforestation-free commodity supply chains, in particular in the beef, soy, palm-oil and pulp & paper industries (TFA, 2021).

According to TFA, nearly 70% of tropical deforestation is due to commercial agriculture and in particular to the four industries mentioned above, which are coined "forest risk commodities" (TFA, 2018). TFA estimates that there is a concrete business case for financial institutions to account for the risks they take in investing in and lending to companies engaged in such activities, given the changes in the regulatory and market landscapes and the fact that such risks are becoming ever more material (TFA, 2018).

Countries are increasingly taking policy and regulatory measures to limit the impact of industrial activities on forests. Such measures can strand assets, meaning they lose their economic value "well ahead of [their] anticipated useful life" (TFA, 2017).

In 2017, TFA estimated that tens of billions of dollars in assets could be at risk of becoming stranded if investors continue with "traditional" investments over the next five to ten years. Up to hundreds of billions of dollars of existing productive assets could be at risk if we consider all historically illegal production areas (TFA, 2017).

To conclude, while all these transition risks are only potentialities, some already are quite palpable. The regulatory framework and public concern are already evolving quite rapidly. A parallel can easily be drawn with increasing climate interest and regulation over the past few years. Quantifying the exposure of entities to such transition risks may be extremely complex, however, measuring **biodiversity footprints** might provide a first clue as to the sensitivity and exposure to transition risks (see Part 3.III. on Impacts).

The correlation between biodiversity and business risk has not yet been well established and scientifically investigated. To date, the causal chain has not been clearly established and quantified, but more and more examples teach us we should not wait until it is established to act. The following Case Study on Biodiversity, Pandemics and Re/insurance illustrates just that.

In this sense, re/insurers face a dilemma as to how they should adapt their strategy (see Box I9). The exposure of businesses to biodiversity-related risks has been far less investigated than the impacts they can have on biodiversity loss. Actions to limit biodiversity loss undertaken by corporate entities so far have been driven more by a willingness to mitigate their impact than by a real sense of risk incurred, even if limiting one's impact is a means to limit risk exposure. For this reason, the next section concentrates on the impact assessment and approach for re/insurers.

BOX I9
THE INSURER'S DILEMMA BETWEEN INCREASING PREMIUMS OR HALTING UNDERWRITING

A report on insurance and climate change, published by the Fondation pour l'Innovation Politique in August 2020, raises a point on the insurer's dilemma (see Fondation pour l'Innovation Politique, 2020).

Re/insurers facing increasing risks have two logical options to protect their business from financial losses, namely increase premiums or stop underwriting risks.

On one hand, re/insurers could choose to align premiums with the "real cost" of the risk to ensure a low combined ratio. However, considering the intensity of climate-change risks and the potential intensity of biodiversity-related risks, insurance premiums could exceed customers' willingness to pay. As a consequence, premiums would rise, but subscriptions would drop, increasing the insurance gap and decreasing profitability. As the International Association of Insurance Supervisors has established, insurance gaps can increase the cascading effects of physical risks across the financial system (IAIS, 2018).

On the other hand, re/insurers could stop underwriting risks which are considered too high. However, given the systemic nature of biodiversity loss, global risks would become more intense and frequent, thus affecting a wide array of risks. This risk-selection strategy would harm the insurance business in terms of the inflow of premiums, damage the investment branch and increase the insurance gap as well. Taking the decision to stop underwriting a certain risk will add "uninsurability" to biodiversity-related risks for companies and individuals.

However, a third pathway might exist by seizing opportunities to fight against biodiversity loss (see Part 3.IV. on Opportunities).

CASE STUDY

EXEMPLIFYING THE CHAIN REACTION FROM BIODIVERSITY LOSS TO MATERIALIZED RISKS FOR RE/INSURERS: THE CASE OF PANDEMICS

It may be painfully obvious to say so, but the COVID-19 outbreak has undeniably questioned our life habits and shaken our beliefs. Wildlife, especially bats and possibly pangolins or other carnivorans, hit the headlines for potentially being the source of a crisis of global magnitude. This brought to light the vulnerability of our societies to the hazards of the natural world we live in. This realization came as a surprise for many in developed countries, because a false sense of protection had spread with the feeling that we humans had developed sufficiently advanced organizations and technologies to shelter us from such natural menaces.

After the surprise came practical questions. How should we deal with this unprecedented sanitary episode that has turned into a global economic and social crisis? What role and responsibilities should everyone accept? Because of its very theoretical mission to mitigate and transfer risks within societies, the re/insurance industry has been caught in the turmoil and blamed for its inaction in view of its presumed mandate.

This case study will attempt, first, to shed light on the scientific knowledge that supports the existence of a concrete correlation between biodiversity loss and pandemic outbreaks, then to explain to what extent the re/insurance industry can be affected by a pandemic episode (using the COVID-19 experience with the empirical lessons learnt). This will lead to a discussion on how to make the needs of biodiversity and the re/insurance industry's concerns converge into building more resilient societies.

***Important notice**. At the time this case study is being written, information on the origin of the COVID-19 outbreak is still insufficient for the scientific community to qualify it as a zoonosis with certainty. The WHO is currently pursuing the investigation. This case study deals with pandemics as a general matter. Some specific parts explicitly refer to the COVID-19 case for the sake of illustration.*

I. FROM BIODIVERSITY LOSS TO PANDEMICS

A. HOW IS BIODIVERSITY LOSS A DRIVER OF DISEASE OUTBREAKS?

In its latest workshop report, the IPBES warned that we are entering an era of more frequent and virulent pandemics correlated to the loss of biodiversity.

In the last 50 years, there has been evidence of an increase in epidemics throughout the world (Fondation pour la Recherche sur la Biodiversité, 2020). According to scientific estimates, there could be 1.7 million undiscovered viruses, more than 45% of which being potentially harmful to humans (IPBES, 2020c). On average, two to three pathogens emerge every year (Fondation pour la Recherche sur la Biodiversité, 2020).

Approximately 70% of the epidemics that emerged during the last half century had zoonotic origins (IPBES, 2020c):

> *A **zoonosis** is an infectious disease that has jumped from a non-human animal to humans. Zoonotic pathogens may be bacterial, viral or parasitic, or may involve unconventional agents and can spread to humans through direct contact or through food, water or the environment.*
>
> (WHO, 2020)

Well-known examples of such diseases are the Ebola, Zika and Nipah viruses, HIV/AIDS or the avian and swine influenzas, SRAS and MERS that are also caused by coronaviruses. COVID-19 could possibly be added to this list. Zoonoses compel us to understand health not only from an anthropogenic perspective but from that of an ecosystem of living beings. That is the basis of the One Health approach.

> ***One Health** is a collaborative, multisectoral, and trans-disciplinary approach - working at local, regional, national, and global levels - to achieve optimal health and well-being outcomes recognizing the interconnections between people, animals, plants and their shared environment.*
>
> (Health Commission, 2020)

How is the ongoing loss of biodiversity related to the outbreak of zoonoses and potential pandemics?

The transmission of an infectious disease of zoonotic origin is determined by the confluence of three main factors (Fondation pour la Recherche sur la Biodiversité, 2020):

— **Danger**: the presence of microorganisms, host species and vectors;

— **Exposure**: behavior or activities that favor interactions between local communities, livestock and wildlife;

— **Vulnerability**: in terms of both immune system resilience (genetic heritage, physiological factors and the microbiota) and socio-economic factors (poverty, access to medical services, diets, etc.).

The ecological interactions within ecosystems enable the regulation of pathogens. In disease ecology, this concept is called the "dilution effect" (Schmidt *et al.*, 2001). It was first explored by Schmidt and Ostfield in 2001 and suggests that, in a given ecosystem, the more abundant and diverse the pathogen hosts and non-hosts are, the lower the prevalence will be.

Therefore, a high level of specific and genetic biodiversity is considered a safeguard against the emergence and spreading of pathogens (Fondation pour la Recherche sur la Biodiversité, 2020).

However, the dilution effect is still disputed by some scientists. And the mechanism of zoonotic emergence can also be explained simply by environmental destruction which increases the interactions and interfaces between wildlife and humans in pathogen hotspots.

The degradation of an ecosystem in all its aspects (e.g. in terms of species loss or decreases in genetic diversity) is a driver of zoonotic-disease emergence via several dynamics (Fondation pour la Recherche sur la Biodiversité, 2020):

— **Ecological factors**: destruction and fragmentation of natural habitats, food-chain disruptions, pollution, stress, etc.;

— **Epidemiological factors**: how the fragmentation and reorganization of populations influence the dilution or spreading of pathogens;

— **Adaptive factors**: how behavioral changes increase interactions between wildlife and human populations. When habitats are destroyed or food resources become scarce, wildlife migrates toward cities leading to synanthropism (when a species benefits from living close to cities, for instance pigeons and rats). For example, deforestation and human-induced forest fires lead bats to migrate to human structures and especially pork farms, resulting in the outbreak of the Nipah virus in 1998-1999. The same process is involved with the dengue virus travelling via human structure.

— **Evolutionary factors**: for humans and most other living beings, pathogens are a driver of selection and evolution of our immune system. The response and shaping of our immune system in the interaction with pathogens is called a coevolution process. There is evidence of a correlation between the virulence of a pathogen outbreak and the phylogenetic distance between humans and the pathogen-host. Therefore, the shift from one host to another can disrupt the co-evolution relations between host and pathogen, leading to the severe outbreak of the disease.

These four dynamics are driven by human activities (Fondation pour la Recherche sur la Biodiversité, 2020):

— **Deforestation** reduces natural habitats, increases human presence in forests and the interfaces between humans and wildlife, thus increasing potential interactions (*exposure*). Deforestation also disrupts food chains, especially by impacting predators, enabling other species, i.e. potential hosts, to proliferate (*danger*). The correlation between **deforestation** and the outbreak of zoonoses has been proven.

— The **hunting, consumption and trading of bushmeat** increases the interaction with wildlife and has been identified in several cases as the origin of the emergence of pathogens such as HIV, Ebola and SRAS. The trade of bushmeat in urban markets and the expansion to national and international markets is driving the risk of transmission (*exposure*).

— **Urbanization** also favors the emergence and spreading of pathogens given high population densities and a favorable environment for the development of rodents and insect populations in cities. Urban spreading also reduces the interface between human populations and wildlife, and consequently the risk of interactions (*exposure*).

— **Intensive livestock farming** has also been proven to be a source of pathogens, e.g. the avian flu and Nipah virus. The proximity between livestock and wildlife, the high density of livestock in contact with human populations, the loss of genetic diversity and the stress generated by the living conditions are factors favoring the emergence and transmission of pathogens (*danger, exposure*).

— **Climate change**, by altering the natural environment, influences species' behavior, activity and distribution, thus potentially impacting the emergence and spreading of pathogens (*danger, exposure*).

— Climate change also drives the **thawing of permafrost**, a thousand to millions year-old ice layer containing bacteria and viruses, i.e. potential pathogens for wildlife, livestock and humans (*danger*).

Because of a lack of studies focusing on local and precisely geo-located data, it is still quite hard to establish the precise point of emergence of pathogens and the specific causal chains from an existing pathogen to its transmission to humans. More research will be needed to go beyond the correlation identified to date.

B. CAN BIODIVERSITY BE A VICTIM OF PANDEMICS?

Pandemics and the measures implemented to mitigate and regulate them can themselves directly and indirectly **threaten biodiversity**.

First, poor control of a pandemic can lead to the prompt, worldwide spreading of the pathogen, due to human flows and interconnections in a globalized era. This widespread dissemination can lead to the transmission of pathogens to wildlife "outside the pathogen initial host range" (IPBES, 2020c). For instance, the H1N1 virus spread from humans to both domestic animals and wildlife (IPBES, 2020c).

Moreover, the post-response measures implemented to control the spreading of diseases have, in some historical cases, had detrimental effects on biodiversity. Some measures included wildlife mass killings, e.g. in the 1950s in Africa to stop the spread of the sleeping sickness, or use of chemicals, e.g. to control malaria, with serious detrimental impacts on aquatic ecosystems. Identification of the primary host species can lead to eradication attempts, e.g., bats in Uganda to control the Marburg virus, an attempt which unfortunately led to increased transmission due to the migration of the targeted animals (Fondation pour la Recherche sur la Biodiversité, 2020).

Indirectly, when governments have imposed lockdowns reducing some anthropogenic environmental impacts, such as oil consumption, these positive effects are only temporary. The attempt to make up for lost time in economic terms could lead to recovery policies neglecting environmental imperatives, reversing positive progress made to date. Moreover, many beneficial activities for biodiversity conservation have also been suspended during lockdowns, including revenue streams from ecotourism to finance conservation efforts, paving the way for an increase in th-e illegal exploitation of natural resources and poaching (IPBES, 2020c).

C. WHY IS BIODIVERSITY ESSENTIAL WHEN FIGHTING A PANDEMIC?

Biodiversity is a key factor when fighting or preventing a pandemic, and not solely through the previously mentioned "dilution effect" which states that the richer the biodiversity (in terms of species and genes), the less chance a virulent, infectious disease has of outbreaking (Fondation pour la Recherche sur la Biodiversité, 2020).

Biodiversity is a reservoir of pathogens, but the genetic diversity of species also holds the key to the development of therapeutic resources against these pathogens. Therefore, the fight against emerging pandemics relies, in part, on the access and "the use of genetic sequence data from biological materials" (IPBES, 2020c), which is regulated by the Nagoya Protocol and will be a hot topic of the COPI5 of the Convention on Biological Diversity (CBD) (IPBES, 2020c).

A thriving biodiversity is the first nature-based preventive and curative resource when dealing with pathogens.

Even though the origins of the COVID-I9 outbreak are still uncertain, this pandemic pointed out anthropic negative externalities for the natural environment and their greater-than-previously-thought consequences. This sanitary crisis is taking us back to the very nature of the human condition as a member of a bigger, complex and interdependent web of living beings, which we call biodiversity.

2. PANDEMICS AND THE RE/INSURANCE INDUSTRY

In April 2020, when the consequences of the COVID-I9 outbreak were only just starting to be felt, Lloyd's of London's DG, John Neal, and SCOR's Chairman & CEO, Denis Kessler, respectively claimed that "*the coronavirus pandemic* [was] *likely to be the most expensive event in history for the insurance industry*" (Financial Times, 2020) and that "*the pandemic* [was] *an event of historic proportions for risk professionals*" (SCOR, 2020c). The question arises as to how re/insurers are exposed to pandemics and, in the specific case of COVID-I9, to what extent and through what channels exactly has the industry been hit so far? Will this shock affect the way re/insurers do business in the future?

A. IN THEORY, IN WHAT WAYS ARE RE/INSURERS EXPOSED TO PANDEMICS?

Pandemics are by nature rare but severe shock risks (SCOR, 2020c). As "known unknowns", they represent one of the most destabilizing and threatening risks for societies and, by extension, for the entities that are designed to ensure risk mitigation within them, i.e. re/insurers.

Pandemic shocks are characterized by their unbounded time and geographic scope. They are "*the very essence of a serial risk that unfolds like an avalanche: the global shock fragments and refragments into billions of microshocks*" (SCOR, 2020c). Their specificity also lies in both the exogenous and endogenous nature of the risk propagation factors. The progression of the disease depends on both individual behavior and collective choices (i.e. policies and regulations) (SCOR, 2020c).

Such shocks will immediately and directly expose and affect re/insurers via each of their business lines.

— ***Life and health insurance***

By its very nature, a pandemic will primarily engender health shocks and translate into a one-time significant deviation of mortality and morbidity (VoxEU, 2020; Institut des actuaires, 2018). The impact of a pandemic on re/insurers will largely depend on their portfolio.

Concerning life insurance, re/insurers provide both mortality and longevity insurance policies. Depending on the balance of each product in the re/insurer's portfolio, the risk of higher claims induced by a higher mortality rate can be offset by decreasing future payments of longevity benefits (VoxEU, 2020).

Concerning health insurance, which includes benefits related to sickness, disability, invalidity and all related costs, the impacts of a pandemic will very much depend on the consequences of the illness itself. However, in case of a high mortality rate, the effect on the health insurance business should be smaller than that on life insurance. Re/insurers will possibly face increasing claims for basic, health-insurance coverage related to increasing doctor visits, hospitalizations and treatments.

The risk of pandemics is not new to life re/insurers, it has already been assessed and modelled by actuaries. Even though considered a shock, pandemic risks are fully integrated in re/insurers prevention strategy, especially in the E.U., in compliance with the Solvency Capital Requirements of the Solvency II framework. The Solvency II framework was implemented in 2009 to reduce the risk of insolvency of re/insurance companies (European Commission, 2015).

The immediate consequences of the shock for the health-insurance business are known with a higher frequency of claims as well as higher medical spending. However, there is still a wide range of uncertainty regarding the long-term consequences on health and potentially on psychological health.

— ***Non-life insurance***

A pandemic being related to health by definition, it should theoretically not affect non-life insurance. One could think the Property & Casualty (P&C) line of business would be sheltered from such a shock.

However, a pandemic does not have health fallouts alone. It affects the economy as a whole via human reactions to the situation and the sanitary restrictions put in place to limit the spreading. It follows that pandemics generate higher, unexpected claims linked, for instance, to non-damage business interruption or event and travel cancellations (The European Actuary, 2020).

In addition to these extra claims and given that many insurance policies adjust to conjunctural factors such as a policyholder's annual turnover, insurers might also have to reimburse a part of the premiums received to their clients if the economic downturn is extreme (Les Echos, 2020b).

— ***Investing***

As seen above, a pandemic shock is characterized by the fact that it "*fragments and refragments into billions of microshocks*" (SCOR, 2020c). The re/insurance industry could suffer few first-tier consequences, particularly considering the fact that insured and reinsured populations are very different from (and hence not representative of) the whole population (Les Echos, 2020a). But the cascading effects of such a shock would generate immense indirect consequences on economies, financial systems and the business environment, which would obviously affect re/insurers in both their underwriting and investing activities.

Over the medium to long term, the re/insurance industry's operations and business would suffer at least from:

- The **fallout of the economic downturn**;
- The **fallout of financial shock**s in the form of "higher credit spreads, potentially widespread downgrades, lower interest rates, and lower equity prices" (VoxEU, 2020), which would affect investors' financial performance and reduce their risk propensity, having feedback effects on financial stability and global economic health;
- Potential **liquidity and solvency challenges**, notably stemming from the large volume of unexpected claims;
- **Operational challenges**, notably stemming from the large volume of unexpected claims, but also from disruptions in business operations that are a direct consequence of the disease outbreak (e.g. absent employees);
- A **reputation downgrade**, if the industry's reaction is considered inadequate or insufficient by the general opinion;
- **Stricter regulatory restrictions**.

B. PRACTICALLY SPEAKING, HOW HAS THE COVID-I9 PANDEMIC HIT THE RE/INSURANCE INDUSTRY SO FAR?

The COVID-I9 pandemic has shown that the re/insurance industry could be hit much harder than previously thought. Mid-2020, Swiss Re disclosed a USD I.I billion loss for the first semester (due to a USD 2.5 billion provision for risks and charges linked to COVID-I9) (L'AGEFI Quotidien, 2020), a net loss that was scaled down to USD 69I million at the end of the third quarter. The total cost (including provisions) of the pandemic for the group in 2020 nonetheless swelled to USD 3 billion (Le Figaro, 2020a). At the end of 2020, the AXA group also estimated that the COVID-I9 had cost them EUR I.5 billion in 2020 (Les Echos, 2020c).

Not only was the industry more impacted than previously thought, but the channels through which it was hit the most were not the ones previously imagined.

As mentioned above, a pandemic being by definition a disease outbreak, the Life and Health branches were expected to be mostly affected. And they were impacted. By November 2020, SCOR estimated that the pandemic had cost them EUR 25I million in terms of life reinsurance (Le Figaro, 2020b). But, as mentioned earlier, given that the insured and reinsured populations are quite different from the population as a whole, it would appear that the direct consequences on morbidity and mortality of the said insured population have so far been quite limited. For now, the sanitary crisis has had more impact on invalidity than on mortality (L'argus de l'assurance, 2020a). It has nonetheless had a perceptible impact on the life-insurance market itself, as 2020 marked the worst year for life-insurance inflows since the I990s (La Tribune, 202Ia).

Surprisingly, it is the Property & Casualty (P&C) branches that concentrate most of the risks. In the - estimates mentioned above, SCOR also disclosed that the COVID-I9 pandemic had cost these business lines EUR 256 million in 2020 (Le Figaro, 2020b).

This is due to the fact that the pandemic led to lockdown situations, which caused business disruptions in virtually all economic sectors. In May 2020, i.e. when the economic fallout of the pandemic had only just started to be measured, the French Insurance Federation estimated that the first lockdown in France caused operating losses of EUR 60 billion, which equates to II0 years of premiums (Les Echos, 2020d).

A significant debate arose regarding the extent to which re/insurers were to cover the financial consequences of business interruptions, a debate that would entail conflicts concerning the interpretation of contractual clauses. Parts of business insurance contracts in Europe do not explicitly exclude losses due to pandemics (The European Actuary, 2020), but insurers have claimed that, a pandemic being a systemic risk (hence affecting virtually everyone, everywhere at the same time), its fallout exceeds the scope of insurability. The Geneva Association estimated that only I% of the global GDP damage for 2020 would be covered (Allianz, 2020). But the debate is just starting as legal proceedings have been launched by businesses that have been forced to interrupt their activities and claim they should be compensated for their loss.

A step further up the chain, reinsurers face the same kind of dilemma, with their own clients turning to them for compensation. But pandemic reinsurance treaties for instance have so far not been activated. They cover increased mortality risks with "stop-loss" insurance that is activated only when the number of supplementary deaths surpasses certain thresholds that have not been reached in the COVID-I9 case, in part (yet again) due to the fact that the re/insured population is very different from the one that has suffered most COVID-I9 deaths (L'argus de l'assurance, 2020a).

Re/insurers could be sentenced to pay in specific cases; but the financial impact will most probably not reach levels that would endanger the insurance system via violations of prudential and solvency principles. The greatest loss will probably be the damage their reputation is suffering in the general public. That being said, this crisis will bring about short- and long-term responses from the industry, which will be dealt with in the following part.

C. WHAT ARE THE RE/INSURERS' EXPECTED SHORT- AND LONG-TERM RESPONSES TO THE COVID-19 CRISIS?

As much as any other business in the service industry, re/insurance companies will have to rethink how their operations are organized in a post-COVID-19 world (see KPMG, 2020). But the re/insurance industry also faces specific challenges, because short- and long-term responses to the COVID-19 situation are expected from them.

Over the short term, re/insurers' response will focus on increased risk aversion, more cautious behavior and more precautions taken in decision-making processes. Most of them are already renegotiating contracts and changing contractual clauses to explicitly exclude pandemics from future coverage (Les Echos, 2020e; Les Echos, 2020f).

In the medium to long run, re/insurers will have to better integrate pandemic risks in the models they use. COVID-19 hit the entire re/insurance chain, i.e. every player and every business line. However, as noted above, some have been impacted more than others and this is in part due to the fact that the P&C lines have been "taken by surprise" more than the Life lines.

The pandemic risk has already been integrated in actuarial models for risk forecasting for life and health insurance. For a long time, that was not the case for the P&C lines. The development of natural-catastrophe risk models has been a vital factor for P&C insurance in the past decades. By providing more rigorous and accurate estimates of probabilities and the scales of natural catastrophes, they have enabled better capital allocation (Willis Towers Watson, 2020a). Integrating the more uncertain factors that drive disease outbreaks and their consequences for insurance, e.g. the biodiversity-loss dynamic, but also political reactions and decisions that play a key part in the economic impacts of pandemics, will prove even more complex and difficult (Willis Towers Watson, 2020a).

In addition to better integration of pandemic risk in models, re/insurers will be reviewing their products and offerings in the medium to long run. No structured insurance offering exists today to cover sanitary risks leading to operating losses without damages (Les Echos, 2020a). Yet, some re/insurers have already excluded the possibility to cover pandemics within the P&C segments (Les Echos, 2020f).

Aside from the most obvious questions concerning insurance of business disruptions, the COVID-19 pandemic will also give rise to questions on how other re/insurance branches are doing business and what products they offer. For instance, what about automobile insurance or professional civil liability in a world that is characterized by more people working from home, moving less and being delivered more products at home? (Les Echos, 2020g)

In the long run, study will also have to be put into the adaptation of prudential and solvency principles, notably those contained in the Solvency II Directive, which already include an obligation to model epidemic risks, but proved to be ill-adapted to the COVID-19 situation (L'argus de l'assurance, 2020a). Regulators have already started to work on that subject (La Tribune, 2021b).

This pandemic also questions the value and pertinence of insurance as we know it today. If re/insurers are not capable of protecting their customers against the biggest threats they could face in the future, could these customers turn to other mechanisms for protection? Will they, for instance, transfer more risks to financial markets? The next part will discuss the future of the re/insurance industry in that regard.

D. HOW WILL THE COVID-19 CRISIS CHANGE THE WAY RE/INSURERS DO BUSINESS?

The severe economic consequences of the COVID-19 crisis have notably translated into increases in claims by insurance policyholders. Re/insurers have been exposed to unexpected fallout, which has forced them to reflect on the core principles of insurance. Is a pandemic insurable? And, if not, why not?

As discussed previously, a struggle emerged between the re/insurance industry and policyholders regarding the insurability of the COVID-19 pandemic. The increase in claims highlighted two very different aspects of this pandemic, the epidemiologic aspect (relating to health and life insurance) and the economic consequences (relating to business interruptions essentially, at least in the short run). Basing his argument on the fundamentals of insurance, Denis Kessler, CEO of SCOR, explains why a pandemic cannot be insured (Les Echos, 2021a):

— An insurable risk must be pooled and relies on the independence of the occurrence of the given risk with respect to each policyholder. The pooling effect is stressed through the diversification of policyholders in terms of industry and geographic location. However, the economic consequences of a pandemic are cascading because sanitary restrictions are applied on a regional or national level, rendering inefficient any diversification principle and leading to an accumulation of risks that is impossible to manage from an insurance point of view.

— In order to price premiums and ensure their own solvency, re/insurers need to be able to forecast risk occurrence through models in order to assess the frequency and intensity of potential claims. Therefore, a risk needs to be modelled. However, even though pandemic risk is already integrated in several models used by the re/insurance industry, the economic consequences of a pandemic are significantly influenced by public policies and are thus unforeseeable and exogenous. It is impossible to forecast claims and to price premiums.

— Finally, offering insurance policies covering against the consequences of pandemics would cause moral-hazard issues. Indeed, this crisis has shed light on the industries that are most exposed to potential pandemic-related restrictions. Consequently, only the most exposed economic sectors would be willing to purchase an (expensive) insurance policy, thus eliminating the possibility of diversification and the pooling of risks for the insurer offering the policy. Except if the purchase of such policies is made mandatory by the regulator.

The challenges for the re/insurance industry therefore rely less on dealing with the pandemic itself than with the behavioral reactions it entails in terms of public policies and economic consequences. The re/insurance industry is facing a growing type of risk, namely **systemic risk**.

"**Systemic risk** refers to the risk of a breakdown of an entire system rather than simply the failure of individual parts" (Systemic Risk Centre, 2021)

These systemic risks, and the way public and private players are reacting, are pushing the re/insurance industry to the **limit** of their capacities.

According to AXA's CEO, Thomas Buberl, the COVID-19 pandemic is the symbol of growing systemic risks that are impossible to pool (Les Echos, 2020c). And other threats are already knocking at the door, including cyberattacks, climate change and biodiversity loss.

Even though systemic risks per se do not fall into the insurance framework, the disastrous consequences of such events force re/insurers, along with the State and other businesses, to react. Diverse responses have already been developed and implemented in the past to bypass the impossible pooling mechanism for exceptional risks as a single player.

— **Transferring risks to financial markets**. When risk pooling is impossible or too expensive, re/insurers can turn to financial markets to bear the risks. This is the case for natural catastrophes with *Cat bonds* (Catastrophe Bonds). *Cat bonds* were created in the 1990s to increase the protection of re/insurers facing natural-catastrophe risks. *Cat bonds* are insurance-linked securities and the financial return for the investor is linked to the occurrence of a natural catastrophe. If the catastrophe occurs, the investor loses part or all of the interest and sometimes the nominal value. In the case of pandemics, the World Bank issued pandemic bonds in 2017. However, at least in France, there is no obligation for re/insurers to protect themselves through this mechanism (L'argus de l'assurance, 2020b). And the comparison between a geographically defined natural catastrophe and a global pandemic can be questioned.

— **The GAREAT** (*Gestion de l'Assurance et de la Réassurance des risques Attentats et actes de Terrorisme*) **mechanism** in France is another example of a possible response by re/insurers to exceptional events, in this case, terrorism. The GAREAT is a market structure which pools insurers with limited liability backed by two levels of support, first the reinsurance industry and second, the State (L'AGEFI Hebdo, 2020a).

In the context of the COVID-19 crisis, these solutions have been put under review to determine whether they could also be implemented. A working group gathered by the French Ministry of Economy has been working for a year now on how to develop a new insurance framework for exceptional catastrophes in light of this pandemic. The idea was to develop a solution combining insurers, reinsurers, the State and the responsibility of companies, leveraging the existing exceptional insurance mechanisms such as Cat bonds and the GAREAT mechanism. Debates have focused on the sources of financing for such a mechanism and to what extent and to whom the protection should be granted. One common ground for these discussions has been the reliance on the concept of the *socialization of pandemic risk* (L'AGEFI Hebdo, 2020b).

But pandemics are very different from natural catastrophes or terrorist attacks. They have no equivalent in terms of geographic and economic spreading, with financial consequences exceeding any possible protection mechanism so far. As an illustration, the French Insurance Federation estimated that the first lockdown in France caused operating losses of EUR 60 billion (Les Echos, 2020d), but Cat bonds represented a stock of EUR 5 billion and the first layer of the GAREAT mechanism can commit up to EUR 2.5 billion (L'AGEFI Hebdo, 2020a). There is obviously a crucial problem of capacity to face the economic consequences of pandemics such as COVID-19. Even existing mechanisms are being restructured because of the increasing scale of exceptional catastrophes, such as climate change.

In the specific COVID-19 case, the Catex (for *Catastrophes Exceptionnelles*, i.e. Exceptional Catastrophes) mechanism that was considered by the previously mentioned French working group has been abandoned because it was deemed too expensive and complex. In the meantime, the French regulator will probably offer tax incentives for companies to build reserves to meet new shocks (La Tribune, 2020).

The search for innovative mechanisms to protect companies against pandemics reveals the limits of the re/insurance industry facing an increasing number of uninsurable events. The re/insurance industry does not have the capacity to manage these emerging risks alone, thus the only way forward is through building partnerships between the State, the industry and other businesses (Allianz, 2020). And, given that systemic risks spread across borders, these partnerships need to be established on multiple levels, from the regional up to the international (SCOR, 2020d). There is one main objective, i.e. it is necessary to **anticipate rather than react**.

3. WHAT IMPORTANCE FOR BIODIVERSITY IN THE INDUSTRY'S RESPONSE TO BUILDING RESILIENCE?

A. IDENTIFYING AND CORRELATING EMERGING RISKS TO FOSTER PREVENTION

Could the COVID-19 pandemic have been predicted? Probably. Since the SRAS outbreak in 2002, the H1N1 influenza in 2009 and Ebola in 2013, the scientific community has been warning about pandemic risks. However, it seems that we were still caught by surprise.

According to risk managers, pandemics belong to *grey rhinos*, the "high-impact, high-probability" events. These events are usually ignored or mistaken for *black swans*, the "low-probability, high-impact" events (Willis Towers Watson, 2020b). Surprisingly or not, the definition of *grey rhino* events corresponds well to environmental risks, notably climate change, biodiversity loss and pandemics.

The first action in order to build up the resilience of our societies against such events is to identify and name these risks. This is the first step to potentially prevent them from happening. Biodiversity loss is a certainty, i.e. biodiversity loss-related events, along with pandemics, need to be considered high-probability events. Understanding *grey rhino* events can help draw links between them and enhance prevention, fostering co-beneficial intervention. As seen in section I of this case study, fighting against biodiversity loss helps mitigate disease outbreaks. Understanding these correlations is key to moving forward. And over time, preparing for the occurrence of *grey rhinos* builds up *resilience* for *black swans* (Willis Towers Watson, 2020b).

As Denis Kessler, CEO of SCOR, points out, "*an invisible risk is more frightening* [...] *and considerably more forceful*" (SCOR, 2020d). The COVID-19 pandemic has highlighted the discrepancy between "subjective awareness" concerning the occurrence of a risk (pandemics were previously seen as a Middle-Age threat) and the "objective characteristics of the risk". This discrepancy led to a *recognition effect* (pandemics are now considered an "absolutely major risk") which is being followed by a *displacement effect* (i.e. a high demand for protection against this risk) (SCOR, 2020d).

In the case of biodiversity-related risks, even though awareness has been rising in the past few years, the attention given and action undertaken are still very insufficient considering their potential devastating consequences. Waiting for a recognition effect to appear before acting against future systemic risks would be ill-advised. As Klaus-Peter Röhler, CEO of Allianz Germany and member of the Board of Management of Allianz SE, puts it, "*In order to live up to our ambition of being more sustainable, we must anticipate rather than just react.*" (Allianz, 2020). Anticipation is not only key to risk mitigation (SCOR, 2020d; Allianz, 2020), it is also a cost-efficient means to prevent history from repeating itself and to make for a more desirable future.

B. BIODIVERSITY NEEDS TO BE PART OF THE RECOVERY

In the words of Fabrice Rossary, Chief Investment Officer, SCOR Investment Partners, "*Climate change and the COVID-19 crisis are making it clear that the negative externalities created by the existing global economic structure are starting to outweigh its advantages*" (SCOR, 2020e).

In the turmoil of the COVID-19 pandemic, companies are fighting for survival and adapting to the situation on a daily basis in a state of emergency. However, once the turbulence is behind us, it will be essential to reflect on and learn from this period. Governments are putting recovery plans at the top of their agenda. As noted in the first section of this case study, these action plans need to be transdisciplinary in order to forge long-term resilience and biodiversity has a key role to play in preventing future pandemics. In this respect, the OECD (OECD, 2020b) recommends that:

— Governmental subsidies to boost the economic recovery should be given in exchange for environmental commitments;

— Governments must avoid stepping back on environmental regulations in order to boost subsidies and recovery of historical industries, which could lead to an increase in negative externalities for biodiversity;

— Governments and companies should make biodiversity a driver of the economic recovery, fostering investments in environmental projects and jobs;

— Governments and companies should generalize the use of tools developed to integrate biodiversity in economic policies;

— All should foster collaboration and pledge to commit to a green recovery with other players.

The Chairman of the Environment Commission of the European Parliament has launched a global call for mobilization to "*reboot & reboost our economies for a sustainable future*" (Green Recovery Alliance, 2020). Its signatories include Allianz, AXA and Generali, among others.

The re/insurance industry can contribute (and in some cases, already is contributing) to these actions in favor of a green recovery plan. As risk experts, re/insurance companies finance several research projects on emerging risks and how to forecast them. These funds can be oriented toward environmental topics. Integrating biodiversity-assessment tools can help understand the impact and exposure of their clients (whether policyholders or investees) to future environmental risks. Re/insurance companies can leverage their risk and damages management expertise and network to foster a quick recovery. Considering the range of actors and industries re/insurers deal with, they can have a wide-ranging impact through awareness raising on environmental issues and their consequences. Despite the uninsurability of an event such as the COVID-19 pandemic, the re/insurance industry could also develop tools to help policyholders manage their influence on systemic risk and protect themselves.

While still fighting an unprecedented sanitary situation, governments and executives are becoming aware of the systemic risks confronting our societies and their interdependencies. This crisis is an opportunity to build momentum and leverage environmental awareness to build back better and more resiliently.

As Klaus-Peter Röhler, CEO of Allianz Germany and member of the Board of Management of Allianz SE, puts it, "*The corona pandemic has accelerated the trend towards greater sustainability. This is a unique opportunity that we must seize.*" (Allianz, 2020).

III. IMPACTS: HOW RE/INSURERS AFFECT BIODIVERSITY

As has been made clear throughout this paper, the interactions between biodiversity and human activities are a two-way street. As discussed in the previous parts (Part 2 and Part 3.II.), human societies highly rely on biodiversity and ecosystem services, and their loss creates risks for all economic sectors, including the re/insurance industry. Conversely, humans have effects on biodiversity, they impact it. Human activities are the leading cause of biodiversity loss. In the following part, we will discuss the extent to which the re/insurance industry, through both investing and underwriting, plays a part in this dynamic.

I. A RE/INSURER'S PERSPECTIVE ON IMPACTS

The role of the re/insurance industry in society, through its underwriting branch, is to ensure the mitigation and mutualization of risks, its mission is to minimize the impact of shocks (SCOR, 2019). Concerning the investment branch, finance has a double impact on natural capital. On the "supply side" of ecosystem services, finance enables investments in conservation and restoration of ecosystems, increasing the regenerative rate of ecosystems. On the "demand side" of human "consumption" of ecosystem services, finance channels financial flows toward economic activities which require ecosystem goods and services to deliver the expected outputs. In some cases, finance also influences the efficiency of our capacity to use ecosystem services through financing research and development (Dasgupta, 2020). Therefore, financial flows and financial institutions have a crucial role and effect on the impacts on biodiversity. Financial flows can be directed toward activities that increase natural capital, ensure the sustainable use of ecosystem services and thus reduce negative impacts (Dasgupta, 2020).

The concept of impact is, in that sense, at the core of a re/insurer's day-to-day business.

As discussed in the previous parts, it is possible to use an impact/dependencies framework to map the interactions between biodiversity loss and the re/insurance industry. Feedback effects between the loss of biodiversity and ecosystem services and human societies must be anticipated and are already visible, as the COVID-19 pandemic is demonstrating. The first step to limiting the impacts of this loss (and the shocks it will entail) on societies is to limit one's own role in the process, i.e. to review and restrict one's own impacts on the loss of biodiversity.

The concept of responsibility is central to the re/insurance industry. Re/insurers provide the financial support that other entities need in order to operate. As such, underwriting and investing activities offer policyholders and investees the capacity to undertake certain activities. The financial sector, including the re/insurance industry, consequently does have an indirect impact on nature (WWF France & AXA, 2019) and does indirectly bear responsibility for the activities they choose to cover or invest in.

Broadly speaking, any company exists to produce goods and services. In the production process however, it generates externalities, both positive and negative.

> *An externality is the cost or benefit that affects a party who did not choose to incur that cost or benefit.*
> (Natural Capital Coalition, 2018)

Because we do not live in a world that is characterized by what economic theory deems "*pure competition*", markets are fallible and those externalities are not "naturally" taken into account by the entities that produce them. But it is crucial for a business to understand what externalities it generates and to integrate them in its strategy and decision criteria if it wants to reduce its impacts on biodiversity and ecosystem services.

Re/insurers can play their part in this respect by creating the right incentives (WWF France & AXA, 2019). Externalities generated by companies and activities can be embedded in underwriting and investing activities through the establishment of clear sustainability criteria.

As the uptake of the Task Force on Climate-related Financial Disclosures (TCFD)'s recommendations has shown, financial actors are willing to integrate climate-related criteria in their strategies. Given that concerns for biodiversity loss are growing too, the integration of more comprehensive nature-related criteria will need to accelerate. To do so, it is crucial to grasp both the harmful and the beneficial impacts industries can have on biodiversity and to set up both negative and positive filters, as is already being done for climate issues (SCOR, 2020b). This will be the topic of the following two parts.

2. THE ECONOMIC ACTIVITIES DRIVING BIODIVERSITY LOSS

As discussed in the previous parts, humanity is changing biodiversity in many indirect and direct ways. The current, underlying characteristics of human societies, i.e. values, demography, technology, economy and governance, constitute indirect drivers or "the root causes of transformations" of nature, according to IPBES (IPBES, 2019c).

These features materialize in the way human activities are organized. These activities and their ramifications constitute the direct drivers of change in nature, i.e. the connection between those indirect drivers and aggregated impacts on biodiversity (IPBES, 2019c). Changes in land and sea use, direct exploitation of organisms, climate change, pollution and invasion of alien species are the five most impactful of those direct drivers (IPBES, 2019a).

These drivers are themselves a consequence of what the Natural Capital Coalition characterized as *impact drivers* in its 2016 Natural Capital Protocol. This protocol is "*a standardized framework for business to identify, measure, and value their direct and indirect impacts (positive and negative) and dependencies on natural capital*" (Natural Capital Coalition, 2018). It adopts a business viewpoint and aims to concretely assess the interactions we have mapped above.

In this framework:

> *An **impact driver** is a measurable quantity of a natural resource that is used as an input to production or a measurable non-product output of business activity.*
>
> (Natural Capital Coalition, 2016)

The following table gives examples of what impact drivers can be.

	Categories	Examples of impact drivers
Business inputs	Water use	Volume of groundwater consumed
		Volume of surface water consumed
	Terrestrial ecosystem use	Area of natural habitat converted (e.g. to monoculture or forest plantation; urbanized/artificialized)
	Freshwater ecosystem use	Area of wetland, ponds, lakes, streams, rivers necessary to provide ecosystem services such as water purification, fish spawning
		Area of peatlands restored
	Marine ecosystem use	Area of aquaculture by type
		Area of seabed mining by type
		Area of coral damaged by coastal engineering or building
	Other resource use	Volume of minerals extracted
Business outputs	GHG emissions	Volume of carbon dioxide (CO_2) Methane (CH_4) Nitrous oxide (N_2O) Sulphur hexafluoride (SF_6) Hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs)
	Non-GHG air pollutants	Volume of fine particulate matter ($PM_{2.5}$) and coarse particulate matter (PM_{10}) Volatile organic compounds (VOCs) Mononitrogen oxides (NO and NO_2, commonly referred to as NOx) Sulphur dioxide (SO_2) Carbon monoxide (CO)
	Water pollutants	Volume of nutrients (e.g. nitrates and phosphates) or other substances (e.g. heavy metals and chemicals) discharged to receiving water bodies
	Soil pollutants	Volume of waste matter discharged and retained in soil over a given period
	Solid waste	Volume of waste by classification (i.e. non-hazardous, hazardous and radioactive), by specific material constituents (e.g. lead, plastic) or by disposal method (e.g. landfill, incineration, recycling, specialist processing)
	Disturbances	Decibels and duration of noise at site of impact
		Lumens and duration of light at site of impact

Table I2. Impact-driver categories and examples. *(Adapted from Natural Capital Coalition, 2018)*

These impact drivers lead to a multitude of impacts on the environment, i.e. "*changes in the quantity or quality of natural capital*" (Natural Capital Coalition, 2016).

By assessing these impact drivers, it is possible to evaluate how and how much an activity (see following Part on impact assessment), a company or a sector impacts the environment and contributes to the vicious circle of losses in biodiversity and ecosystem services and their consequences on humans. In this respect, the ENCORE (Exploring Natural Capital Opportunities, Risks and Exposure) tool, developed by the Natural Capital Finance Alliance in a partnership with UNEP-WCMC, provides valuable insights into the impacts (and dependencies which will be discussed in next part) by sector, sub-industry and even production process.

According to ENCORE, the production of services by the re/insurance industry involves only one category of impact drivers, i.e. the production of solid waste by offices and service centers (ENCORE, 2020). However, ENCORE lists only direct dependencies and impacts, it does not include the whole supply chain (ENCORE, 2020). For example, in the specific case of the financial sector, the dependencies and impacts embedded in the energy used by those offices and service centers are not accounted for.

What is more, as mentioned above, the very essence of the re/insurance industry is to provide other activities and businesses with the necessary means to run their own operations. Theoretically speaking, re/insurers may have to finance or cover all economic sectors. Consequently, they need to adopt a broader approach to sectoral impacts and integrate this analysis in their decision criteria for underwriting and investing.

In its 2019 Global Assessment report, IPBES reviews what sectors have constituted the most important direct drivers of NCP loss. Its broad conclusions are as follows (IPBES, 2019c):

— "**Fisheries** have the largest footprint – with all of industrial extraction, aquaculture and mariculture, and the small fisheries critical for the livelihoods of millions (*well established*)."

— "**Agriculture**, including grazing, has immense impacts upon terrestrial ecosystems, with important differences depending upon an enterprise's intensity and size (*well established*)."

— "**Industrial roundwood harvests** have risen, while bioenergy use rose dramatically in the rural areas of poorer regions, with some sustainable forest management (*well established*)."

— "**Harvesting wild plants and animals** from land-and seascapes supports the livelihoods of a large share of the globe's population, raising sustainability concerns (*well established*)."

— "**Mining** has risen dramatically, with big impacts on terrestrial biodiversity hotspots and global oceans, most in developing areas with weaker regulation (*established but incomplete*)."

— "**Dams, roads, and cities** have strong local negative impacts on nature, yet they also can have positive spillovers associated to increased efficiency and innovation (*well established*)."

— "**Tourism** has risen dramatically with huge impacts on nature overall, higher impacts for the higher-end options, and mixed outcomes from nature-based options (*well established*)."

— "Both **airborne and seaborne transportation of goods and people** has risen dramatically, causing both increased pollution and a significant rise in invasive species (*well established*)."

— "**Restoration** can offset current degradation levels, with varied intensities and outcomes, although global initiatives have focused mostly on our forests (*established but incomplete*)."

— "**Illegal extraction** – including fishing, forestry and poaching –adds to unsustainability, yet is fostered by markets (local, global) and poor governance (*established but incomplete*)."

Several institutions and entities have also reviewed sectors and tried to rank and map which pose the greatest threats to biodiversity. According to the UN Environment Program World Conservation Monitoring Center (UNEP-WCMC), financial institutions willing to reduce their impacts on biodiversity loss should concentrate their efforts on Agricultural Products; Distribution; Mining; Oil & Gas Exploration & Production; and Oil & Gas Storage & Transportation, because at least one of the production processes of these sub-industries is deemed to have high or very high potential impacts on biodiversity and because the financial flows they receive are particularly high compared to other sub-industries (UNEP-WCMC, 2020). UNEP-WCMC also notes that Airport Services; Marine Ports & Services; and Oil & Gas Drilling are sub-industries with potentially intense impacts on biodiversity (UNEP-WCMC, 2020), while others such as the Construction sector are suspected of tending toward greater impacts in the future (UNEP-WCMC, 2020).

The ESG guide developed by the UN Environment Program Finance Initiative (UNEP-FI) in the framework of the UNEP Principles for Sustainable Insurance Initiative (PSI) presented a heat map of the risks posed by diverse economic sectors. This heat provides insight into which industries a re/insurer should focus on if willing to mitigate its (indirect) impacts on the loss of biodiversity and ecosystem services (see Table I3).

THEME	RISK CRITERIA	RISK MITIGATION EXAMPLES & GOOD PRACTICE	ECONOMIC SECTORS
			Agriculture / Livestock · Agriculture / Fishing · Agriculture / Paper & Forestry · Chemicals · Defence · Electronics / Technology · Energy Operation · Construction / Coal · Construction / Hydro Dams · Construction / Nuclear · Exploration & Construction / Oil & Gas · Production of Fuels / Derivatives from Oil & Gas · Finance (depending on client and/or transaction) · Gambling · Healthcare / Pharma / Biotech / Life Science · Infrastructure / Construction · Food / Beverage Manufacturing · Garment Manufacturing · Real Estate · Utilities (Waste & Water) · Mining · Transport / Shipping
Climate change	Air pollution, greenhouse gas emissions, and transition risks	Disclosure of climate-related emissions in operations and/or products	
		Breakdown of fuel / material / carbon intensity mix relevant to the client or transaction	
		Environmental & social impact assessment (ESIA) covering negative health impacts, mitigation and decommissioning where relevant	
		Decarbonisation transition plan/targets	
	Physical risks (e.g. heat, wildfire, flood, sea level rise, water stress)	Nature-based solutions (e.g. sustainable flood or coastal defence management, broader climate resilience adaptation plans)	
Environmental degradation	Exposure to unconventional mining practices (e.g. deep-sea mining)	Involvement in initiatives: Extractive Industries Transparency Initiative, International Council on Mining & Metals, Kimberley Process (diamonds)	
	Deforestation or controversial site clearance (e.g. palm oil on peatlands or fragile slopes)	Certification for palm oil, paper, etc. Dam construction standards: IHA Hydropower Sustainability Assessment Protocol, UNEP Dams & Development, Equator Principles	
	Soil pollution	ESIA covering possible negative health impacts, mitigation measures and decommissioning plans where relevant	
	Water pollution	Water management practices (e.g. quality, scarcity, overconsumption). Effective ESIA process covering water pollution. External audits/certification	
Protected sites / species	Impacts on World Heritage Sites or other protected areas	ESIA that covers impacts on endangered species and sites including mitigation. Specialist lists: Ramsar, UNESCO World Heritage Sites	
	Impacts on species on IUCN Red List of Threatened Species	ESIA that covers impacts on endangered species and sites including necessary mitigation measures	
Unsustainable practices	Exposure to unconventional energy practices (e.g. hydraulic fracturing, tar sands)	Various energy initiatives: IPIECA, IFC EH&S Guidelines, Energy & Biodiversity Initiative for Oil & Gas, Arctic Council, Oil Sands Leadership Initiative	
	Illegal fishing vessels, controversial fishing practices or aquaculture techniques	PSI-Oceans guide on illegal, unreported & unregulated (IUU) fishing, IUU fishing lists, Aquaculture Stewardship Council certification	

Table 13. Heat map of environmental risks by economic sectors. *(Adapted from UNEP-Fi, 2019)*

Going even a step further, the UNEP-FI analysis indicates which lines of business are the most concerned by these same risks (see Table I4).

THEME	RISK CRITERIA	RISK MITIGATION EXAMPLES & GOOD PRACTICE	BUSINESS LINES													
			Agribusiness	Property	Liability	Product Liability	Worker Compensation	Construction & Engineering	Credit & Surety	Cyber	D&O	Financial Lines	Marine	P&I	Aviation	Cargo
Climate change	Air pollution, greenhouse gas emissions, and transition risks	Disclosure of climate-related emissions in operations and/or products														
		Breakdown of fuel / material / carbon intensity mix relevant to the client or transaction														
		Environmental & social impact assessment (ESIA) covering negative health impacts, mitigation and decommissioning where relevant														
		Decarbonisation transition plan/targets														
	Physical risks (e.g. heat, wildfire, flood, sea level rise, water stress)	Nature-based solutions (e.g. sustainable flood or coastal defence management, broader climate resilience adaptation plans)														
Environmental degradation	Exposure to unconventional mining practices (e.g. deep-sea mining)	Involvement in initiatives: Extractive Industries Transparency Initiative, International Council on Mining & Metals, Kimberley Process (diamonds)														
	Deforestation or controversial site clearance (e.g. palm oil on peatlands or fragile slopes)	Certification for palm oil, paper, etc. Dam construction standards: IHA Hydropower Sustainability Assessment Protocol, UNEP Dams & Development, Equator Principles														
	Soil pollution	ESIA covering possible negative health impacts, mitigation measures and decommissioning plans where relevant														
	Water pollution	Water management practices (e.g. quality, scarcity, overconsumption). Effective ESIA process covering water pollution. External audits/certification														
Protected sites / species	Impacts on World Heritage Sites or other protected areas	ESIA that covers impacts on endangered species and sites including mitigation. Specialist lists: Ramsar, UNESCO World Heritage Sites														
	Impacts on species on IUCN Red List of Threatened Species	ESIA that covers impacts on endangered species and sites including necessary mitigation measures														
Unsustainable practices	Exposure to unconventional energy practices (e.g. hydraulic fracturing, tar sands)	Various energy initiatives: IPIECA, IFC EH&S Guidelines, Energy & Biodiversity Initiative for Oil & Gas, Arctic Council, Oil Sands Leadership Initiative														
	Illegal fishing vessels, controversial fishing practices or aquaculture techniques	PSI-Oceans guide on illegal, unreported & unregulated (IUU) fishing, IUU fishing lists, Aquaculture Stewardship Council certification														

Table I4. Heat map of environmental risks by non-life insurance business lines. *(Adapted from UNEP-FI, 2019)*

BOX 20
ILLUSTRATING HARMFUL IMPACTS ON BIODIVERSITY: THE FASHION-INDUSTRY EXAMPLE

The textile sector is facing increasing criticism concerning its impacts on the environment because it is one of the most polluting industries worldwide (ADEME, 2018a). According to ADEME, 100 billion pieces of clothing are sold every year (ADEME, 2018b), a level of production that doubled between 2000 and 2014 (ADEME, 2018b). The overall demand for apparel is projected to continue rising in the coming decades from 62 million tons in 2015 to 102 million tons in 2030 (Global Fashion Agenda & BCG, 2017).

This growth is far from neutral from an environmental viewpoint. The textile industry ranks 3rd in terms of water consumption in the world, after wheat and rice cropping (ADEME, 2018b), is responsible for 20% of worldwide wastewater discharge (OECD, 2019) and emits 1.7 billion tons of CO_2 per year (Global Fashion Agenda & BCG, 2017), with a greater impact than air and maritime traffic taken together (ADEME, 2018b).

Fashion production processes today are essentially based on a linear system which exploits and negatively impacts the environment and biodiversity at all stages of a product life cycle.

— *Raw-materials production*: exploitation of significant amounts of non-renewable resources, unsustainable production of vegetal and animal materials and high volumes of water inputs, resulting in soil and water over-exploitation and pollution, as well as changes in land use. *Cotton cultivation represents only 3% of arable land, but is responsible for 24% of insecticide use and 11% of pesticide spraying* (OECD, 2019)).

— *Manufacturing*: use of toxic chemicals to dye and fix colors, resulting in soil and water pollution. *20% of water pollution is imputable to textile dying and treatment* (ADEME, 2018b).

— *Transportation*: worldwide shipments, resulting in increased climate and environmental pressure from air, maritime and road traffic. *A pair of jeans travels 65 000 km on average (a 1.5 round-the-globe trip) from the cotton field to the retail store* (OXFAM France, 2020).

— *Textile use and care*: use of water, microparticles and toxic chemicals release, resulting in water pollution. *14 000 liters or 12% of the water consumed yearly by each French household is attributable solely to washing machines* (ADEME, 2018b).

— *Disposal and waste*: unrecycled waste. *4 million tons of textiles are disposed of in Europe each year, 80% of which being simply buried in landfills or burnt* (ADEME, 2018b).

Soil and water pollution and depletion, changes in land use as well as greenhouse-gas emissions and their consequences for climate change have direct impacts on ecosystems and biodiversity. The role of the fashion industry in this harmful process is concrete and established. In 2017, the Kering luxury group estimated that the overall impact on the environment of its activities and supply chain amounted to EUR 482 million (OECD, 2019). These impacts could quickly materialize into financial consequences. Rising costs of labor, raw materials and energy in a "business as usual" scenario could lead to a EUR 45 billion reduction in profits per year for fashion brands by 2030 (Global Fashion Agenda & BCG, 2017).

In addition, policy-makers are starting to implement measures in this sector. For instance, the 2020 French Law on Waste and the Circular Economy prohibits the disposal of unsold textile products (this measure will enter into force on 31 December 2021 at the latest) (MTE, 2020a).

In 2017, WWF Switzerland analyzed and rated industry players in a report titled "Changing fashion: The clothing and textile industry at the brink of radical transformation" (see WWF Switzerland, 2017) and Greenpeace published "Fashion at the cross roads: A review of initiatives to slow and close the loop in the fashion industry", a report presenting options for the fashion industry to change its practices (see Greenpeace, 2017).

3. RETHINKING PRACTICES TO MITIGATE RE/INSURERS' IMPACT ON BIODIVERSITY

A. SETTING SCIENCE-BASED TARGETS

Halting the vicious circle of impacts between human activities and biodiversity loss cannot be achieved exclusively through exclusions. Good practices are required and can support biodiversity conservation and counteract otherwise harmful impacts.

Many international initiatives have undertaken to set standards and guidelines for entities willing to work in that direction. Methods exist to identify and integrate good practices. For instance, financial institutions can adopt or follow the Equator Principles, UNEP Principles for Sustainable Insurance (PSI), UN Principles for Responsible Investment (PRI), OECD Guidelines for Multinational Enterprises or the International Finance Corporation (IFC)'s guidance on environmental and social issues in projects (UNEP FI, 2019), among others. They can also become signatories to the *Finance for Biodiversity Pledge*, a call for action launched by 26 worldwide financial institutions in September 2020 which, as of December 2020, had gathered 37 signatories with a total of EUR 4.8 trillion in assets under management (Finance for Biodiversity Pledge, 2020).

In parallel with this increase in commitments in favor of biodiversity, the United Nations Convention on Biological Diversity (UN CBD) ambitions to have approved a new framework during the COP-15 in Kunming, the Post-2020 Global Biodiversity Framework. The objective is for all stakeholders to assess and report their biodiversity-related impacts and act upon them.

With this in mind, the *science-based targets* developed by the **Science-Based Targets** Network (SBTN) provide a method for companies to achieve the new targets that will be set for the Post-2020 Framework of the UNCBD. Science-based targets are defined as "*measurable, actionable, and time-bound objectives, based on the best available science, that allow actors to align with Earth's limits and societal sustainability goals*" (SBTN, 2020). The SBTN has developed a comprehensive five-step method described in Figure 16.

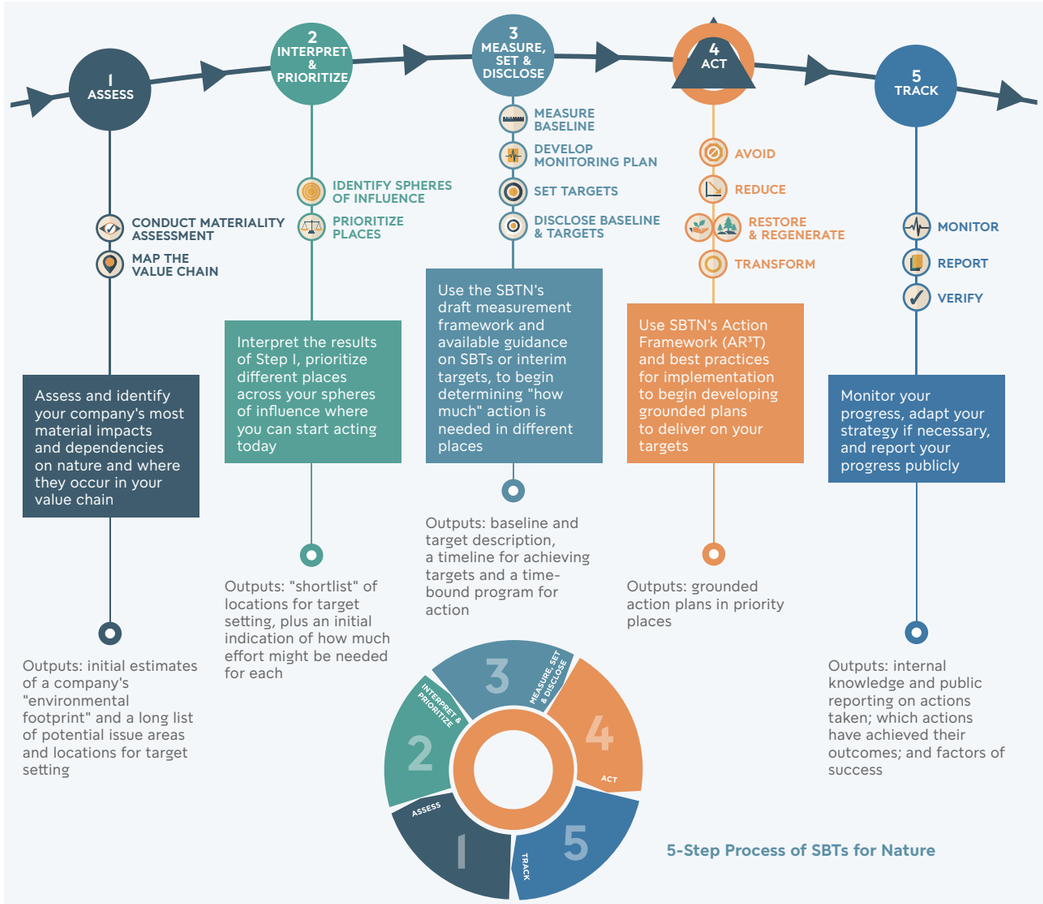


Figure 16. Science-based targets, a five-step process. *(Source: SBTN, 2020)*

The aim of this method is to assist companies in aligning with the CBD's Post-2020 Global Biodiversity Framework, the UNCCD 2018-2030 Strategic Framework, the UNFCCC Paris Agreement and the UN General Assembly's 2030 Agenda for Sustainable Development.

Step 3, in particular, focuses on principles useful in defining measurement indicators. According to the SBTN, measurement indicators of companies' impacts on biodiversity should be (SBTN, 2020):

— Location-specific;
— Practical, meaning the company has the available data to measure;
— Controllable, meaning companies can have a significant impact on the measured value;
— Predictable, meaning the company can assess in advance how their actions will impact the indicator;
— Transparent, meaning the company uses open-source and available data and tools;
— Incentives, meaning the indicators incentivize the right actions;
— Comprehensive, meaning the indicators are as exhaustive as possible concerning the company's impact;
— Science-based, meaning the indicators can be used to assess the compliance with the Earth's limits.

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B. MEASURING AND MITIGATING IMPACTS

In view of concretely assessing and expressing their impacts on biodiversity, and avoiding to engage in harmful activities, entities can start by evaluating their ***biodiversity footprint***:

> *A biodiversity footprint can be based on monitoring of actual changes in biodiversity through time (assessment of actual impact), or by assessing the 'potential' or expected impact, based on the contribution of an economic activity to drivers of biodiversity loss or biodiversity gain (assessment of potential impacts). (…) Both methodologies discussed here measure biodiversity impact in terms of a loss or gain in species richness.*
>
> (Berger *et al.*, 2018)

Not only can they calculate their own direct biodiversity footprint (through e.g. their use of energy, their production of waste, the construction of their buildings), re/insurers may also calculate the impact of the activities they cover or invest in to select them in an informed manner (Berger *et al.*, 2018). A financial institution's impact on biodiversity comes quasi exclusively from the services it provides rather than from its own direct operations (Mulder & Koellner, 2011).

Many initiatives have emerged and are on-going in order to propose footprinting methods and their associated indicators. For instance, CDC Biodiversité, in collaboration with the "Businesses for Positive Biodiversity" club (Club B4B+), has developed its Global Biodiversity Score (GBS), which evaluates the impact or footprint of a company on biodiversity and expresses it as a percentage of the MSA.km² unit (where MSA means Mean Species Abundance). This unit characterizes the integrity of ecosystems and can be used as a basis for the development of key performance indicators (KPIs) by entities (CDC Biodiversité, 2019; WWF France & AXA, 2019). Another example is the tool developed by ASN Bank, the "Biodiversity Footprint for Financial Institutions" (BFFI) method, which uses the Potentially Disappeared Fraction of Species (PDF) unit as an indicator (PwC & WWF, 2020). The ASN Bank itself conducted its own assessment to determine the impact of its loans and investments on biodiversity (see Box 2I).

BOX 2I
ASSESSING ONE'S OWN BIODIVERSITY IMPACT: THE ASN BANK EXAMPLE

The Dutch ASN Bank set itself as a long-term goal to have a net positive effect on biodiversity through its loans and investments by 2030 (ASN Bank, 2021).

The bank has been assessing the biodiversity impact of its investments since 2016 on a dataset dating back to 2014. A 2021 report concluded that the ASN Bank was responsible for the equivalent of 19 422 hectares of biodiversity loss through its investment in bonds and loans, and 67 886 hectares through its investments in equities (ABB branch) (PRé Sustainability, 2021). This impact decreased between 2018 and 2019 after having increased between 2014 and 2016 and again between 2017 and 2018. The following diagram shows how the ASN Bank portfolio impacts biodiversity (expressed in terms of hectares).

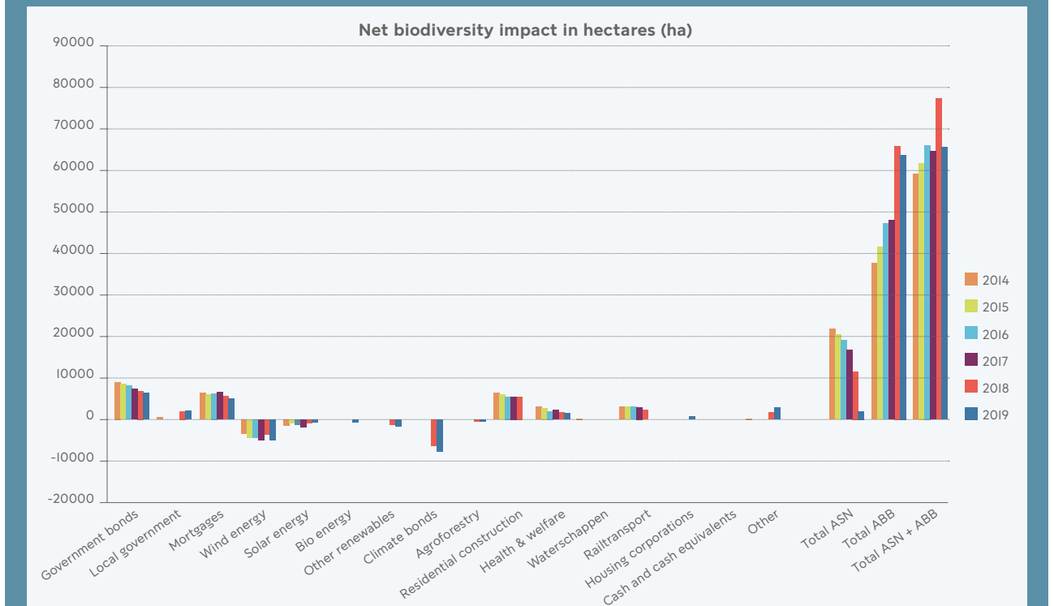


Figure 17. Net biodiversity impact in hectares of ASN Bank, 2021. *(Source: PRé Sustainability, 2021)*

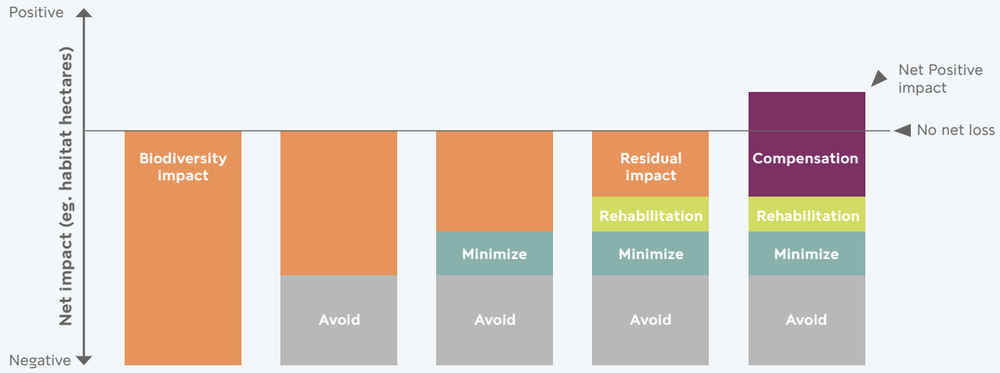
N.B. "The footprint result is expressed as the number of hectares where all biodiversity is lost" (PRé Sustainability, 2021).

Conducting this type of analysis is the first step toward mitigating one's own impact on biodiversity.

Different types of footprinting methods take different characteristics into account. They aim at supporting different types of decisions (from "strategic" to more "operational" ones) and should be used in different contexts (e.g. for public policy-making, for corporates and portfolio management, for project and site evaluations) (Berger *et al.*, 2018). In 2018, the One Planet Program on Sustainable Food Systems and the E.U. Business@Biodiversity Platform each drafted a technical report on these methods and tools. Their reports (see Lammerant *et al.* 2018 and Core initiative on Biodiversity; One Planet Program on Sustainable Food Systems, 2018) can serve as guides for further research into those issues (Berger *et al.*, 2018; WWF France & AXA, 2019).

Indicators and tools to assess organizations' impacts, whether in terms of drivers of change for biodiversity, in ecological terms or in economic terms, among others, are a major issue in rallying private actors to assist in mitigating the biodiversity crisis. **Tools and indicators are flourishing** to assess and measure different interactions between organizations and biodiversity from different perspectives. In 2019, WWF France developed a comprehensive guide to these tools and methods (see WWF, 2019b).

Having a net positive impact on biodiversity (i.e. looking at the combined actions of an entity and not only isolated actions) can be achieved through the combination of multiple types of actions, e.g. avoiding or minimizing negative impacts, actually increasing biodiversity (*rehabilitation*) and offsetting or compensating for biodiversity loss (CREM & PRé Sustainability, 2019). The calculation of such actions can result, through the "mitigation hierarchy" (Lanius *et al.*, 2013), in *no-net-loss* or *net-positive-gain* of the entity for biodiversity.



"This version of the mitigation hierarchy was modified by the authors and is used by the mining industry
Source: ICMM IUCN (2012)"

Figure 18. The "mitigation hierarchy". *(Source: Lanius* et al., *2013)*

Re/insurers can aim for no-net-loss or net-positive-gain through both their underwriting and investing activities. This approach has limitations though in that living beings and their ecological interactions are not interchangeable or replaceable (see Box 22).

BOX 22
CONSERVATION OR RESTORATION?

It is important to bear in mind that biodiversity involves complex interactions between living beings. Entities that compose the "web of life" are not interchangeable or substitutable. One should be cautious when making use of these "no-net-loss" or "net-positive-gain" concepts.

While biodiversity conservation refers to the act of preventing and protecting biodiversity and ecosystem services from declining, restoration is a post-response to the degradation of biodiversity in order to assist its recovery process. Biodiversity restoration is key to limiting the impacts of biodiversity loss, avoiding the cost of inaction (see Table 8) and rebuilding ecosystem services. To be fully effective, it must be accompanied by a reduction of the initial pressure leading to degradation. Therefore, there is a rationale for ecosystem restoration (OECD, 2019), nevertheless, according to the IPBES Assessment Report on Land Degradation and Restoration, conservation is a more cost-effective approach. Protecting, mitigating and avoiding is always easier than reversing the process of environmental degradation. A last and powerful argument is that it is unknown to what extent biodiversity degradation is irreversible and thus at what point restoration is no longer possible (IPBES, 2018).

The World Economic Forum in collaboration with AlphaBeta identified 15 systemic transitions to be achieved and determined that the Insurance & Asset Management sector could have an "enabling role" (i.e. "could potentially support key activities in the transition") in all but two of those 15 needed transformations (WEF & AlphaBeta, 2020) (see Table 15).

A number of key sectors in the economy will be critical to engage in the business agenda across socio-economic systems

Sector role in
Principal[1]
Enabling[2]

Sectors \ Transition	Ecosystem restoration and avoided expansion	Productive and regenerative agriculture	Healthy and productive ocean	Sustainable management of forests	Planet-compatible consumption	Transparent and sustainable supply chains	Densification of the urban environment	Nature-positive built environment design	Planet-compatible urban utilities	Nature as infrastructure	Nature-positive connecting infrastructure	Circular and resource-efficient models	Nature-positive metals and minerals extraction	Sustainable materials supply chains	Nature-positive energy transition
	Food, land and ocean use						Infrastructure and the built environment					Energy and extractives			
Advanced manufacturing			P		E	E	E	E	E	E	E	P			E
Aerospace											E	E			E
Agriculture, food & beverages	P	P	P	P	P	P	E			E		P			E
Automotive							P					P			P
Aviation, travel & tourism	P		P				P	P	P	E	P				E
Banking & investors	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Chemicals & advanced materials	E	P	P	E								P	P	E	E
Electronics												P		E	E
Energy & utilities	P	E	P	E			P	P	P	P	E		E	E	P
Health & healthcare	E	E	E	P	E		E	E				E			E
IT & digital communications	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Infrastructure & urban development		E	E	E		E	P	P	P	P	P	P	E		E
Insurance & asset management	E	E	E	E		E	E	E	E	E	E	E		E	E
Media, entertainment & information					E	E						E		E	E
Mining & metals	P		E	E								P	P	P	E
Oil & gas	P	E	E	E				E	E			P	E	E	P
Professional services	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Retail, consumer goods & lifestyle		P	E		P	P						P		E	E
Supply chain & transportation		P				P	P		E		P			P	E

"1. Principal role implies that the sector is directly involved in components of the transition that will halt and reverse biodiversity loss"
"2. Enabling role implies that the sector can potentially support key activities in the transition"

Table 15. The role of sectors in the 15 systemic transitions. *(Source: WEF & AlphaBeta, 2020)*

Re/insurers can cover or invest in virtually every type of economic sector. They therefore have a key role to play in ensuring that human activities contribute positively to nature preservation.

BOX 23
TAKING ACTION FOR POSITIVE IMPACT THROUGH THE MOBILIZATION OF VALUE CHAINS

Not only can financial institutions mitigate their impact on biodiversity through their investment decisions (as seen in Box 21), they can also directly mobilize and influence their entire value chain. In particular, they can engage their clients in the development of better practices toward biodiversity. In that respect, each member of the re/insurance ecosystem can be involved.

The Marsh example

Marsh is a leader in the insurance-brokering and risk-management sector. The company has been developing specific products and expertise for the transformation of site use. The underlying idea is to **facilitate the use of non-virgin soils and, consequently, to preserve natural areas** (EPE, 2020).

They notably provide policyholders with what can be called a "ten-year environmental insurance" policy that covers claims and ordinances to further engage in depolluting activities on (and even off) the premises, up to scrapping of units and reconstruction (EPE, 2020). In the first quarter of 2020, Marsh secured a total of 40 000 m² in rehabilitation. Its objective is to secure a total of 160 000 m² by the end of 2021, 380 000 m² by the end of 2023 and 600 000 m² by the end of 2025 (EPE, 2020).

The Korean Aquaculture Disaster Insurance (ADI) scheme

Seaweed aquaculture is rising fast globally and this expansion is taking place at a certain ecological cost (UNU-INWEH & SAMS, 2016). Some consequences of the rapid industry growth are *"disease outbreaks, introduction of non-indigenous pests and pathogens, reduction in the genetic diversity of native seaweed stocks and changes in farm management practices"* (UNU-INWEH & SAMS, 2016). The illegal use of algicides and pesticides is also likely to be detrimental to the marine environment (UNU-INWEH & SAMS, 2016).

But another negative aspect of the growth of this industry is its vulnerability to natural disasters. Aquaculture facilities are directly exposed to severe weather conditions and extreme wave action. When they are hit, parts of the infrastructure (nets, etc.) can sink and cause long-term damage to the seabed and in some cases prevent use of the site in the future (UNU-INWEH & SAMS, 2016).

The Korean government initiated the Aquaculture Disaster Insurance (ADI) scheme in 2007 to tackle the lack of incentives for seaweed farmers (whose businesses were bankrupted due to such disasters) to remove the damaged infrastructure and restart their business (UNU-INWEH & SAMS, 2016).

Concretely, after a natural disaster has occurred (primarily physical damages, but now biological hazards such as red tides and disease outbreaks as well), insurance companies will reimburse the farmer for 70 to 80 % of his average yearly production, provided that he repairs the damage and returns the site to its prior condition (UNU-INWEH & SAMS, 2016). Farmers can choose the scope of their insurance policy and the Korean government subsidizes half of the fee (UNU-INWEH & SAMS, 2016).

Not only has this scheme incentivized sea farmers to retrieve damaged infrastructure from the seabed, it has also enhanced their reporting of disease outbreaks (UNU-INWEH & SAMS, 2016).

C. INVESTING FOR POSITIVE IMPACT

No indicator or criterion has been internationally agreed upon yet concerning biodiversity protection. The E.U. Sustainable Finance Taxonomy, which tackles biodiversity along with other key sustainability issues, including climate mitigation and adaptation, was released in March 2020 and will be the basis for further E.U. regulations in the coming months, which will set clear disclosure obligations (EU TEG, 2020).

The biodiversity challenge is massive and complex, however financial institutions already have at their disposal a range of options to act. To start with, they can align their own targets with national targets and priorities (Natural Capital Coalition, 2018) and make the most of lessons learnt from good practices already implemented in climate-related issues. They can act now toward the creation of SMART (Specific, Measurable, Ambitious, Realistic and Time-bound) biodiversity targets (Natural Capital Coalition, 2018) and, as investors, focus on biodiversity-positive investments.

> *"Biodiversity positive investments are investments in interventions resulting in net biodiversity conservation gain, either through averted loss and/or degradation of biodiversity and improving protection status, or through positive management actions (restoration, enhancement) that improve biodiversity condition."*
> (CREM & PRé Sustainability, 2019)

A report commissioned by the Dutch Ministry of Agriculture, Nature and Food Quality and The Netherlands Enterprise Agency, and drafted by CREM and PRé Sustainability in September 2019, reviews approaches to investments and positive impacts (CREM & PRé Sustainability, 2019). The report found eight types of positive investments.

"Investments with the aim to contribute to ('impact investing'):

1. *Investments in the **enhancement of existing biodiversity**.*
2. *Investments in the **restoration of biodiversity** to a specific prior state.*
3. ***Reduced negative impacts** on biodiversity resulting from investments that address one or more of the drivers of biodiversity loss of existing economic activities.*
4. ***Avoided negative impacts** on biodiversity resulting from investments in the production of energy or resources that replace energy or resources with a higher impact on biodiversity.*
5. ***Avoided negative impacts** on biodiversity resulting from investments in alternative livelihoods preventing unsustainable resource extraction leading to biodiversity loss.*
6. *Avoided negative impacts on biodiversity resulting from investments in interventions designed to avert known future risks to biodiversity.*

Investments complying with investment criteria contributing to:

7. ***Reduced negative impacts** on biodiversity resulting from investment criteria addressing one or more of the drivers of biodiversity loss of existing economic activities.*

Investments under engagement contributing to:

8. ***Reduced negative impacts** on biodiversity by addressing one or more of the drivers of biodiversity loss of existing economic activities." (CREM & PRé Sustainability, 2019).*

With this taxonomy in mind, financial institutions can then decide on what goals and what types of activity they will prioritize. They can then rely on existing disclosure standards, sector-specific scores (e.g. the Agrobiodiversity Index (ABD Index) or the Biodiversity Indicator for Extractive Companies developed by UNEP-WCMC) and wider indicators on their biodiversity return, using for instance the Biodiversity Return on Investment Metric developed by IUCN (PwC & WWF, 2020).

Thanks to the development of footprinting methods, impact and risk assessments and standards, financial institutions are starting to develop new investment approaches to reduce their negative impacts on biodiversity. The most widely used framework is ESG (environmental, social and governance) investing. ESG investing is a first step toward integrating sustainability criteria where investors take into account company non-financial performance indicators on their sustainable, ethical and corporate governance practices and impacts, in addition to the future financial returns. Another approach developed in the last years is impact investing where private investors directly invest in projects or companies with a clear social or environmental objective in addition to a financial return. In July 2019, AXA Investment Managers launched a EUR 200 million impact fund focusing on Climate & Biodiversity (AXA Research Fund, 2019).

However, these sustainable or green investment initiatives are still marginal and are not even focused on biodiversity. In terms of biodiversity alone, a study by ShareAction has pointed out that none of the 75 largest asset managers include biodiversity in their investment policy (ShareAction, 2020).

Despite the rise of private financial flows toward natural capital, there is no business case yet for investments in the conservation or restoration of ecosystems. "Sustainable" or "green" investments are solely directed to projects or companies with sustainable practices. There are three main hurdles to the mainstreaming of biodiversity finance for private investors (Dasgupta, 2020):

— First, conservation and restoration activities do not always provide financial returns. Conservation and restoration activities are long-term oriented and therefore do not meet the usual requirements of private investors. In addition, market prices might not be aligned with accounting prices and revenue streams could take time or be irregular, reducing the financial attractiveness for investors;

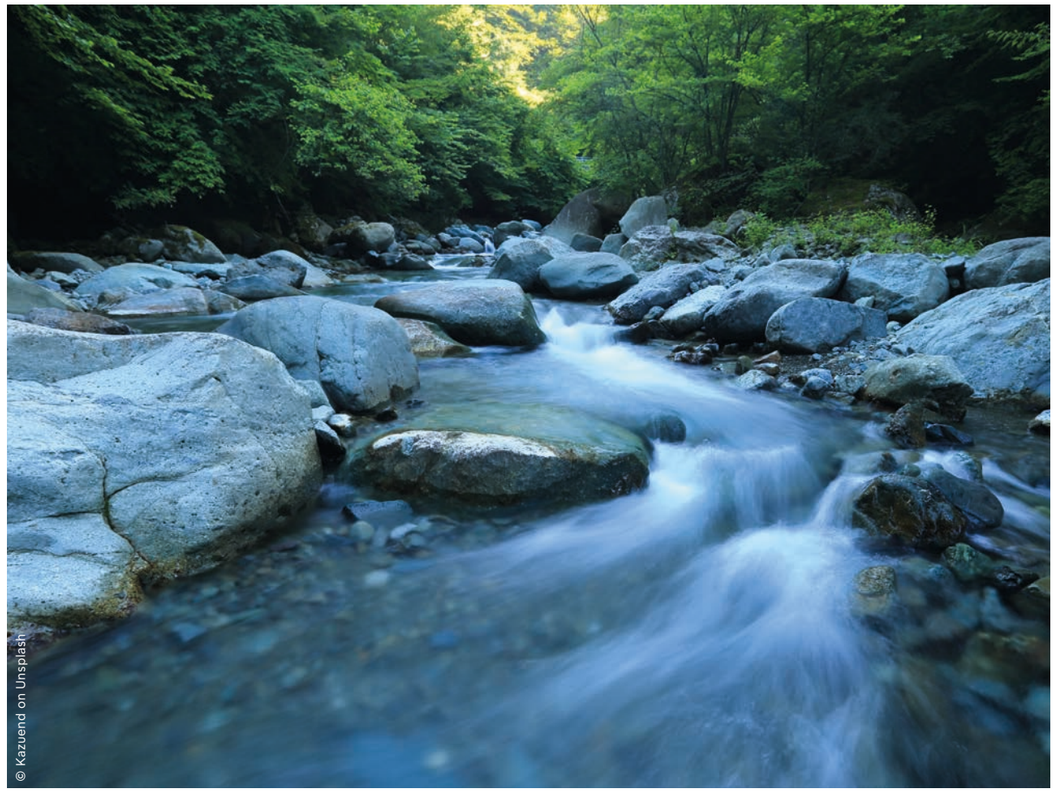
— Second, conservation and restoration projects do not meet the critical-size criterion for private investors. Small-scale projects are less attractive because they increase the risk factor of the project and the time needed to build the project versus its financial return;

— Third, the lack of data standardization and transparency has resulted in little information on previous investments. With no historical records, it is hard to prove the outcome of the investments.

However, the innovation capacity of the financial sector in terms of financial products will enable it to develop solutions to attract private capital into conservation and restoration. For instance, blended finance uses public funds to attract private funds by providing guarantees and lowering the risks. Pooled funds gather different projects into a single fund to reach a minimum size and to diversify risks for private investors.

Other private initiatives have emerged such as the Intrinsic Value Exchange which creates "natural equity", a new type of asset based on natural assets exchanged on financial markets and designed to attract private investment. Many other actors are now engaging in biodiversity finance. The UNDP has developed platforms and tools in the BIOFIN catalogue and the Global Canopy just published its "Little Book of Investing in Nature" to detail existing biodiversity financing mechanisms (Dasgupta, 2020).

Several approaches and solutions are emerging to overcome the traditional barriers of investing in nature and shift financial flows out of detrimental extractive activities. However, the road is long. In May 2020, a consortium of financial institutions formed by BNP Paribas Asset Management, AXA Investment Managers, Sycomore Asset Management and Mirova gathered to call for the creation of impact measures for biodiversity. They pointed out major gaps on that road to limiting companies' impact (AXA Investment Managers Press Release, 2020).



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IV. OPPORTUNITIES TO ALIGN RE/INSURERS' AGENDA WITH BIODIVERSITY

The impossibility of forecasting the consequences of biodiversity loss and the lack of resilience of our societies are already producing short-term consequences and are expected to incur increasingly harmful impacts over the long term if we fail to transition to sustainable and resilient models.

As was the case for climate change more than a decade ago, NGOs, governments, the private sector and civil society are making commitments and taking action to reduce our contribution to climate change and our risk exposure to climate-related natural disasters. Mitigation and adaptation measures against climate change are on the rise and they have been the source of emerging new markets such as the development of the renewable-energy industry. A changing risk environment is a threat to the stability of the current world, however, it is also a driver of development of a new form of stability, a new societal organization and new business opportunities.

As noted in the previous section, the re/insurance industry could experience significant losses for their business and for their reputation. However, emerging risks also represent emerging opportunities when stakeholders engage in addressing them. Committing to address biodiversity loss by fostering mitigation and adaptation solutions is a source of opportunities for insurers to ensure the sustainability of their business, seize new business opportunities, enhance their reputation and relationships, and to potentially redefine their social role in building a resilient society.

1. SUSTAINABLE AND RESPONSIBLE BUSINESS

The environmental crisis has raised awareness about our unsustainable use of natural resources and highlighted the lack of long-term viability of most business models. Integrating biodiversity and ecosystem issues in business models is an opportunity to ensure the sustainability of those models and long-term value creation for companies (OECD, 2019). Companies need to adapt not only to an increasingly competitive landscape and changing customer demands, but also to the natural environment on which they depend directly or indirectly in order to overcome the emerging risks discussed in Part 2.

For re/insurance companies, ensuring the sustainability of their business model means preserving the *insurability of risks*, i.e. ensuring the availability and affordability of insurance coverage (Herweijer *et al.*, 2009). Establishing a sustainable business model for re/insurers entails reducing the biodiversity-related risk exposure of policyholders. Additionally, given that re/insurers generate revenues through investing, ensuring long-term value creation will require reductions in the risk exposure of financial portfolios.

Re/insurers have several means to incentivize customers to reduce their risk exposure:

— Promote biodiversity-related risk awareness through education for their customers;

— Promote biodiversity-related risk awareness through risk-based pricing, a method of pricing which directly reflects the value of losses to which the policyholder is exposed;

— Offer risk prevention and advisory services to clients;

— Create financial incentives for policyholders in order to lower their risk exposure, e.g. a no-claim bonus system;

— Directly finance risk-reduction and adaptation measures through their investment portfolio;

— Foster biodiversity-related risk research to deepen our understanding and enhance risk-prevention measures and actions;

— Invest in financial products characterized by their low environmental impact.

In addressing biodiversity loss by encouraging reductions in risk exposure, re/insurers seize an opportunity to build a more resilient economic and social system in which insurance coverage is available and affordable, ensuring a sustainable business landscape for the industry. Further, studies have shown that companies with strong and sustainable business practices improve their long-term returns and outperform their peers in both accounting terms and stock market valuation (Dasgupta, 2020).

According to Herweijer *et al.*, a "*successful adaptation will be fundamental to maintaining and extending insurability*" (Herweijer *et al.*, 2009). It follows that **opportunities are not only about reducing risks, but also about developing new markets**.

2. DEVELOPING BUSINESS OPPORTUNITIES IN LINE WITH BIODIVERSITY

The business of re/insurers is based on risk coverage. A more threatening risk environment could logically benefit their business (see Box 19 on The insurer's dilemma). According to the single literature review to date on the transmission of nature risk to financial risk, the rise of biodiversity-related risks can indeed boost premiums in terms of amount as well as number of subscriptions (Busch, Timo *et al.*, 2019).

However, it is impossible to determine if this increase in premiums would exceed the cost of the rise of nature risks for re/insurers and thus to know how much they would benefit from it. The economic benefit of a rise in the risk environment due to biodiversity-related risk is uncertain and this approach denies the existence of an intrinsic value of biodiversity.

Nevertheless, re/insurance companies could develop insurance policies covering biodiversity-loss- risks, in case these risks become measurable and insurable in the future.

On the other hand, emerging risks will trigger changing demand from policyholders. And there are opportunities to develop new insurance products for policyholders and for biodiversity itself, as well as new financial products.

— **Dealing with systemic risks**. The systemic aspect of nature-related risks makes them uninsurable by definition. The physical consequences of nature-related risks, such as natural disasters, have large geographical impacts making it impossible to diversify and pool risks on a national level and thus to provide insurance coverage. In extreme situations, citizens and organizations usually turn to their government as a last resort to manage the physical and financial damages. However, emergency relief in response to natural disasters comes later in time, thus creating more uncertainty about the potential recovery compared to an insurance policy. Moreover, given the increasing frequency, intensity and magnitude of nature-related risks, the consequences can be disastrous for countries with an economy highly dependent on natural assets. The results can severely undermine infrastructure and the fiscal capacity of the country, preventing even the government from deploying emergency relief for its citizens (Dasgupta, 2020).

Solutions have been implemented or are being studied to overcome the rise of common risks worldwide. Insurers are starting to offer insurance policies that partially cover the consequences of common risks, such as the Crop Shortfall Insurance covering extreme weather consequences for farmers in the U.K. (see Box 24).

For countries with limited financial capacities confronted with major nature-related risks, the international community is required to develop emergency relief. To manage the intensity of nature-related risks, insurance companies and States can collaborate to offer coverage and emergency assistance. For nature-related events impacting a whole country, a global risk-pooling mechanism could assist the most vulnerable countries in recovering from extreme situations. A global insurance scheme for biodiversity-related risks could be developed on a regional or multi-country level (Dasgupta, 2020) (See Box 24).

BOX 24
INSURANCE VERSUS SYSTEMIC RISK

Crop Shortfall Insurance by Lycetts and the Farmers & Mercantile Insurance Brokers

An example is the Crop Shortfall Insurance in the U.K. created by Lycetts and the Farmers & Mercantile Insurance Brokers. The insurance policy was launched in 2019 to cover British farmers in case of shortfalls in yields due to extreme weather. The insurance policy covers crop shortfalls from 10 to 25% of the projected crop production and automatically pays-out the difference between the year's actual regional yield and the average regional yield of the past 8 years. This new insurance policy enables farmers to manage and reduce crop-yield volatility (Lycetts, 2020).

The African Risk Capacity by the African Union

The African Risk Capacity (ARC) is an agency developed by the African Union to support African governments in preparing a response to the increasing numbers of climate and nature-related extreme events. The ARC has developed a parametric insurance scheme to cover extreme weather-related events through risk pooling and risk transfer. The first risk pool was launched in 2014 with four countries and the sixth risk pool for the 2019/2020 agricultural seasons comprised 11 countries. The objective of the ARC is to provide a solution to individual countries on the African continent to "manage their risk as a group in a financially efficient manner" (African Risk Capacity, 2021). The premiums are collected from the participating countries as well as from other donating contributors. For now, the ARC covers only drought events, but pilot projects are currently being tested for floods, disease outbreaks and epidemics. An insurance policy should soon be proposed for tropical cyclones in 2021 (African Risk capacity, 2021).

The Caribbean Catastrophe Risk Insurance Facility by CCRIF SPC

The Caribbean Catastrophe Risk Insurance Facility is another example. It was created in 2007 and developed a solution similar to that of the ARC in that it covers hurricanes, earthquakes and excess rainfall for 19 Caribbean and 3 Central American countries (CCRIF, 2021).

The idea to create a climate-risk pool on a multinational level was first developed by Schoenmaker and Zachmann in a paper in 2015 (see Bruegel, 2015). The idea is to create a **global, layered insurance scheme** to cover the consequences of nature-related disasters for the most vulnerable countries. The first layer of coverage would be supported by the insured country itself to incentivize investment in ecosystem conservation and restoration. The second layer would be insured by the premiums collected. Premiums would be collected from both insured countries and donor countries (developed countries) and would be linked to the national ecological footprint to incentivize a reduction in environmental pressures. For the insured countries, the premiums would be calculated according to their vulnerability and for donor countries according to their GDP. Pay-outs would be triggered only for natural disasters exceeding a certain threshold, based on the extremeness of the event (not on the damages) (Bruegel, 2015). The uncertainty regarding the extremeness of future climate events would make premiums unaffordable for countries if they were to buy private insurance coverage. However, even for such a global pooling mechanism, knowledge gaps concerning the impacts of climate change on a regional scale make it difficult to implement. A similar approach could be taken for biodiversity-related risks, but the complexity and the uncertainty in terms of the timing, intensity, frequency and geographic magnitude of the consequences of biodiversity loss also make it difficult (Dasgupta, 2020).

— **Biodiversity-risk management advisory**. As mentioned in the previous paragraph, re/insurers could capitalize on their risk management skills and develop an understanding of biodiversity-related risk exposure and impacts to offer new advisory services to customers, thus reducing their own risk exposure.

— **Environmental-liability insurance**. Even though the development of environmental-liability insurance began almost 30 years ago, it still constitutes an opportunity for the re/insurance industry to grow. Customer awareness of environmental impacts is growing, environmental legislation is strengthening and the market is growing in step (AXA XL, 2019). Today, the insurance offering is still focused essentially on pollution issues, however, with the scientific community steadily gaining knowledge of our impact on biodiversity, the scope of environmental insurance could broaden to other drivers of biodiversity loss.

— **Insurance products for nature**. Re/insurers focus on protecting individuals and companies at risk, however, the first part of this report showed that biodiversity itself is at risk. Therefore, another solution is to insure against biodiversity loss itself with insurance products for nature, given that protecting biodiversity directly protects individuals and businesses. The idea is to buy insurance coverage in case the ecosystem collapses, similar to insurance for a home. The problem with this type of product is that biodiversity is a common good and falls under the *theory of the commons or public goods* with the free-rider effect, where single individuals find few incentives to purchase insurance because the benefits are enjoyed by all. This type of coverage could therefore be supported by local governments under a tax scheme to fuel a restoration fund (Dasgupta, 2020). For example, The Nature Conservancy has partnered with Swiss Re to develop the first insurance product for nature, namely a policy for coral reefs in the state of Quintana Roo in Mexico (The Nature Conservancy, 2020) (see Box 25).

BOX 25
A CORAL-REEF INSURANCE AGAINST HURRICANES (The Nature Conservancy, 2020)

In 2020, the Quintana Roo government renewed the purchase of its coral-reef insurance policy, via its Trust for Coastal Zone Management, Social Development and Security. This first ever insurance product for nature was developed by a partnership between The Nature Conservancy, the Quintana Roo Government and the National Commission of Natural Protected Areas (CONANP). The insurance policy is a parametric insurance policy covering coral reefs and beaches against Category 3 hurricanes and higher (180 km/h and higher) in the Mexican Caribbean area.

The importance of coral reefs

Besides, protecting coastlines from waves during storms and protecting beaches from erosion, coral reefs also sustain a USD 9 billion tourism economy in the state of Quintana Roo with USD 60 million generated directly by activities around the reefs each year. The coral reefs support the local economy as well as the safety of the population of the State of Quintana Roo.

The threatened reefs

Coral reefs suffer from many threats such as disease, pollution and bleaching. However, the increasing frequency and intensity of hurricanes have been identified as a serious emerging threat, with Category 3 hurricanes and higher capable of damaging 10 to 50% of a reef in one strike.

Why develop insurance policies?

It is possible to protect and regenerate coral reefs after a hurricane with a prompt post-storm response by cleaning damaged reefs, healing damaged corals and setting up nurseries for future transplanting. However, these post-storm responses require the rapid release of significant funds to mobilize a trained brigade. A delayed or no response would be costly because it would harm the local economy in the long run. Therefore, buying an insurance policy ensures the availability of funds for a prompt post-storm response with adequate skills to avoid the cost of inaction.

How does the insurance work?

The insurance bought by the Trust is parametric, meaning it is activated only under certain conditions. There are three parameters:

— Wind speed;
— A perimeter within which the wind speed must occur;
— A maximum payout.

The insurance policy was first purchased in 2019 and renewed in 2020. It was triggered for the first time in October 2020, following the damage caused by hurricane Delta, resulting in the payout of USD 800 000 which will be used by a brigade of 80 to repair the reefs and beaches.

— **Innovative financial products**. In terms of their investment activities, re/insurers can take the opportunity to invest in new markets as well as develop new financial products for nature. For instance, concerning the development of financial products, AXA XL and The Nature Conservancy partnered to develop blue resilience carbon credits in order to create a market value for the services provided by coastal wetlands and drive investment into the protection and restoration of these ecosystems (AXA Research Fund, 2019).

Addressing biodiversity loss through mitigation, adaptation, protection and restoration measures can develop new demand from customers and regulators, and new opportunities to seize for the re/insurance industry. As seen for climate change, companies are also increasingly judged on their ESG rating and/or performance, with significant consequences for their reputation. By addressing biodiversity issues, re/insurers can strengthen their leadership and enhance their reputation.

3. REPUTATION AND LEADERSHIP

Companies are increasingly judged by investors and customers in terms of their sustainability. Demonstrating awareness and action for environmental issues is an opportunity to increase the reputation of companies and improve their relationships and leadership status.

For re/insurers, demonstrating environmental responsibility can help to build relationships with policymakers, regulators and local communities (Herweijer *et al.*, 2009).

In addition, addressing environmental issues can attract environmentally conscious consumers and provide the company with a competitive advantage to acquire greater market share.

What is more, similar to climate change and as was seen in Box I7, biodiversity issues are the topic of international negotiations, notably in the context of the Conference of the Parties of the UN Convention on Biological Diversity. These international agreements must be transposed into national regulations. Governments take more or less binding action that can affect companies. On the corporate level, companies are pressured by the government, NGOs and civil society to take action on environmental issues and reduce their negative impacts. Several corporate initiatives have been launched, in the form of research studies, task forces, calls for action and working groups. Companies are also making commitments, for instance through the Act4Nature initiative.

This momentum is an opportunity for companies and specially re/insurers to take a leading role for change. Because environmental issues require systemic changes in our society, it is in the interest of each company to be proactive. The UN CBD urges companies to take part in international negotiations on the Post-2020 Framework, which was scheduled to be debated in 2020 (but postponed to 2021) in Kunming, China. Leading companies have the opportunity to participate in the discussions and decision-making processes for a new framework which will be applicable on the national level. Companies can take part in setting standards, methods and indicators for the binding regulations that governments will impose on the business sector.

The latest remarkable initiatives in the corporate world are the launch of a Task Force on Nature-related Financial Disclosures, backed by AXA among others, and the call in 2020 by 30 European investors for the creation of measures to reduce impacts on biodiversity, led by AXA Investment Managers.

Addressing biodiversity-loss issues would bring visibility to re/insurers, enhancing their attractiveness through improved reputations, improving business relations with regulators, policymakers and other stakeholders, and potentially increasing their influence on the international and national environmental scene.

To sum-up, biodiversity loss and disruption of ecosystem services are a source of uncertainty, financial losses and market failure for the re/insurance industry, however this changing natural environment also brings new opportunities. Given that not addressing biodiversity loss is not an option, re/insurers must rapidly identify the potential opportunities. These opportunities, if developed early enough, could be the solution to counter looming threats and compensate for future financial losses. These opportunities have the triple advantage of benefiting the re/insurers' business by opening new revenue streams, limiting risk exposure and enhancing their leadership in taking action against biodiversity loss and to ensure greater social and economic stability.

PART III. KEY TAKE-AWAYS

Through risk-transfer and risk management activities, re/insurers have developed **expertise in assessing, modelling and pricing risk**. Because it deals with the majority of economic sectors and individuals, the re/insurance industry is uniquely positioned in the economic landscape and benefits from a global perspective on social and economic dynamics. Building resilience and ensuring the stability of human societies is both the theoretical role and in the business interest of re/insurers.

Understanding, forecasting and mitigating emerging risks, notably the current environmental changes and their consequences, is therefore a major issue for re/insurers. And the intricate dependencies of all individuals and companies on biodiversity is a significant **vector of risk exposure** for both the underwriting and investing activities.

Similar to all private actors, re/insurers are **exposed to the physical and transition risks** of biodiversity loss, but also to **transmitted risks**, i.e. those confronting re/insurers due to the exposure of policyholders and investees to biodiversity-related risks.

— The **underwriting** business is threatened by **transmitted** risks because they increase the level of uncertainty of occurrence of existing risks and foster the emergence of new risks. To date, the frequency, intensity and concentration of biodiversity-related risks are unpredictable, thus putting into question the very **insurability** of risks. Biodiversity loss may increase the aggregation and concentration of existing risks, with operational consequences including low risk pricing and higher claims payouts.

— The **investing** business is also threatened by **transmitted** risks. A lack of nature-related risk assessment can lead to overexposure to the consequences of biodiversity loss. Re/insurers are exposed to credit risks, market risks, solvency risks as well as stranded assets, potentially leading to adverse financial returns.

— **Transition** risks also threaten re/insurers through reputational aspects, market shifts, regulatory changes and increased litigation, as well as financial consequences.

By covering or investing in certain economic sectors, re/insurers can indirectly **impact biodiversity negatively**. Through underwriting and investing, re/insurers provide their customers with a license to operate and can therefore be associated with their respective impacts on biodiversity. Through **impact assessment and footprinting methods**, re/insurers can learn about the most harmful activities and processes for biodiversity, and understand to what extent they are involved.

Re/insurers can **integrate biodiversity in their business to foster positive impacts**, through adaptation and mitigation, and promote better practices on the part of their clients. Their actions should be driven by **science-based targets** and be in line with the upcoming Post-2020 Global Biodiversity Framework launched during the UNCBD COP-15.

Due to the characteristics of their business and their unique position in the economy, re/insurers have the resources and ability to adapt to this new reality by translating risks into **opportunities**:

— By shifting to a sustainable business model, promoting society's resilience and mitigation of biodiversity risks, to preserve risk insurability and ensure long-term value creation through investing;

— By developing suitable products linked to the new environmental dynamics;

— By leading the change on multiple levels, ranging from the specific business sector up to the international forums.

GENERAL CONCLUSION

Reconciling business interests, driven by short-term profitability imperatives, with the necessity to preserve biological diversity for the common good of current and future generations, a long-term consideration, would appear virtually impossible. Is there a path to reconciliation?

While actions should be driven by the *certainty* that biodiversity loss will have unprecedented consequences, they are paralyzed by the *uncertainties* regarding their timing, geographic scale, intensity and frequency. The complexity of interdependencies between ecological processes and the virtually unpredictable evolutionary dynamics of each component of biodiversity make any solution elusive. Nature cannot be modelled. Navigating through this uncertainty and making decisions without full data-based arguments will certainly be a major challenge.

Clearly, the time for doubt is over. For decades, scientists have been warning about environmental risks. Our access to clean water, clean air and diversified food is at stake. Our health, safety, security and cultural identity are at stake.

There is hope. The momentum is growing, environmental concerns are placed increasingly high on agendas. Awareness is rising among employees, in terms of both understanding the dependencies of their company on natural capital and taking action to mitigate the detrimental impacts on biodiversity. The need to align corporate goals with sustainable objectives is becoming clearer every day, to the point of becoming a matter of viability and competitiveness for companies. Calls for actions are multiplying, indicators are blossoming, innovative products for nature are flourishing and corporate strategies are starting to become transdisciplinary.

The way forward is through collective action, in which all stakeholders take responsibility, define their capacities and their role. We will need the scientific community to guide the actions through science-based evidence, the regulators to lay out a roadmap and create a fair system where the same rules apply to all, and individuals and companies to take action for change. Each and every one of these stakeholders is part of the ecosystem as a whole and each and every one of us must contribute to meeting the challenges facing us as a society.

Humans have championed the art of adaptation, a capacity observable throughout their social organization and not least in the business world. Therefore, the pivotal question is no longer what the re/insurance industry has to lose, but rather what re/insurers can in fact do to contribute to meeting the challenge. How can these companies adapt and foster synergies with the natural world to support a long-term development model? As private companies with expertise and knowledge, financial and human capital, how can they leverage their attributes and participate in taking action for nature?

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Rebecca Cheetham, Senior Risk Manager – SCOR
David Cosserat, Global Head of Energy – SCOR P&C
Philippe Csakvary, Global Segment Leader Mining – SCOR P&C
Jim Finnamore, Divisional Head, Environmental and Transactional Liability – SCOR P&C
Augustin Gas, Senior Underwriter and Property Team Leader – SCOR P&C
Bill Kaplan, Professional Liability Team Leader – SCOR P&C
Isabelle Kowalski, Global Head of Construction – SCOR P&C
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Irene Merk, Head of Emerging Risk – SCOR Global Life
Daria Ossipova, Chief Pricing Actuary – SCOR Global Life
Paul Nunn, P&C CEO senior Advisor – SCOR
Olivier Perraut, Global Lines Chief Underwriting Officer – SCOR P&C
Didier Schütz, Risk Control Practice Leader – SCOR P&C
Junaid Seria, Head of Analytics and Governance – SCOR P&C

OTHER CONTRIBUTORS

Sebastian Bekker, Programme Officer – Business and Biodiversity Programme - UNEP-WCMC
Hugo Bluet, Head of Green Finance – WWF France
Chris Bonnet, Head of ESG Business Services – Allianz Global Corporate & Specialty
Sylvain Boucherand, CEO - B&L Evolution
Odile Conchou, Financial sector expert – UN Biodiversity
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Romain Svartzman, Economist, Sustinable Finance Division – Banque de France
Joris van Toor, Strategy Advisor – De Nederlandsche Bank (DNB)
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57 rue Cuvier — 75005 Paris
mnhn.fr

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