Chapter 5. Future scenarios of sustainable use of wild species[1,2]

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[2] This is the final text version of Chapter 5 from the Assessment Report on the Sustainable Use of Wild Species. A laid-out version of the full assessment report will be made available in the coming months.

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Schematic and adapted figures can be found in the following Zenodo repository: https://doi.org/10.5281/zenodo.7009828

Contents

Executive Summary

Changes in economic development, population growth, societal values and demands, as well as environmental and climate change, make the sustainable use of wild species a challenging and dynamic process that requires adaptive management and that will benefit from the use of scenarios.

1) **Scenarios depict plausible futures for indirect and direct drivers, alternative policies and human development strategies that may affect the sustainability of wild species use.** Options for sustainable use can be conceptualized as multiple pathways and trajectories {5.2} which depend on social, technological, economic, environmental, political, and cultural factors. This chapter performs a systematic review and assessment {5.3} of the sustainable use of wild species scenario literature for individual practices {5.4} and considers the integration of indigenous peoples and local communities and indigenous and local knowledge in scenarios {5.5}. Based on the review, it then evaluates the literature in the context of scenario frameworks and other relevant conceptual lenses, including archetypal scenarios {5.6}, the nature futures framework {5.7}, transformative change and leverage points {5.8}, and inequality issues {5.9}. Finally, knowledge gaps arising from the synthesis are identified {5.10}.

2) **Scenario analyses indicate that climate change poses a challenge to sustainable use across all practices *(well established)* {5.4}.** Impacts can include changes in species distributions and ecology, increased uncertainty around both biological change and management outcomes into the future, and an increase in extreme events. Scenario analyses also indicate that for many practices, demand is linked to demographic trends and consumption rates, and thus indicate increasing pressure into the future as the human population increases. In some cases, however, this can be moderated by effective governance, policy, and institutional performance, and through changing social or cultural norms *(well established)* {5.4}.

3) **Technological advances are likely to make many extractive practices more efficient and may contribute to overexploitation; however, they are also likely to contribute to an enhanced ability to conduct monitoring, surveillance, and enforcement, in addition to, in some instances, reducing environmental impacts *(well established)* {5.4}.**

4) **Fishing: production is expected to remain at high levels, global fish demand and consumption is expected to increase, against a backdrop of climate change impacting catch potential and food-security for fisheries-dependent communities in some regions (e.g., more substantially in the tropics) *(well established)* {5.4}.** Effective management measures, such as harvest control rules and recovery plans, may also help to buffer against some climate change impacts, though climate hazards are likely to pose threats to nutritional, social, economic, and environmental incomes

worldwide, especially for wild-capture fisheries in the Global South. Small-scale fisheries will likely play an important role in those regions. Demand will also be affected by the balance of global food production between agriculture, aquaculture, and wild capture fisheries.

5) **Gathering: scenarios and projections for wild gathered products are relatively limited *(well established)* {5.4}.** A lack of baseline data in many cases makes it difficult to determine trends, although sustainability under exploitation depends greatly on the individual species and context *(well established)*. Long-term unsustainable harvesting can negatively affect livelihoods of local people with low socio-economic status *(established but incomplete)*. Climate change is likely to affect many of the conditions that affect sustainability of gathering into the future, including impacts on species distributions and wildfires *(well established)*. Changes in land-use and land-cover will also have an important impact *(well established)*. Policies that support gathering as a contribution to food security and the well-being of communities will be of benefit to both people and conservation, as will identifying and correcting regulations that mis-match current or future conditions *(well established)*. Gathering has and will continue to play an important cultural role for many peoples, including indigenous and local peoples, with their knowledge playing an important role in the sustainability of practices *(well established)*. Localized models and scenarios, as well as monitoring and assessment, can help to inform policy and practice *(well established)*.

6) **Terrestrial animal harvesting: scenarios and projections around sustainable use for terrestrial animal harvesting are limited, but key factors affecting sustainable use include legislation and regulation, values, illegal hunting and poaching, institutions, technological drivers, and climate change *(well established)* {5.4}.** The limited presence of scenario/projection studies in hunting is a clear knowledge gap; most studies are around drivers *per se* rather than scenarios. Attitudes towards terrestrial animal harvesting are evolving, including those around the social acceptability of hunting, legislation and hunting bans, and poaching. Technological drivers are also likely to continue to evolve, with improved technology both for hunting but also for surveillance and detection of illegal hunting *(established but incomplete)* {5.4}. Climate change has implications for both hunting practices and underlying population dynamics (e.g., changing sea ice conditions). The demand for wild meat products shows differing regional trends with projected increases in some areas but declines in others due to changing cultural norms, social acceptability, values, and preferences.

7) **Logging: future changes in food production and agricultural practices, population increases in rural areas, and climate change are all likely to affect forest cover *(well established)* {5.4}.** There is a continuing reduction in global forest cover, despite increasing forest restoration, suggesting a trend of net forest loss and fragmentation. In the future, land conversion and deforestation rates will be affected by changes in agricultural practices and rural population densities. Furthermore, the demand for wood-

based bioenergy continues to increase. Forest plantations may meet some of this growing demand. Scenario studies suggest that climate change may increase tree mortality and change forest composition but that integrated management including sustainable practices, multi-use forests, and food systems transformation can help to support sustainable use *(well established)* {5.4}. There are likely to be trade-offs between intensified logging, such as for bioenergy, and reduced logging to preserve biodiversity. Technological innovations that enhance efficiency and reduce waste may help with sustainable use, as may economic and political initiatives; however, customary and tenure rights, as well as land-use rights for local communities, also need to be integrated.

8) **Non-extractive practices: there is very limited exploration of sustainable use with specific regard to non-extractive practices in the scenario literature, leading to considerable uncertainty, particularly around generalizations *(well established)* {5.4}.** While scenarios exist of sustainable tourism more broadly, those that directly and specifically incorporate the sustainable use of wild species in non-extractive practices are much rarer. However, there is an expectation that the non-extractive use of wild species will continue to grow and rebound from the COVID-19 pandemic. This expectation is based on global trends including economic growth, media impacts, increasing environmental awareness, and the feasibility of travel *(established but incomplete)* {5.4}. The demand for both connectedness to nature and for visiting natural areas is affected by socio-cultural trends such as increasing urbanization. Technological changes in information and communication technologies have the potential to help enable sustainable non-extractive wild species use, such as through virtual wild species viewing. Wild species tourism represents an important source of income for many communities and regions, and may generate funds for conservation. However, nature-based tourism itself can contribute to negative environmental trends. Thus, projections of increasing tourism suggest that significant additional efforts will be necessary to mitigate negative impacts *(well established)*. Climate-driven impacts on wild species and ecosystems may also affect tourism potential in many regions.

9) **Scenarios from indigenous peoples and local communities, currently still scarce, will play a significant role in exploring sustainable futures for wild species use at the local and regional levels, promoting collective and participatory co-creation of sustainable futures rooted in local cultures *(well established)* {5.5}.**

10) **Linking the literature review for each practice to a set of archetype scenarios suggests there may be multiple pathways and solutions that can lead to more sustainable use of wild species, but that this understanding is limited due to the substantial knowledge gaps that remain in the exploration of archetypes focusing on sustainable use *(well established)* {5.6}.** The mechanisms by which sustainable use can be reached are very different for different practices, but generally include sustainable solutions that appear to benefit from market or policy support, even when

solutions are bottom-up or technological in nature, and empowering local communities to help moving towards sustainable use irrespective of the practice. There is limited exploration of transformative change and radically different futures around sustainable use. In general, it is easier to link fishing and logging practices to archetypes due to their greater prevalence in the relevant scenarios' literature. Non-extractive practices have distinctively different example solutions in relation to extractive practices.

11) **The decision to follow specific management strategies at any time is complex and must be regularly reviewed and updated as environmental and socioeconomic conditions evolve.** That is where scenarios represent important contributions to envision outcomes *(well established)* {5.2.3}.

12) **Regardless of the future trajectory of society, archetypical scenario exploration indicates that some actions can be taken to contribute towards the sustainable use of wild species *(well established)* {5.6}.**

13) **Transformative change in the sustainable use of wild species may also be feasible through identifying and acting on multiple leverage points, identifying an outcome-based vision for nature and people, political prioritization of nature, aligning incentives, and changing social norms, among other approaches (*established but incomplete)* {5.8}.** These approaches must be effected within the context of clearly understanding cost-benefit trade-offs, particularly in terms of who benefits and who pays, and how interventions can enhance or exacerbate these trade-offs. They must also integrate transparent, participatory processes and adaptive management to help enhance transformative change. Consideration of a plurality of values, especially from indigenous peoples and local communities, is also needed.

14) **The nature futures framework can be applied to the sustainable use of wild species to help envisage positive futures centered around human-nature relationships and multiple values.** By promoting participatory and inclusive approaches to scenario development through co-creating narratives and frameworks with stakeholders, the nature futures framework can help facilitate and enable transformative change (*established but incomplete*) {5.7}.

15) **Critical reflection on social equity issues is crucial for the interpretation and evaluation of scenarios exploring the future of wild species use, and potential trajectories towards sustainability *(well established)* {5.9}.** Issues around social marginalization and exclusion, lack of alternatives to wild species use, market-based resource management, and inequity of wealth distribution may all tamper efforts to move towards sustainability.

16) **Substantial knowledge gaps remain in the literature of scenarios of sustainable wild species use *(well established)* {5.4, 5.6}.** Examples of scenarios that assess the

future of sustainable use are limited in number, but also in diversity. There are scenarios on fishing and logging, yet other practices remain greatly under-represented in the literature, for example around terrestrial animal harvesting, indigenous and local knowledge, non-extractive practices and gathering of plants, algae and fungi. There is also a deficit of scenarios that explore cultural aspects and equity issues. In addition, while there are many scenario studies around the future of biodiversity and ecosystems *per se,* studies focused on sustainable use that are embedded within these broader futures remain less prevalent *(well established)* {5.4, 5.6}**.** Thus, there is a need for a greater focus on scenarios of sustainable use within the context of more integrated solutions, and consideration of how sustainable use interacts with conservation and other elements of a sustainable society. Issues around inequalities and people in vulnerable situation who are dependent upon wild species are also not well represented in the scenarios' literature.

5.1 Background and introduction

5.1.1 Focus and structure of the chapter

Chapter 5 assesses pathways toward sustainable futures and examines a range of future scenarios for the drivers of sustainable use and their effects on the conservation and management of wild species in their wider social-ecological context. Specifically, this chapter:

- Examines the literature on modelling and scenarios of drivers of sustainable use and policy responses across a wide range of practices to synthesize information on pathways towards the sustainable use of wild populations, potential tipping points, and areas in which further scientific understanding and knowledge generation is needed.
- Assesses the implications and trade-offs of these driver trajectories for the future levels of wild species use.
- Explores the implications of various levels of use for the future of wild species populations and the future contributions of wild species to people.
- Examines how scenarios might be used in decision-making under uncertainty and given the gaps identified herein.
- Explores visions for transformative change through synthesizing the scientific knowledge into archetypal scenarios, recommending leverage points and positive actions to enhance the sustainable use of wild species.
- Integrates visions for transformative change and leverage points for the sustainable use of wild species in plausible futures.
- Explore issues of equity, indigenous peoples and local communities and indigenous and local knowledge, and their representation in scenarios.

The objectives of this chapter are therefore to review the available range of knowledge on future scenarios and modelling of the drivers of sustainable use of wild species, including indigenous and local knowledge and the scientific consensus when such exists, and draw lessons for future transformative change. The different practices considered in the assessment will be treated in detail in order to critically examine the specific drivers of sustainable use that affect each one. This chapter also explores the IPBES scenarios and models frameworks, and in particular the nature futures framework (being developed by the IPBES task force on scenarios and models), through the lens of the sustainable use of wild species. The conceptual structure of the chapter is depicted in Figure 5.1.

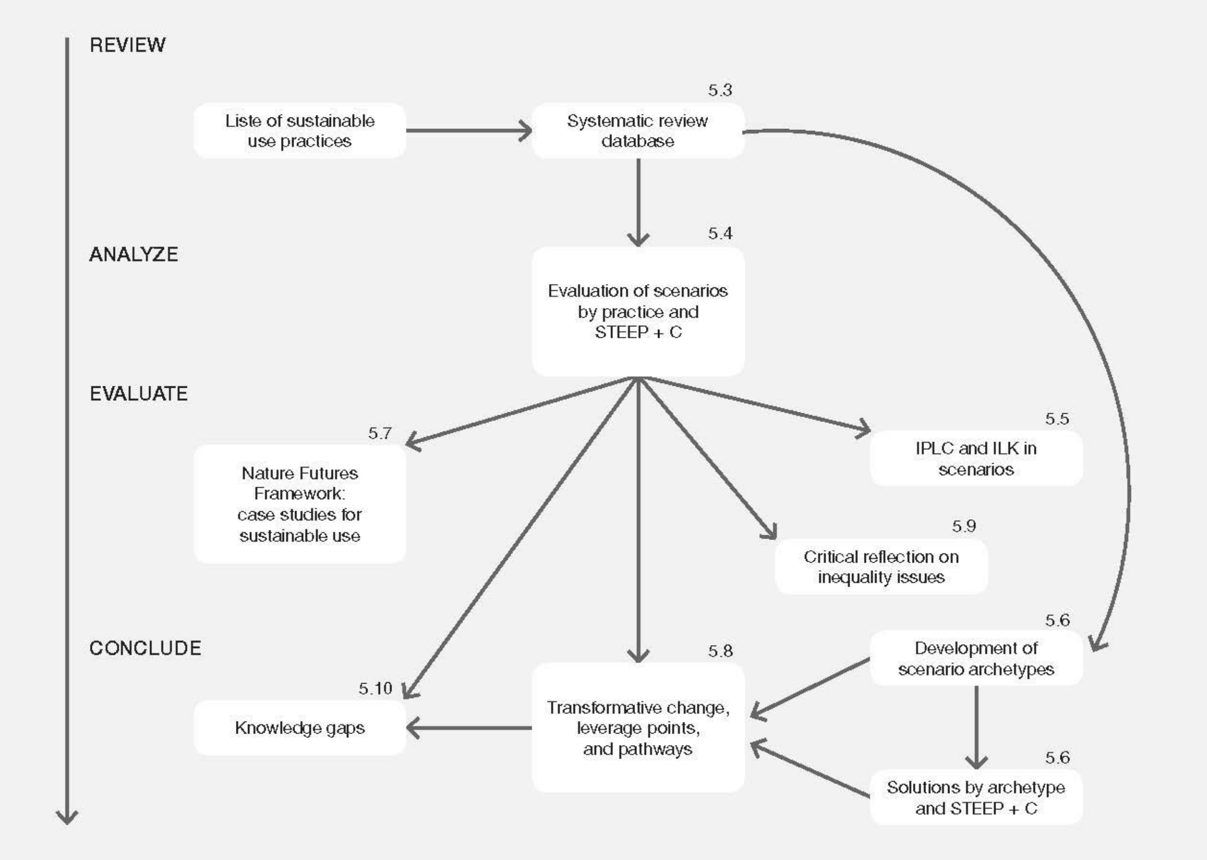


Figure 5.1 Conceptual outline of Chapter 5. Numbers refer to chapter sections.

5.1.2 Framing within IPBES assessments and the assessment of the sustainable use of wild species as a whole

The chapter builds on the chapters of the IPBES Global Assessment of Biodiversity and Ecosystem Services on scenarios and transformative change towards sustainability (IPBES, 2019), IPBES Regional Assessments (e.g., IPBES, 2018), and the Methodological Assessment Report on Scenarios and Models of Biodiversity and Ecosystem Services (IPBES, 2016). It draws on Chapter 4 of the IPBES Global Assessment of Biodiversity and Ecosystem Services (particularly the archetype scenarios) and attempts, where possible, to mirror the structure of that chapter. It also makes use of the examples, models and data from the IPBES Global Assessment, where applicable. The chapter differs from the IPBES Global Assessment in two respects:

i) The IPBES Global Assessment examined published global scenarios of biodiversity change and projected their future interactions with nature, nature's contribution to people and good quality of life. In particular, the IPBES Global Assessment focused on direct drivers of biodiversity change, such as climate change and changes in land use, and indirect drivers such as demography, economics, and governance. In contrast, this chapter considers scenarios of the underlying drivers of sustainable use of wild species rather than biodiversity change, which are in places equivalent to the indirect drivers in the global assessment, since they are frequently management or policy actions or socio-economic changes. In part, this is because the approaches needed to ensure sustainable use across multiple sectors result from addressing these underlying societal drivers in policies and strategies. In common with IPBES Global Assessment, however, the downstream impacts of changes in drivers of sustainable use are considered, as well as the interventions (levers) to generate sustainable use.

ii) While the IPBES Global Assessment predominantly assessed global scenarios of biodiversity, this chapter also includes scenarios of and impacts on the sustainable use of wild species at multiple scales, including local and national levels.

Within the IPBES assessment of the sustainable use of wild species, the chapter draws on Chapter 3 (status of and trends in the use of wild species, the environment and people) – particularly for the present status of and historical trends in the sustainable use of wild species. It also draws heavily on Chapter 4 (drivers of the sustainable use of wild species) to identify the influencing factors that affect extractive and non-extractive practices and how they influence nature, nature contributions to people and good quality of life. The archetype scenarios described herein are used to develop plausible futures for these drivers wherever possible. Chapter 5 also provides material around scenarios and the futures of sustainable use to help inform the governance strategies and policy options explored in Chapter 6.

5.2 What is meant by scenarios

With the increase of the use of scenarios and the number of publications reporting on them, the number of definitions of what a "scenario" is also increased. Some scholars treat scenarios as being tightly connected to models, and therefore use both terms inseparably. This chapter follows the definition of scenarios as provided in the IPBES Methodological Assessment Report on Scenarios and Models of Biodiversity and Ecosystem Services: "Scenarios are representations of possible futures for one or more components of a system, particularly, in this assessment, for drivers of change in nature and nature's benefits, including alternative policy or management options" (IPBES, 2016). It is important to highlight the last part of this definition, as it points at a crucial distinction that most scholars acknowledge (e.g., Börjeson, Höjer, Dreborg, Ekvall, & Finnveden, 2006; Kok et al. 2011), namely between exploratory scenarios and target-seeking scenarios. This fundamental division is also highlighted in several IPBES assessments, notably the Methodological Assessment Report on Scenarios and Models, where four types of scenarios are discerned, three of which are of importance here: (i) "exploratory scenarios", which represent different plausible futures, often based on storylines; (ii) "target-seeking scenarios", also known as "normative scenarios", which represent an agreed-upon future target and scenarios that provide alternative pathways for reaching this target; and (iii) "policy-screening scenarios", also known as "ex-ante scenarios", which represent various policy options under consideration (IPBES, 2016).

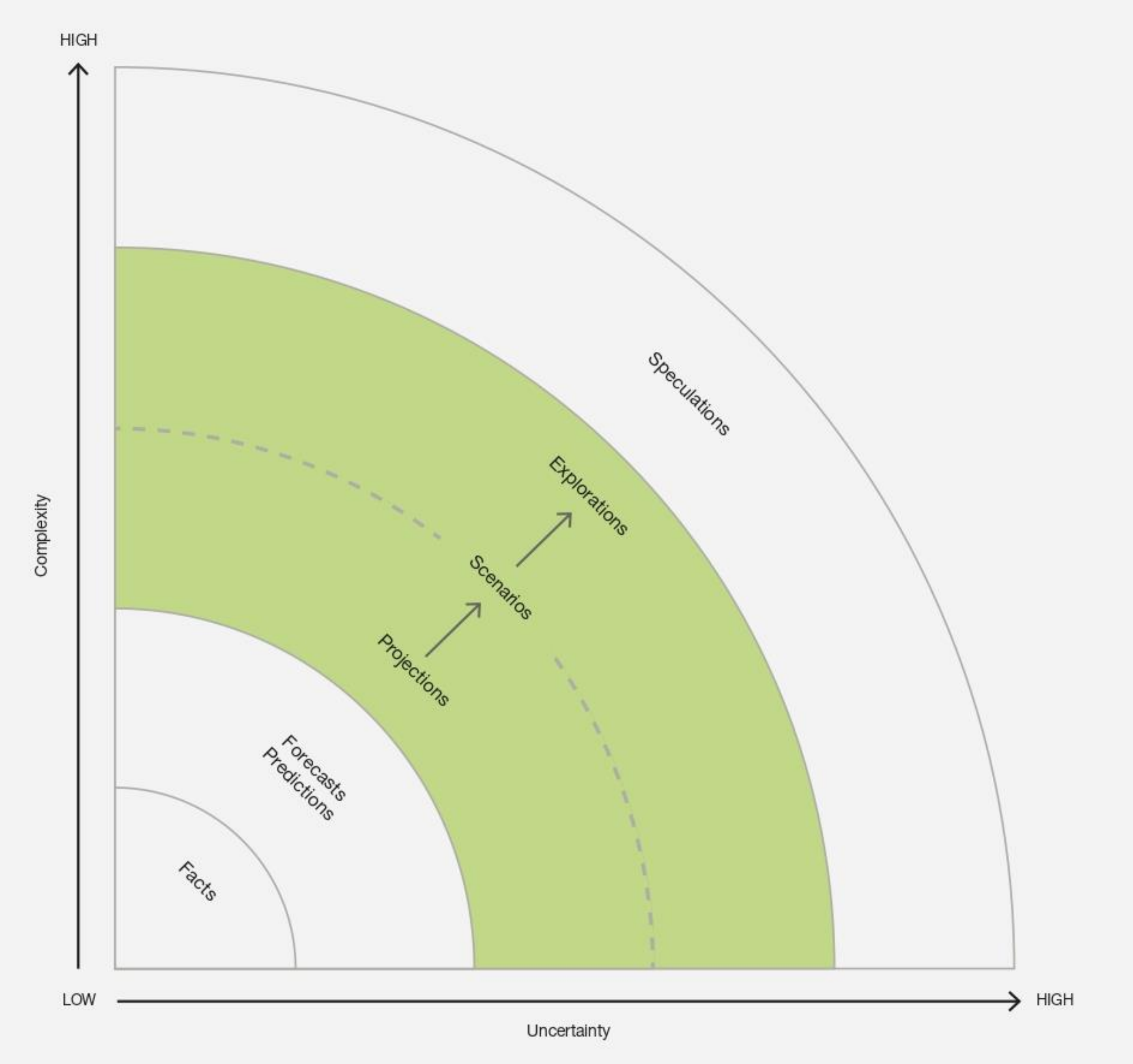


Figure 5.2 Scenarios in the spectrum of complexity and uncertainty. Source: Zurek & Henrichs (2007) © 2006 Elsevier Inc., license number 5154260505736.

Scenarios are distinguished from other approaches to future assessment, such as forecasting and risk assessment, by being specifically intended for situations in which the factors shaping the future are highly uncertain and largely uncontrollable (Biggs et al., 2008; see Figure 5.2). Scenarios thus serve to structure the uncertainty of future developments of complex systems, and to provide a palette of plausible futures and possible actions.

In this chapter, scenarios are used both to explore what could happen (exploratory scenarios) and to present strategies and actions for what should happen (target-seeking and policy-screening scenarios). Analyses of the scenarios' literature based on the different projections and plurality of visions were conducted to evaluate what drives sustainable use in general. Section 5.2.1 elaborates on the most important aspects of scenarios and how to understand them in this chapter.

5.2.1 Types of scenarios included

5.2.1.1 Terminology

The term "scenario" is used by many different communities across scientific domains, scales, as well as in policy and practice. The scenario literature is therefore, vast, rapidly increasing, and in partial disagreement on what a scenario is, what it can be used for, what methods are most appropriate, and what results it generates. In general, the term "scenario" is most often used by those that set out to develop exploratory scenarios and translate those into model projections. It is reasonable to assume that papers included in this assessment will largely belong to the category of model-based explorations. More importantly, target seeking scenarios are often not referred to as scenarios. Particularly at local scales, normative scenarios are mostly referred to as "pathways". When it concerns policy screening scenarios, a range of other terms is often used to describe them, including strategies, plans, policies, options, or actions. It is also reasonable to assume that the papers included in this assessment might not have picked up on all the target-seeking scenarios. A number of keywords were added to the search string to ensure that the database was not limited by terminological differences.

5.2.1.2 Exploratory scenarios

Exploratory scenarios (Van Notten et al., 2003; Van der Heijden, 2005; Avin & Goodspeed, 2020) examine plausible futures, based on potential trajectories of drivers, either indirect (e.g., socio-political, economic and technological factors) or direct (e.g., habitat conversion and climate change). Exploratory scenarios can illuminate the discourse on specific problems, by illustrating various potential futures starting from the current point in time. Despite the relatively short history of developing exploratory scenarios – that started with the publication of the Global Scenario Group scenarios (Gallopin et al., 1997; P. Raskin et al., 2002) – an enormous number of scenarios have been developed across the full range of scales from local to global (e.g., Hunt et al. (2012); Amer et al., (2013); Priess & Hauck (2014); Rothman (2008); Rounsevell & Metzger (2010). Influential global scenarios include those of the Global Environment Outlook 3 and 4 (United Nations Environment Programme & Earthscan, 2002; United Nations Environment Programme, 2007), the Intergovernmental Panel on Climate Change Special Report on Emissions Scenarios (Nakicenovic et al., 2000), the shared socio-economic pathways-representative concentration pathways (SSP-RCP; van Vuuren et al., 2011; O'Neill et al., 2013), and perhaps most relevant in this context, those developed within the Millennium Ecosystem Assessment (Cork et al. 2006). Likewise, there are a large variety of (global) models that provide quantifications of one or more of the sets of storylines. Examples of sectoral models that address environmental change include, water (WaterGAP; Alcamo et al., 2003), agriculture (IMPACT; Rosegrant 2012; GLOBIOM, Havlik et al., 2011), natural vegetation (LPJ; Smith, Prentice, & Sykes, 2001), and biodiversity (GLOBIO; (Alkemade et al., 2009). In summary, there are a large and growing number of initiatives that have developed qualitative stories and/or quantitative models to explore what could happen to a range of environmental issues, including biodiversity and nature's contributions to people.

5.2.1.3 Exploratory scenario archetypes

“Scenario archetypes” describe different general patterns of future developments and can be useful in summarizing and harmonizing the overwhelming amount of information in individual sets of scenarios. The scenario archetype approach (IPBES, 2016) has been recognized by IPBES as a way to help to synthesize findings from scenarios for the IPBES Global Assessment of Biodiversity and Ecosystem Services (IPBES, 2019) and throughout the four IPBES Regional Assessment Reports. A set of six global scenario archetypes was used, based on scenario families described by van Vuuren et al., 2012. In the regional assessments, these six archetypes were also used, although in some cases with slight modifications. In the IPBES Regional Assessment on Biodiversity and Ecosystem Services for Europe and Central Asia, for example, “reformed markets” was omitted as a separate archetype, and another sixth archetype was added (“inequality”).

In this chapter, a set of four main archetypes is used, most of which are further subdivided into 2 or 3 subtypes (Box 5.1). This set does not completely match any earlier proposed set, but it does include all archetypes used in the global and regional assessments. The main reason for deviation from previous sets is the fact that they will not be used on their own, but in combination with target-seeking scenarios. This set was seen as the best option to facilitate combination with normative scenarios, while maintaining a similar selection.

Box 5.1 The 8 types of scenarios considered

1. Market forces. Global developments steered by economic growth result in a strong dominance of international markets with a decreasing degree of regulation. Environmental problems are only dealt with when solutions are of economic interest. This archetype includes two recurrent variants:

1a. A less extreme variant includes **business-as-usual** and reference type of scenarios, as well as those scenarios typified as strongly market-driven. All assume current trends to continue without strong, nonlinear changes. Typical examples: Shared socioeconomic pathway 2 (O’Neill et al., 2017) and Markets first (from the Global Environment Outlook 3, United Nations Environment Programme & Earthscan, 2002).

1b. A more extreme variant of **market-led environmental management** with highly equal and healthy societies. In terms of biodiversity and nature’s contributions to people, this archetype can range from devastating (environmental destruction) to positive (economically viable nature-based solutions). Typical example: Shared socioeconomic pathway 5 (O’Neill et al., 2017).

2. New sustainability paradigm. A world with an increasingly proactive attitude of policymakers and the public at large towards environmental issues and a high level of regulation. All variants of this archetype are beneficial for biodiversity, either through behavioral change, top-down “green” policies, or through green technology development. In all cases, this is reinforced by a proactive attitude to dealing with environmental problems. Three main variants can be discerned:

2a. **Technological solutions** with strong technological development in all sectors, including for example engineered ecosystems to deliver ecosystem services. Typical example: TechnoGarden (Cork et al., 2006).

2b. **Global sustainable development** with strong, mostly top-down, governance structures that are effective in realizing a more sustainable world. Typical example: Policy first (from the Global Environment Outlook 3, United Nations Environment Programme & Earthscan, 2002).

2c. **Regional sustainability** with fundamental change being initiated by a broadly supported, and bottom-up enforced paradigm shift, often accompanied by a dematerialization process and a "back to nature" attitude. Typical example: Rural revival (in OpenNESS scenarios, Priess et al., 2018) or B2 (Intergovernmental Panel on Climate Change Special Report on Emissions Scenarios, IPCC, 2000).

3. Fortress world. A regionalized world based on economic development. The market mechanism fails, leading to a growing gap between the rich and the poor. In turn, this results in increasing problems with crime, violence and terrorism, which eventuate in strong trade and other barriers. Two variants exist:

3a**. Regional economic growth.** A less extreme variant where, despite strong barriers, the quality of life for most is secured and most problems are dealt with adequately. Typical example: Order from strength (Cork et al., 2006; Millenium Ecosystem Assessment, 2005).

3b**. Breakdown.** A more extreme variant, where organized crime and terrorism eventually lead to institutional disintegration and economic collapse. This variant is rarely elaborated in the literature. Typical example: Breakdown (Gallopin et al., 1997).

The effects on the environment and biodiversity are mixed. Overall, there is a tendency towards increased security, which can either be positive (protect biodiversity) or negative (intensify agricultural production). Particularly in low-income countries, deforestation and loss of natural areas is a risk.

4. Inequality. A world of growing inequalities, both within and between countries. The increasingly powerful elite takes environmental responsibility, while the large lower class is poor but kept satisfied. The effects on the environment differ greatly, depending on location and type of issue. Importantly, the global "green" elite actively combats globally important issues, such as climate change, which has a positive impact on biodiversity. Although increasing inequalities have negative consequences for economic and social development, biodiversity and ecosystems by and large benefit. Typical example: Shared socioeconomic Pathway 4 (O'Neill et al., 2017).

Of particular relevance to the focus of this assessment, the exploratory archetypes encompass important obstacles and limitations for sustainable use, such as follows:

1. **Market forces**: there is a lack of interest in the environment. Sustainable development is not a focus and many wild species that generate less direct economic revenue might not be protected sufficiently.

2a. **Technological solutions**: there is a very strong emphasis on technological "end-of-pipe" solutions. Not all wild species can be used sustainably this way, and technological solutions are likely to have a limited scope.

2b. **Global sustainability**: top-down enforcement of laws and regulations might be ineffective for many local-specific contexts.

2c. **Regional sustainability**: bottom-up solutions will hamper those aspects that need global coordination, such as climate change mitigation; pandemics; or ecological corridors.

3 & 4. **Fortress world and inequality**: in these archetypes, social and human problems will worsen, including increased poverty and inequality. This is likely to strongly inhibit sustainable development, because of a lack of financial support, lack of public and political interests, and/or lack of general importance.

In this chapter, the archetypes will be used in an overarching way, but the analysis is not confined to these archetypes. As these scenario archetypes are constructed to categorize exploratory scenarios, the set as shown above cannot be directly adopted, but needs to be linked and combined with target-seeking scenarios. The procedure used to do this will be explained in section 5.2.1.6.

5.2.1.4 Intervention scenarios: target-seeking and policy scenarios

"Intervention scenarios" evaluate alternative policy or management options, by developing either "target-seeking" or "policy-screening" scenarios. In policy-screening scenarios, a policy, or set of policies, is applied and an assessment of how the policy modifies the future is carried out. Target-seeking scenarios (also known as "normative scenarios") are a valuable tool for examining the viability and effectiveness of alternative pathways to the desired outcome. They start with the definition of a clear objective or a set of objectives that can either be specified in terms of achievable targets or as an objective function to be optimized. Both have in common the search for effective policies or actions to reach a commonly agreed (normative) target. In contrast to exploratory scenarios, intervention scenarios are much less developed at the global level, and as a result, there is a much larger diversity. This is due to the disconnectedness of communities of practices, but also the more diverse set of locally or regionally contextualized issues that need to be addressed. As a result, it is much more difficult to provide a concise overview or attempt to categorize that overview into a limited number of archetypical descriptions. To illustrate this diversity, this chapter refers to the different IPBES Regional Assessment Reports, all of which include a section on pathways and other normative scenarios.

5.2.1.5 Pathway archetypes

To illustrate an attempt to categorize archetypes at the regional level, the IPBES Regional Assessment Report on Biodiversity and Ecosystem Services for Europe and Central Asia recognizes four "clusters of internally consistent pathways" based on Luederitz et al. (2017):

- The "green economy" pathway addresses transitions toward decreased environmental degradation and resource depletion through green growth supported by policy instruments that stimulate specific economic activities.

- The “low carbon transformation” pathway encompasses all pathways focusing primarily on mitigating climate change and adapting to climate change impacts, locally and globally.
- The “ecotopian solutions” pathway addresses transitions towards increased social-ecological integrity. It does this by challenging current belief systems, lifestyles and living spaces with bottom-up, politically alternative initiatives of self-organization at the community or neighborhood level to work towards local-scale, self-sufficiency.
- The “transition movements” pathway also focuses on fundamental individual and social changes, but in contrast to ecotopian solutions, transition movements aim to scale-up to a whole system transformation.

5.2.1.6 Integrated scenarios and pathways

Exploratory scenarios, target-seeking pathways and intervention scenarios provide a palette of plausible futures and possible policies, actions, and other management options. Often, they are used together in what is referred to as “scenario planning”. Exploratory scenarios sketch future possibilities and are used as multiple baselines against which the effectiveness of policies and pathways can be tested. This approach yields “robust” or “no-regret” policies that would work in all plausible different future outlooks.

Here, this chapter takes a different approach by combining exploratory and normative scenarios in one set of integrated archetypes. The starting point is the exploratory scenario archetypes that are combined with the pathway archetypes by indicating whether or not a specific pathway of interventions is compatible with the archetype (Table 5.1). There are strong matches between the market forces and green economy archetypes as well as between regional sustainability and ecotopian solutions. The low carbon society could be combined with many archetypes but is less relevant for the assessment of the sustainability of use of wild species, while the transition archetype combines top-down and bottom-up elements from almost all archetypes and would thus partly work in all archetypes.

Table 5.1 Combining exploratory and normative archetypes. The symbols indicate the degree of matching (xxx=strong; xx=medium; x=weak; -=no match)

Archetype	Green economy	Low carbon	Ecotopian	Transition
Market forces	xxx	xx	-	x
New sustainability Technology Global Regional	 xxx xx x	 xx xxx x	 - - xxx	 x x xx
Fortress world	-	-	x	x
Inequality	-	xx	xx	x

This set of plausible changes and possible intervention archetypes will be the starting point for the elaboration of the scenarios in this chapter.

5.2.2 Methodological considerations for scenario development

This chapter assesses the scenarios and interventions that have been proposed in the literature, thus focusing on the resulting future outlooks and measures, and much less on the process and methods that were used to develop the scenarios. There are, however, a number of methodological aspects that are strongly tied to the outcome of this assessment. The methods employed can also facilitate processes of change that can be part of the solution. Scenarios can be co-created with stakeholders and this participatory process offers the possibility to aim for, among others, social learning, conflict management, or understanding of multiple perspectives. As such, scenarios can be a platform for public participation, and the process of deliberation and negotiation (Patel et al., 2007; Reed et al., 2013; Rounsevell & Metzger, 2010). This transdisciplinary process of stakeholder engagement resonates well with the regional sustainability/ecotopian pathway archetype and is often seen as essential for its implementation. Box 5.2 elaborates on an example of multi-scale participatory scenario development.

Many scenario-development methods advocate the development of multi-scale scenarios. Kok et al. (2016) advise on an overall strategy for incorporating multiple scales in IPBES assessments. In a landmark paper, based on the experience within the Millennium Ecosystem Assessment, Zurek & Henrichs (2007) provide an overview of the degree to which scenarios can be linked across scales. The process of multi-scale scenario development can either be predominantly top-down (e.g., Millennium Ecosystem Assessment, see Biggs et al., 2007; Kok, Biggs, & Zurek, 2007) or predominantly bottom-up (e.g., Seeds of a good Anthropocene, Bennett et al., 2016). Top-down scenarios can easily be classified as they are linked to higher-level, often global, scenarios. Local scenarios developed through bottom-up processes can benefit from alignment with scenario archetypes to facilitate comparison and synthesis. The fact that many scenarios are either bottom-up or stand-alone studies, was an important justification for the consideration of scenario archetypes in this chapter.

One essential feature of scenarios is their ability to integrate. This can be across scale, sectors, actor groups, or topics. Particularly when combining narratives and models, scenarios are an excellent tool to deal with the complexity of the entire social-ecological system under study. The level of integration increases further when exploratory and target-seeking scenarios are combined. Not all scenario studies make use of the potential for integration – many modelling studies use a single, sectoral model and scenario to provide model input – but here scenario archetypes are combined with other approaches to sketch a more complete picture of potential futures.

Box 5.2 Co-creation and participatory processes in scenarios of sustainable use

Scenarios and scenario planning have a long history, initiated by the Rand cooperation in the 1950s (Kahn & Wiener, 1967; Bradfield et al., 2005), and extensively used by oil companies, such as Royal Dutch Shell (Wack, 1985). Up to 75% of all Fortune 100 companies were using scenario techniques in the 1980s (Rounsevell & Metzger, 2010); however, despite early environmental studies – notably the Limits to Growth report in 1972 (Meadows, 1972) and follow-up reports for the Rio Summits in 1992 and 2012 – scenarios only became popular as a tool to assess environmental change around the turn of the century. Global scenarios published by the Global Scenario Group (Gallopin et al., 1997; P. Raskin et al., 2002) and the Intergovernmental Panel on Climate Change (IPCC, 2000) were quickly followed by the Global Environment Outlook (United Nations Environment Programme & Earthscan, 2002; United Nations Environment Programme, 2007; United Nations Environment Programme, 2012), the Millenium Ecosystem Assessment (2005) and others. These early practitioners paved the way by showing the power of scenario assessments (Raskin, 2005), which also contributed to a rapid expansion of national and local scenario studies, for example through the sub-global assessments of the Millennium Ecosystem Assessment (Lebel et al., 2006).

With this increase in use came an equally swift increase in the number of different methods employed to develop scenarios. An important dichotomy was the choice between qualitative and quantitative approaches. Recognizing their complementarity, Alcamo (2009) described an approach to develop scenarios by combining and integrating qualitative stories and quantitative models. This story-and-simulation approach shows how stakeholders can be involved in a participatory process of storyline development, and how stories can be translated into model inputs and outputs that can be discussed with the stakeholders in an iterative procedure. A wide range of participatory methods have since been developed and used to engage stakeholders in the process of scenario development. In a landmark paper, Reed et al. (2013) provide an overview of methods that have been employed and present a methodological framework including all steps from defining the context and aims of the process to the actual co-production methods. First described by Schwartz (1991), the "intuitive logic" or what has become known as the "2x2 matrix approach", is a way to develop a set of four scenarios with stakeholders that has now been mainstreamed (Ramirez & Wilkinson, 2014). Likewise, target-seeking scenarios have been closely linked to co-production techniques (IPBES, 2016). In the 1980s, the term "backcasting" was coined (Robinson, 1982), followed later by descriptions of participatory backcasting methods (Robinson, 2003), which is still being successfully applied (Vergragt & Quist, 2011; De Bruin, Kok, & Hoogstra-Klein, 2017). Other approaches that engage stakeholders in the process of developing target-seeking scenarios include transition management (Loorbach & Rotmans, 2010), visioning (van der Helm, 2009), or strategic niche management (Schot & Geels, 2008). Overall, a wide range of tools for scenario development exists, many of which can either be participatory or can be innovatively combined with a participatory component to answer different questions about the future. However, a gap persists in integrating these quantitative and qualitative methods at the global level (Pereira et al., 2021).

Participatory scenarios have been applied to natural resource management and climate change mitigation as powerful, multi-scale processes. Some examples include integrated scenarios for: multi-scale stakeholder engagement (Gramberger et al., 2015); qualitative stories (Pedde et al., 2019); sectoral and integrated models (Integrated Assessment Platform, Harrison, Dunford, & Holman, 2019); and exploratory (Kok et al., 2019) and target-seeking scenarios (Frantzeskaki et al., 2019). Figure 5.3 shows the sequence of events, the types of scenarios and type of stakeholder engagement that were undertaken in the European Union-funded projects CLIMSAVE and IMPRESSIONS. Figure 5.4 exemplifies different products that were developed in a series of stakeholder workshops, preceded by interviews and interlaced with online questionnaires and email exchanges, where exploratory scenarios were developed and combined with pathways to identify sets of (robust) transformative solutions across scale. The effort convincingly demonstrates how using participatory methods in a co-creation process will not only yield qualitative products such as stories or cartoons but can also be used to determine model input and output. These products in turn are fundamental to discussions on target-seeking pathways and finding the most promising solutions, both for a single case study but also in a multi-scale design, providing insights in other places or at another scale.

Within the biodiversity and broader sustainability scenario area, participatory scenario processes have been widely used at the local level (Oteros-Rozas et al., 2015). An attempt to collect these social-ecological scenarios into a database is now underway (https://www.biospherefutures.net/). One of the biggest benefits of participatory processes in co-creating futures with stakeholders is the ability to engage the imagination; something that has largely been lacking in global-level scenario processes, especially those used in assessments (Pereira et al., 2020). Following the Methodological Assessment Report on Scenarios and Models of Biodiversity and Ecosystem Services (IPBES, 2016), the IPBES former expert group on scenarios and models undertook to stimulate the development of new global scenarios that put nature at the center of the story (Rosa et al., 2017). The culmination of this process, following a participatory visioning process, has been the development of the nature futures framework (Pereira et al., 2020, Figure 5.6) that has the participation of diverse stakeholders at its core.

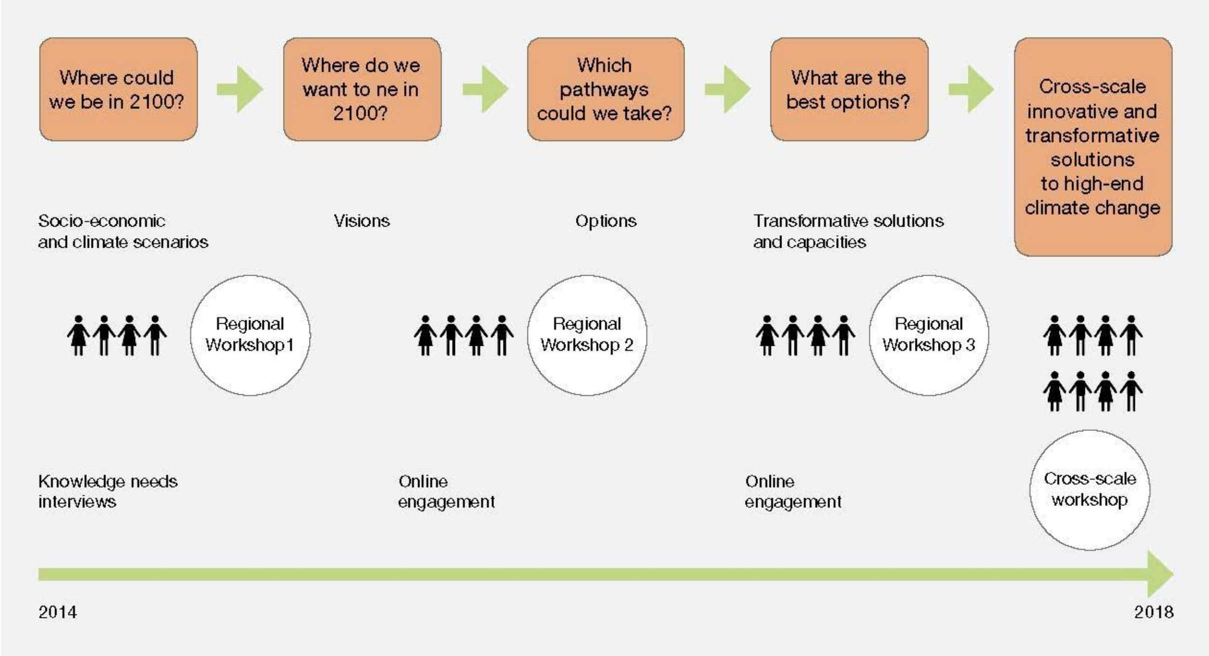


Figure 5.3 Scenario development and type of stakeholder engagement undertaken in the European Union-funded projects CLIMSAVE and IMPRESSIONS. Source: Tabara et al., (2018) under license CC BY-NC-ND 4.0.

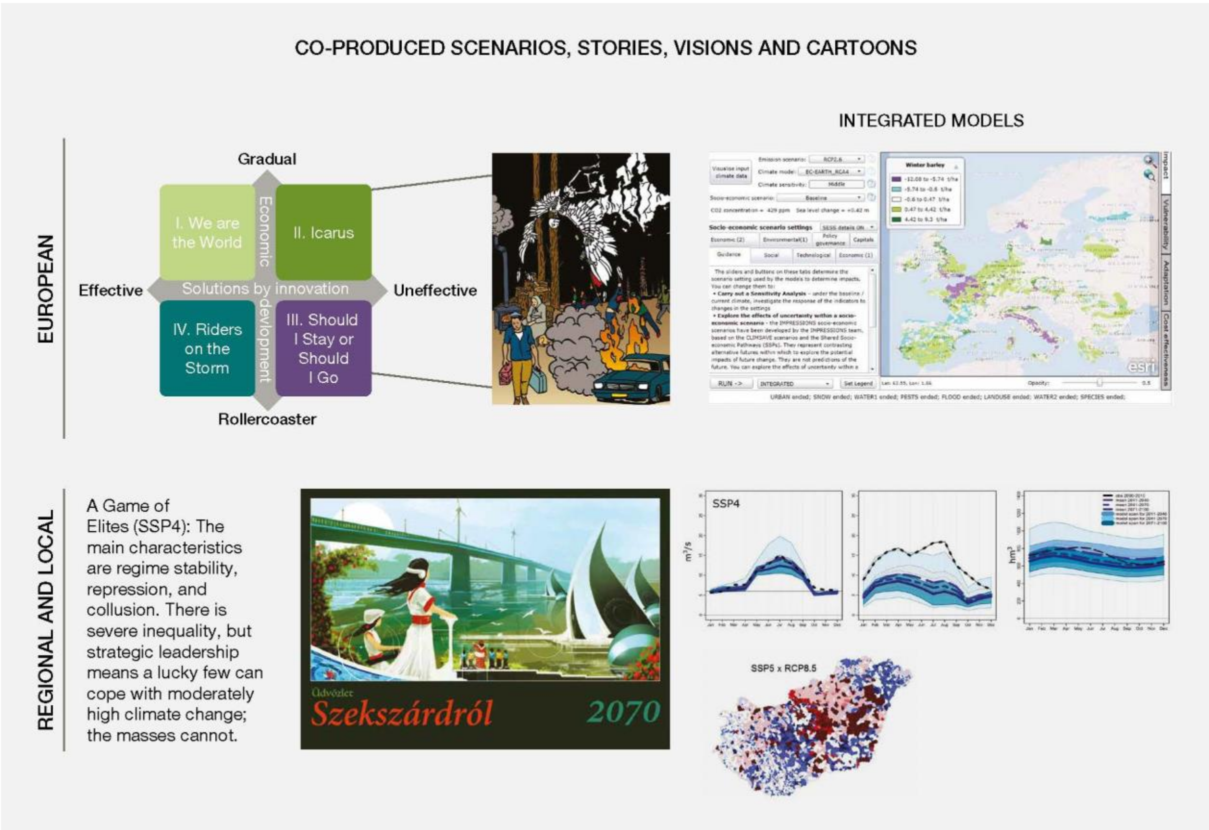


Figure 5.4 Sequence of events, the types of scenarios and type of stakeholder engagement in the European Union-funded projects CLIMSAVE and IMPRESSIONS. Source: CLIMSAVE (http://www.climsave.eu), CLIMSAVE IAP (http://www.impressions-project.eu); illustration by © Talitha Dijkhuizen under license CC BY.

5.2.3 How scenarios might be used in decision-making under uncertain conditions

To summarize the previous sections, scenarios are an excellent tool to use when the system under study is complex and its future changes therefore uncertain. Scenarios come in many shapes and forms and can address fundamentally different questions that directly or indirectly speak to decision-makers. "What should happen?" is perhaps more often asked by decision-makers, and target-seeking or other intervention scenarios can help answering it. "What could happen?" seems to bear less direct relevance to decision-makers but is often an essential first step to map out the "uncertainty space", providing insights into changes beyond the control of the decision-maker, which will influence the solutions required. Scenarios can thus help to facilitate the process of identifying actions that need to be taken, given an uncertain future outlook that is continuously changing. A large diversity of concepts, methods and tools can assist this process. It is not a matter of wondering whether scenarios are good tools to use, but a matter of how scenarios might be best used in decision-making to help identify the actions that can be taken to move towards a better sustainability of the use of wild species.

5.3 Assessment methods used in this chapter

5.3.1 Steps and processes for the assessment

The data used in this chapter were derived from both a systematic review of the literature and from expert knowledge. The literature review was used as a baseline that was then complemented by additional relevant papers that the review did not pick up. While the original search was conducted in November 2019, it was further updated in late 2020, in both cases using an expert-solicited search string on the Scopus and Web of Science databases.

Building on the IPBES global scenarios search string (IPBES, 2019), an expert solicitation method was used to further revise and fine-tune the search string specific to the assessment of the sustainable use of wild species, with the procedure as follows:

1. Search the literature using agreed search terms – aligned with the IPBES global scenarios search string;
2. Refine the search terms, based on the outcomes of Step 1;
3. Evaluate the search terms by checking whether known (existing and recommended) literature is found using them, and refine the search terms accordingly;
4. Identify key drivers that feature in the scenario literature found in 1) and 2) plus those provided by Chapter 4 of the IPBES assessment of the sustainable use of wild species;
5. Code scenarios according to keywords in a spreadsheet to create a uniform coding template;
6. Apply archetype scenarios to these key drivers;
7. Elaborate new archetypes based on the drivers of sustainable use;
8. Document plausible futures for key drivers of sustainable use.

The final search terms used in Steps 1-3 were: plants, algae and fungi

Web of Science Search terms (Number of resulting bibliographies: 959 + 175):
(TS=(("Future impact*" OR "Future response*" OR "Future effect*" OR "scenario*" OR "vision*" OR "trajector*" OR "pathway*") AND ("use" OR "utilization" OR "utilisation" OR "contributions to people") NEAR/5 ("species" OR "nature" OR "biodiversity" OR "natural resource*" OR "ecosystem*" OR "ecological service*" OR "non-timber" OR "NTFP" OR "timber" OR "forestry" OR "wildlife" OR "fish*" OR "charcoal") NOT "land-use NOT "land use" NOT "nitrogen use" NOT "water use") AND SU=((Agriculture OR Environmental Sciences & Ecology OR Biodiversity & Conservation OR Fisheries OR Forestry OR Marine & Freshwater Biology OR Meteorology & Atmospheric Sciences OR Oceanography OR Acoustics OR Social Sciences Other Topics) NOT Biochemistry)) AND DOCUMENT TYPES: (Article OR Book OR Book Chapter OR Book Review OR Review). Indexes=SCI-EXPANDED, SSCI, A&HCI, ESCI Timespan=2010-2019.
SCOPUS Search terms (Number of resulting bibliographies: 1378):
TITLE-ABS-KEY ((("future impact" * OR "future response" * OR "future effect" * OR "scenario" * OR "vision" *) AND ("species" OR "nature" OR "biodiversity " OR "natural resource" OR "ecosystem" OR "ecological service") W/5 ("use" OR "utilisation" OR "utilization" OR "contributions to people") AND NOT ("land use" OR "land-use" OR "nitrogen use" OR "water use"))) AND SUBJAREA (agri OR envi OR eart OR soci OR econ) AND PUBYEAR > 1999 AND (LIMIT-TO (SRCTYPE , "j") OR LIMIT-TO (SRCTYPE , "b")) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "re") OR LIMIT-TO (DOCTYPE , "ch") OR LIMIT-TO (DOCTYPE , "bk")) AND (EXCLUDE (SUBJAREA , "BIOC"))

The coding template in Step 5 was carried out to completion for the 2019 search, and for essential columns for the 2020 update. Classifying the material in this manner assisted with identifying relevant papers both for practices, and for the construction of archetypes (Step 7). The summary of the coding criteria is shown in Table 5.2 and in figures 5.5 and 5.6.

Table 5.2 Summary of the criteria used in coding the literature

Basic information	**Methodological information**	**Analytical information**
Year of publication	Key question/focus	Type of scenario
Type of paper (original; reviewer meta-analysis)	Importance or significance of paper	Driver of use
Inclusion of indigenous and local knowledge	Scale of analysis	Scenario archetype
Mention of the Aichi Biodiversity Targets from the Convention on Biological Diversity	Geographic area of study	Model name and type

Mention of Sustainable Development Goals	Main type of ecosystem	Nature's futures (impact on ecosystems)
	Main practice	Nature's futures (nature's contribution to people)
	Units of analysis	Nature's future (good quality of life)
	Purpose of use	
	Scale of use	
	Mode of use	

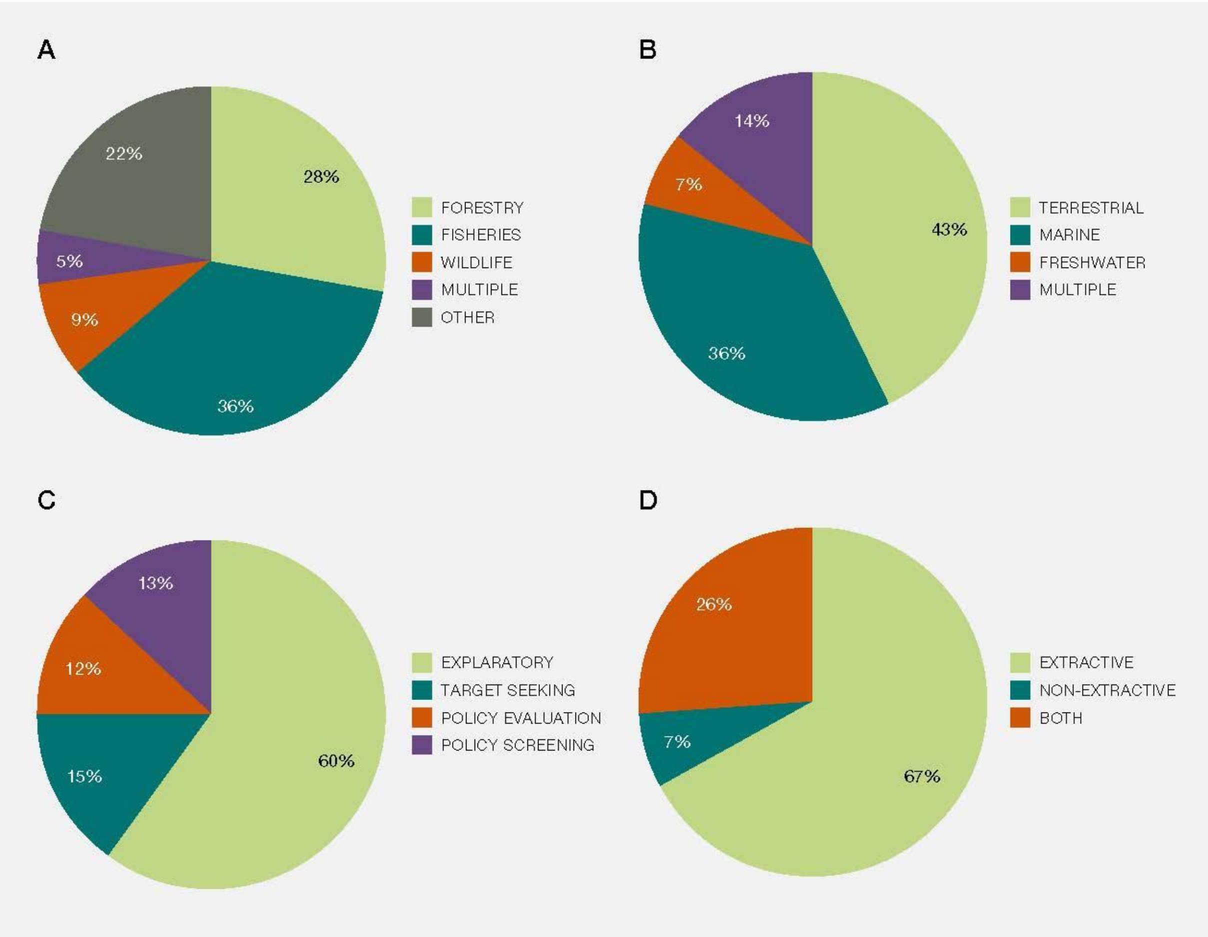


Figure 5.5 Distribution of scenario studies from the literature search and coding, separated by practices and types

Figure 5.6 Classification of scenario studies on the sustainable use of wild species from the systematic literature search and coding

After the search was completed and analyzed, additional papers were added for the purposes of the chapter and evaluation of each practice based on expert knowledge.

5.3.2 Incorporating the perspectives of indigenous peoples and local communities into the scenarios

In the systematic literature review, very few (six) publications were found that discussed scenarios and models from the perspective of indigenous peoples and local communities. The results were therefore supplemented with the dialogues conducted on the IPBES assessment of the sustainable use of wild species in May 2019 and October 2019 with indigenous peoples and local community representatives from Africa, Asia, Europe, Latin America, and North America, as well as submissions solicited by the IPBES technical support unit on indigenous and local knowledge. Input from consultations with organizations working with indigenous communities such as the ICCA consortium, the Non-timber forest products exchange programme, the Asian indigenous peoples pact etc. were included in the review. Community plans were also consulted, as well as workshop reports from indigenous and local knowledge dialogues, which observed the principles of free, prior, and informed consent of indigenous and local community participants in the dialogues.

5.4 Scenarios by practice

5.4.1 Introduction

In this section, scenario material from the literature search, supplemented with expert knowledge (see data management report at https://doi.org/10.5281/zenodo.6451922), is assessed by resource use practice, based on social, technological, economic, environmental, political (STEEP) categories (Reed et al., 2016), including cultural, here through referred as STEEP+C. Crucially, it is important to recognize that for some practices (e.g., gathering), scenarios and projections are extremely limited and/or unavailable in the literature. In such circumstances, rather than leaving the sections empty, “scenario-based drivers” of sustainable use are explored instead; that is, studies of factors that could affect sustainable use when integrated into scenarios. These sections are then identified as knowledge gaps.

5.4.2 Fishing

5.4.2.1 Introduction

Fisheries contribute to food security with fish being a major source of animal protein for about 1 billion people worldwide (FAO, 2020b). Annual marine fisheries production has been relatively stagnant over the past 3 decades. In 2018, global catch totaled 84 million tons with about 73% of catches destined for human consumption and the remaining 27% for fishmeal and fish oil. Fisheries production is expected to stay at high levels, reaching about 96 million tonnes in 2030 (FAO, 2020b) and almost 100 by 2050 (United Nations Nutrition, 2021). The proportion of fish production destined for human consumption is projected to continue to grow, reaching 89 percent by 2030 (FAO, 2020b) and 92% in 2050 (United Nations Nutrition, 2021). Future patterns of demand for marine biological resources will be shaped by social, environmental and economic factors including stagnating capture fishery production, a growing population, increasing wealth (Garcia & Grainger, 2005; Garcia & Rosenberg, 2010; Guillen et al., 2019), increasing aquaculture production and competition with wild capture fisheries for natural resources (Kristofersson & Anderson, 2006; Tacon & Metian, 2008, 2009, 2015), dietary preferences, and the impacts of climate change on existing and novel fisheries.

As well as providing a source of calories and protein, aquatic species provide many nutritional benefits to the human population. An assessment of the nutritional value of aquatic animal food-sources in comparison to terrestrial has shown that the top seven categories of aquatic food, including pelagic fishes, some shellfish, and salmonids are more nutritious than beef, lamb, goat, chicken or pork when averaging across the seven nutrients assessed (i.e., omega-3 long-chain polyunsaturated fatty acids, vitamins A and B12, calcium, iodine, iron and zinc) (Golden et al., 2021). In addition to their contributions to global and local food security and nutrition, fisheries are economically and culturally important, providing social opportunities such as for recreation and contributing to cultural/traditional heritage.

Nevertheless, the development of modern fishing practices driven by advances in technology and growing demand, particularly with the advent of industrialized fishing practices, has led to the depletion of numerous individual fish stocks and a decline of the genetic diversity of harvested fish populations (Pinsky & Palumbi, 2014). According to the most recent Food and Agriculture Organization Report of the State of World Fisheries and Aquaculture (FAO, 2020b), in 2017 just under 66% of assessed fisheries remain within biologically sustainable levels, meaning that about 34% of fish stocks are overexploited. Annual marine fisheries production has been relatively stagnant over the past 3 decades. In 2018, global catch totaled 84 million tons with about 74% of catches destined for human consumption and the remaining 27% for fishmeal and fish-oil.

In the following sections, models and scenarios for the future of fisheries are explored, to examine what insight can be gained around the challenges and solutions that lie ahead.

Projections of the future of fisheries at multiple scales are examined from social, technological, economic, environmental, political and cultural perspectives.

5.4.2.2 Social

Small-scale fisheries are prevalent in tropical and developing countries where dependence on fish for food and livelihoods is high. Fish consumption can address micronutrient (e.g., vitamin A, calcium and iron) deficiencies and improve human health by providing the dominant source of the omega-3 long-chain polyunsaturated fatty acids (Golden et al., 2021). In some countries with inadequate nutrient intakes, fish catches exceed dietary requirements for populations within 100km of the coast, emphasizing the local and regional nutritional and income benefits from fishing (Hicks et al., 2019). Climate change is broadly expected to reduce fish catch potential in many regions (e.g., Lotze et al., 2019; Lam et al., 2020; Tittensor et al., 2021), disrupting food security and livelihoods. For instance, domestic demand for fish in the Solomon Islands is expected to exceed supply from domestic capture fisheries and aquaculture if no climate adaptation action is taken (FAO, 2020b). Expected decreases in global crop production after 2050 due to warmer temperatures will exacerbate food insecurity, and impose additional pressure on small-scale fisheries to fill the food gap with some countries facing a "double-jeopardy" of simultaneous impacts on both marine and terrestrial production (Rosenzweig et al., 2014; Blanchard et al., 2017). Demographic pressures such as high population growth both globally and in individual regions, conflicts in sea-use, and land-use practices that degrade marine habitats may aggravate climate impacts and amplify fisheries overexploitation, biodiversity loss and environmental degradation. Given the diversified nature of small-scale fisheries, fishers may be able to shift to exploit less climate-impacted fish species, but this is contingent on fishers' knowledge, gear and spatial use practices, and the status of alternate fish stocks (Bell et al., 2018).

Projected demographic and social trends may also affect recreational fisheries. Arlinghaus et al., 2015 argued that urbanization reduces individuals' exposure to traditional rural recreational activities like fishing, which may lead to reduced participation rates. However, human population growth also could maintain or even increase absolute levels of recreational fishing (Hunt et al., 2017).

Future socio-economic conditions will also influence the fleet behavior of large-scale fisheries. The application of a scenario planning approach for the Indian Ocean tuna purse seine fishery identified some critical aspects of fleet dynamics to take into account for future management interventions, such as a switch in fishing practices, a reallocation of effort in space, or an exit from the fishery (Davies, 2015).

On the other hand, the emergence of social responsibility principles that adhere to a human rights-based approach to management in recent policy discourse could steer fisheries development along a fairer path. Such a path would enable vulnerable groups such as small-scale fishers and indigenous and local communities to continue accessing their resource base and the significant benefits that fisheries provide (Teh et al., 2019).

Projections of both fish production and per capita consumption by 2050 under 3 different scenarios are indicated in Table 5.3. It is notable that production from aquaculture will substantially surpass capture fisheries in all scenarios. This might attract more interest in aquaculture than in fishing with implications in policy and management shifts (e.g., a diminishing importance of fisheries management with reduced investment which would severely affect sustainable use).

Table 5.3 Projection of production and per capita consumption of fish under 3 different scenarios. Source: United Nations Nutrition (2021). Abbreviations: mt: million tons.

	Business-as-usual	Low road	High road
Marine capture (mt)	85.4	65.8	95.5
Inlande capture (mt)	13.0	10.1	13.5
Total capture (mt)	**98.3**	**75.8**	**109.0**
Inland aquaculture (mt)	89.9	75.6	98.4
Marine aquaculture (mt)	50.1	45.3	62.0
Total aquaculture (mt)	**140.0**	**120.8**	**160.3**
Total production (mt)	238.3	196.7	269.3
Fish for direct food (mt)	217.4	180.5	248.2
Per capita apparent consumption (kg/year)	**22.3**	**18.5**	**25.5**

It is pertinent to note that projections indicate that increasing fish yield reduces land and water use by up to half, and optimizing gears reduces capture fishery emissions by more than half for some species groups, which highlights opportunities to improve environmental performance (Gephart et al., 2021).With regard to demand and supply scenarios, projections showed that edible food from the sea could increase by 21-44 million tons by 2050, a 36–74% increase compared to current yields (Costello et al., 2020).

The social benefits of small-scale fisheries (SSF) are broader than economic value alone. Small-scale fisheries are important for food and nutrition security, and globalization can force trade-offs between economic gains from distant markets and a reduction in nutritional benefits to local communities (Short et al., 2021). Maintaining and expanding the diversity and flexibility of small-scale fisheries and addressing possible unintended consequences will be crucial. Characteristics such as gender but also class, education, and identity strongly affect the experiences of different small-scale fisheries participants (including women in post-harvest and trading), and future projections and scenarios could recognize that those characteristics have particular consequences for local communities (Short et al., 2021).

5.4.2.3 Technological

Technological advances have been identified as a key aspect affecting the economic viability of fisheries, and need to be incorporated into scenarios and storylines (Maury et al., 2017). Broadly speaking, this includes technologies that lead to an increased ability to find fish and reduce bycatch or catch of undersized fish, improvements in gear design and processing capacity, and so forth. “Technological creep” has been identified as increasing catchability by around 2-4% per year (Palomares & Pauly, 2019) , a trend which is likely to continue. However, future scenarios of the global tuna supply chain suggest a limitation of technical efficiency as a potential countermeasure to reduce the negative effects of increasing demand (Mullon et al., 2017).

Technological advances to reduce environmental impacts may also play a role that could be captured in scenarios and projections. Regarding climate change, reducing fuel use represents the primary stressor improvement opportunity. In this sense, projections show that increasing stock biomass could reduce fuel use per tonne of fish landed, where a 13% catch increase with 56% of the effort corresponds to a 50% reduction in greenhouse gas emissions (Gephart et al., 2021). Alternatively, prioritizing low-fuel gears within each fishery could reduce greenhouse gas emissions by 4–61%, depending on the species. In some cases, this could create co-benefits for biodiversity impacts. Another important strategy is to transition fishing fleets to low-emission technologies (Gephart et al., 2021).

5.4.2.4 Economic

Fish is among the most traded food commodities, with about 38% of global fish production entering international trade in 2018 (an export value of 164 billion United States dollars), an annual growth rate of 8 percent in nominal terms from 1976 (FAO, 2020b). International trade expansion has been facilitated by globalization and rapid improvements in logistics (i.e., transportation, post-harvest handling, processing, preservation, packaging and storage). In addition, population and economic growth drive higher demand for seafood. The average global per capita consumption of marine fish (including shellfish) was approximately 8 kg per annum in 2016, and seafood demand is expected to rise in line with projected growth in national economies and spending power. However, the relationship between per capita fish consumption and gross domestic product per capita is significantly weaker for fish than for terrestrial meat (Naylor et al., 2021).

The interlinkages between social and economic scenarios are considerable. According to Naylor et al. (2021), global fish demand is projected to almost double by mid-century, and will increase in all regions of the world. Asia will continue to lead in freshwater fish consumption and is projected to have the highest demand for fish overall in 2050, with China remaining the world's largest fish consumer and demand in India greatly increasing (FAO, 2020b). While the individual species consumed by different nations is likely to remain variable, increasing fish consumption is likely to benefit diets in terms of micronutrients (Golden et al., 2021; Naylor et al., 2021). Estimates show China, Europe, North America and South America consuming a diverse set of species in 2050, including crustaceans, demersal fish, and cephalopods, while Ghana and Peru will continue to dominate the consumption of small pelagic fish.

Projections of future food systems to 2030 suggest that high levels of growth in aquatic animal-source food production may decrease food prices by up to a quarter, resulting in increased consumption and potentially causing reductions in both consumptions of red and processed meats and micronutrient deficiencies (Golden et al., 2021).

The operating cost of global fisheries was approximately 73 billion United States dollars in the mid-2000s (Lam, 2011). Fishing costs and cost structures vary widely by type of fishery and country. For example, global estimates of operating and total cost associated with catching a ton of fish using nets typical of small-scale coastal fisheries averaged 180 and 241 United States dollars respectively (2005 values), while costs of off-shore fishing for tuna using longlines were 2,604 and 2,903 United States dollars respectively (Lam, 2011). On the other hand, the financial subsidies given to industrial fleets - even to those causing overfishing - are key elements for future scenarios and are very much aligned with the need for a reduction of overcapacity. Indeed, the analysis of global marine fisheries subsidies revealed that almost 90% of capacity enhancing subsidies (22.2 billion United States dollars) are provided to large-scale industrialized fisheries, which impair the viability of small-scale fisheries (Schuhbauer et al., 2017). In addition to impacts on the level of fishing, harmful subsidies result in increased greenhouse gas emissions (Machado et al., 2021).

Another ongoing economic consideration is the blue economy initiatives that are making their mark on national and international agendas. In the context of fisheries, blue growth policies lean towards a rights-based approach to fisheries management, which aim to achieve economic efficiency in resource exploitation by defining exclusive ownership or access to fisheries resources. However, this conversion of public goods to private goods can potentially lead to inequalities in how stakeholders access and share ocean benefits. Furthermore, climate change may exacerbate disparities between fishing sectors. Simulations of Australian and New Zealand fisheries using the Intergovernmental Panel on Climate Change Special Report on Emissions A2 emissions scenario and moderate global economic growth revealed a relative increase in the value of large-scale commercial fisheries by 90% but decreases in small-scale and recreational fisheries of between 30% and 50% (Fulton, 2011). Small-scale fishers often engage in alternative economic activities to supplement their income, but these too may become threatened by climate change, thereby limiting small-scale fishers' livelihood options and perpetuating pressure on fisheries.

Allocating a relatively small amount of time to fishing can make a notable contribution to livelihoods with modest investment and minimal exposure to risks. However fishing strategies such as damming channels, applying destructive fishing methods, or using fine mesh nets could threaten future fish stocks (Bailey & Sumaila, 2015; Short et al., 2019; Sugden, & Punch, 2011; Sumaila et al., 2021). Moreover, weak governance and erosion of cultural norms can produce social-ecological interactions that create more hardship for small-scale fisheries. Participatory modelling approaches with greater stakeholder involvement at the local level are useful for applications involving the sustainable governance of natural resources, including the management of fisheries (Daw et al., 2015).

The economic impacts of climate change on marine fisheries are likely to be substantial, particularly given the ongoing shifting redistribution of fish stocks in response to climate change (Cheung et al., 2010; Pinsky, Selden, & Kitchel, 2020). Projections of bio-economic impacts on wild-capture fisheries operating in European waters highlight the importance of future developments in fuel and fish price to the viability of these fisheries (Hamon et al., 2021). In tropical fisheries, climate change impacts are expected to affect sustainable development of both local economies and communities in these regions and the maximum revenue potential is projected to decline by an average of 33% by the middle of 21st century under the Representative Concentration Pathway (RCP) 8.5 high-emissions scenario (Lam et al., 2020). In the high seas, projections suggest that catches of 30 major straddling fish stocks could decline by 11% (Standard deviation ±7%) in the middle of the 21st century relative to 2000 under the Representative Concentration Pathway 8.5 (Cheung et al., 2016). The projected annual losses under high relative to low emissions have been estimated at 278-901 million United States dollars by 2100 for sixteen major United States of America fisheries, based on predicted changes in thermal habitat (Moore et al., 2021). However, complex networks of resource use may help to buffer the impacts of climate shocks (Fisher et al., 2021).

Financial subsidies given to industrial fleets that promote overfishing could be eliminated (Sumaila et al., 2021), while the global efforts to reduce illegal, unreported, and unregulated fishing in the high-seas will require investments in surveillance and international coordination. These economic factors will also shape future scenarios.

5.4.2.5 Environmental

Climate is a key factor in biophysical, chemical and ecological changes that regulate the distribution of fish species, their abundance, physical condition, and their use of habitat. In a future with high greenhouse gas emissions (Representative Concentration Pathway 8.5), marine species in the Atlantic and Pacific oceans are projected to generally shift poleward following the coastline, with many species shifting more than 1,000km (Morley et al., 2018). Fisheries management will have to be anticipatory rather than responsive to predicted climate impacts on marine ecosystems in order to ensure that use remains sustainable as ecosystems change. Indeed, climate change impacts might affect exploitation reference points and the associated level of catch (Travers-Trolet et al., 2020). Yet uncertainties over adaptation and evolutionary processes in marine organisms and the temporal scale at which they occur, the influence of climate change on life history traits, impacts of extreme events (e.g., Babcock et al., 2019) and morphological constraints that limit certain species' response to environmental change, may reduce the effectiveness of climate mitigating measures. For example, even in the absence of fishing, climate change has been projected to decrease marine animal biomass (which underlies wild capture fisheries) by around 5% for every one degree of warming (Lotze et al., 2019), and historical modelling supports an impact of warming on stock biomass, though the impacts on individual species vary (Free et al., 2019). However, effective management, including transboundary management, can help to offset these impacts (Gaines et al., 2018), emphasizing the crucial importance of governance structures (Free et al., 2019). Despite these projections many uncertainties abound. Surprises may also emerge as the future veers into environmental conditions that have not been previously experienced. For example, climatic changes may increase some species' susceptibility to disease and has the potential to cause unforeseen collapse in fisheries. Climate impacts on fisheries will be felt unevenly, with the tropics predicted to bear the brunt of losses in fish catch potential and fisheries revenues. On the other hand, climate change may open up the potential for new Arctic marine fisheries through increased access to fish stocks and increased catch potential (Burgass et al., 2019).

To give a specific example of an important commercial taxon, most of the 14 distinct species of tuna from 4 main genera (*Auxis, Euthynnus, Katsuwonus* and *Thunnus*) are commercially harvested. Tuna have high economic value, representing about 9% of the internationally traded fish and fishery products in terms of value in 2018 (FAO, 2020b). Climate change will affect the phenology, physiology, biology and ecology of tuna and the ecosystems within which they exist, and the impacts will vary across species, life history stage and population/region. The outcomes of climate change on tuna will have knock-on effects on the distribution, composition and timing of tuna catches worldwide.

Rising water temperature impacts tuna survival by affecting habitat suitability for tuna species at different life stages. By 2100, climate change projections suggest that Western Central Pacific water temperatures will be too warm for *T. obesus* to spawn, while temperatures will be optimal in subtropical latitudes and the Eastern Tropical Pacific (Lehodey et al., 2010). Rising temperatures will lead to an expansion of favorable habitat for adult skipjack tuna (*Katsuwonus pelamis*) throughout the tropics; however more recent estimates indicate a deterioration of tropical habitats and an improvement of habitat at higher latitudes. Nonetheless, there is agreement that rising temperatures will drive moderate increases in skipjack tuna catch and biomass until 2050. On the other hand, under current fishing pressure the population of albacore tuna (*Thunnus alalonga*) in the South Pacific is predicted to keep declining until 2035 when they may begin to stabilize. By 2080, new spawning grounds are predicted to emerge in the North Tasman Sea, helping reverse some of the decline (Lehodey, 2015).

Small pelagic fish are extremely abundant and support large capture fisheries for human consumption, aquaculture feed, and fish oil. Between 2005 and 2014, 16.2 million tons of small pelagic fishes were caught each year, representing 20% of the global catch of all fish species (FAO, 2018). Small pelagic fishes exhibit natural, multidecadal fluctuations in abundance (Soutar & Isaacs, 1969; Soutar et al., 1974; Baumgartner., Soutar, and Ferreira-Bartrina, 1992; McClatchie et al., 2017) that have led to rapid and dramatic fluctuations in industrial and small-scale fisheries (Chavez et al., 2003). Due to the observed occurrence of these fluctuations prior to large-scale exploitation, these changes in small pelagic fish biomass are usually attributed to variations in oceanic climate rather than overexploitation. Small pelagic fishes typically respond to warming water temperatures by undergoing poleward distribution shifts (Beare et al., 2004; Hsieh et al., 2008; Nye et al., 2009; Kanamori et al., 2019). Projections of the spatial distribution of seven of the most harvested small pelagic fish species in Europe suggested that environmental suitability for most of these species may strongly decrease and local extinction are expected under the "business-as-usual" (Representative Concentration Pathway 8.5) climate change scenario (Schickele et al., 2021). In addition to spatio-temporal distribution shifts, changes in the productivity of upwelling ecosystems and plankton species composition under global warming (Marinov et al., 2010; Rykaczewski et al., 2015; Rykaczewski & Dunne, 2010) are likely to impact fisheries for small pelagic species. Under a high emissions climate change scenario habitat suitability for sardines in the Gulf of California is projected to decline by as much as 95% (Petatán-Ramírez et al., 2020). Further, ocean acidification has been associated with reduced survival of small pelagic fish eggs (Shen et al., 2016), while habitat compression can potentially alter the fishes' mortality rate by increasing spatial overlap between small pelagic species and their predators (Netburn & Anthony Koslow, 2015). In the Eastern

Mediterranean Sea, future scenarios of marine resources showed that alien species invasions may have substantial impacts on fisheries and ecosystems in addition to sea warming (Corrales et al., 2018).

Human use of small pelagic fishes is expected to increase in the future due to both greater demand for aquaculture feed and for fish-based protein due to population growth and projected declines in agricultural productivity under climate change (Checkley et al., 2017). However, improved ecological forecasts that anticipate climate-related fluctuations in fish abundance may aid sustainable exploitation of small pelagic fishes in the future (Kaplan et al., 2017; Tommasi et al., 2017). Additionally, trends such as the shift away from fish protein to seaweed in aquaculture could improve sustainability (Emblemsvåg et al., 2020).

Finally, coral reef fish are important for livelihoods and food security in many tropical countries. Climate change impacts on coral reef fishes are varied and difficult to predict, and are influenced by species' sensitivity to increased temperatures and rising CO2 levels as well as their capacity to adapt to environmental change (Pratchett et al., 2017). Research on climate change effects on coral reef fishes has been limited to relatively few species. Recent studies on the sensitivity of commercially valuable coral grouper (*P. leopardus*) to climate change indicates that sustained increases in ocean temperature will negatively affect the performance and fitness of coral groupers (Pratchett et al., 2017). This will potentially decrease catchability and availability of the fish, and ultimately lead to a drop in coral grouper catches in the tropics, where much of the world's *Plectropomus* fisheries occur. Ecosystem models of Caribbean coral reefs show that deoxygenation from warming temperature and rising CO2 levels will lead to a drop in fish biomass and produce negative economic consequences, with the sharpest biomass declines likely to be in some commercially important species such as sharks, snappers, lobsters, shrimps and bivalves (Alva-Basurto & Arias-González, 2014).

5.4.2.6 Political

Effective fisheries management, combined with broader marine spatial planning efforts and a wider recognition of sustainable small-scale fisheries to food security, will together play a key role in the sustainability of wild capture fisheries into the future. Managing all fisheries to maximize long-term food production would result in 2050 in an increase of 16% of total harvest (Costello et al., 2020), requiring governance at local, national and inter-regional levels to ensure equity and sustainability.

Fisheries face constant change in their social, economic and governance spheres, and drivers in these systems may interact with, amplify, or overshadow climate impacts on fish stocks. Data scarcity undermines fisheries management, particularly for tropical fisheries, increasing their vulnerabilities.

Climate-driven impacts on ocean biomass are also likely to widen the socioeconomic equity gaps between nations (Boyce et al., 2020), and interact with impacts on agricultural food sources (Blanchard et al., 2017). These interactions compound the uncertainty associated with predicting how climate impacts will actually play out, particularly at the household and community level.

Enhanced fisheries management may be able to reduce the negative effects of climate change, or at least reduce the pace at which multiple climate drivers act upon the ocean and buy time for marine social-ecological systems to adapt (Gaines et al., 2018). A better understanding of the relationship between people, their communities and the environment will be required to enhance adaptation planning for communities that are most dependent on climate-impacted fisheries. Transboundary management will also become crucial; geopolitical issues may arise from the redistribution of resources in and out of countries' jurisdictional areas. Sustainable management of fisheries that straddle the high seas may be able to mitigate climate impacts on fisheries within countries' exclusive economic zones, but the extent to which this generates benefits to society and biodiversity varies depending on the type of ocean governance that prevails. At the extreme, a full closure of the high seas to fishing would increase the resilience of many commercially important fish stocks to both climate change and fishing (Cheung et al., 2016).

Scenarios of global governance, management, and economy (the "oceanic system pathways"), including geopolitics and corporate influence, have been developed for oceanic fisheries (Maury et al., 2017), broadly mapping on to the shared socio-economic pathways. However, they have not yet been fully applied in making explicit projections around the sustainability of stocks into the future. A nationalistic outlook where fisheries are propped up by subsidies would cause fishing profits to fall in all countries, as would scenarios characterized by a fossil fueled lifestyle, while ecological productivity would be negatively affected in both scenarios. More stark inequalities may emerge under worsening climate change. High seas fisheries could become increasingly economically viable for high-income countries under high carbon emissions (Representative Concentration Pathway 8.5) and a rapid economic development model, but the increased fishing intensity could potentially deprive middle and low-income countries of fishing opportunities. With multiple interactions taking place across spatial and temporal scales, outcomes will vary depending on whether they are viewed from ecological, economic, or social perspectives. Furthermore, an exploratory scenario approach based on socio-economic and political trends suggests that overfishing and climate change could increase the likelihood of fishery conflicts in the mid-century (Spijkers et al., 2021).

Marine protected areas for biodiversity conservation can also provide benefits for food provisioning (e.g., Gill et al. (2019), but social equity and the systematic assessment of the marine protected areas local impacts are critical to success, as is the case for fisheries more generally (Cochrane, 2020). Expanding the global marine protected areas network to cover 28% of the ocean could increase food provisioning by 5.9 million tonnes, as well as provide carbon sequestration benefits in addition to their biodiversity conservation benefits (Sala et al., 2021). As with fisheries, it is also important to build climate resilience into marine protected areas and to recognize the challenges that climate change poses to their effectiveness (Tittensor et al., 2019). In addition to marine protected areas, "human-used areas" (Hilborn & Sinclair, 2021) and other spatial management such as Other Effective Area-based Conservation Measures which can define fishery closures or areas with fishery restrictions, can also contribute to sustainable use (e.g., Petza et al., 2019). The focus for the future must be on learning how to merge enhanced human food security with the long-term persistence of biota needed for the stability of ecosystems.

Overall, improving fisheries management and effective harvest control rules imply a reduction of overfishing in addition to the rebuilding of depleted stocks. Management actions show cumulative benefits and a broad suite of management measures at local, national and international levels appears to be key to sustaining fish populations and food production (Melnychuk et al., 2021). Among the most effective actions are rebuilding plans that rapidly lower fishing pressure towards target levels, enabling overfished populations to recover (Melnychuk et al., 2021). Additionally, the ratification of international fishing agreements, and harvest control rules specifying how catch limits should vary with population biomass help to reduce overfishing and rebuild biomass. Notably, the cumulative benefits of management actions lead to stock status improvements and predicted long-term catch increases (Melnychuk et al., 2021).

Regarding policies for securing sustainable small-scale fisheries, investments in alternative livelihoods have been insufficient and deeper structural changes, such as changes to property rights that explicitly recognize securing sustainable small-scale fisheries and their unique needs are required. Policies that recognize, rather than undermine, traditional and indigenous rights and access rights, but that may also support more inclusive relationships with state and/or corporate actors may be an important element (Short et al., 2021).

5.4.2.7 Cultural

Localized subsistence and indigenous fisheries tend to fall outside the scale at which global climate assessments are conducted, yet subsistence fishing in many developing countries takes place in intertidal areas including shallow reef flats and mangroves that are threatened by climate change. A large proportion of subsistence catch is made up of bivalves, gastropods and other invertebrates; calcifying species that are expected to be negatively impacted by ocean acidification. The predicted loss for subsistence fishing is likely to reduce overall household well-being, including health and socio-cultural aspects. However, at a local scale, invertebrates in the Pacific islands are expected to experience only moderate decline from climate change, thus subsistence gleaning may become even more important in the face of reduced coral reef fish catch. On a global scale, many of the world’s poorest countries are also the most heavily reliant on fish for protein, thus future climate-driven impacts are likely to result in additional socio-economic hardship in countries that are more reliant on fisheries but have limited capacity to adapt (Nash et al., 2020).

In North America, climate impacts on indigenous fisheries are expected to be variable. In western Canada, warmer-water species such as Pacific sardines are projected to increase and provide an opportunity to develop or expand new commercial harvests. However, declines are expected in commercial herring and salmon stocks that contribute significantly to First Nations’ fisheries revenues, as well as in species important for food and ceremonial purposes (Weatherdon, 2016). From a nutritional perspective, health may be negatively impacted as nutrient intake derived from traditional seafood consumption declines, and this nutrient deficit is not easily substituted by other food sources. In order to meet future challenges related to food security, livelihoods, cultural integrity and equity provided by small-scale fisheries, it becomes important to support the diversity of small-scale actors through appropriate policies (Short et al., 2021). and the inclusion of cultural asset preservation and benefits in future scenarios.

5.4.2.8 Summary of plausible futures for fisheries

Fisheries provide significant socio-economic benefits by contributing to local and global food security and employment. Characterizing the plausible futures of fisheries is key to assessing fish provision, demand and consumption in the next decades under differing projections of population, income growth and climate change.

Global catches are projected to stay at high levels with fluctuations due to the El Nino phenomenon in South America (FAO, 2020b). A continued trend of industrial exploitation rates (business-as-usual) may likely increase the number of overfished stocks. This could be reversed by improving harvest control rules, technological advances on surveillance, and recovery plans in fisheries management. Projections indicate that an increase of fish yields could also reduce land and water use by a half.

Climate change is recognized as a major threat, which will affect multiple aspects of marine ecosystems (e.g., species distribution, biological invasions, species life history traits, etc.) and impact aquatic food systems from production to consumption worldwide. The effects of climate change on fisheries production systems are already visible in some regions of the world and are projected to have higher impacts on the food security of fisheries-dependent communities, which could put more pressure on small-scale and subsistence fisheries. Additional pressures due to demographic growth and conflicts in sea use may aggravate climate impacts and lead these communities to adapt their fishing behavior and affect socio-cultural aspects of their practices. Climate-driven impacts on species ranges and changes in fisheries productivity are expected to profoundly affect the benefits that wild capture fisheries provide to the human population, including aspects such as food provision, nutrients, social benefits, and livelihoods.

Climate change projections from high-emission scenarios from the Intergovernmental Panel on Climate Change show a decrease in 2050 global ocean biomass; the global catch is projected to be potentially reduced, and more substantially in tropical systems.

Therefore, evaluating governance, fishing practices and economic factors to mitigate changes on current production systems could help transition operations and build climate resilience. This is even more important as global fish demand is projected to almost double by mid-century. In order to meet challenges related to food security, livelihoods, cultural integrity and equity, it is important to support the diversity of small-scale fisheries. Projections of bio-economic impacts on wild-capture fisheries show they are likely to be substantial for many regions of the world (in particular the Global South) both for small- and large-scale fisheries. Furthermore, future socio-economic and political trends show that overfishing and climate change could increase the likelihood of fishery conflicts by the mid-century.

Overall, the consequences of climate impacts on fisheries will reverberate into different sectors of society worldwide with those dependent on fishing for food, livelihoods and cultural purposes most severely affected. Climate change will interact in complex ways with other drivers of change in fishing practices and intensity, at multiple scales and across jurisdictions.

Hence the need for effective coastal and high seas fisheries management into the future to ensure the sustainability of wild capture fisheries and the resilience of fish stock.

Preventing overfishing and developing management strategies that are robust to environmentally driven changes in productivity are essential to maintain and rebuild the capacity for global wild-capture fisheries to supply food. Harvest control rules and marine protected areas are among the management approaches that may provide benefits, help to prevent overfishing, and rebuild depleted populations. Yet the poor current status of many stocks combined with potentially maladaptive responses to range shifts could reduce future global fisheries yields and profits. However, reforming fisheries in ways that jointly fix current inefficiencies, adapt to fisheries productivity changes, and proactively create effective transboundary institutions to provide continuity in management practices are key elements for sustaining wild capture species and food production.

5.4.3 Gathering

5.4.3.1 Introduction

Globally, thousands of species of algae, fungi and plants are gathered for food, medicine, construction and other uses. Gathering occurs in ecosystems from boreal forests (Uprety, 2012) to semi-arid savannahs (Schumann, 2010), and from high altitude environments (Pradhan & Badola, 2015; Rana et al., 2020) to near shore environments (McDermid et al., 2019). Humans have been gathering for millennia (Delgado-Lemus et al., 2014; Uprety et al., 2012) but a lack of baseline data, as well as the highly dispersed, low entry cost of this practice make it challenging to determine trends in the number of people who gather and the volumes of all algae, fungi and plants gathered at a global scale. However, although incomplete, data are available for some gathered materials that are commercially traded and a number of studies detail the social, including cultural and economic significance of gathering and uses of gathered materials in all regions of the world.

Overexploitation has been identified as an important driver of global plant extinctions (Kor et al., 2021). However, a systematic review of 101 ecological studies addressing population-level consequences of gathering (Stanley et al., 2012) found that in almost two-thirds (63.3%) of the cases examined, rates of extraction were or likely were sustainable while less than one-fifth (17.8%) were unsustainable. Few scenarios explicitly address the sustainability of gathering (but see Bondé et al., 2020), although scenarios that project possible futures for forests and other ecosystems in which wild algae, fungi and plants occur are relevant, as are broader climate change scenarios. In contrast, several modelling methods are commonly applied to predict the future social and ecological sustainability of gathering. Many models designed to assess ecological sustainability focus on changes in habitat extent and distribution under climate change alone or in combination with other drivers (Ardestani & Ghahfarrokhi, 2021; Asase & Peterson, 2019; Chitale, Silwal, & Matin, 2018; Groner et al., 2021; Jansen et al., 2018; Munt et al., 2016; Yadav et al., 2021; del Castillo et al., 2013). Harvest response models are another common approach (Lázaro-Zermeño et al., 2011; Gaoue, Sack, & Ticktin, 2011; Tilahun et al., 2011; Chamberlain et al., 2013; Pérez-Negrón, Dávila, & Casas, 2014;

Hernández-Barrios, Anten, & Martínez-Ramos, 2015; Kindscher, Martin, & Long, 2019), some examining the interactions of harvest techniques with other social and environmental factors (Groner et al., 2021; Hart-Fredeluces, Ticktin, & Lake, 2021; Isaza et al., 2016). Projections of economic sustainability generally emphasize the financial returns to gatherers and/or the state (Saha & Sundriyal, 2012; Stanley et al., 2012; Van Andel et al., 2015), with the contributions of subsistence uses to local livelihoods rarely incorporated into models.

5.4.3.2 Social

Millions of people worldwide participate in gathering algae, fungi and plants (Gaoue et al., 2011). One systematic literature review estimates that 80% of people living in developing countries rely on wild algae, fungi and plants as the main source to meet their nutrition and health needs (de Mello et al., 2020). Gathering of algae, fungi and plants make important contributions to food security (Campbell et al., 2021; Pérez-Moreno et al., 2021), but knowledge regarding their nutritional contributions is limited (Vinceti et al., 2013). In some places, however, participation in gathering and reliance on gathered materials may be declining in response to urbanization and increased access to infrastructure and services (Gray et al., 2015). Nevertheless, few scenarios and modelling studies explicitly include non-economic social factors in their parameters and this remains a knowledge gap regarding sustainable gathering.

5.4.3.3 Technological

Typically, the tools used in gathering are manual. Thus, the methods or techniques used to gather wild algae, fungi and plants and the knowledge underlying those methods constitute the most significant technological aspects of gathering. Key dimensions of gathering techniques include the places and times in which harvesting does or does not occur, the individual specimen and part or parts thereof to be harvested and volumes of material to be taken. Harvest impact studies and models make it clear that the sustainability of harvesting techniques are species- and context-specific. While there are cases in which empirical data and models indicate that the techniques in use have or could reduce populations of the gathered species (García et al., 2016; Hernández-Barrios et al., 2015; Isaza et al., 2016) and may present a risk of localized extinctions (De Angeli et al., 2021) there are also cases in which the outcomes of gathering can be neutral at the population level or may even enhance the vital rates (i.e., growth, reproductive success and survival) of individual plants and/or populations (Hart-Fredeluces et al., 2021; Kurttila, Pukkala, & Miina, 2018; Varghese et al., 2015).

Modelling corroborates empirical findings that gathering techniques tailored to the biology, ecology and life stage of the target species are more likely to be sustainable. For many species, size and age class play an important role in whether gathering is sustainable (Groner et al., 2021; Isaza et al., 2017; Jansen et al., 2018). For example, models of methods used in the harvest of natal lily (*Clivia miniata* (Lindl.) Verschaff) in South Africa found that gathering individuals from all life stages would have a more negative effect on the overall population than would the harvest of only juvenile plants (Groner et al., 2021). Likewise, the sustainability of gathering frequently is contingent upon the habitat in which it takes place (Klimas et al., 2012; Isaza et al., 2016). For example, modelled effects of the compatibility of gathering seeds from the medicinal tree *Carapas guianensis* Aubl. and logging it for timber in western Amazonia indicate that there is no sustainable harvest level for seeds and full-tree harvest in upland forests, while in occasionally flooded forest lands populations could sustain gathering of 10% of seeds and logging of all trees over 50 centimeters in diameter. Landscape ecology also exerts a strong influence over the sustainability of gathering practices. One example is the interaction of gathering leaves from the western North American species beargrass (*Xerophyllum tenax* (Pursh) Nutt.). Scenarios examining this interaction forecast that in a business-as-usual future, in which there is a greater than 50% chance of high-intensity fire, and a future in which all fires are excluded, beargrass populations would be significantly lower than in a future characterized by cultural burning of the landscape by indigenous peoples (Hart-Fredeluces et al., 2021).

5.4.3.4 Economic

Gathering provides essential livelihood resources to millions of people worldwide on an ongoing basis (Gaoue et al., 2011; Jansen et al., 2018) through subsistence consumption of gathered materials (De Angeli et al., 2021; Pérez-Moreno et al., 2021; Saha & Sundriyal, 2012; Stanley et al., 2012) and income derived from trade (Mumcu Kucuker & Baskent, 2015; Van Andel et al., 2015; Walsh & Douglas, 2011). In addition, gathering and gathered materials are important safety nets in times of environmental and economic shocks (de Mello et al., 2020). Both subsistence uses of wild algae, fungi and plants and trade in them have particular importance for low-income and marginalized peoples (Pérez-Moreno et al., 2021), although gathered materials are used by households across the economic spectrum. Subsistence use of and trade in gathered materials is fundamental to the lives and livelihoods of indigenous peoples (Isaza et al., 2016, 2017) and local communities (Papageorgiou et al., 2020) and a source of empowerment for women (Pérez-Moreno et al., 2021).

A subset of the thousands of species gathered worldwide are commercially traded, with fewer still entering large-scale commodity markets. Most modelling and scenario development focuses on commercially traded species. In the case of wild algae, fungi and plants that enter large-scale commercial markets, gatherers can face the dilemma of maximizing harvest for short-term income, eventually reducing populations of the target species below commercially viable levels, or gathering lower volumes of material to sustain species populations and ensure income through time (Hernández-Barrios et al., 2015). This dilemma may be particularly acute where the price per unit of raw gathered material is low and gatherers must increase harvest volumes to meet their economic needs or goals (de Mello et al., 2020). Further, a review of 87 cases of hunting and gathering in developing countries found that, together with high species resilience, low gross domestic product per capita and high poverty ratios were strong predictors of unsustainable outcomes (Leao et al., 2017). Over the long term unsustainable gathering adversely affects the livelihoods and well-being of local peoples (Vallejo et al., 2014).

Modelling studies suggest a number of strategies to enhance the sustainability of gathering, with a focus on commercially traded species. Agroforestry may increase production to meet demand and decrease pressure on wild populations, while fair trade schemes may help to ensure equitable sharing of benefits with gatherers (Bondé et al., 2020; Pérez-Negrón et al., 2014). Some models indicate that multiple-use forest management can increase economic returns for forest owners and identify the optimal mix of logging and gathering under current and future conditions (Kurttila et al., 2018; Miina et al., 2020; Mumcu Kucuker & Baskent, 2015). Managing forests for both logging and gathering may enhance populations of gathered species. Where income from commercially traded wild fungi or plants becomes a priority for forest owners and forest managers, there is likely to be an increased emphasis on controlling access to such species.

5.4.3.5 Environmental

Scenarios and models, as well as empirical data, indicate that the future sustainability of gathering will be a function of interacting gathering techniques, environmental conditions and anthropogenic and biophysical drivers, including climate change (del Castillo et al., 2013; Hart-Fredeluces et al., 2021; Mandle et al., 2015). These factors may interact in additive, synergistic or antagonistic ways (Groner et al., 2021), producing species-, habitat- and site-specific outcomes for the sustainability of gathering. As a result, gathering regimes that are sustainable for one species may not be for another. Similarly, gathering techniques that are sustainable for a species in one location may not be so in a place where environmental conditions and drivers are significantly different.

As previously noted, species biology (e.g., growth rate, reproductive strategy and, sometimes, population density), plays an important role in their response to gathering (De Angeli et al., 2021; Isaza et al., 2016; Papageorgiou et al., 2020; Walsh & Douglas, 2011; Yadav et al., 2021), as does heterogeneity in individual specimens' responses to gathering given characteristics such as size and age (Jansen et al., 2018). Landscape ecology also plays a determinative role, with habitat conditions such as topography and hydrology strongly influencing the outcomes of gathering (Benítez-Badillo et al., 2018; Isaza et al., 2016, 2017; Mumcu Kucuker & Baskent, 2015; Pradhan & Badola, 2015; Varghese et al., 2015). Land-use and land-cover change is expected to accelerate, along with its adverse effects on the sustainability of gathering. Among the causes of land-uses and land-cover changes identified in scenarios and models as having significant impact on the sustainability of gathering worldwide are agriculture (Hertel & de Lima, 2020) and chemical runoff from it (Papageorgiou et al., 2020), grazing (Benítez-Badillo et al., 2018; Lima et al., 2020; Mandle et al., 2015; Walsh & Douglas, 2011) and changes in forest structure due to logging (Benítez-Badillo et al., 2018; del Castillo et al., 2013). Some land-cover changes and landscape management systems have been identified as enhancing the sustainability of gathering of particular species. For example, fungal biodiversity in Mediterranean scrublands is increased by carefully timed treatments including controlled burning and clearance of vegetation (Hernández-Rodríguez et al., 2015), while forest fragmentation has increased populations of the epiphytic bromeliad *Catopsis compacta* Mez. in Mexico by opening up the canopy and increasing the area of forest perimeter (del Castillo et al., 2013).

Similar patterns hold true for macrofungi gathered for food, medicine and other purposes. Mycorrhizal fungi associated with boreal pine forests are less adapted to high-intensity wildfires than are those in Mediterranean pine forests (Franco-Manchón et al., 2019). In some cases, silvicultural prescriptions can increase fruiting by edible wild fungi, although the degree of this effect depends on the extent of thinning of the forest canopy and site hydrology and temperature (Miina et al., 2020; Herrero et al., 2019; Kurttila et al., 2018; de-Miguel et al., 2014).

Climate change will affect most of the variables that will determine the sustainability of gathering in the future. Many studies have modelled the probable occurrence of suitable habitats for individual species or taxa of gathered species under climate change scenarios (Heubes et al., 2012; Miina et al., 2020; Rana et al., 2020; Sinasson et al., 2021), as well as the effects of potential changes in precipitation and/or temperature (Ardestani & Ghahfarrokhi, 2021; Kumar et al., 2021; Yadav et al., 2021). Results suggest that some species will benefit from expanded distribution (Chitale et al., 2018; Yadav et al., 2021), the distribution of other species can be expected to decrease (Ardestani & Ghahfarrokhi, 2021; Chitale et al., 2018; Uprety et al., 2012; Yadav et al., 2021), while some will remain largely stable (Asase & Peterson, 2019). A shift in range to higher latitudes and altitudes is expected for some species (Ardestani & Ghahfarrokhi, 2021).

Climate change may also affect the use of fire as a landscape management tool, as well as the frequency and severity of wildfires, which are expected to increase, with attendant effects on populations of gathered species (Franco-Manchón et al., 2019; Hart-Fredeluces et al., 2021; Sinasson et al., 2021; Varghese et al., 2015; Walsh & Douglas, 2011). However, different modelling approaches may produce divergent results about the impacts of fire on specific species (Klimas et al., 2017). Models further suggest that outcomes of fire are a function of interactions with other factors (Mandle et al., 2015).

5.4.3.6 Political

Although no model or scenario that explicitly addresses the outcomes of policies and governance for the sustainability of gathering was identified, many have clear policy implications. Models and scenarios help identify needs and opportunities for policy to support the social and ecological sustainability of gathering. The likelihood of shifting ranges for gathered species (Ardestani & Ghahfarrokhi, 2021; Sinasson et al., 2021) makes it clear that existing governance regimes such as protected areas may no longer encompass important populations. Similarly, some species may migrate outside the territories of indigenous peoples and local communities, depriving them of important livelihood and cultural resources. Policies that support the contributions of gathering to food security and community well-being will benefit both people and conservation (Campbell et al., 2021; Kor et al., 2021). The results of several models also highlight current and likely future mismatches between regulations and other measures necessary to ensure sustainable gathering (de Mello et al., 2020; Hernández-Barrios et al., 2015), while assisting in the identification of locations where harvest regulations and monitoring can be especially effective (Franco-Maass et al., 2016), as well as species that would benefit from strengthened legal and institutional frameworks (Garcia-Barreda et al., 2018) and flexible management policies and plans tailored to species and context (Delgado-Lemus et al., 2014; Franco-Maass et al., 2016; Garcia-Barreda et al., 2018; Kor et al., 2021).

5.4.3.7 *Cultural*

Gathering has particular importance in the culture, myths, identity and spiritual practices of communities throughout the world including, but not exclusively, indigenous peoples. Notwithstanding this importance, less than half of studies examined in a systematic review of the literature on the social-ecological sustainability of non-timber forest products mention cultural dimensions of gathering (de Mello et al., 2020) although it is a common focus of research in the fields of ethnobotany (Balick & Cox, 2020) and biocultural diversity (Baumflek et al., 2021; Kassam, 2010). While not explicitly included in the parameters of scenarios and models relevant to gathering, modelling studies frequently make mention of cultural uses of gathered materials. Examples include use of the leaves from the cycad *Dioon merolae* (De Luca & Sabato; Nance 2009) for ceremonial purposes by indigenous and mestizo communities in Chiapas, Mexico (Lázaro-Zermeño et al., 2011) and ceremonial uses of ectomycorrhizal fungi (Pérez-Moreno et al., 2021), as well as tensions between commercial and cultural values (Walsh & Douglas, 2011). The effects of commercialization on the cultural values and ceremonial uses of gathered species has received little attention and remains an important knowledge gap.

As the case of beargrass above illustrates (Hart-Fredeluces et al., 2021), the knowledge base on which gatherers draw can also exert a fundamental influence on the sustainability of their practices. Indigenous and local knowledge can, and often does, provide a foundation for sustainable gathering (Hart-Fredeluces et al., 2021; Kor et al., 2021; Papageorgiou et al., 2020; Saha & Sundriyal, 2012; Walsh & Douglas, 2011). In western Australia, research shows that the ecological and economic future of small-scale trade in bush food will depend on intergenerational transfer of Aboriginal knowledge and skills (Walsh & Douglas, 2011). However, in many places indigenous and local knowledge has been subject to erosion (Uprety et al., 2012). A study on the Greek island of Lemnos notes that new gatherers with limited knowledge and experience may diminish the future sustainability of gathering wild medicinal plants there (Papageorgiou et al., 2020). Partnerships between indigenous peoples and local communities and scientists can also produce knowledge that will help sustain gathering in novel and changing landscapes (de Mello et al., 2020).

5.4.3.8 *Summary of possible futures for gathering*

The gathering scenarios and modelling literature suggests that four interacting factors will determine the sustainability of gathering: (i) species biology and ecology (Gaoue et al., 2011; Herrero-Jáuregui et al., 2011; Jansen et al., 2018; C. M. Klimas et al., 2012), (ii) land-use/land-cover and land-use/land-cover change (Ardestani & Ghahfarrokhi, 2021; Groner et al., 2021; Heubes et al., 2012), (iii) climate change (Ardestani & Ghahfarrokhi, 2021; Groner et al., 2021; Herrero et al., 2019; Heubes et al., 2012; Kumar et al., 2021; Yadav et al., 2021; Munt et al., 2016; Herrero et al., 2019; Karavani et al., 2018) and (iv) gathering technique (del Castillo et al., 2013; García et al., 2016; Hart-Fredeluces et al., 2021; Isaza et al., 2016, 2017; Jansen et al., 2018; Mandle et al., 2015; Vallejo et al., 2014). These factors can interact additively, antagonistically or synergistically (del Castillo et al., 2013; Groner et al., 2021; Hart-Fredeluces et al., 2021; Mandle et al., 2015), producing outcomes that are highly specific by species and social and geographic location.

While general trends at global and regional scales can be identified, policy and practice pathways will lead most surely toward sustainable gathering in the future when they are context-specific and build in the capacity for adaptation to changing conditions (Hart-Fredeluces et al., 2021; Sinasson et al., 2021). Localized monitoring and assessment can supply appropriately scaled information (Papageorgiou et al., 2020; Sinasson et al., 2021) to support adaptation. Similarly, local-scale scenarios and models can inform policy and practice about possible futures for gathering (Bondé et al., 2020) and will be particularly valuable when they are transparent about the uncertainties built into the modelling process itself (Klimas et al., 2017), validated with field studies, and when they take into account the interacting effects of species biology and ecology, land-use/land-cover change, the effects of climate change and gathering techniques (Groner et al., 2021).

In the case of gathering that feeds commercial markets, agroforestry and cultivation may relieve pressure on wild populations of target species (Bondé et al., 2020; Rana et al., 2020; Pérez-Negrón et al., 2014; Gaoue et al., 2011) but can also shift the distribution of benefits from gathering. Fair trade schemes may help to ensure that local communities benefit from commerce in local resources and are invested in its long-term sustainability (Bondé et al., 2020; Pérez-Negrón et al., 2014).

Protecting habitat for gathered species will be especially important for the long-term sustainability of gathering (Rist et al., 2010; Klauberg et al., 2014; García et al., 2016; Isaza et al., 2016; Munt et al., 2016; Isaza et al., 2017; Bondé et al., 2020; Sinasson et al., 2021) with land-use and land-cover change likely to represent a particular threat (Groner et al., 2021). In some cases, population- and landscape-scale management will help to create and/or maintain such habitat (de-Miguel et al., 2014; Hart-Fredeluces et al., 2021; Herrero et al., 2019). Measures to support, promote and enforce sustainable gathering techniques will also be essential (Groner et al., 2021; Hart-Fredeluces et al., 2021; Isaza et al., 2016, 2017; Jansen et al., 2018; Klimas et al., 2012) but, again, must be tailored to the context within which the gathering occurs. Indigenous and local knowledge can serve as a source for design and implementation of sustainable landscape management and gathering techniques (Hart-Fredeluces et al., 2021; Papageorgiou et al., 2020; Walsh & Douglas, 2011) and offers valuable input to modelling processes where principles of free, prior and informed consent are observed. However, in many places indigenous and local knowledge is being eroded and sustainable gathering will require efforts on the part of communities and policymakers to ensure that youth and future generations have the opportunity to acquire and use such knowledge (Walsh & Douglas, 2011). Participatory research (Varghese et al., 2015) and bringing science and indigenous and local knowledge into conversation with each other will also advance design and implementation of policies to address the challenges of sustainable gathering in the novel ecologies emerging from climate change and other local and global changes (Hart-Fredeluces et al., 2021).

5.4.4 Terrestrial animal harvesting

5.4.4.1 *Introduction*

In this present assessment, terrestrial animal harvesting is defined as the removal from their habitat of animals (vertebrates and invertebrates) that spend some or all of their life cycle in terrestrial environments. Terrestrial animal harvesting often results in the death of the animal, but it also includes temporary or permanent capture of live animals from their habitat without intended mortality, such as for pet trade, falconry or green hunting. This chapter focuses on hunting, i.e., the lethal category of terrestrial animal harvesting which leads to the killing of the animal.

It is important to add a few notes in terms of approach at the start of this section. There were, in fact, very few studies addressing scenarios for hunting in the literature search database; these were complemented with literature derived from expert sources. Of those, almost none could really be considered as “scenario” papers in the strict sense. The studies evaluated did, amongst other foci, consider some drivers of changes in hunting practice, but usually did not engage in future projections, with a few exceptions. Often studies would have a generic discussion at the end considering, in broad terms, what the future might be for hunting in that specific case/area. This is, of course, very different to a rigorous consideration of plausible futures, and means that the evaluation of scenarios generally is limited. In addition, the majority of studies consider legislation, or the legal framework as a key driver of changes in hunting practice (even where this is not the key focus of the paper). Although many papers (including those focused on here) discuss hunting with respect to local sustainability, there is also a need to explore the drivers and sustainability of the international trade in wild species (Harfoot et al., 2018; ‘t Sas-Rolfes et al., 2019; Tittensor et al., 2020), and in particular scenarios of the future of the legal and illegal trade in wild species. Finally, Booth et al., (2021) highlight the risk of food insecurity from wild meat prohibitions, with 15 countries already identified as being food insecure that would be affected. Thus, while COVID-19 has given rise to calls for increased regulation of and/or bans of wild meat trade and consumption to protect both public health and biodiversity (see, for example, the discussion in Box 5.6), a complete removal of wild meat from diets and markets would severely impact both food security and biodiversity (Booth, Clark, et al., 2021).

5.4.4.2 *Social*

Illegal hunting can be driven by a social context (for example, poverty driving illegal poaching in parts of southern Africa), with the recognition that this applies at certain scales and in combination with other drivers (Box 5.3). For example, the actual act of poaching may be socially driven, but the market for products are an economic driver. In the case of large carnivore species such as tigers, Carter et al. (2019) consider overhunting and illegal hunting as one driver of changes in tiger space use and population persistence, referring in turn to drivers of such change in hunting practice as legal control. However, this study is far more about hunting as one of a range of drivers of species change itself rather than about which drivers affect hunting practice. Travers et al. (2019) used an unmatched count technique to identify the drivers of illegal hunting in communities adjacent to Ugandan national parks. They discovered that poverty, victims of human-wild species conflict, and exclusion from revenue of nature-based tourism often triggered poaching within the parks. They also explained that intervention programs that mitigated the identified drivers would reduce illegal hunting. However, there is limited evidence of threats of imprisonment or fines changing hunter behavior (Dobson et al., 2019).

5.4.4.3 Technological

Only two of the studies under consideration indirectly considered technological changes as a driver of changes in hunting practice. In their approach to the use of hunting dogs (highly detailed, but not, as in the case of many other papers, a "scenario" paper), Koster & Noss (2013) show how the intensification of hunting by dogs (a technological change) is largely driven by increases in population (in certain areas) and changing cultural and market demands (in others). Such intensification has implications for the conservation of hunted species, and, if a future trend, conservation of hunted species in those areas would be increasingly challenged.

Easily available and cheap light emitting diode (LED) flashlight technology enables hunters to pursue game more intensively at night than before, affecting killing rate and the number of kills made. In Brazil, these findings were supported by harvest data. This poses a major threat to wild species (Bowler et al., 2020). Likewise, the availability of motorized snowmobiles makes it easier for Alaskan Native American hunters to access hunting areas (Huntington et al., 2017), reducing the need for overnight stays and camping, thus changing the temporal and spatial nature of the hunting practice. Such technological changes in how driving affects hunting practice interact with, for example, significant ongoing changes in the physical environment, including major changes in the sea ice. Other technologies have increased the effectiveness of hunting and trapping, including (but not limited to) the use of airboats, surface-drive boats and further use of outboard motor boats. Detection of hunted animals is further supported by the increased affordability of technology such as game cameras and unmanned aerial vehicles.

In terms of hunting methods, snaring is almost universal in the tropics, whereas firearms require more of a financial and time investment (Dobson et al., 2019). Thus technology use depends on capital and time availability and physical capability, as well as social and cultural constraints (Dobson et al., 2019). Technologies and their evolution in temperate regions were mentioned above.

Wild species farming has been considered a conservation strategy that can help reduce harvesting pressure on some wild populations (Tensen, 2016). Broadly speaking, domestication and farming of wild animals of commercial value and high demand can also help to reduce the pressure on wild stocks (Nogueira & Nogueira-Filho, 2011; Tensen, 2016), although it may affect land-use pressures, and in some parts of the world the options are limited (Secretariat of the Convention on Biological Diversity, 2011). Expanding wild species production cannot occur at the expense of other species, biodiversity or ecosystem services (Gortázar et al.,2006; Mustin et al., 2018). Other concerns regarding farming of wild species have been raised elsewhere (e.g., Tensen, 2016 considers the particular conditions under which wild species farming may actually benefit species conservation). Insect farming is a potentially viable option to reduce dependence on wild meat and unsustainable hunting of wild animals for protein. Van Huis & Oonincx (2017), discuss the potential of small-scale and locally managed edible insect farming as well as industrial production.

5.4.4.4 Economic

As discussed above, studies (again, not "scenario" studies per se) show how changing market demand may drive, in certain areas, intensification of hunting using dogs (Koster & Noss, 2013; Huntington et al., 2017). Poverty, unemployment, economic hardship and poor law enforcement are important motivators for poaching, especially when risks are low due to e.g., corruption and wages. Increased per capita incomes in East Asia are an important factor influencing consumer demand for wild species parts and products. Huntington et al. (2017) observed that reduced demand for wild species products (such as animal skins) has changed hunting practice (amongst other drivers of change) in their study sites in northern and western Alaska.

Box 5.3 Demand for wild meat: feedbacks between global and local drivers

Many rural communities rely on wild meat hunting for their income and subsistence needs. However, as population levels and urbanization rise, hunting can become unsustainable, due to a higher urban market demand driving the commercial trade of wild meat. This, in turn, is likely to impact the long-term food security of communities, as well as wild species conservation projects. In the greater Serengeti ecosystem area, the influence of available meat substitutes (chicken, lamb, beef, fish and goat), socio-economic aspects and location all played a major role in the price as well as demand for wild meat (Walelign et al., 2019). An increase in the price of wild meat led to a decrease in the demand. The authors argue that it would thus be better to target poachers to increase their costs, rather than decrease the costs of substitutes. To reduce demand, policy interventions could be implemented that not only address a long-lasting conservation culture, but that also provide alternative means for income generation for hunters/poachers. The demand for wild meat in the future is, however, likely to change due to changes in cultural norms as well as preferences, whereby the younger "westernized" generation has a lower consumption of wild meat (Luiselli et al., 2019). Wild animals and the trade of their meat have a large impact on many countries' economies, as well as ecological impacts. Since the recent COVID-19 outbreak, the trade in wild meat has been under increased scrutiny due to the risks associated with an increasing urban population and decreasing natural habitats, which in turn can allow for rapid transmission of zoonotic diseases to humans. The wild meat trade has significant influence not only in terms of wild species impacts, but also on the livelihoods of those who rely on the trade. Many factors thus play a role in the supply and demand for wild meat (McNamara et al., 2020). For example, a country's commitment to reduce the illegal trade in wild species and a ban of terrestrial wild animal consumption will have significant impacts on those relying on that trade for income, as well as on the risk of emergence of zoonotic disease. Legalized markets could, in theory, allow for more regulations and strict protocols to be implemented, thus allowing better law enforcement and more control in order to reduce the spread of zoonotic diseases.

5.4.4.5 Environmental

Few of the studies considered specifically environmental factors as a driver of changes in hunting practice. This is a clear gap. A study in northern and western Alaska, interviews with 110 individuals in 14 Alaska native communities point to a rapidly changing marine environment not only affecting the survival rate of mammals but also rendering sea-ice unsafe to travel on, thus making hunting more dangerous (Huntington et al., 2017). Further, sea-ice changes modify the seasonal nature of hunting (there are, thus, both spatial and temporal changes). Changes in the physical environment are both expected to be ongoing and to interact with changing drivers in the social and technological dimensions. It is important to note that this study is not, strictly, a scenario-based analysis. Rather, climate projections are referred to as indications that currently observed trends (climatic trends influencing hunting practice and, thus sustainable use) are likely to continue.

5.4.4.6 Political

Legislation appears to be a key driver for changes in hunting practice. For example, Antunes et al. (2019) found that subsistence hunting in Amazonia has an unclear and controversial legal status, thus creating challenges in establishing consistent sustainable hunting management practices (changes have occurred since the 1967 legislation making hunting of all wild animals illegal). A range of studies examine legislative changes as drivers of changes in hunting practice, including changes from a total ban on hunting (for example, in Brazil) to fragmented or confusing legislative frameworks (for example, in the case of Brazil, although this certainly applies elsewhere). In Brazil, Nascimento et al. (2016) found that the hunting of other species posed an indirect threat to the species on which they focused. In this case, changes in the practice of hunting of other species were largely driven by changes in public policies.

Travers et al. (2017) used the unmatched count technique to identify the drivers of illegal hunting in communities adjacent to Murchison Falls and Queen Elizabeth National Parks in Uganda. Based on the identified drivers, they compiled a list of intervention options to reduce unsustainable and illegal hunting. The authors thereafter conducted surveys with stakeholders, including the local communities, to determine their preference for the intervention options and predict how they would respond to their implementation. The findings showed that livelihood was the main driver of wild species-related crime in both national parks, while the respondents preferred management practices that mitigated human-wild species conflict, and wild species-friendly enterprises in which local communities sign agreements to stop wild species crime in turn for average earnings of 500,000 shillings per year per household. The authors also noted that wild species laws and implementation such as arrests, imprisonment, and fines are not effective in deterring wild species-related crimes. The study observes, however, that protectionist policies are having some influence in these areas (at both Murchison Falls and Queen Elizabeth National Parks). Aerial surveys some years ago show for both parks increasing or stable populations of nearly all surveyed species (Wanyama et al., 2014).

Bollig & Schwieger (2014) consider local institutional change as a key driver of changes in natural resource management in Namibia, including hunting practices (here, commercial hunting is allowed as a permitted land-use under conservancies established by communities). As local institutions such as conservancies evolve, together with challenges in their establishment, control over hunting practices (amongst other land-uses) affects such practices. This includes, for example, issues of monitoring and sanctions. This trend is likely to continue in the future, as hunting regulation in Namibia evolves.

Alternative income generating strategies have been advocated by conservation managers, including wild species farming. However, Brown (2003) showed that wild species farming has not been successful in tropical regions, while the economic viability of wild species farming has been challenged by Mockrin et al. (2005). An "enhanced livelihood approach" (Blum, 2009) was used in Mount Cameroon tropical forests. It included hunting regulations through the issue of hunting licenses, allocation of hunting quotas and punishment of poachers (Blum, 2009). While this pilot project had been implemented since 1994 (Akumsi, 2003), it faced challenges, such as inadequate knowledge of natural history and population dynamics of wild species in the region, as well as a lack of long-term monitoring data to evaluate success of the project and facilitate adaptive management (Blum, 2009). Other hunting regulations focused on seasonal hunting, hunting methods which discouraged the use of traps and allocation of hunting tags to members of organized hunting groups with subsequent monitoring along the wild meat value chain (Olsen et al., 2001). Observations from Gashaka Gumti National Park in Nigeria showed that community-based management through allowing seasonal hunting and involving hunters in enforcing laws in "no-take zones" was very effective (Dunn, 1994).

Wilkie et al. (2016) examined overhunting in Africa and the four challenges to effective conservation, including lack of commitment by local communities, unsustainable harvesting methods, inability to expand wild species production like livestock, and habitat loss due to land-use change. They further identified the drivers and actors in wild meat consumption, and provided a synthesis of solutions to this intractable issue. They discussed the fact that wild species are harvested by local people, and mainly consumed by both rural and urban families, with economic incentives for the local hunters. They concluded that wild species can be best protected by effective protected area management and enforcement of wild species conservation laws (Wilkie et al. 2016). In a broad review of hunting, Dobson et al. (2019) further suggest that the effectiveness of interventions would need to be evaluated against alternatives.

Box 5.4 Trade-offs between wild species, livestock and livelihoods

Trade-offs exist between wild species, livestock, and people's livelihoods in many areas, which may allow for conflicts to arise between both human and wild species needs. In east African savannas, this challenge is addressed in part by habitat being provided for both wild species and livestock production. Improved integration between livestock and wild species may alleviate the conflicts that arise and allow for certain ecological benefits, such as a reduction in tick loads, thus preventing tick-borne diseases, as well as improved vegetation and forage cover. In addition, this allows for socio-economic as well as financial benefits from tourism and wild species-livestock production systems. The integration of livestock with wild species land-use therefore can provide benefits to wild species and human well-being. The political and governance implications of future conflicts over land and resources may, however, influence trade-offs; and equitable land ownership serves as a key driver of wild species-livestock coexistence (Keesing et al., 2018). Similar trends and issues are evident in North America and Europe (in the case, for example, of wild boar and agricultural land-use conflict). Globally, a shift in the way livestock and wild species interact is needed, via management frameworks that empower communities and allow for direct benefits from both wild species and livestock farming (du Toit et al., 2017). This is particularly the case now that pandemic disease risk has come into focus as an issue relating to the interface between wild species hunting and agriculture (Rohr et al., 2019).

Box 5.5 Trade-offs between trophy hunting, wild species protection, nature-based tourism and local livelihoods

Well-regulated trophy hunting is recognized as a conservation tool. However, there is a debate as to its sustainability. Muposhi et al. (2016) conducted a review on the various trade-offs, as well as implications of trophy hunting when used as a conservation tool.They found that in some countries the populations as well as quality of the species hunted are declining due to hunting pressure influencing the overall flight and foraging activity, which in turn affects species fitness levels. In addition, selective harvesting of trophy species ultimately leads to a decrease in the desirable phenotypic traits of the species, as well as increases their physiological stress levels. Effectively, trophy hunting can provide financial support and resources but requires sustainable practices.

There is frequent debate between, for example, conservation non-governmental organizations and governments on the effectiveness as well as acceptability of using trophy hunting as a tool for conservation, possibly in part driven by a lack of reliable information on its economic and ecological impacts. Trophy hunting can provide economic incentives for conservation of large areas that might otherwise be unsuitable for other wild species-based land-use (Lindsey et al., 2006). There are, however, aspects of the industry in certain areas that may hinder the conservation benefits. Factors limiting the role of trophy hunting as a conservation tool include issues relating to private and public land-use, over- and under-offtake, corruption, competition, the Convention on International Trade in Endangered Species of Wild Fauna and Flora limitations and inadequate regulation of the industry.

In a specific example, Parker et al. (2020) addressed the impacts that hunting bans have on private land conservation in South Africa, particularly on biodiversity hotspots. Landowners observed a significant drop in biodiversity following a hunting ban, as well as a transition to other forms of income generating activities such as livestock farming. On the other hand, there are case studies where trophy hunting bans have had positive effects on, in this case, lion demographics (Decker et al., 2016; Mweetwa et al., 2018). Essentially, the incorrect management and inappropriate regulation of trophy hunting can lead to negative consequences. However, there are also conservation and economic benefits that occur. More evidence needs to be provided on the economic and ecological impacts of trophy hunting to ensure appropriate trade-offs with multiple benefits.

Detailed studies on countries need to be undertaken to assess the role of hunting in conservation, diagnose problems, and propose sustainable site-specific solutions. Improved monitoring and enforcement of existing legislation, as well as the creation of new legislation and incentives for conservation performance are all aspects that need to be addressed to ensure that sustainable wild species management is practiced, both now and in the future, as such tradeoffs may become more difficult to achieve.

5.4.4.7 Cultural

Values and/or cultural practices can serve as key drivers of changes in hunting practice. For example, Glas et al. (2019), using an Indiana case study in the United States of America, show how wild species value orientations (fundamental beliefs or mental constructs that people use to view wild species) can help (in certain circumstances) show how certain wild species-related actions may be viewed and accepted (or not) by the public. In this case study, wild species value orientations are interestingly most predictive for lethal management actions (such as hunting), and the acceptance of such management actions increased as wild species-human conflict increased (with, presumably, knock-on effects on the engagement of such actions). As a result, wild species value orientations can be useful in informing wild species management using lethal actions, for example, in the management of large predators.

In their approach to wild species governance in the 21st century, Decker et al. (2016) observe a decline in interest in hunting in the United States of America, and show how sustainable use principles may affect wild species governance principles which could, in turn, affect the social acceptability of particularly wild species uses (such as hunting). Such views will have significant impacts on whether a particular wild species use or management is viewed as legitimate, with, as above, presumably knock-on effects on hunting practice (Box 5.5).

In Alaska, changes in cultural practices among Native American Inuits, such as reduced use of animal skins for clothing, have influenced demand for hunted marine mammals (Huntington et al., 2017). Further, the extent to which hunters in these study sites in northern and western Alaska use indigenous knowledge in adaptation to a changing environment, and also integrate new knowledge, is key to how their hunting practices adapt to multidimensional changing conditions.

Changes in human values, for example the rise of the animal rights movement (e.g., Hampton et al., 2021) and animal empathy could be important factors affecting the cultural acceptability of consuming wild animals, on the one hand, while driving a demand for certain wild plant products on the other. This could have negative impacts on livelihoods depending on wild species trade or hunting, and positive impacts on livelihoods derived from marketing wild plant products. There is also a move in Europe and North America for rising consumption demand for game meat, as well as in South Africa, in part due to perceived health benefits and the meat being considered (on occasion) "organic" (Archer et al., 2015). Saif et al. (2020) use the wild species tolerance model to understand what drives tolerance of Asian elephants in rural Bangladesh, finding that monetary costs do not have a significant influence, while intangible costs and benefits do (Box 5.4), with important implications for future conservation decision-making. Finally, Lopes & Atallah (2020) consider the importance of the spiritual value accorded to certain species in some indigenous communities, looking at population dynamics of tigers in a reserve in India under several management scenarios. A key finding shows that if the Soligas tribe, who consider tigers as sacred, are evicted from the reserve (losing security of tenure), localized tiger extinction is likely.

Box 5.6 Case of wild species use for cultural purposes and potential links to the spread of the COVID-19 coronavirus

In the context of the COVID-19 pandemic, a range of studies has tried to determine the source of the virus, with a wild source (probably a bat) considered (WHO, 2021). Wild species have been used for centuries for cultural purposes (including food and medicinal use), and the conditions in which animals are kept while in transit from source to final destination are often extremely poor (noting that wet markets do not always include live animals). A clear priority for action to reduce the risk of future pandemics is to conserve wild species and their habitats. Turcios-Casco & Cazzolla Gatti (2020) for example suggest four actions. Firstly, closing wet markets could reduce zoonotic disease spread (as well as illegal wild species trading). Secondly, the authors recommend conservation of natural areas and reduction of human-animal interaction. Thirdly, pangolins, bats and other species could be conserved rather than exploited (with some recommended measures). Finally, the authors recommend further regulation of medicinal use of such species. The authors argue that with increased control and stricter regulations, fewer animals would be illegally exploited and the risk of zoonotic disease spread will decrease. However, the issue is complex and the best approach is still contested (e.g., Roe & Lee, 2021), both because of the reliance of many poor communities on trade in wild species for their livelihoods (Booth et al., 2021a) and because of the potential for unintended consequences for both conservation and food security (Booth et al., 2021b). A pandemics treaty (proposed at the May 2021 World Health Assembly) could be key in terms of legally binding instruments to address these public health risks.

5.4.4.8 Summary of plausible futures for terrestrial animal harvesting

As indicated earlier (5.4.4.1), few studies explicitly address scenarios for hunting. Few papers could really be considered as "scenario" papers, and they largely considered drivers of hunting practice. However, some key trends can be identified and considered as likely to continue in the future. Firstly, key social drivers include legislation and regulation, illegal hunting and poaching, values around hunting and institutional change, linked in some areas to changes in legislation. Certainly, attitudes to terrestrial animal harvesting, or hunting, are evolving and, in certain areas, appear to be shifting in a way that affect their recognition. In addition, in certain countries, legislation regarding, for example, illegal hunting and poaching is both evolving and being more stringently implemented, with impacts on hunting practice on the ground.

Secondly, technological drivers of changes in hunting practices are likely, in some areas, to continue to evolve, including intensification of hunting due to improved technology, such as high beam hunting spotlights and faster vehicles. Conversely, in some areas, technologies to detect poaching and illegal trade are improving, providing improved support to anti-poaching measures (for example, the integrated surveillance system developed for South Africa's Kruger National Park, with a command center near the main camp, Skukuza). Another trend here that is likely to only intensify in the future is the increased availability of motorized vehicles for hunting.

Thirdly, the environment in which hunting occurs is changing and, particularly in regard to climate change, this can be considered an ongoing and intensifying trend. Examples here would include higher temperatures and changing sea-ice conditions, with clear implications for hunting practice in these areas.

Economic changes affecting hunting practice include changing market demand, including the demand for wild meat, which, in some areas, is projected to increase in the future. In other areas, however, reduced market demand for wild species products is a clear future trend, in addition to being currently observed.

Political drivers include aforementioned ongoing legislative changes (including the rise in hunting bans in some countries), as well as non-governmental organization participation in the Convention on International Trade in Endangered Species of Wild Fauna and Flora, which is likely to increase in the future.

Finally, cultural drivers of change in hunting practice are, in certain areas, likely to continue to change in the future, including changes of social acceptability of hunting in some areas, as well as loss of traditional knowledge regarding sustainable hunting practice (a clear ongoing trend in certain sites).

It is clear that the limited presence of scenario studies in hunting is a key knowledge gap. One key finding of this assessment is that such studies would have significant value, if using scenarios approaches explicitly and in a way that would allow for comparison across regions where possible.

5.4.5 Logging

5.4.5.1 Introduction

This assessment has a focus on sustainable use of wild species; therefore, the definition of sustainable logging focuses on activities in natural forests and secondary regrowth, and does not include plantations, which are often established using exotic species. Logging from planted forests often acts as a substitute for wood supply from natural forests, yet depends on the regional context of timber extraction and the end-uses of wood, mediated by global trade (see section 3.3.4 in Chapter 3).

Logging is defined as the removal of whole trees or woody parts of trees from their habitat. It generally results in the death of the tree, but also includes cases in which it may not, such as coppicing. Some activities that constitute part of forest management and use such as extraction of plants, algae, and fungi products (e.g., resins or fruits) are in some cases undertaken along with logging as part of integrated forest management practices.

Most scenarios analyzed here are associated with forest futures in the context of climate mitigation — linked to carbon emissions and removals — and energy supply, and their trade-offs. Often, such scenarios tend to focus on planted forests, or do not make a distinction between planted and natural forests, nor capture the substitution effects between these two different types of forest. Much less attention has been paid to scenarios of the sustainable use of natural forests in the context of climate change, development, biodiversity protection and poverty reduction, which tend to differ depending on biomes (tropics, subtropics, temperate and boreal).

Multiple drivers influence the future of wild or natural forests vis-à-vis planted forests, and furthermore sustainability differs depending on whether harvesting is for diverse wood-based products (e.g., furniture, plywood, paper and paper-like products) or energy, and is influenced by consumption, trade and material substitution dynamics. In addition, increasing human disturbance, along with climate change (e.g., fires, drought) and biotic factors (e.g., pest infestations) create additional stress on forests, particularly natural forests, with direct implications for forest condition that also affect their actual and future capacity to respond and adapt to climate-related risks. The future of natural forests is also intimately associated with plantation development, which may reduce the pressure on natural forests to meet demand for harvested wood products. It is also linked to the different forest management systems used for logging, which can affect forest population structure and genetic diversity (Ratnam et al., 2014). The dynamics of forest regeneration also play a role, with impacts not only on wood supply but also on the provision of (forest-related) nature’s contributions to people (Shimamoto et al., 2018). Finally, the future of natural forests, and thus logging, is directly and indirectly linked to wider land-use dynamics.

The total global forest cover area has decreased over time, including a persistent trend of natural forest decline, despite gains from natural forest regeneration (FAO, 2020a). In addition, a significant portion of the remaining cover of natural forests is degraded due to effects of conventional logging, edge effects due to fragmentation, and incidence of fire (Finegan, 2016). If current trends continue, natural forests will be much smaller, simpler, steeper and emptier in the future. This is because natural tropical forests are expected to keep diminishing in size and become more fragmented, with larger areas in edges and patches, and with reduced structural and species complexity. The better-preserved forests will be restricted to steeper and less accessible areas (Edwards et al., 2019). In addition, forests in the future may be more exposed to fires and diseases, which can also affect the survival of species less resilient to stress (Anderegg et al., 2020).

The demand for wood-based panels, paper and paperboard has been estimated to double between 2005 and 2030, and the demand for sawn wood to increase by 50% over the same period (FAO, 2010), though with a growing share of recycled materials and wood residues lowering the demand for primary timber. Logging in natural forests is expected to continue, yet this supply will also be substituted over time by timber from plantations to keep up with global demand for industrial roundwood (WWF, 2012; FAO, 2015). Planted forests and trees outside forests will also become an important source of wood production but probably for domestic markets (FAO, 2019). Demand will also depend on the prospects for the use of wood for construction and buildings, and innovations to increase the durability of wood as a construction material in the building sector.

5.4.5.2 Social

Market demand is influenced by population growth, and urbanization is a key driver affecting the area of natural forests threatened by conversion to agriculture and the volume of wood (or fuelwood) supply originating from natural forests. Population increases in rural areas may lead to further occupation of land for commercial agriculture (Haller, 2014). This is likely one of the most important drivers of deforestation in the tropics and sub-tropics (Pacheco et al., 2021). A major proportion of projected global population growth is predicted to take place in Africa. Of the additional 2.4 billion people projected between 2015 and 2050, 1.3 billion will be added in Africa, 0.9 billion in Asia and only 0.2 billion in the rest of the world (UN DESA, 2016). Population growth may lead to an increase in the unsustainable consumption of forest products. Yet changes in consumption behavior may reduce the demand for forest-risk commodities, and protect forests from further conversion, as explored in future positive scenarios for Para State, Brazilian Amazon (Siqueira-Gay et al., 2020). A global analysis suggests that food systems transformation is one of the pathways towards terrestrial biodiversity conservation, and thus protection of natural forests (Leclère et al., 2020), yet it could constrain wood supply.

Wood demand is linked to product substitution with metals and plastics, the digital era (McEwan et al., 2020), and the potential demand from bioenergy markets for wood-based biomass (Nepal et al., 2019). Urban population growth expands demand for energy, which in countries in Central and East Africa predominantly originates from traditional sources such as fuelwood and charcoal (Ahrends et al., 2010). Global demand for charcoal will continue to increase due to urban population growth in developing countries, mainly in sub-Saharan Africa where demand for charcoal and fuelwood relates to its affordability, easy access and transport, and tradition. Currently one third of residential energy use is based on traditional bioenergy, including charcoal (Santos et al., 2017). Projections of charcoal production and use in urban households in Central & South America, Africa and Indonesia to 2100 using scenarios based on the shared socio-economic pathways and an energy model (Santos et al., 2017) estimated an increase in demand for forest biomass for bioenergy ranging from 31.5 million tons in the most sustainable scenario to 450 million tons in the least sustainable scenario by 2100 (Santos et al., 2017). However, this study showed that all of the regions examined have the forest biomass capacity to meet this demand, especially in Africa and South America, although of course there can be substantial ramifications of changes in biomass use for bioenergy.

5.4.5.3 Technological

Technological innovations could support sustainable use of natural forests through multiple routes. Improving the uptake of technologies for sustainably advancing agricultural intensification, particularly in working lands of producer countries, could enable land to be spared for forest conservation, conditional on the type of governance in place (Ceddia et al., 2014). Technologies in wood manufacturing will also contribute to the expansion of their use in buildings (Ramage et al., 2017), along with the wider adoption of technologies for improving the efficiency of wood-biomass use for energy production (Proskurina et al., 2019). Yet, much of this wood supply may originate from plantations, which may substitute for wood from natural forests, thus reducing the pressures on natural forests as a source of wood supply. Expansion of forest cover can be facilitated by forest restoration — mainly linked to assisted natural regeneration or reforestation — which will benefit from the increasing use of technologies and data to determine the technical potential of large-scale restoration, machine learning to determine tree species composition (Lang et al., 2018), and the potential use of aerial seeding by drones or other aircraft, among others. The success of regeneration can depend on silvicultural practices that ensure the survival and establishment of tree saplings and also affect economic viability (e.g., Graefe et al., 2020). Routa et al. (2019) investigated this in *Picea abies* and *Pinus sylvestris* in Finland, finding that during a 50 to70-year rotation, the use of improved varieties of tree species, with or without nitrogen fertilization, increased timber production by up to 28% and economic profitability (net present value) by up to 60%, regardless of the tree species and the impacts of climate change. This highlights that the use of improved practices can increase the output of forest plantations and promote sustainable forestry management.

In addition, a greater uptake of sustainable forest management practices in natural forests (e.g., reduced impact logging) has the benefit of ensuring higher rates of forest regeneration compared to traditional harvesting methods, thus making it possible to sustain future logging but with comparatively lower volumes over time (Putz et al., 2012). Furthermore, innovations in forest management systems are expected in industrial timber production (e.g., technology used in harvesting machines, and the choice of harvesting machines, systems and methods) linked to variations in tree size, plantation areas and forest composition, including harvesting in more difficult terrain (McEwan et al., 2020). Still, a source of debate is whether the use of improved technologies in small-scale artisanal logging will significantly enhance the sustainable supply of timber from natural forests, particularly in tropical areas where smallholders constitute the main forest users (Asamoah et al., 2011). Finally, the application of timber tracking and origin verification may offer quick and reliable information to support the implementation of sustainable practices and monitoring for compliance (Lowe & Cross, 2011), and in natural forests such practices can be expected to supply consumer markets with more stringent import regulations. In developing economies, forests may increase their contribution to economic development and well-being if the industry is restructured in ways that increase the value of the harvested wood, which can then compete with traditional sources of income from extractive industries (e.g., oil and gas), and reduce forest depletion (Izursa & Tilley, 2015).

5.4.5.4 Environmental

Moderate increases in average temperatures can likely be absorbed by forest ecosystems, since most species are capable of acclimating to small increases in temperature (Yamori et al., 2014; Way & Yamori, 2014; Reich et al., 2016; Slot & Winter, 2017). However, more extreme climate-change driven weather fluctuations, particularly the combination of high temperature and drought, can induce tree mortality, or may weaken forests and make them prone to insect attacks, which then finish them off (Anderegg et al., 2015). Extreme temperatures can also lead to leaf damage and death, which reduces the overall health of the trees and predisposes them to other potentially lethal agents. There is also a greater likelihood of fire outbreaks in drier seasons, and droughts, which also expand fire incidence and have important direct consequences for tree mortality (Brando et al., 2014). Furthermore, at higher temperatures insect herbivores need to consume larger quantities of food to meet their metabolic demands, which could increase the amount of herbivore damage to plants (Jamieson et al., 2015). In addition, fast-growing species may tend to perform better in adapting to high temperatures than more conservative, slow-growing species. This might reflect the fact that the early-successional fast growers tend to germinate and grow in hotter, sun-exposed sites, whereas the slow-growing species tend to germinate and grow in the cooler understory. Therefore, climate change may tend to induce changes in forest composition through a range of direct and indirect processes which vary across biomes (Halofsky et al., 2020). Such changes in forest composition can have lasting impacts on sustainable forestry management practices and other drivers of the use of wild species.

Longer rotation periods are important for silvicultural management and have economic and environmental impacts. Using expert-based evaluation in a multi-criteria decision analysis framework, Eggers et al. (2019) investigated the effect of 10 forest management scenarios in two municipalities in Sweden. Modelling a hundred-year period, current forest management practices (business-as-usual) with a focus on wood production were economically beneficial but fell short of environmental and social goals (Eggers et al., 2019). Alternative scenarios of integrated forest management policy that supports longer rotation periods, have reduced thinning, and set aside forests for strict protection better balance economic, environmental and social impacts (Eggers et al., 2019). A literature review supports the environmental benefits of longer rotation periods, including supporting and provisioning ecosystem services and climate mitigation (Roberge et al., 2016).

Lundholm et al. (2020) modelled species-specific climate change adaptation and the dynamics of timber prices for 11 tree species in the Irish peatland forests. The objective was to assess the net present value of Irish peatland forests based on several regulating, provisioning, and cultural ecosystem services indicators. Scenarios to 2100 assessed a baseline model, a reference model of increased global temperature with forest set-asides, and two alternative models describing the European Union’s and global efforts to mitigate climate change through increased bioeconomy (Lundholm et al. 2020). Ecosystem services indicators were mainly affected by intensified logging caused by global timber prices; the greatest differences were noted in estimated carbon storage and windthrow risk. The outcomes of the different scenarios also highlight complex interactions among the ecosystem services indicators, which may result in conflicting management objectives. For example, increased use of bioenergy reduced dependence on fossil fuel in Ireland, but resulted in shorter rotation periods and reduced forest biodiversity, while longer rotation periods and forest set-asides were effective for short-term carbon sequestration. Furthermore, intensified logging led to short-term freshwater nutrient enrichment and reductions in forest carbon storage (Lundholm et al. 2020). Overall, the models suggest higher levels of carbon storage, regulatory, provisioning, and cultural ecosystem services from longer rotation periods which allow individual trees to mature. However, these benefits may be offset by greater windthrow risks (Lundholm et al. 2020).

It is important to note that intraspecific variations due to micro-ecological conditions may warrant varying management practices for populations of a tree species occupying different habitat conditions within the species geographical range. Greater population genetic differentiation due to divergent microhabitat conditions, and isolation by geographic distance and by environment patterns, have been widely reported for many plant species (Borokini et al., 2021; Sexton et al., 2014), including trees (Buzatti et al., 2019; Garot et al., 2019; DeSilva & Dodd, 2020). Likewise, different biotic and abiotic selection pressures such as climatic heterogeneity, wind speed, frequencies of parasitism (pest density and pathogenic load), pollination and herbivory across a species range can drive local adaptations resulting in intraspecific genetic and morphological variations within a tree species (Savolainen et al., 2007; Sobral et al., 2015; Zhang et al., 2021). Differences in microhabitat conditions can affect post-harvest regeneration rates in natural forest as well as recovery rates for plants, algae and fungi (Foahom et al., 2008; Cunningham et al., 2017). Therefore, effective forest management policies need to move beyond species-specific to landscape approach based on the prevailing site environmental conditions. Box 5.7 illustrates how varying vulnerability to climate change necessitates different management practices across Finnish boreal forests.

Box 5.7 Lessons learned from the environmental effects on forest management in Finland

To give a specific example, a study on management scenarios in Finland under a strong climate change scenario showed that timber production, net present values, and carbon stocks of forests would be reduced in southern Finland and increased in northern Finland (Zubizarreta-Gerendiain et al., 2016). In central Finland, climate change would have little effect. The use of optimized management plans resulted in higher timber yield, net present values, and carbon stock of forests compared with the use of a single management scenario, regardless of forest region and climate scenario applied. This suggests the need to modify the current business-as-usual management to adapt to the changing climate (Zubizarreta-Gerendiain et al., 2016). Another potential impact comes through increasing wind damage due to climate change. A study on Finnish boreal forests used a forest ecosystem and a mechanistic wind damage risk model to predict wind speeds from global climate model predictions using two representative concentration pathway scenarios (representative concentration pathways 4.5 and 8.5) over the period 2010–2099 (Ikonen et al., 2020). Predicted wind damage was projected to be more severe in southern Finland's forests dominated by *Picea abies* and *Betula pendula*, which are more vulnerable to such impacts. Therefore, climate change-induced wind damage needs to be considered to ensure sustainable forestry management and productivity in regenerated forests (Ikonen et al., 2020).

5.4.5.5 Economic

Economic drivers have an important influence in shaping the future of logging and natural forests, including land competition driven by the opportunity costs of land-use (Smith et al., 2010). Given the greater profits obtained from agricultural land-uses, and since the ecosystem services of forests are often not internalized, transaction costs associated with keeping standing forests tend to be higher; thus, there is a trend for logged-over forests to be converted to agriculture. In the tropics, the economic value of land with no forest tends to be higher than similar lands with standing forests (Pokorny & Pacheco, 2014). While sustainable forest management may be costlier than predatory logging, benefits tend to be higher in the long term. However, it still cannot compete with agricultural land-uses. As indicated in the gathering section (see 5.4.3), forest multi-use and integrated management that allow for plants, algae and fungi cultivation and collections between timber rotation periods may increase the economic value of natural forests (Klimas et al., 2012; Sist et al., 2014). Global trends analysis signals that competition for land to meet food supply will persist, yet there will be scope for reducing food waste and opportunities for shrinking the land demand for animal feed (Griscom et al., 2020). There is also the potential for contributions to human diets from aquaculture, fisheries and other sources to change. However, future projections suggest that meat production will keep growing to meet a projected expansion of urban demand, particularly in Africa (Byerlee et al., 2017). In addition, analysis of the pathways for achieving climate targets stress the importance of forest restoration and reforestation for carbon removals from the atmosphere, which may also place additional pressure on non-forest land and ultimately food production (IPCC, 2019). Recent analysis of the cost-effectiveness of options for climate mitigation suggests that avoided deforestation would rank higher in the list than reforestation and planting trees in agricultural lands (Griscom et al., 2020). When looking at the costs of stabilizing the climate, an analysis using the global timber model projects the mitigation potential and costs for four abatement activities across 16 regions for carbon price scenarios of 5 to 100 United States dollars/tons of CO_2 (Austin et al., 2020). This analysis predicts global mitigation by 2055 to cost 2 to 393 billion United States dollars in year-1, with avoided tropical deforestation comprising 30 to 54% of total mitigation. Higher prices incentivize greater mitigation via rotation and forest management activities in temperate and boreal biomes. Forest area increases by 415 to 875 million hectares relative to the baseline by 2055 at prices of 35 to 100 United States dollars/tons of CO_2, with intensive plantations comprising <7% of this increase. Yet for forests to contribute about 10% of the mitigation needed to limit global warming to 1.5 °C, carbon prices will need to reach 281 United States dollars/tons of CO_2 in 2055 (Austin et al., 2020). Payments for avoidance of carbon emission through limiting deforestation may affect land-use decisions (Fuss et al., 2020), though it is important to recognize that for these climate mitigation approaches, considerations of equity and implementation remain crucial (Demaze et al., 2020;

Dieterle & Karsenty, 2020). Explorations of sustainable utilization of forests for bioenergy have been conducted (e.g., Hernández, Jaeger, & Samperio, 2020). Changes in technologies and forest management practices are expected to unfold in the future, associated with the increased competition between wood for energy (Nepal et al., 2012) and carbon removal since reforestation has been identified as the most cost-effective option for natural climate mitigation (Griscom et al., 2017). More uncertain is whether enhancing innovations in plantation management will lead to reduced logging of natural forests due to market competition.

The trends in forest loss could be reversed if forest regeneration increases, but this is uncertain (Holl & Brancalion, 2020), and may result in favoring planted forests over natural forest regeneration. The total technical potential of areas suitable for forest restoration has been estimated at nearly 1 billion hectares (Bastin et al., 2019), but the actual potential could be much lower, as has been suggested for the Southeast Asia region (Zeng et al., 2020). The total area of plantations has tended to slow down, linked to a weak demand for wood due to product substitution with metals and plastics, and the digital era (McEwan et al., 2020). Future expansion of planted forests will likely be more strongly linked to efforts for carbon dioxide removals (Bernal et al., 2018) and the potential demand for wood-based biomass for bioenergy (Nepal et al., 2019). This forest expansion will likely be due to higher economic benefit-cost ratios, and potential for carbon capture (Bernal et al., 2018), but with adverse impacts on food security (Smith et al., 2020). These trends will partially be reversed if greater investments are directed to supporting natural forest regeneration and agroforestry, as part of efforts to enhance local livelihoods and restore forest environmental functions within wider initiatives to enhance forest landscape resilience (Löf et al., 2019).

The situation varies significantly by region. Africa's share of the global wood products trade is quite low, and the production of low-value-added products is absorbed by the domestic markets, with other timber exported. A significant portion of the timber cut in Africa supplies domestic fuelwood consumption (FAO, 2010). In Asia and the Pacific, plantations are projected to expand — mainly in the most developed countries — incentivized by a growing demand for industrial roundwood, following the growth in population and income, and logging of natural forests will continue in less developed forest-rich countries (FAO, 2010). In Latin America, demand for wood from natural forests is expected to gradually be substituted by the expansion of planted forests, yet the timber industry will face increased competition from wood products from Asia. Given persistent pressure for forest conversion some timber will continue to originate from natural forests converted to agriculture after logging. In Europe, the demand for wood (materials and energy) was projected to increase by about 20 to 50% over the period 2010-2030, with the largest share increase due to bioenergy (FAO, 2015). In North America, wood production was projected to double in this same period of time (FAO, 2010), and projected to increase by 60 to 110% in Russia (Petrov & Lobovikov, 2012).

The European Union is the major consumer of biomass for energy and also the main importer of most biomass products, particularly wood pellets (Proskurina et al., 2019). Price oscillations in oil markets will influence timber prices as well (Härtl & Knoke, 2014). It is likely that more wood biomass and forest residues will be used for energy (e.g., thermal, electricity) than for material purposes, at least in some developed economies adopting targets for fossil fuel substitution more actively. Although much of that supply will originate from large-scale plantations, it may also impact timber extraction from natural forests, as has happened in the past. For example, it was argued that European Union bioenergy targets have led to a significant and growing share of biomass for energy being imported to the European Union from countries in the Global South, as well as from regions rich in natural forests, such as Canada, the United States of America and Russia (Andersen, 2016).

5.4.5.6 Political

Many political drivers have an influence on the protection of natural forests and the future of logging. For example, Oduro et al. (2014) showed that illegal logging, weak forest governance, high demand for timber due to population growth, and increasing land-use change to cocoa production facilitated forest degradation in Ghana. With a 2% population growth projection in Ghana, they developed and described four management scenarios for the timber industry in Ghana. These scenarios included a legal forestry scenario with well-enforced government regulation and fiscal policies, a degradation scenario with continued illegal logging and weak regulation, a transition scenario with tenure reforms that would give more rights to communities and farmers, and a timber substitution scenario with weak governance and incentives, and declining forest resources. A juxtaposition of the four scenarios showed that legal forestry best ensures timber use efficiency and promotes sustainable logging, followed by the forest transition scenario, underscoring the importance of effective governance. Similarly, analysis of positive scenarios in Para State, Brazilian Amazon suggests that effective land management is needed to avoid further forest conversion (Siqueira-Gay et al., 2020). However, an exploratory analysis on the implications of tenure and forest regulations in the Caribbean forest shows that general harvest regulations do not guarantee sustainable forest management, thus applying rigid rules which do not take into account the current conditions of the stands entail a long-term risk of forest degradation (Gräfe et al., 2020). At the international scale, regulations for reducing illegal timber trade (e.g., Forest law enforcement, governance and trade voluntary partnership agreements signed between the European Union and participant countries) have proven that voluntary partnership agreements have had positive outcomes in terms of improved forest governance, but have not solved illegality in domestic markets (Cerutti et al., 2020).

Natural harvested timber may not regenerate to previous levels after harvesting, even if a forest is managed sustainably. An important trade-off in managing forests consists of reconciling aims for production and conservation, which may tend to diverge over time. For example, an assessment of the restoration potential for southern-boreal forests in the Border Lakes Region of northern Minnesota and Ontario, Canada, found that it may not be possible to achieve all objectives under a single management scenario (Shinneman et al., 2012). Modelled outcomes of six different management scenarios suggested that fire management may be incongruent with forest restoration management, but reduces fire risks in protected forests, while logging and fire regimes that emulated natural disturbance patterns can transition forest landscapes closer to a natural condition (Shinneman et al., 2012).

Estimations of forest carbon stocks and greenhouse gas emissions are not limited to logging events, but also consider downstream sectors, processing and use of the harvested wood and recycling of wood wastes. Chen et al. (2018) compared a baseline scenario (business-as-usual) of logging and use of wood-based products, based on historical rates (1990-2009) of logging below maximum allowable levels, with six alternative scenarios in Ontario, Canada, to simulate forest carbon stocks and emissions throughout the forest value chain system. These six alternative scenarios describe increased logging at different intensities coupled with harvested wood products end-use and substitution, as well as greenhouse gas emissions from the decomposition of harvested wood products wastes. Using forest carbon stocks and emissions as criteria, the authors observed that increasing logging beyond the current baseline but producing primarily solid harvested wood products for construction would minimize wastes which cause emissions from landfills (Chen et al., 2018). However, these alternative scenarios would require between 20 and 60 years to achieve net greenhouse gas emission reduction; therefore, the authors recommended an integrated approach to forest harvesting to reduce emissions in the short-term (Chen et al., 2018).

Similar results were obtained in Japan from projections using a harvested wood products carbon balance model. An estimated maximum 8.4 million tons carbon mitigation per year to 2050 was projected from the use of harvested wood products in place of fossil fuel-based energy (Kayo et al., 2015). Of this, approximately half was projected to be generated from energy substitution sourced mainly from logging residues. Kayo et al. (2015) also highlighted the significant contribution of substituting non-wooden building materials with harvested wood products. In all modelling, they cautioned that business-as-usual is unsustainable and results in more greenhouse gas emissions (Kayo et al., 2015). Similarly, Matsumoto et al. (2016) projected climate mitigation via a reduction in greenhouse gas emissions using a forest-carbon integrated model with three scenarios (baseline, moderate and rapid increases) of harvesting and use of timber products to 2050. They found that a baseline scenario, describing current and constant levels of logging (at 41,000 hectares), 64% replanting of harvested areas using existing tree varieties, the use of 35% of harvested wood for construction, coupled with recycling of 21% and 83% of residues from processing and waste wood respectively for bioenergy use, was the most effective in reducing greenhouse gas emissions at both short and long term (Matsumoto et al., 2016). However, increased use of wood products and reforestation using high-yielding tree varieties, which characterised the rapid increase (70% harvesting increase from baseline) scenario also facilitated greenhouse gas emissions in the longer term. They concluded that in the long term, construction material and bioenergy substitutions with wood-based products were more effective in reducing greenhouse gas emissions (Matsumoto et al. 2016).

However, the case is different in the United States of America, where projections of intensified wood energy consumption and the growth of the global economy were associated with a substantial reduction in timber stocks and a significant increase in greenhouse gas emissions by 2060 (Nepal et al., 2019). Similar trends in growth of the global economy but less wood energy consumption would result in a projected increase in forest carbon stocks. The authors used four global economic scenarios, three of which projected a reduction in global fossil fuel production post-2030, indicating a likely increase in reliance on bioenergy, and the fourth a business-as-usual scenario based on historical fuelwood use (Nepal et al., 2019). Thus, differences in the projections of forest carbon stocks and greenhouse gas emissions across different countries may be associated with differing forest management policies.

The projected retention of forest carbon stocks depends on reforestation. Across the world, harvested timber is replaced mainly with plantations of exotic tree species, mainly for the pulp and paper industries and bioenergy. Rodríguez-Loinaz et al. (2013) investigated forest carbon stocks in exotic tree plantations versus native broadleaf tree species in Biscay, northern Spain. The authors compared future scenarios of carbon sequestration in exotic tree plantations to reforestation with native tree species, using a business-as-usual model for the next 150 years as a reference (Rodríguez-Loinaz et al., 2013). The main finding was that the long-term reforestation with native tree species would have higher carbon stocks than plantations of exotic eucalyptus and pine trees.

Analysis of global pathways to reverse biodiversity degradation highlights the importance of increased protection of natural forests, but these analyses need to be combined with other pathways supporting system change such as food systems transformation, otherwise the full picture of the dynamics of the system as a whole will be missed (FABLE et al., 2020).

5.4.5.7 Cultural

Enhancing the efficiency of logging may impact local people's cultural values and livelihoods. For example, logging in the tropics has often transitioned from large-scale conventional logging to more sustainable forest management incorporating reduced impact logging (Finegan, 2016). Yet, the costs of sustainable management operations have tended to impair the uptake of recommended practices by smallholders and communities, who often tend to opt for non-planned informal logging. This works against the potential for local forest users to capture a higher portion of the benefits from logging (Pacheco, 2012). Nothing suggests that these trends will be reversed in the future if institutional and policy drivers continue unaltered. With regard to the recognition of customary tenure rights in forest management, there is still a major gap between indigenous peoples' land-use rights and the actual recognition of those rights (Khare et al., 2020).

5.4.5.8 Summary of plausible futures for logging

There is a continued reduction in global forest cover despite the increase in global forest restoration, which suggests a trend of net forest loss. This trend is further exacerbated by forest fragmentation due to logging. Changes in food production and agricultural practices in the future, as well as population increases in rural areas, will affect deforestation and land conversion rates. Additionally, climate change may increase tree mortality due to drought, changes in pest attacks and insect herbivory, wind damage, and wildfires, while post-disturbance passive restoration may favor early successional tree species and alter forest composition. The global demand for wood products depends partly on product substitution, especially in developed countries. Demand for wood-based bioenergy continues to increase both in developing countries where growth in population and urbanization drive charcoal and fuelwood production and markets, and in developed countries adopting fossil fuel substitution policies that can stimulate the use of wood-based biomass for energy purposes. Forest plantations may meet some of the growing demand for wood and reduce the overexploitation of natural forests.

Scenarios and future projections suggest that integrated management that includes sustainable forest management practices, multi-use forests (logging and plants, algae and fungi gathering), forest restoration using fast-growing tree varieties, and food systems transformation can support sustainable use. Technological innovations including sustainably intensifying agricultural production, reducing wasteful logging and processing, increasing efficiency of wood biomass use and increasing the success of large-scale reforestation projects can also help support the sustainability of natural forests. Economic and political initiatives that may incentivize the forest sector towards sustainability can include higher forest carbon pricing, payments for emission avoidance through avoiding deforestation, and sustainable land management. Such policies are more efficient when they consider customary, tenure and land-use rights for local communities. There may be trade-offs between the use of natural forests for logging, conservation, and/or carbon sequestration. Reforestation with native species and longer rotation periods may also facilitate higher forest carbon stocks.

5.4.6 Non-extractive practices

5.4.6.1 Introduction

For the purposes of this assessment, non-extractive practices are defined as "practices based on the observation of wild species in a way that does not involve the harvest or removal of any part of the organism. The observation can imply some interaction with the wild species, such as the activities of wildlife and whale watching or no interaction with the wild species, such as remote photography". This includes activities such as wildlife watching, photographic safaris, whale watching, botanizing, and hiking. Although non-extractive practices are primarily observational, there can be some interaction with the wild species, such as activities that involve handling, touching or feeding wild species. According to this definition, regulatory ecosystem services such as carbon sequestration are not included in this assessment. Thus, non-extractive practices are considered to be part of a range of uses where there are no direct offtakes of resources from nature, such as non-material benefits and cultural ecosystem services (Costanza et al., 1997; Watson, 2005).

The trends in demand for non-extractive use of wild species for ceremonial and cultural uses (e.g., worship in sacred groves) are not well documented, but changing social contracts with nature and an erosion of traditional ways of life are a threat to both local use and local protection of wild species (see Chapter 3, Findlay & Twine, 2018; Fournier, 2011; Juhé-Beaulaton & Salpeteur, 2017; von Heland & Folke, 2014). There is some evidence that the non-extractive use of wild species for mental and physical health through preventive and restorative practices may be increasing, such as the use of trees in "forest bathing" (Shin et al., 2017) or bird-watching to support life satisfaction (Methorst et al., 2021). Indeed, the use of national parks and green spaces for tranquility and general recreation increased dramatically during the COVID-19 pandemic (Spenceley et al., 2021; Venter et al., 2020). For example, visitation to nature areas around Oslo, Norway has increased up to 290% (Venter et al., 2020), while some national parks in Sweden witnessed a 75% increase in visitors even before the peak season (Hansson, 2020).

The demand for non-extractive recreational use of wild species (e.g., bird-watching tours, scuba diving), especially commercial tourism, is projected to grow exponentially in the future, potentially with a short-term decline at the global level due to COVID-19 (Gössling et al., 2021). For instance, in both Africa and Asia-Pacific, it is predicted that demand for wildlife watching tourism will increase, particularly within protected areas (Frost et al., 2014). Drivers of this growth include the following "megatrends": social (population growth, urbanization, changes in household composition, aging populations, health and well-being, changing work patterns, gender equality, values, and lifestyle); technological (transportation, high-tech equipment, information and communication technologies); economic (economic growth, sharing economy, fuel costs); environmental (climate change, land-use and landscape change); and political (political turbulence, changes in border regulations, health risks, geopolitics) (Elmahdy et al., 2017).

Growth in wildlife watching tourism may manifest itself in overdevelopment and overuse of natural areas. These global trends and commercialization of wild species have raised concerns of unsustainable use and an increasing disconnectedness of people from nature (see Chapter 3). Nature-based tourism is increasingly becoming characterized by the importance of experiences, well-planned activities, and a sense of adventure and achievement, rather than appreciating wild species through simple leisure and observation (Buckley, 2000; Buckley et al., 2015; Curtin, 2005; Dwyer, 2003; Elmahdy et al., 2017). There is a trend towards recreational activities in nature becoming specialized, motorized, sportified and adventurized (Öhman et al., 2016; Sandell et al., 2011), an opportunity for photographic "selfies" with wild species (World Animal Protection, 2017), with nature transformed into a scenic backdrop for tourist experiences. These experiences affect tourists' expectations regarding the availability of "pristine" nature that simultaneously has high levels of comfort, accessibility, and high-quality experiences (Elmahdy et al., 2017; Fredman et al., 2012). Increasingly, tourism brochures feature herds of teeming game, absent of local communities that live alongside these wild species (Montgomery et al., 2020).

But the projected increasing interest in wildlife watching tourism also provides opportunities for a significant tourism economy, supporting conservation and the livelihoods of local communities, as well as contributing to the enjoyment and education of wildlife watching tourists (Dou & Day, 2020; Tapper, 2006; WTTC, 2019b). Drastic decreases in tourism revenues due to COVID-19 pandemic have also demonstrated the important role of this practice for wild species conservation, especially in developing countries (Newsome, 2020). It has been suggested that the ultimate outcome related to the impacts of COVID-19 pandemic on wildlife watching tourism depends on political support, funding of protected areas, role of non-governmental organizations and the renewed confidence of local communities (Newsome, 2020).

While there are studies that examine scenarios of sustainable tourism broadly (i.e., in terms of many axes of sustainability (Stratigea & Katsoni, 2015), including scenarios of emissions footprints (Whittlesea & Owen, 2012), a focus on non-extractive use of wild species is substantially rarer (i.e., specific incorporation or discussion within scenarios of sustainability for wildlife watching and nature-based tourism or other non-extractive practices). Similarly, while there are numerous studies of sustainable nature-based tourism in terms of drivers, historical changes over time, conceptual frameworks, or strategies for enhancing sustainability (Reynolds & Braithwaite, 2001; D'Lima et al., 2018; Finkler & Higham, 2020), studies on non-extractive practices that include scenarios or scenario development are much rarer, and suggest that this aspect may be less explored. Non-extractive practice scenarios that do exist have been conducted mostly for multiple species and at system level, rather than single species scenarios. Models have been used to explore different futures, including tourism, and explore trade-offs with other uses and values (Fulton et al., 2015). While non-extractive practices are a growing phenomenon, these uses are unlikely to halt extractive uses, which can also contribute to livelihoods and/or foster cultural practices. Careful consideration of the relative trade-offs between practices and uses are needed to guide interventions that favor one over the other.

5.4.6.2 Social

The global population is projected to increase to 9.7 billion people by 2050, 68% of which are forecast to live in urban areas (UNDESA, 2019), and the number of people seeking experiences with wild species as an escape from urbanized environments will also rise. With fewer people living in rural areas, natural areas are increasingly perceived as spaces for leisure experiences. Animal roles in leisure have become especially evident during the COVID-19 pandemic, as social isolation created demand for interaction with animals in general and wildlife-related leisure practices in particular (DeMello, 2021). Urbanized populations are known to have views of nature different from those of rural inhabitants, which include, for example, romanticisation and anthropomorphisation of wild species, often coupled with unrealistic expectations of safety and control in nature (Gstaettner et al., 2020). There is an increase in novelty-seeking behavior, driving up the demand for unique nature experiences, which is likely to drive strong tourism demand both regionally and globally (Frost et al., 2014). Lin & Lee (2020) found that recreational experiences positively influenced both environmental attitudes and place attachment in Taiwan, province of China, and can indirectly engender pro-environmental behaviors. It is also expected that knowledge about biodiversity degradation and endangered species may raise interest towards the "last remaining" wild area and species (Jackson, 2016; Tapper, 2006; World Animal Protection, 2017; WTTC, 2019a).

5.4.6.3 Technological

Information and communication technologies have the potential to enable sustainable non-extractive forms of wild species use, such as virtual wild species viewing. For example, experiences may be obtained through tailor-made, interactive, real-time nature tours, through 5G streaming using 360-degree view cameras, webcams, or drones, given the appropriate hardware, software and infrastructure (Fennell, 2020). These technological innovations are forecast to change how people consume tourism experiences, to create new markets and disrupt value networks. While new technologies may create opportunities for wildlife watching tourists to stay at home whilst gaining some of the benefits of travel virtually, technological innovations can also enrich the experiences of tourists during *in situ* wild species viewing by, for example, providing additional educational content. In this regard, technology can become a powerful driver for sustainable wildlife watching tourism. If virtual experiences replace *in situ* experiences, they have the potential to alleviate travel-associated carbon emissions, but will have knock-on repercussions for tourism-based economies. However, current evidence suggests the growth of media documenting wild species (e.g., BBC Planet Earth documentaries) has stimulated demand for real-life experiences with wild species in their natural habitat (Jackson, 2016; The World Bank, 2018; World Animal Protection, 2017; WTTC, 2019b). The interlinkages between tourism, representations of wild species on media (social media, documentaries, virtual tours etc.), conservation and sustainability have acquired great importance and warrant further research and policy attention.

5.4.6.4 Economic

The wildlife watching tourism industry expects long-term growth, and one can reason that this growth is desirable (from an economic, though not necessarily sustainable) perspective for the sector. Such growth is mainly a result of rising global integration in trade and business, and generally rising wealth and incomes. Travelling has become easier, faster and cheaper. Addressing the detrimental impacts of increasing travel and travel-related impacts on natural systems remains a challenge. As well as indirect travel-related impacts such as carbon emissions (Peeters et al., 2018.), there are direct impacts from an increased physical presence on wild species and ecosystems, some of which may be harder to quantify (see Chapter 3 for details). Yet wildlife watching tourism has the potential to benefit local communities, accrue considerable funds for conservation and raise public awareness of the need for conservation (Tapper, 2006). In addition to wildlife watching tourism, there are other emerging novel financial instruments that have potential to affect future non-extractive uses of wild species economies. For example, existing or proposed instruments include Rhino Impact Bonds (rhinoimpact.com), Lion Carbon (www.lionlandscapes.org/lioncarbon), The Lion's Share Fund (www.thelionssharefund.com).

5.4.6.5 Environmental

Wild species habitats that are major tourism destinations are projected to undergo large climate-driven changes that may threaten biodiversity (Weber et al., 2017). Indeed, the tourism sector contributes to the problem of climate change. Climate change impacts on tourism, wild species and local communities requires intensive and urgent attention, particularly for regions in the Global South where adaptation and mitigation options are underexplored (Hoogendoorn & Fitchett, 2018). Wild species tourism is dependent on wild species, whose existence may be threatened by climate change, and largely occurs outdoors, which requires amenable weather conditions (Hoogendoorn & Fitchett, 2018). Climate change adaptation and mitigation options in the context of wildlife watching tourism are likely to be highly contextual and will need to be assessed on a case-by-case basis (Hoogendoorn & Fitchett, 2018). Climate change effects can also impact wild species use through indirect pathways, such as differing cultural and traditional knowledge from climate migrants (Fournier, 2011).

The environmental consequences of species or ecosystem restoration initiatives can also impact non-extractive practices. For example, as tourists prefer areas they deem "pristine" (i.e., more ecologically and aesthetically "sound"), there are opportunities to boost tourism-based economies through ecosystem restoration. Research on wetlands in India listed under the Convention on Wetlands of International Importance especially as Waterfowl Habitat (the Ramsar Convention) suggests that annual recreational visits could increase by 13% if the water quality could be improved to maintain wild species and fisheries diversity and abundance (Sinclair et al., 2019). Although the nature of interrelationships between tourism and landscape-scale ecological restoration are largely unknown (Clark & Nyaupane, 2020), it appears that many nature-based solutions and rewilding projects have embedded in them a component of wildlife watching tourism, which could result in a significant growth of the industry or redirection away from more harmful activities, potentially helping in part to combat some of the impacts of increased tourism.

5.4.6.6 Political

Political drivers influence non-extractive practices of wild species in a variety of ways. The recognition of local-scale non-extractive users and uses by governance systems plays a substantive role in which non-extractive contributions from wild species are incorporated into regional, national and global ecosystem and species management plans (Brondizio et al., 2009; Chaudhary et al., 2019). Political recognition also has the potential to mitigate the unsustainable use of wild species. This is particularly important in cases where local protection has eroded, as the vacuum can be filled by more formal protection, such as in Estonia where government, in conjunction with local communities (Maausk) conferred legal protection to 550 sacred groves (Kaasik, 2012). Similarly, the Korean government has recognized the importance of forest therapy in mitigating modern day health crises and has passed legislation specifically for "health forests", gazetting the use and restoration of forests for health reasons (Shin et al., 2017). Government and other stakeholder laws and guidelines (even if only voluntary) have been very effective in mitigating the negative impacts of tourism on wild species and wildlife watching tourism sustainability (see Chapter 3 for details). This is particularly effective when management has inclusive stakeholder engagement. For example, Projeto Tamar worked with local communities and fishermen to promote turtle conservation on the Brazilian coastline resulting in improved hatching success and alternative employment and income opportunities based on tourism and turtle protection (Tapper, 2006). A public-private initiative in Majete Wildlife Reserve, Malawi, was so effective at reducing poaching and providing alternative revenue that wild species are again abundant in the reserve (Twining-Ward et al., 2018).

5.4.6.7 Cultural

A growing middle-class seeking rest, spiritual experiences, a deeper connection to historical roots and a frame for cultural identity in natural settings that are seen as authentic and transformative supports the non-extractive use of wild species. However, it can also threaten the supply of these experiences, through commodification and failure to protect fragile environments from overuse (Frost et al., 2014).

The contributions of wild species to human well-being (e.g., spiritual, recreational) are perceived and valued differently by different stakeholders, which influences the type and extent of use (Pascual et al., 2017; Satz et al., 2013). In addition, the different uses and values of wild species have the potential to create conflict between stakeholders (Pascual et al., 2017). For example, residents near ski resorts placed high emphasis on recreational access whereas urban residents preferred the mountain area "pristine" with no visible tourism infrastructure (Saremba & Gill, 1991). Recreational users may also disagree with local communities' consumptive natural resource use. Conflicts have been documented between tourists and indigenous Inuit hunters in Arctic wilderness areas where seals and narwhales are hunted for both subsistence and income (Buckley, 2005). Conflict may also arise out of exclusion from traditional practices or impediments to livelihoods through conservation or tourism restrictions on local communities (Stone, 2015; West et al., 2006). Cases of prohibition of traditional activities that involve unsustainable use of natural resources in favor of conservation have been reported in many countries (see Chapter 3). A high dependence on natural resources for subsistence (Belsky, 2009; Moswete et al., 2009; Prachvuthy, 2006; Rozemeijer, 2000; Wunder, 1999) may leave communities with little choice but to engage in activities that have been criminalized. This highlights the need to manage both physical and cultural conflicts between recreational users and indigenous peoples and local communities, through temporal or spatial zoning, as well as by addressing the disparate cultural and social values of the respective stakeholders sensitively and realistically (Zeppel, 2010).

Another potential driver of cultural change is environmental education. Environmental education is recognized as the key aspect of social sustainability of wildlife watching (see Chapter 2). However, there was no consensus in the environmental education research that interventions resulted in long-term improved attitudes towards wild species and a desire to look after the environment (see Chapter 3).

5.4.6.8 Summary of plausible futures for non-extractive practices

A systematic literature review indicates that there is a paucity of research on scenarios of non-extractive practices in general and wildlife watching in particular. The majority of studies discuss trends and drivers, which have the potential to affect future development directions of this practice (addressed in Chapter 3 and 4 in greater detail), while existing scenarios are exploratory at best. Wildlife watching is the best researched practice when it comes to trends/scenarios of non-extractive use of wild species. There seems to be an overarching global consensus that non-extractive use of wild species will continue to grow and will bounce back successfully after the COVID-19 pandemic, perhaps even with a renewed interest in and demand for nature-related experiences, primarily through tourism and recreation, but also through recognition of mental health benefits. Predicted growth is based on a number of supporting global trends, including economic growth, media impacts on demand, greater environmental awareness and feasibility of travel.

Global socio-cultural trends (e.g., increasing urbanization) will continue to contribute to a growing human disconnectedness from nature in everyday life, resulting in a change in views on and modes of engagement with nature and wild species, such as a growing demand in visitation to natural areas as part of leisure, as well as increased facilitation of wildlife-based experiences. More and more wild species are integrated into commercial processes of non-extractive practices, as sources of experiences, both directly (through immediate interaction with visitors) or indirectly (through image circulation via media channels or "virtual" wild species viewing). This has resulted in an unprecedented increase in environmental awareness among the global population and created a positive feedback loop in growing demand for wildlife watching and other "shareable" nature-based experiences. This, in turn, has potential to facilitate more pro-environmental and sustainable behavior in the long term, but the "value-action gap" remains. There also remains the potential for conflict and differing perceptions of wild species use between stakeholders from different backgrounds or cultural settings.

The distribution of costs and benefits, i.e., positive and negative impacts of this growth, however, remain uneven and unequal. On the one hand, tourism generates a much-needed alternative source of income for communities and regions where few such opportunities exist, as well as generates funds for conservation. This is particularly crucial for wild species conservation in developing countries. The collapse of tourism due to the COVID-19 pandemic has demonstrated the vital role of tourism-generated income for multiple protected areas and wild species conservation projects in many parts of the world. On the other hand, tourism itself is a contributing force to a number of negative environmental trends, such as climate change and carbon emissions or biodiversity decline. Under the projected international tourism growth scenario, therefore, significant additional efforts will be necessary to mitigate negative impacts. Furthermore, climate-driven impacts on wild species and ecosystems may affect tourism potential in many regions.

Overall, the research on non-extractive use of wild species is dominated by discrete case studies, often micro-level, and the lack of higher-level or longitudinal studies and syntheses makes this sector notoriously challenging for generalizations (see also Chapter 2). Similarly, a lack of consistent global and regional-level governance, weak legal base and scarcity of reliable scientific information makes this practice particularly high in uncertainty when it comes to global scenario development.

5.4.7 Examples of factors affecting sustainable use in scenarios

The scenario literature on the five practices of wild species use (fishing, gathering, terrestrial animal harvesting, logging and non-extractive practices) described in the previous sections indicated several factors that can drive more sustainable or unsustainable futures.

Some examples are summarized in Table 5.4. covering the multidimensional aspects (social, technological, economic, environmental, political, and cultural) that could be considered in scenario-building processes.

Table 5.4 Examples of factors that will impact scenarios of sustainable use of wild species, organized into social, technological, economic, environmental, political and cultural categories. For details and references, see sections dedicated to each practice.

	Terrestrial animal harvesting	**Fishing**	**Logging**	**Gathering**	**Non-extractive**
Social	- Legislation/regulation - Illegal hunting - Attitudes and values regarding hunting - Recognition of traditional and indigenous knowledge systems - Institutional change - Social trends influencing food consumption patterns (e.g., organic products consumption, demand for game meat) - Increased social pressures (e.g., using social media to refrain from lethal extractive activities)	- Demographic trends - Domestic demand and supply - Increase in urbanization - Conflicts in sea use - Switch in fishing practices - Traditional fishers' rights - Gender and other aspects of identity for small-scale fisheries	- Urbanization and demand for fuelwood and charcoal - Rural population increases and conversion of land for agriculture - Product substitution with non-wood derived alternatives	- Urbanization - Distance from natural systems - Access of local communities to local markets - Educational level - Household size - Community structure	- Population growth and increasing urbanization - Greater environmental awareness - Pandemic impacts on tourism (including wildlife watching)

Technological	- Availability of more efficient gears enabling intensification of hunting (e.g., firearms, modes of transportation, lights) - Technologies to detect poaching and illegal trade - Domestication and farming of animals of commercial value and/or for a protein alternative	- Technology creep affecting catchability - Transition of fishing fleets to low-emission technologies - Technological advances to reduce bycatch species and improve selectivity	- Technologies to intensify food production to reduce land conversion from forest to agriculture - Technologies to enhance the efficiency of wood-biomass use for energy production - Planning, monitoring and tracking technologies for forest restoration and regeneration (e.g., aerial seeding using drones) - Timber tracking and origin verification	- Cultivation of commercially viable species - Tools used (e.g., for tree debarking) - Research and development of improved varieties to support plants, algae, and fungi cultivation - Rotation period for tree bark harvesting	- Technologies enabling virtual wild species viewing (e.g., webcams, drones) - Technologies enhancing tourist experiences - Media and social media impacts on demand

Economic	- Changing market demand for wild and domesticated species - Incomes and preferences of consumers affecting demand - Alternative income streams - Alternative livelihoods - Increased co-operation between countries and regions to detect and reduce illegal wild species products trafficking - Increased engagement of indigenous peoples and local communities in wild species management and wild species-related law enforcement	- Livelihood options for small-scale fishers - Industrialisation of fishing fleets - Improvements in logistics - Financial subsidies	- Land competition from agriculture to meet food supply needs - Payments/price for avoided deforestation and restoration for climate mitigation - Forest plantations, using improved tree varieties to support increased demand for bioenergy and reduce logging of natural forests - Changes in timber prices - Demand for bioenergy	- Market demand - Income diversification and multiple uses - Incentives for sustainably harvested or cultivated plants, algae, and fungi	- Global economic growth leading to rising incomes and increased demand for wildlife watching tourism - Ease and price of travel

Environmental	- Changing climate conditions - Temporal changes to hunting practices - Zoonotic disease spread - Land-use change	- Climate change impacts on fish distribution - Ocean acification - Marine biomass, species compositions and ecosystem dynamics	- Extreme weather fluctuations (high temperatures and drought) - Changes in wind damage due to climate change	- Biological traits of gathered species - Ecosystem type (e.g., level of water stress) - Habitat quality - Understanding of individual species functional traits (e.g., growth rates) to determine harvest rotations	- Climate change impacts on wild species tourism - Species and ecosystem restoration impacts on tourism potential

Political	- Legislative changes (including hunting bans) - Effective protected area management - Enforcement of wild species conservation laws - Equitable land ownership - Increased governance/controls for invasive species - Increased penalties for poaching and illegal wild species trafficking - Increased emphasis on identification and prosecution of criminal organizations responsible for large-scale poaching	- Transboundary management - Marine protected area networks - Strong fisheries management to limit impacts of climate change - Geopolitical issues	- Regulations for reducing illegal timber trade - Effective governance - Trade-offs between forest management policies for production, conservation, and/or carbon sequestration - Reforestation policies for native versus exotic species	- The International Union for Conservation of Nature Red List/Convention on International Trade in Endangered Species of Wild Fauna and Flora listing of heavily exploited species - Traceable supply chains for cultivated species - Awareness and enforcement of local laws - Education for tourists and local people to reduce illegal wild species trade - Incentives for sustainably harvested or cultivated species	- Recognition of non-extractive users and uses in management plans and formal protection - Legal frameworks and guidelines to mitigate negative impacts of tourism on wild species - Projects to provide alternative revenue streams for local communities from non-extractive practices

Cultural	- Changes in social acceptability of certain wild species uses (including hunting) and cultural norms - Wild species value orientations - Loss of traditional knowledge about sustainable use	- Climate change impacts on subsistence fishing - Changes in social acceptability of some fishing activities	- Impacts of enhanced efficiency of logging on local cultural values - Recognition of customary tenure rights in forest management	- Integration of cultural uses and traditional ecological knowledge in management approaches - Strong traditional institutions and knowledge - Respect for traditional laws, institutions, and cultural norms	- A growing middle-class seeking spiritual experiences and cultural identity in natural settings - Differing perceptions of wild species use and conflict between stakeholders (e.g., urban/rural) - Conflicts arising from exclusion from traditional practices through conservation or tourism restrictions

5.5 Involvement of indigenous peoples and local communities and their knowledge in scenarios

Almost 500 million people that self-identified indigenous in more than 90 countries around the world have a special role to play in the sustainable use and management of natural resources. Their in-depth, varied and locally rooted knowledge can help the world adapt to, and mitigate the consequences of climate change, being also stewards of cultural and natural diversity (Padulosi et al., 2019).

In this section, examples of incorporating indigenous peoples and local communities and their knowledge into scenarios are presented for three practices (fishing, gathering and logging). These are not necessarily scenarios that are used for future projections *per se*, but nonetheless demonstrate how indigenous peoples and local communities and their knowledge can be included into scenario development, recognizing that this is an important but under-represented aspect in the scenario literature for sustainable use (e.g., see section 5.4 above). Some examples from indigenous peoples and local communities have been formulated focusing on narratives rather than on models.

5.5.1 Fishing

Merrie et al. (2018) represent narrative scenarios in a two-dimensional space, with each scenario showing a key defining element for one of four "radical ocean futures" (Figure 5.7). The archetypal characters of the scenarios in Figure 5.7 can be both desirable and undesirable, because desirability is relative. For example, a fishing conglomerate that is aiming for a large-scale harvest of skipjack tuna *Katsuwonus pelamis* in the Western Pacific is likely to have very different ideas about what is "desirable" (or even what is "sustainable") compared to a group of small-scale fishers in Palau (Merrie et al., 2018). This points to the importance of including indigenous and local perspectives into visions and scenarios, to ensure that multiple views of desirable outcomes and aspects of future projections are accounted for.

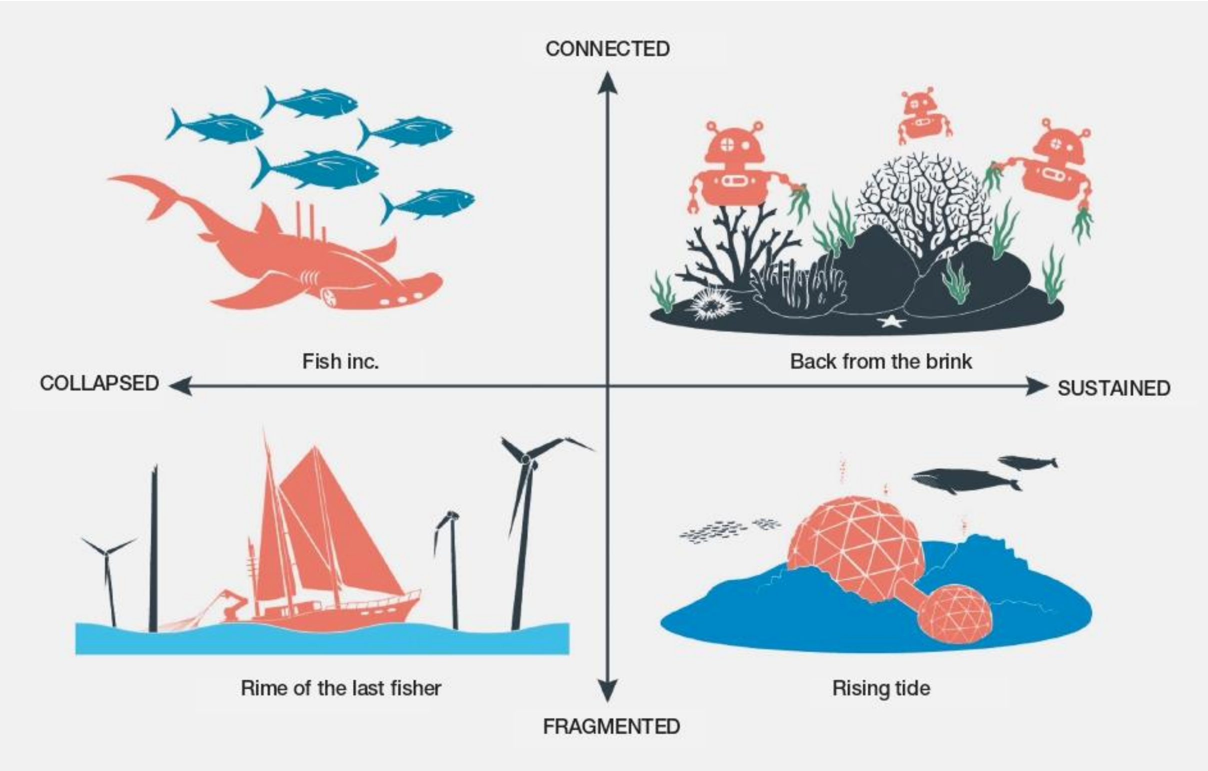


Figure 5.7 The scenario space. The "collapsed to sustained" horizontal axis refers to the ecological dimension and the "fragmented to connected" vertical axis refers to the societal dimension. Source: Merrie et al. (2018) under license CC BY-NC-ND 4.0.

Many scenarios are based on modelling of the relative outcomes of cooperative and uncooperative behavior. For example, Gutierrez et al. (2017) compared a cooperative harvesting scenario where divers consistently targeted areas with higher yields, avoiding low-quality sea urchins, against a non-cooperative situation where divers harvested at random or based only on densities of sea urchins. The sea urchin population at the end of the simulation period was 20% higher for the most cooperative scenario compared to the non-cooperative fishery. Further, for the most cooperative scenario where information sharing among divers was greatest and harvest coordinated, sea urchin catches were at least 10% higher and gonad yield 35% higher than in the non-cooperative scenario. In this model, information sharing and organized harvesting typical of well-functioning cooperatives allowed fishers to optimize the use of the resource in terms of higher gonad yields per unit of effort while maintaining the productivity of the stock.

Similarly, in Spain, a management scenario explored limiting the fishing season of one of the main types of fishing gear (fish traps, locally known as "paranzas"). Results showed that a reduction in fishing mortality of two overexploited species (*Sparus aurata* and *Lithognathus mormyrus*) would help recover the biomass of these stocks by more than 40% as well as increase the economic value of the fishery, with profits increasing by 17% over a 4-year period (Maynou et al., 2014).

5.5.2 Gathering and logging

Examples from discussions with indigenous peoples and local communities provide examples of scenario-based thinking. For example, in Asia, indigenous honey hunters prefer healthy forests because an abundant honey world - where bees are able to go about their usual business of building hives on tree branches, crevices, and logs - can only exist in such a setting (NTFP-EP, 2021a). However, with external shocks from strong climate change, the indigenous honey hunters foresee that this may no longer be possible.

COVID-19 was another shock to society in general, but areas conserved by indigenous peoples and local communities in places such as the Philippines proved to be wild food-resilient as the food supply within the community was sufficient to supply their needs and they did not have to go to the city or outside their communities to buy food (NTFP-EP, 2021b). Thus, one vision of indigenous communities in the "new normal" after COVID-19 is to ensure increased self-sufficiency under a scenario of reduced global market forces.

In Vietnam, indigenous women in the village of Binh Son actively participate in conservation and forest management and clearly understand the dynamics of forest conservation, believing that sustainable development of forests is anchored through the sound application of traditional knowledge (Tebtebba Foundation, 2011). Conversely, indigenous women believe that "if the forests continue to be unprotected in another ten years, the natural forest area will become smaller and the quality of the forest resources will decrease, while forests newly planted with pure species will increase". The indigenous women "wish to recover natural forests because these provide them with diverse and precious resources" (Tebtebba Foundation, 2011). This type of information and preference, including beliefs around the forest's future without protection, can be readily integrated into scenarios.

A case study in Norway conducted a scenario building exercise with a local community, Vega, which developed scenarios that fall into the exploratory category, i.e., probing of several alternative and plausible futures, including around use of natural resources. They were not predictive or normative in the sense that they did not try to ascertain what Vega will or should look like in 2025, although there are inevitably some normative and predictive elements that enter into the process when a group of local people think creatively about their future. In this particular case the scenario group developed four alternative scenarios constructed around the following themes: community/society, commerce, transportation, energy supply, landscape and tourism. In each scenario the group applied a particular selection of development paths and drivers. These were assumptions about population development, land-use management, state subsidies, tourism management and regulation, climate change, research monitoring and documentation of changes. A cross-cutting issue in all of the scenarios is the balance between the conservation and use of natural and cultural heritage resources (Kaltenborn et al., 2012).

5.5.3. General considerations on involving indigenous peoples and local communities in future-making

Sustainable use by indigenous peoples and local communities based on customary laws (e.g., in the case of mushroom collection, leaving some mushrooms for animals or for other people) will be impacted by several drivers of change (Table 5.5). These might include policies that prohibit traditional practices like rotational agriculture, traditional fishing canoe construction, hunting or ceremonies. Tourism is also expected to further impact indigenous peoples and local communities' customary management of resources, e.g., in marine areas by the sound of motors due to tourist boats. Education systems will also have crucial and potentially adverse impacts if they devalue small-scale food production, farming or practices considered of low prestige, even though such production systems generate 70% of the global food stock. This may drive youth to either exploit resources unsustainably to gain income, or to leave their communities to live in cities. Global markets (e.g., palm oil), business exploitation (e.g., pharmaceutical companies) and large-scale infrastructure development (e.g., dams and roads) will interact with indigenous peoples and local communities' customary management of wild species (IPBES, 2019).

Scenarios of the effects of climate change on wild species use could also consider the impacted ability of elders and communities to predict the weather and phenology (i.e., life stages of wild species) using indigenous and local knowledge, making it harder for communities to plan their activities such as harvesting, and leaving them more exposed to climate related risks such as droughts. Climate change may also lead to a greater reliance on wild species, rather than cultivated species which may need more water and be less resilient, and if crops fail or domesticated animals die, people may turn increasingly to wild species to supplement diets. This can have both positive and negative consequences for sustainable use and indigenous peoples and local communities' culture (e.g., declines in wild species, or a resurgence in traditional gathering and hunting) (IPBES, 2019).

Table 5.5 Identified drivers of sustainable use, or approaches to assessing sustainability, based on specific indigenous and local knowledge studies which use scenarios-based approaches, by category

Category	**Outcomes**
Social	Information gathering and sharing is usually enhanced in fishing communities with strong and well-organized local institutions such as cooperatives or committees (Gutierrez et al., 2017).
	Management regimes can be fairly restrictive, but well established since objectives and regulations are well understood and accepted locally and in line with community values (Kaltenborn et al., 2012).
	The scenario analysis showed that increased monitoring and punishment (including societal pressure) could enhance compliance, especially among younger fishermen, who claimed not to depend solely on fisheries (Karper & Lopes, 2014).

Technological	Agent-based models can evaluate the benefits of cooperative and coordinated harvesting, which requires a model that includes the biological dynamics of the resource, the dynamics of the harvesters and their choice of fishing times and locations, and the feedback between these two elements (Gutierrez et al., 2017).
Economic	Agriculture and coastal fisheries are central economic pillars and modern aquaculture/fish farming is well controlled in terms of diseases and fish escaping from the nets (Kaltenborn et al., 2012).
	Constant or increased income and cheap fuel costs (Maynou et al., 2014).
	To promote sustainable management, the current marketing chain can be targeted. Since the middlemen occupy a bottleneck in the marketing chain, they are a more suitable target for regulatory measures than the local community of fishermen (S. Sen & Homechaudhuri, 2017).
Environmental	Stable climate (Kaltenborn et al., 2012)
	Population dynamics of fish stocks in the adjacent sea (in this case, Mediterranean) (Maynou et al., 2014).
	The traditional knowledge of the fishermen can be a source of information about the life cycle, migration and preferable habitat for crabs and evolving fishing pressure over the years (S. Sen & Homechaudhuri, 2017).
	Harvesting of crabs should not be done during breeding season (S. Sen & Homechaudhuri, 2017).
Political (Governance)	High level of cooperation between local and state management agencies and strict regulations imposed on fish farming (Kaltenborn et al., 2012).
	Closed fishing seasons (Maynou et al., 2014).
Cultural	The use of logbooks, information-sharing groups, folk knowledge, and other informal methods to track and monitor differences in spatial abundance and productivity of target fish species (Gutierrez et al., 2017).
	Conservation of local heritage and environment has also added new opportunities in the employment structure (Kaltenborn et al., 2012).
	The artisanal fishermen of Indian Sundarban inherit the knowledge of crab fishing through generations. Their involvement may help in laying grounds for the management of the fishery as a sound way of improving community livelihoods and management of resources (S. Sen & Homechaudhuri, 2017).
	Intraspecific variation, which includes the genomic and phenotypic diversity found within and among species populations, is often implicitly recognized by indigenous peoples due to consistent long-term observation (Des Roches et al., 2021)

5.6 Exploring archetype scenarios and narratives for sustainable use

After synthesizing material on scenario explorations in individual practices (section 5.4; data management report https://doi.org/10.5281/zenodo.6451922), drafting narratives of the sustainable use of wild species required examining the links between the exploratory and the normative archetypes described earlier in this chapter. A start was made in Table 5.3 which provided examples of factors affecting sustainable use by practice, but Table 5.6 below provides a many-to-many link. This suggests that most, but not all, target-seeking scenarios of sustainable use of wild species could be developed under most plausible exploratory future outlooks.

Table 5.6 Combining exploratory and normative archetypes (see data management report https://doi.org/10.5281/zenodo.6451922)

Archetype	Green economy	Low carbon	Ecotopian	Transition
1. Market forces	**yes**	**yes**		
2. New sustainability				
2a. Technology	**yes**			**yes**
2b. Global	**yes**	**yes**		
2c. Regional			**yes**	**yes**
3. Fortress world			**yes**	**yes**
4. Inequality		**yes**	**yes**	

However, the remainder of this section is based on the choice to reduce the number of possibilities to one target-seeking overall strategy per exploratory archetype. In some cases, a clearly described mix is proposed. The purpose of the set of integrated archetypes is not to reduce uncertainty or to increase predictability, but only to ensure that the diversity in the number of futures that are included is maximized. This chapter refrained from using more formalized methods to decide on the combinations that would maximize diversity, because existing methods would have needed to be adapted and tested, as they are not developed to combine archetypical information.

The final archetype combinations that were explored were selected to be logically consistent, while equally emphasizing all normative types, and maximizing diversity in combinations of future outlooks and possible solutions. While by no means the only or even the best set of archetypes, this set does sketch a number of very different future directions for the sustainable use of wild species.

Once these archetypes were identified, first the main challenges and opportunities presented by the exploratory archetypes were summarized. This was followed by an elaboration of how changes related to the target-seeking pathways would play out against that backdrop. This led to an overall assessment of how sustainable use of wild species would be achieved in each archetype. This process is captured in tables 5.7 and 5.8, which are followed by a short summary for each archetype combination.

Table 5.7 Challenges and opportunities related to the exploratory archetypes (see data management report https://doi.org/10.5281/zenodo.6451922)

	Social	Technological	Economical	Environmental	Political	Cultural	
Exploratory archetype	**Population growth**	**Technology development**	**Economic growth**	**Environmental quality**	**Political effectiveness**	**Societal values**	**Overall challenge level**
1. Market forces	More people, more consumption	More technology, but not always for sustainable use	More growth, more purchasing power, more demand, but also more financial resources	Not a main focus	Effective and global, but not with sustainability goals	Materialistic: most people do not care for sustainability	++
2. New sustainability paradigm *2a. Technological solutions*	More people, but effect limited through technological innovations	Widespread green technologies	Less growth, less demand increase	Engineered nature	Effective, but not of central importance	Nobody needs to care as technology saved the day	- -
2. New sustainability paradigm *2b. Top-down governance structures*	More people, but effect limited through lifestyle changes	More (green) technology, but not a main focus	Low but consistent growth	High level of environmental protection	Very effective, focus on sustainability	Decision-makers care	- -

2. New sustainability paradigm *2c. Bottom-up enforced shift*	Growth slows and strong behavioral change	Limited spread and higher challenges	Low growth or even de-growth	Increases, but with regional (high) pressure	Ineffective as the world fragments	Everybody cares	- - -
3. Fortress world	More people, more needs	Limited development and transfer	No growth, no increased purchasing power, less pressure but also less opportunities	Under pressure, but partly protected	Strong and effective at national level. No sustainable priority	Survival: most people do not have the luxury to care	++
4. Inequality	Strong increase in inequality	More technology, but only for the elite	Growth, but very unequal	Lower, except where in the interest of the elite	Internationally effective, regionally weak	Most people are not well informed	+

Table 5.8 Target-seeking pathways and sustainable use of wild species

	Social	Technological	Economic	Environmental	Political	Cultural	
Target-seeking pathways	**Population growth**	**Technology development**	**Economic growth**	**Environmental quality**	**Political effectiveness**	**Societal values**	**Key direction of sustainable use of wild species**
1. Market forces and green economy	The growing population is a growing market for sustainable products	Once a market for wild species is created, green technologies are developed	Financial resources provide opportunities for investments	Nature for society: nature's contributions to people are maximized	Environmental policies ensure sustainable use	As wild species and the environment provide crucial services, social preferences shift	Commercialization and intensification
2. New sustainability paradigm *2a. Technological solutions*	Carrying capacity of the world increases through technologies	Widespread green technologies	High investments in green technologies	Engineered nature where needed, nature as nature where possible	Facilitating a transition to high-tech solutions	High-tech solutions are paired with increased valuation of nature	High-tech solutions and improvements
2. New sustainability paradigm *2b. Top-down governance structures*	The growing population changes its preference towards sustainable products	Increased green tech helps increasing sustainable use	Growth is sufficient to allow green investments	Strong environmental protection	Very effective, ensures and enforces sustainable practices	Global collaboration and strong stakeholder participation guide a shift towards sustainability	Governmental control and protection

2. New sustainability paradigm *2c. Bottom-up enforced shift*	A strong bottom-up enforced behavioral change	Technology development and transfer slow but key investments continue	Slowing growth and transformation away from capitalist model	Nature for culture dominates as people live with nature. There is a growing recognition of nature's intrinsic value, with wild animals regarded as sentient beings	Political collaboration around environmental issues	Living with nature ensures a sustainable use of wild species	Re-evaluation and respect for nature and wild species
3. Fortress world	Eventually a change towards local communities	The lack of global collaboration leads to case-based grounded, low-tech solutions	The lack of economic development takes off the pressure of global markets	Nature for society dominates, but demands are relatively low	Policies are national and relate to solving national issues effectively	Sustainability eventually as current structures first break down before change happens	Strong transition through bottom-up change
4. Inequality	Increased inequality provides possibilities for the poor	Technological change solved global issues and ensures quick transfer and high adoption rates	Sufficient growth to allow key investments, while demands are rather low	Environment is partly protected through the nature for society attitude of the elite and partly protected by local initiatives	Strong global policies ensure that global issues are controlled and solved	Eventually a strong bottom-up change is met by a globally enforced low carbon trend	Global-local joined forces

1. Market forces-green economy:
Context: In a globalized world, behavioral change and innovations lead to a new business model where sustainability sells. A large-scale circular economy sets the stage for a marketable sustainable use of wild species within the planetary boundaries. There is a strong focus on reducing greenhouse gas emissions.
Sustainable use of wild species: Strong focus on nature for society and the use of nature's contributions to people, and thus also a large market for the sustainable use of wild species, which becomes a market instrument in a (globally connected) circular economy.

2a. Technology-transition/green economy:
Context: Technological innovations in many areas, but importantly including green technologies, lead to high-tech solutions towards sustainability. There is a strong focus on tech-fixes, which limits transformative changes in society.
Sustainable use of wild species: Green technologies will reduce the environmental impact of the use of wild species, while also reducing the demand, in a world that moves towards nature as nature. The sustainable use of wild species is ensured by innovative high-tech solutions.

2b. Global sustainability paradigm-local carbon:
Context: In a globalized world, strong global policies in close collaboration with business opportunities open the door for strongly reduced greenhouse gas emissions. Against this backdrop, there is a strong top-down regulatory force towards sustainable use.
Sustainable use of wild species: A globally coordinated set of policies enforce a change in behavior towards a highly regulated and controlled use of wild species.

2c. Regional sustainability paradigm-ecotopian:
Context: In this regionalized, small is beautiful world, there is a strong trend towards reruralisation. This community-based foundation could lead to small local supply chains, but could also be the starting point for a transition towards broader collaborations. Eventually, solutions are upscaled.
Sustainable use of wild species: The bottom-up initiatives lead to a re-evaluation of nature with strong communities resulting in a central role for sustainable use of wild species across the globe.

3. Fortress world-transition:
Context: The phoenix rises from the ashes in this world where initial trade blocs and regionalization lead to a break-down, from which new structures might emerge that allow for a bottom-up transition.
Sustainable use of wild species: The strong bottom-up rebuilding of values includes a strong change towards sustainable use of wild species. The lack of regulatory frameworks helps a quick transition.

4. Inequality-ecotopian/low carbon:

Context: In a world that is characterized by a strong elite, there are opportunities for the masses to self-organize in smaller communities, while global policies ensure a successful combating of global issues. In a world with many challenges, there are many opportunities as well.
Sustainable use of wild species: The simultaneous efforts to combat global and local issues result in a strong path towards sustainable use of wild species with the combined strength of local knowledge and global technological know-how and collaboration.

Evidence from literature:
All papers in the literature review database were classified by labelling the scenarios that were used as belonging to the most appropriate scenario archetype. A total of 239 papers were thus related to one (or more) of the scenario archetypes. The other papers did not offer a clear link to the sustainable use of wild species. About two thirds of that set (152 papers) with concrete solutions related to an archetype were then used to characterize the archetypes. Results are presented in Table 5.9. Archetype 3 (2 papers) and Archetype 4 (0 papers) were excluded.

Table 5.9 Literature review database

	Archetype 1	**Archetype 2a**	**Archetype 2b**	**Archetype 2c**
Total papers	45	9	47	51
Logging (%)	64	22	38	22
Fishing (%)	22	33	40	35
Starting point scenario	Business-as-usual	Strong technological change	Business-as-usual	Transformative change
Main approach	Effect of single instrument/policy measures	Effect of single technology, when applied uniformly and globally	Effect of single policy measure, but role for integrated approaches	Integration, multi-use, cooperation, and community-based
Main method	Modelling study	Mixed, modelling and more qualitative	Modelling study	Mixed, importantly also qualitative
Most mentioned solutions	Carbon pricing, biodiversity offsets, price	Technology improvement	Restoration, management	Small-scale, decentralized, diversified strategies

Most important topics	Bioenergy, fish demand	Mixed, but often specialized, focusing on single species	Fish stocks, forest protection	Mixed, often integrated with human aspect and trade-offs
Comments	Strong link with climate change impacts and mitigation	Small group with relatively extreme solutions for specialized cases	Common element relates to a global, top-down approach and dominance of (existing) policy measures	Common theme is the ineffectiveness of current approaches and the need for local embedment

Some broad conclusions can be drawn from the analysis of this literature. Overall, there was a strong domination of logging and fishing papers, but with a marked shift from a very high contribution in business-as-usual-related studies to a much lower share when papers related to more extreme changes (Archetypes 2a and 2c). Furthermore, there were clear differences between the archetypes that all have their own identity. The dominance of logging and fishing papers might also in part be attributable to the choice of search terms.

Overall, the conceptually hypothesized archetypes (Table 5.9) were partly present in the literature, and partly (completely) absent. Archetypes 1, 2b, and 2c are all present with an almost equal share. They represent the three most important manners in which the future can be studied: business-as-usual; top-down, global measures; bottom-up local measures. Archetypes 3 and 4 are almost completely absent. A small number of papers relate to the exploratory archetypes "fortress world" and "inequality", but with only a few exceptions, these scenarios are not linked to sustainable use.

The archetypes serve to categorize the multitude of sustainable use aspects across sectors, scales, topics, and types of solutions into a meaningful and clear – archetypical – overview. A main conclusion is that there is a strong focus on modelling single-measure effects for a single practice, particularly in logging (pricing, bioenergy) and fishing (fish demand/stock and management). Other, more integrated, solutions are studied, but often from a systemic viewpoint. This often implies a weaker link with (the sustainable use of) wild species. There is a clear gap related to studies that focus on wild species within broader systemic, integrated future changes.

5.7 Linking the archetypes to the practices

The information presented in section 5.4 and above allows to build towards an understanding of pathways of change, and how to link scenario studies from individual practices to archetype exploration. In section 5.4, existing studies on scenarios for the sustainable use of wild species were analyzed and evaluated by practice. This yielded a wealth of information and in-depth insights on possible solutions, from which generalities can be extracted. This section approached the issue from the angle of existing societal scenarios (i.e., focused on broad societal trends rather than sustainable use of wild species *per se*) and scenario archetypes, which allowed a set of conclusions specific for each archetypical future, but does not provide detailed practice-oriented concrete solutions. These two streams of information can be tied together to explore solutions that are both scenario- and practice-specific, while also being concrete. This furthermore allows to identify critical gaps in the literature on scenarios of sustainable use. Table 5.10 presents examples of solutions and/or pathways elements for all combinations of scenario archetype and practice.

Table 5.10 Linking practices and exploratory archetypes through potential practice- and scenario-specific solutions. Note that solutions are only examples, and are not intended to be exhaustive or definitive. The bottom two rows are blank due to limited exploration in the sustainable use scenario literature.

		Practice				
Scenario	**Key direction of policy/approach for sustainable use of wild species**	**Fishing**	**Gathering**	**Terrestrial animal harvesting**	**Logging**	**Non-extractive practices**
Market forces and green economy	Commercialization (1) and intensification (2)	1. Adding value and food through fish byproducts (Stevens et al., 2018) 2. Valuation of tribal subsistence fishing (Morton et al., 2017) Increasing the diversity and flexibility of small-scale fisheries, as well as gender recognition	1. Cultivation of commercially viable species (Cunningham et al., 2017) 2. Research into improved varieties to support cultivation (Chen et al., 2016)	1. Increasing demand for sustainably harvested wild products (e.g., venison) 2. Market incentives for sustainable use in hunting product labelling	1. Globally accepted and implemented high carbon price (Austin et al., 2020) 2. Increased agricultural intensification sparing land for forests (Ceddia et al., 2014)	1. Novel financial instruments related to non-extractive practices (e.g., Rhino Impact Bonds; www.rhinoimpact.com; Debt for nature swap) 2. Increased demand for wild species experiences influencing environmental attitudes (Lin & Lee, 2020)
New sustainability paradigm: *Technological solutions*	High-tech solutions and improvements	Technological advances for surveillance and compliance (Kroodsma et al., 2018)	Technology to online monitoring of illegal online sales of wild species (Ticktin et al., 2020)	More sophisticated anti-poaching measures (e.g., drones, lidar)	Aerial seeding by drones for reforestation (Lang et al., 2018), improved efficiency of wood-biomass use for energy production	Increased use of technologies to enable virtual species viewing (Fennell, 2020)

					(Proskurina et al., 2019), product substitution and the digital era (McEwan et al., 2020)	
New sustainability paradigm: *Top-down governance structures*	Governmental control and protection	Improving harvest control rules and recovery plans	Domestic and international regulation of harvesting and sales of wild species	Deploy policies designed to tilt sellers and buyers from wild meat towards consumption of other wild species (Wilkie et al., 2016)	Sustainable forest management practices (Putz et al., 2012), regulations to reduce illegal timber trade	Improved recognition and incorporation of non-extractive practices in governance systems (Chaudhary et al. 2019)
New sustainability paradigm: *Bottom-up enforced shift*	Re-evaluation and respect for nature and wild species	Community-based fisheries management, incorporating traditional ecological knowledge and customary tenures	Greater respect for traditional, local, and indigenous ecological knowledge around sustainable harvesting practices (Papageorgiou et al., 2020)	Greater respect for traditional, local, and indigenous ecological knowledge around sustainable harvesting practices	Recognition of customary tenure rights in forest management	Increased wildlife watching tourism supporting conservation and local livelihoods (Dou & Day, 2020)
Fortress world (international authoritarian system)	Strong transition through bottom-up change					
Inequality	Global-local joined forces					

There are some conclusions that can be drawn from linking the practices to the archetype scenarios. In particular:

- **Multiple solutions**: The results show that there are multiple pathways and solutions that can lead to a more sustainable use of wild species. The market forces and new sustainability paradigm scenario archetypes (and sub-archetypes) contain promising solutions. Mechanisms by which this is reached are very different, but practices such as fishing and logging show that there is not a single path to sustainable use, and sustainable solutions for one practice might not work for others.
- **Limited exploration of transformative change in archetypes**: Radically different futures that would require fundamentally different solutions are not generally explored in the scenario literature. This suggests a knowledge gap, whereby leverage points and approaches to transformative change (see section 5.8) need further exploration within an archetypal scenario framework.
- **Generalities**: Many sustainable solutions would appear to benefit from market or policy support. Without favoring top-down approaches, even when solutions are sought through bottom-up initiatives or technological development, governments and markets might have a decisive role to play. In addition, bottom-up solutions are very integrative and essentially work for any practice; empowering local communities will help move towards sustainable use irrespective of the practice. In contrast, non-extractive practices have distinctively different example solutions in relation to extractive practices.
- **Knowledge gaps**: Important archetypes have not been explored at all in the sustainable use literature, and as per the previous section, in particular the fortress world and inequality archetypes. A full set of scenarios is needed to better understand what adaptation/mitigation options are needed and feasible. Similarly, as per the previous section, it is also easier to link fishing and logging practices to archetypes due to their greater prevalence in the relevant scenario literature.
- **Leverage points**: The scenario archetypes that are most commonly explored have some elements of the framework of the 3-horizons approach, with established practices giving way over time to transitional activities and ultimately a long-term shift to new innovations (Sharpe et al., 2016).
    - **First horizon (market forces)**: address current concerns and maintain essential features
    - **Second horizon (top-down governance/bottom-up enforced shift)**: scale up current innovations and foster existing niches
    - **Third horizon (bottom-up enforced shift/top-down governance)**: start new inspirational practices and link to future aspirations.

That is, transformative change may be reached by three concurring types of action: Phasing out existing practices (horizon one); fostering and strengthening current niches (horizon two); initiate novel transformational actions (horizon three). While the archetypes exploration here has shown that there are substantial knowledge gaps around transformative change, it is further explored in section 5.8.

5.8 Applying the nature futures framework case-studies to the sustainable use of wild species

The nature futures framework (being developed by the IPBES task force on scenarios and models) provides a foundation for envisaging positive futures for sustainable use of wild species, since it places human-nature relations at its core and reflects the multiple ways in which both people and nature can benefit from the use of wild species (Lundquist et al., 2017). Importantly, these visions are not mutually exclusive, but rather they offer a plurality of approaches for how sustainable use of wild species can be realized (Figure 5.8).

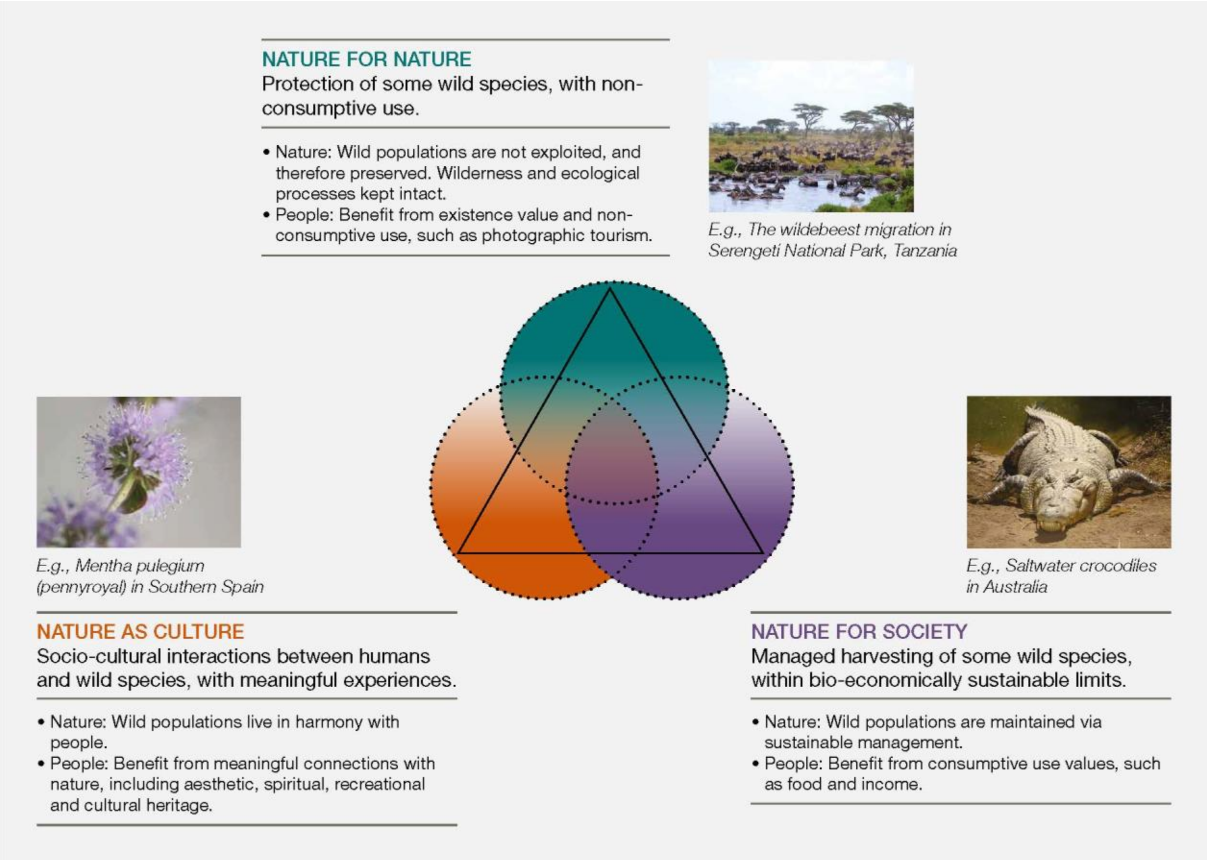


Figure 5.8 A plurality of visions for sustainable use of wild species, based on the nature futures framework. Adapted from Pereira et al. (2020), under license CC BY-NC-ND 4.0.

The nature futures framework is a heuristic tool developed by the IPBES task force on scenarios and models that can help to explore and define positive relationships of humans with nature in order to create desirable nature scenarios (Pereira et al., 2020). In the context of the sustainable use of wild species, the framework could be applied across different scales to target and achieve positive futures. When designing interventions to enhance sustainable use of wild species within the nature futures framework, a plurality of values needs to be included. Importantly, there is a need to "build on common interests between conservationists and [wild species users] wherever these occur, but also engage in honest discussion about genuine conflicts of interest where these exist and work towards negotiated solutions" (Newing & Perram, 2019).

Box 5.8 presents an example of a conceptual application of the nature futures framework to wild species use in a fisheries management context under the three most distinct nature perspectives identified by IPBES, i.e., the points of the triangle: nature for nature (intrinsic values of nature), nature for society (nature's benefits to people) and nature as culture (relational values with nature). Box 5.9 shows an example of sustainable use in the Amazon as envisioned within the nature futures framework.

Box 5.8 Nature futures framework in fisheries management for the sustainable use of marine resources

This example (Figure 5.9) represents a simple conceptual illustration of the potential application of the nature futures framework to develop desirable future scenarios for both people (fishing activities) and nature (exploited wild species in marine ecosystems) under three different values perspectives (IPBES, 2021). This example aims to build different narratives related to fisheries management, focusing primarily on reference points. Here, these narratives have shared outcomes referred to as "common features" that are essential assumptions for achieving any of the positive visions embodied in the nature futures framework (e.g., application of the precautionary approach). The common features as shared elements aim to ensure a reference baseline for sustainable use. The specific features distinguish these narratives from one another. In this example, the differences between narratives were highlighted through three categories: (i) restriction strategies in mixed fisheries (output control in multispecies fisheries), (ii) management scale, and (iii) indicators of interest. These categories are not exhaustive and could be enriched to better describe different exploitation scenarios for marine species under the nature futures framework.

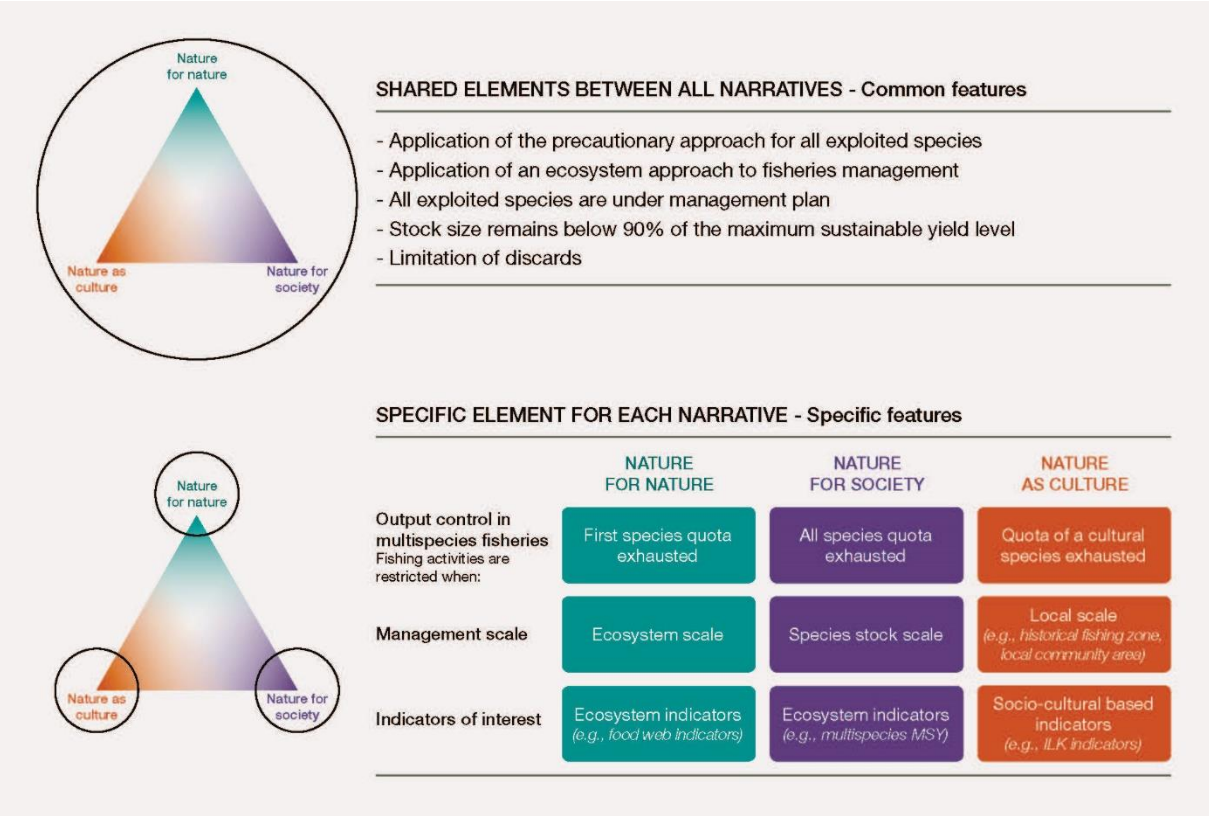


Figure 5.9 Potential application of the nature futures framework in fisheries management. Source: Halouani et al (in prep). Abbreviations: MSY: maximum sustainable yield; ILK: indigenous and local knowledge.

Box 5.9 Nature futures framework scenarios for the sustainable use of forest resources in the Brazilian Amazon

The nature futures framework promotes participatory and inclusive approaches to develop scenarios with stakeholders by co-creating narratives and modelling frameworks and co-identifying or developing indicators to inform decision-making (Pereira et al., 2020; Kim et al., 2021). By doing this, the goal is for the nature futures framework to facilitate and enable transformative change by helping people to reflect on different decision options from diverse value perspectives.

Using the nature futures framework and the framework on nature's contributions to people (Díaz et al. 2018), Siqueira-Gay et al. (2020) identified trajectories leading to positive futures in the Brazilian Amazon of Pará State, including indigenous peoples and local communities' perspectives. They created three positive scenarios addressing negative anthropogenic drivers:

1. Land management to tackle illegal deforestation (Pará minus)
2. Changes in consumption behavior (Pará consumo)
3. Combining (i) and (ii)

The Pará minus scenario includes policies that address rural land occupation, agriculture and pasture expansion, unofficial road building and forest degradation with co-management, and decentralized environmental governance with user-coordinated actions for sustainable management of natural resources. The Pará consumo scenario includes policies to reduce excessive meat consumption and clearing of forest areas for soy plantation for feeding animals through environmental education to modify consumption behavior (Siqueira-Gay et al., 2020). The core actions for the implementation of policies in these scenarios are listed in Table 5.11.

Table 5.11. Core actions for policy implementation in two sustainable forest scenarios named Pará minus and Pára consume. Source: (Siqueira-Gay et al. 2020).

Pará minus scenario: *Land management to tackle illegal deforestation*	**Pará consumo scenario:** *Changes in consumption behavior*
i. **Enforce forest decentralization efforts** to allow small governance units to take decisions about their resources in a sustainable way ii. **Provide technological tools and training** to communities to facilitate sustainable development and monitoring efforts iii. **Enforce the protection of indigenous territories and protected areas** by creating an inheritance tax scheme and fines for illegally clearing forest areas	i. **Create an educational program** to promote awareness on nature's contributions to people provision, the value of forest conservation, and damage caused by cattle ranching. This program would be integrated into the educational system by restructuring the curriculum ii. **Promote alternative options for protein consumption** instead of beef iii. **Create a tax incentive for large companies that join the beef moratorium** (an agreement not to buy

iv. **Perform a land reform** to distribute underused or abandoned land to individuals or organizations committed to sustainability and conservation efforts or return the land to indigenous or traditional communities **v.** **Regulate for mandatory sustainable use** of undesignated public lands, and **prohibit (with fines applicable) clearing of pristine forest areas** **vi.** **Create new and strengthen existing alliances** to make forest monitoring and controlling efforts more effective, while facilitating social learning processes in local communities	meat from newly deforested areas) or that supports the educational program of awareness on nature's contributions to people provision (action i)

The three positive scenarios formulated for the Pará State in Siqueira-Gay et al. (2020) anticipate different positive outcomes. In the Pará minus scenario, land reform and regulation strengthen conservation values, social learning promotes collaboration between stakeholders and integrates their knowledge, and economic development does not depend on the extractive use of natural resources while traditional extractive activities continue in a sustainable manner. In the Pará consumo scenario, the food market motivates local production and consumption, reducing carbon emissions from transportation of goods and creating nature-based recreational opportunities for people. There is active urban farming and recycling to reduce waste, and values transformation through social welfare and innovation. In the scenario that combines the two, sustainable economic development is envisaged with green solutions and enhanced social empowerment through social learning and education. Overall, the policies implemented in these scenarios make positive steps towards sustainable land-use and land change, consider and help to mitigate climate change, and sustain natural resources (Siqueira-Gay et al., 2020).

As illustrated in Pará State's scenarios, scientific and local knowledge, models, and indicators generate diverse and complementary evidence for evaluating the roles and impacts of different policy and management options in conserving nature and providing benefits to people (Kim et al., 2021; Tengo et al., 2014). The illustrative scenario and modelling framework for Pará State (Figure 5.10) could be developed for and applied to other places or systems to explore the consequences of nature- and people-positive visions in informing future policy and management decisions in a more solution- and action-oriented way. By bringing diverse value perspectives on nature (i.e., intrinsic, instrumental and relational values) into scenario development, the nature futures framework can help stakeholders recognize the multiple benefits of conserving nature and its ecological processes, while preserving and creating space for culture. In this sense, the nature futures framework becomes a heuristic and an entry point for visioning and assessing radical yet plausible pathways towards living in harmony with nature.

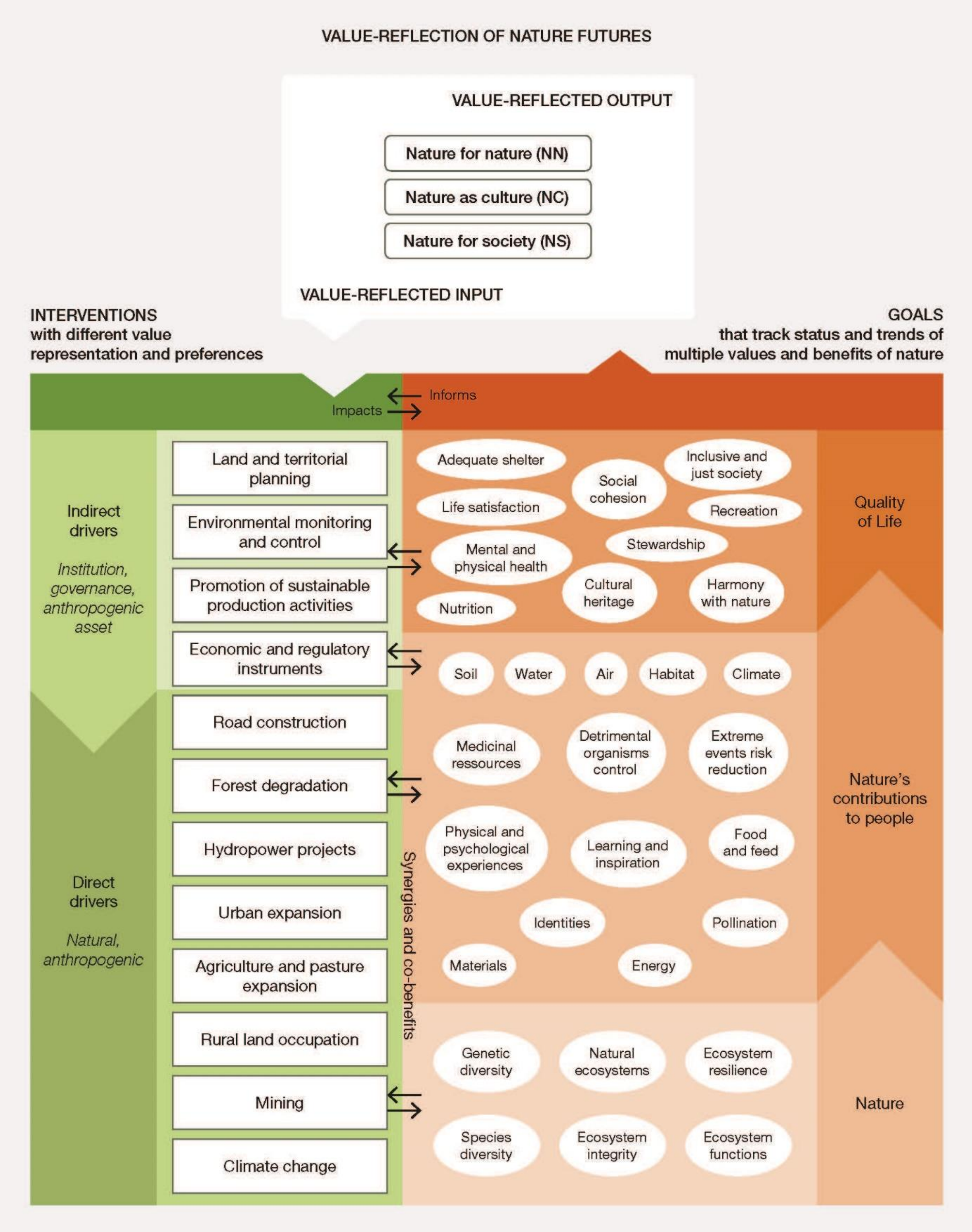


Figure 5.10 An illustrative nature futures framework in the Brazilian Amazon of Pará State for assessing the potential consequences of different policies on nature and people. Source: Based on Siqueira-Gay et al. (2020).

5.9 Transformative change, leverage points and pathways to enhance the sustainable use of wild species

Enhancing the sustainable use of wild species could provide benefits to both people and nature, but transformative change is needed if these benefits are to be realized. Given the vast diversity of life on earth, and the range of contexts and values that shape human uses of wild species, a pluralistic approach will be required, which recognizes and celebrates diversity in the relationships between people and wild species (see also section 5.8). As the previous section has indicated, the nature futures framework may also be a useful tool to help to envision these transformations and highlight leverage points and pathways. In this section some approaches towards transformative change are explored, as applied to scenarios of sustainable use.

5.9.1 Transformative change, scenarios and sustainable use

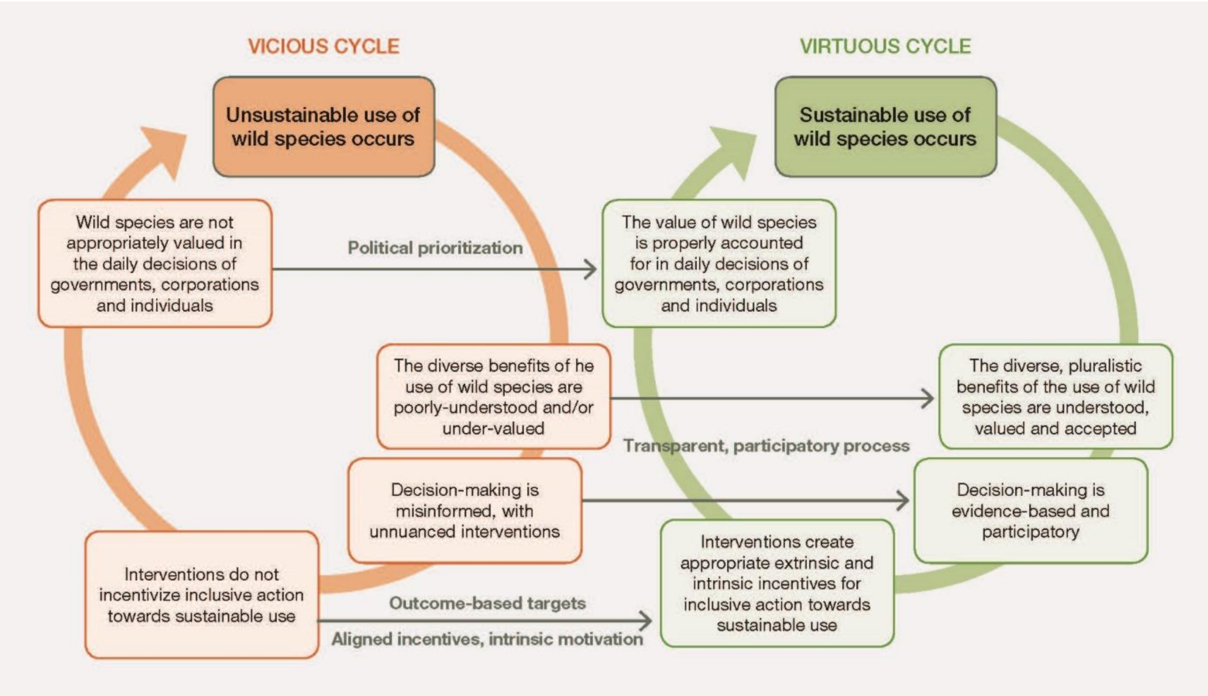
Transformative change through "deliberative transformations" (i.e., those caused by intentional interventions) very often involves a move towards collaborative adaptive management – which is precipitated by crisis or turmoil (Gelcich et al., 2010). Actors such as policymakers, donor agencies, non-governmental organizations, private corporations, and scientists can play a catalytic role when acting in appropriate ways at the right place and at the right time (Olsson et al., 2004).

Regulation has been a predominant approach to controlling wild species use. Regulations can take multiple forms, from strict spatial and species-specific prohibitions to rules for how and where species can be used (e.g., gear restrictions in fisheries, protected areas) and in what quantities (e.g., quotas). Some form of regulation is often necessary to support the sustainable use of wild species. However, it is not usually sufficient for positive transformative outcomes. Firstly, in order to be effective, regulations require appropriate compliance management, such as through monitoring and enforcement. Secondly, excessive and indiscriminate regulation can undermine incentives for sustainable use and lead to polarized narratives and an over-focus on illegality (Challender et al., 2015). This may drive "vicious cycles" that constrain pathways to transformative change (Figure 5.11). Yet if appropriately and anticipatorily governed via a mix of regulatory and economic instruments which are aligned with a plurality of values and visions, wild species can be sustainably used (noting that "use" can be associated to extractive and non-extractive practices, as per the nature futures framework, Figure 5.9). It can simultaneously support the pursuit of the Sustainable Development Goals (Box 5.10) and international conservation goals such as the Convention on Biological Diversity's new post-2020 global biodiversity framework, which is expected to be adopted at the 15th Conference of the Parties ('t Sas-Rolfes et al., 2019).

Importantly, there is a need to understand trade-offs between the costs and benefits of different types of wild species use, how interventions might enhance or exacerbate them, and for whom (Box 5.10). A plurality of values can be considered to understand these costs and benefits (e.g., economic, social, ethical), as per the nature futures framework (see section 5.8). In particular, the value systems of people who will be most affected by interventions are foremost in the design of these interventions.

An appropriate mix of interventions, predicated on a good understanding of such costs and benefits, could promote a transition from vicious cycles of unsustainable use to virtuous cycles of sustainable use (Figure 5.11a). In order to be effective, these interventions need to target both micro-level changes to transform individual human actions, and macro-level changes, which can transform social structures and norms (Naito et al., 2021). For example, regulations can act as structural interventions which recraft the choice environment, while behavioral interventions, such as enforcement of regulations, positive economic incentives or promotion of goodwill values, can address socio-psychological barriers and act as enablers which promote pro-environmental social change (Figure 5.11b).

A



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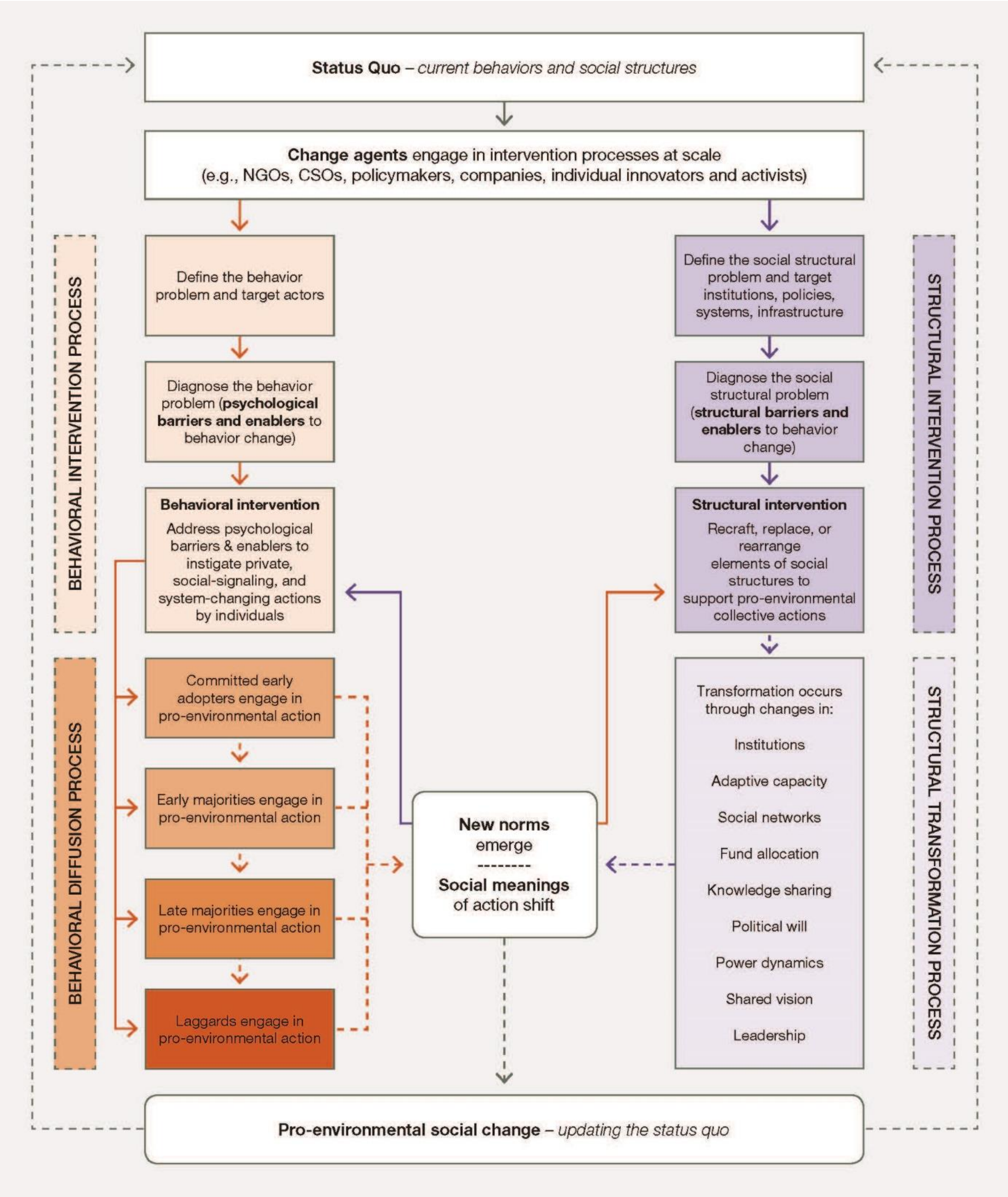

Figure 5.11 A) The vicious cycle of unsustainable use and the virtuous cycle of sustainable use, with illustrations of how leverage points can cause shifts between them. These leverage points need to be applied in concert to obtain transformative change. One alone is unlikely to shift the system effectively. **B) An integrative framework for pro-environmental social change**. Abbreviations: NGO: Non-governmental organization, CSO: Civil society organization. Source: Naito et al. (2021). Copyright © 2022, Springer Japan KK, part of Springer Nature, under license CC BY-NC-ND 4.0.

Box 5.10 Wild species use and sustainable development

Enhancing the sustainable use of wild species requires a holistic understanding of how different use regimes can contribute to society. Moreover, by focusing on an outcome goal such as "sustainable development", heterogeneous pathways to this goal can be devised. Figure 5.12 below shows illustrative examples of how interventions under differing value systems aligned with the nature futures framework can alter progress towards the Sustainable Development Goals relative to a business-as-usual framework.

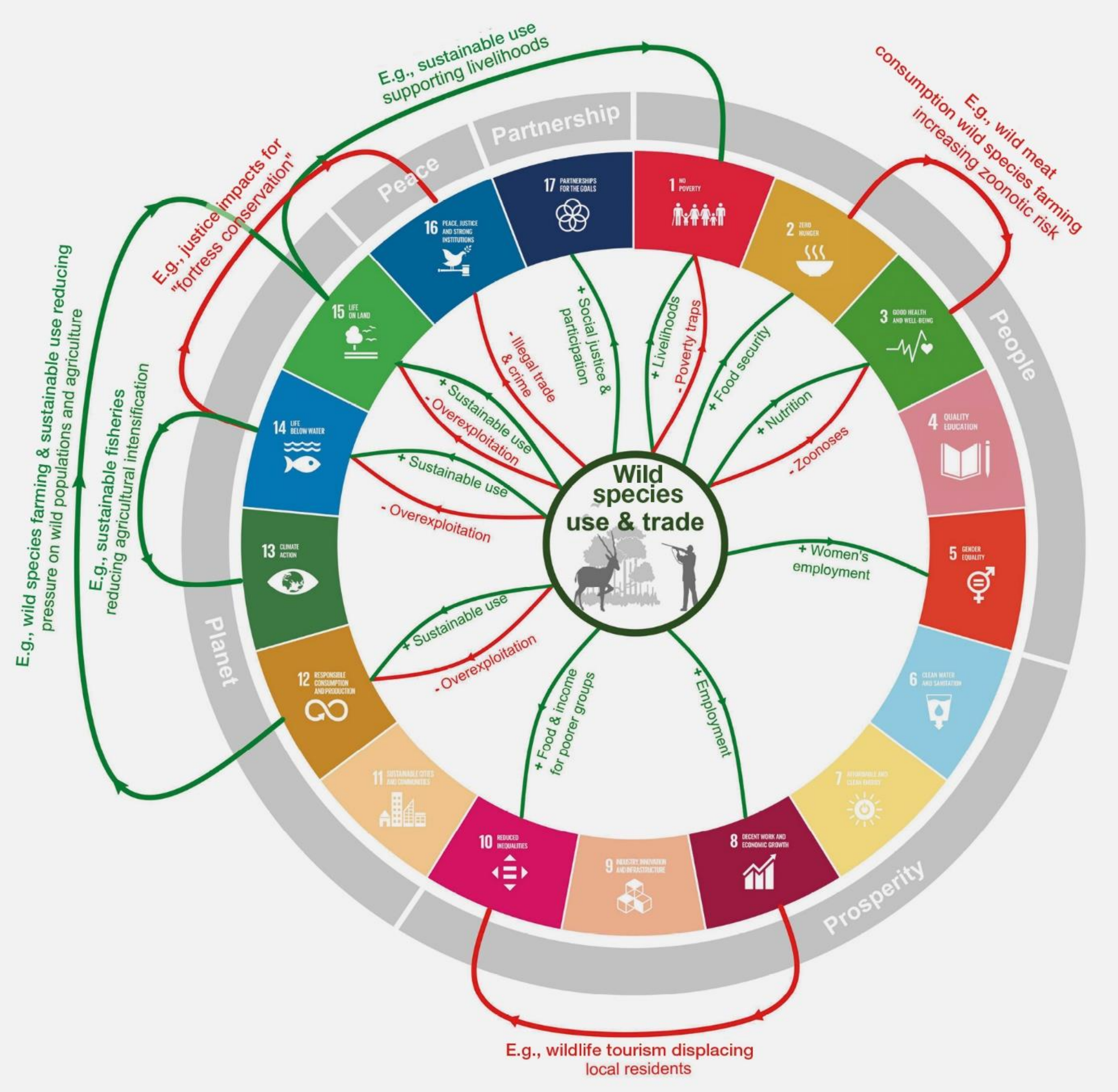

Figure 5.12 Examples of positive (green) and negative (red) contributions of wild species trade to the Sustainable Development Goals. Source: Booth et al. (2021) under license CC-BY 4.0.

A transformative shift to a virtuous cycle may be feasible under almost all of the IPBES archetype scenarios and positive visions (Lundquist et al., 2017), provided certain enabling conditions and leverage points are in place.

Transformative processes may start with technological innovation which, if combined with social transformation, can signal a fundamental transition in a new direction. Enabling conditions (Pereira et al., 2015) for transformations to sustainability include emancipation and empowerment, knowledge co-production, iterative learning and a political environment that encourages and nurtures innovations. Building blocks are intermediate conditions for transition. In small-scale fisheries, for example, five building blocks (local leadership, secure funding, support from local government, cooperation and awareness) were identified in a Vietnamese lagoon fishery (Andrachuk et al., 2018; Figure 5.13).

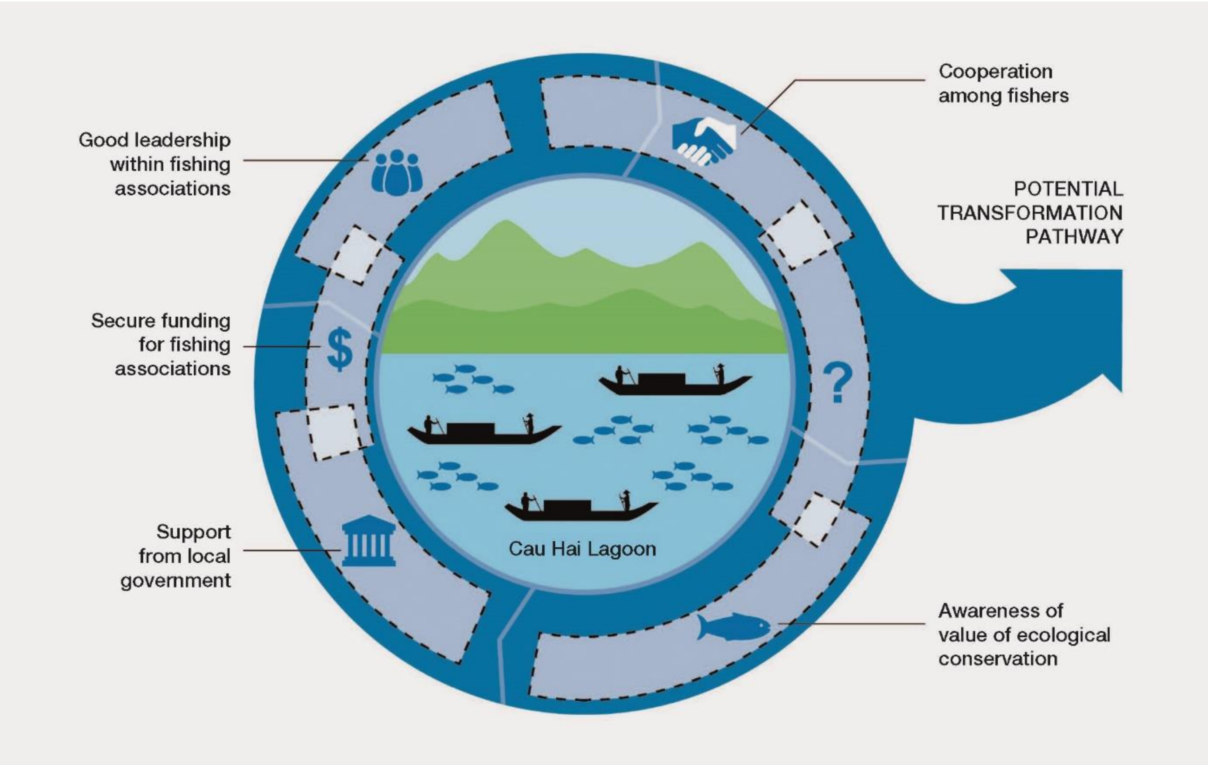

Figure 5.13 Building blocks for social-ecological transformation in the Cau Hai Lagoon. Dotted blocks suggest supporting conditions for transformation; the nonlinear arrangements of blocks along the pathway is a reminder that building blocks will not be the same for all fishing associations. Source: Andrachuk et al. (2018) under license CC BY-NC-ND 4.0.

To drive transformative change at scale, it will be necessary to set a united outcome-based vision for nature and people, which will provide an overarching "direction of travel" for other leverage points. These leverage points include: political prioritization (including coordinated policy at the international, national and local levels), aligned incentives and participatory processes (including transparent decision-making), which enable social change at micro- and macro-levels, supported by positively-framed approaches to adaptation and technological advances (Box 5.11, Figure 5.14).

Box 5.11. Leverage points for transformation to sustainability

Drawing on the findings of the IPBES Global Assessment of Biodiversity and Ecosystem Services, Chan et al. (2020) highlight eight leverage points for transformation to sustainability, which may equally apply to sustainable use (Figure 5.14). These leverage points can be shifted, using five interrelated "levers". Chan et al. (2020) make the point that these elements are "non-substitutable", and, when used together, may lead to "synergistic benefits".

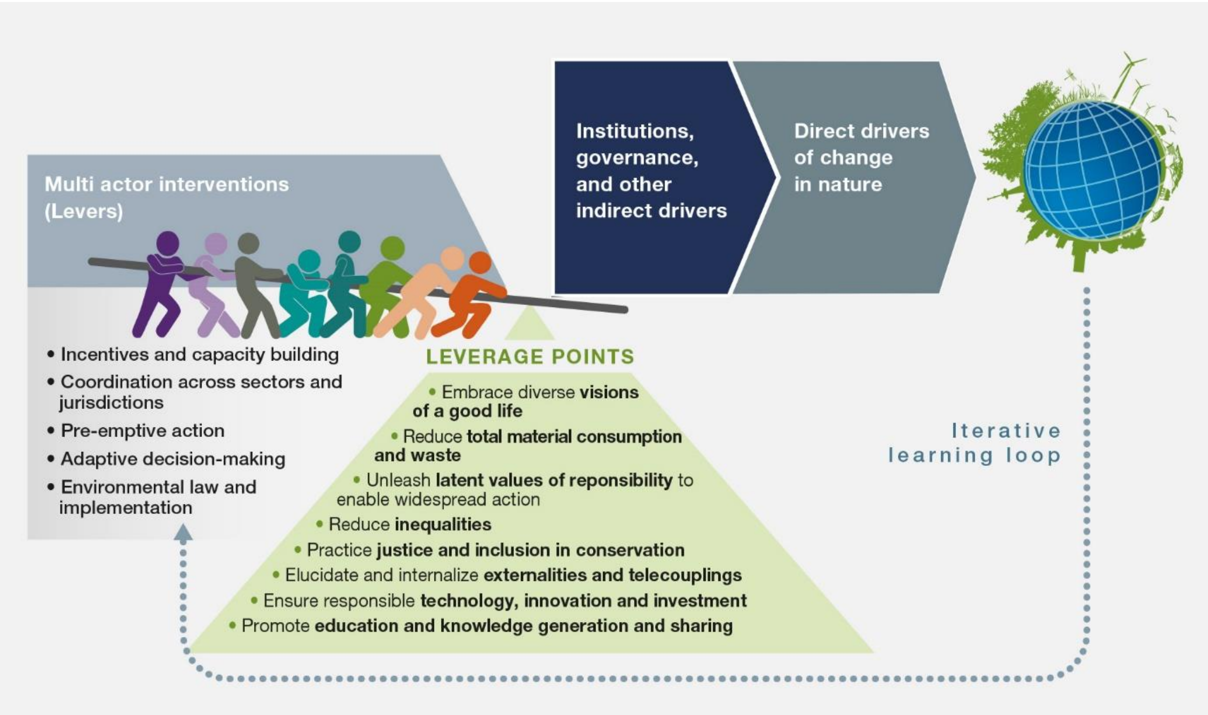

Figure 5.14 Implementation of interventions (levers) targeting key leverage points to enable transformative change towards greater sustainability. A range of actors (such as intergovernmental organizations, governments, non-governmental organizations, citizen and community groups, indigenous peoples and local communities, donor agencies, science and educational organizations and the private sector) can apply the levers at multiple leverage points. Source: Chan et al. (2020), under license CC-BY 4.0.

5.9.2 Setting an outcome-based vision for nature and people

A key first step in enhancing sustainable use of wild species is to set a united and aspirational outcome goal for nature and people, which focuses on a desired end state (Bull et al., 2020; Maron et al., 2021). This is in contrast to process- or performance-based goals, which outline specific approaches or standards for achieving the end state (i.e., outcome goals focus on the ends, while process- or performance-based goals typically focus on the means).

In this case, the desired goal(s) may be, for example, sustainable use of wild species helping to "create a better and more sustainable future for all" and/or to "save lives, protect livelihoods and safeguard nature" (Booth et al., 2021; Settele et al., 2020). Similarly, the Convention on Biological Diversity's 2050 vision of "living in harmony with nature", underpinned by a target of nature recovery, could provide a broad aspirational outcome goal within which to embed diverse strategies for enhancing the sustainable use of wild species. Importantly, these outcome goals allow for a plurality of values (as per the nature futures framework), which can consider the multi-dimensional well-being of all living things, both humans and non-human.

Such outcome-based goals can provide a common vision towards which diverse stakeholders at multiple levels of society can work, whilst allowing for a plurality of approaches to get there. This means specific interventions can be designed to suit different species and contexts, allowing room for different values (i.e., as per the nature futures framework, nature for nature, nature for society and nature as culture), and integrating multiple international priorities (Box 5.10; Box 5.11) under different multilateral environmental agreements. It also limits potential perverse ecological outcomes, cost inefficiencies and social losses that can come from setting "one-size-fits-all" process-based or activity-based goals (e.g., for protected area coverage; Banks-Leite et al., 2021).

However, ambitious outcome goals alone are not enough to drive transformative change. There is a need to "mainstream" nature, by translating high-level goals into meaningful and inclusive actions at multiple scales throughout society (Box 5.11). Coordination between multilateral conventions and between different arms of government, business and civil society may lead to the "enabling" leverage points.

5.9.3 Political prioritization: embedding nature within high-level political targets

Enhancing sustainable use of wild species requires making the management of human-nature interactions a top political priority, with decision-makers committed to inclusive, equitable, and evidence-based policies and nature mainstreamed across all government sectors. Policy windows ("the emergence of junctures or openings for concerted action", Armitage et al., 2011) are crucial to overcoming political inertia, particularly in the early stages of transformation, and may open new possibilities for incentive systems and new ways of allocating access rights.

In light of the COVID-19 pandemic, there have been calls for a "green recovery". Nature is also increasingly acknowledged as an economic priority, as reflected in the 2020 World Economic Risk Report and the Dasgupta review (Dasgupta, 2021b). This high-level prioritization and mainstreaming of nature into economic decisions could help to pave the way for enhancing sustainable use of wild species in the future. As reflected in the seven IPBES visions, to ensure a full societal shift towards sustainable use, this needs to be supported by shifts in high-level political targets, from growth-oriented goals which over-represent economic welfare (i.e., gross domestic product) relative to goals based on holistic social welfare and long-term sustainability. Changing this focus could help facilitate moves towards de-growth, ecological optimization and/or circular economy paradigms, which ensure that economic activities do not overexploit wild species.

5.9.4 Aligned incentives: ensuring people are not worse off via appropriate instrument mixes

Enhancing sustainable use of wild species will require behavior change and innovation across all sectors of society. Broadly speaking, there are two main types of instruments which can facilitate this transformational change: regulatory and market-based interventions (Young & Gunningham, 1997). Regulations are needed which consider both the bio-economics of the sustainable use of different species and ecosystems and the socio-economic costs and benefits of their use. Under the nature futures framework, in situations in which "nature for nature" is a dominant paradigm, extractive use of wild species can be prohibited while allowing for well-regulated non-extractive practices such as photographic tourism. In "nature for society" situations, regulations such as standards and quotas can help to ensure that use is compatible with the survival of wild species. Such regulations are effective safeguards for sustainability when they are also associated with robust monitoring and adaptive management, as well as with strong institutions which can insulate against poor governance (Young & Gunningham, 1997).

Regulations can also be supported by complementary rights- and incentive-based instruments for aligning socio-economic and sustainable use objectives, especially where indigenous peoples and local communities may be impacted. For example, in "nature for society" situations, where commercial use of wild species can be compatible with their survival in the wild, and with the economic welfare of society, mechanisms need to be put in place to ensure appropriate distribution of these economic benefits to people who are living in association with wild species, or who can act as stewards of wild populations and/or their habitats. An example is the commercial hunting of bighorn sheep in Mexico, where local people provide access and guiding services to hunters, and income from hunting permits supports habitat management and payments to communities (Cooney et al., 2019). Another is the harvesting of saltwater crocodile eggs in the Northern Territory of Australia, where indigenous communities have use rights to benefit directly from egg harvesting, while outsiders can harvest eggs for an access fee (Fukuda & Webb, 2019). Appropriate interventions to enhance sustainability may include supporting local communities to achieve secure tenure of their resources, and promoting social justice and equity, such as implementation of conservation basic income schemes (Fletcher & Büscher, 2020).

In "nature for nature" situations, it may be necessary to directly reward or compensate people for protecting wild species and their habitats. Examples include shark reef in Fiji, where fisher communities are directly paid for protecting a no-take zone (WCS, 2020), and performance-based payments to protect endangered ibis in Cambodia (Clements et al., 2010). Similarly, it may be necessary to develop negative incentives for unsustainable damage to wild species, for example through systems of "green" or "blue" taxes which are levied against corporations that exploit wild species (Zhou & Segerson, 2012).

In general, it will be important to set social outcome goals alongside nature outcome goals, such as ensuring people have higher well-being as a result of conservation interventions (Griffiths et al., 2019).

5.9.5 Intrinsic motivations: driving behavioral tipping points though social norms

Intrinsic motivations, such as social norms, can interact with regulatory and market-based approaches and drive large-scale behavioral change across systems (Nyborg et al., 2016). For example, leveraging social change through social marketing techniques could create positive outcomes for wild species, by both discouraging illegal and unsustainable use of wild species (e.g., products directly derived from protected or endangered wild species, and products that indirectly drive loss of nature such as industrial domestic animal production, Chaves et al., 2018; Doughty et al., 2020) and promoting behavioral shifts towards more environmentally-friendly diets (e.g., more plant-based diets and sustainably sourced animal products, Nyborg et al., 2016). Novel approaches to producing social change include deploying social media and mobile technology, for example through targeted advertisements or inducing peer pressure via online social networks (Doughty et al., 2020; Mani et al., 2013), or through improved supply chain traceability and sharing of knowledge and data on the impacts of different actors on wild species (Österblom et al., 2017).

Consumer awareness and social change can also drive corporate social responsibility for sustainable use of wild species or work in synergy with corporate activism. For example, a global science-business initiative for ocean stewardship has been created to enhance sustainable use of wild fish stocks by using data and transparency to drive corporate and consumer change (Österblom et al., 2017).

5.9.6 Transparent, participatory processes and adaptive management

Good policy interventions and socio-economic instruments are co-designed with affected people, and consider in particular social justice and equity, both in terms of process and outcomes. To do so, participatory processes and transparency with respect to value-based judgements are useful (DeFries & Nagendra, 2017; Kenter et al., 2011). They can in turn improve the social legitimacy of interventions promoting the sustainability of the use of wild species and their effectiveness in driving sustainability through behavior change (Bonwitt et al., 2018; Levi et al., 2009). In cases where the values of different stakeholders diverge, techniques such as describing and sharing mental models can help to improve common understanding about complex issues (Biggs et al., 2011), while positive message framing can promote inclusive action (Jacobson et al., 2019).

All interventions to enhance sustainable use of wild species will also require adaptive management. For complex, dynamic issues like wild species use, there is rarely one static universal solution. This requires that the impacts of interventions are assessed, with room for "optimistic" and "fail safe" adaptation, that provides room for learning from failures, and allows challenges to contribute to institutional knowledge (Catalano et al., 2019). Horizon scanning may also be a useful component of an adaptive approach to transformative change in dynamic systems, which can be used to inform scenario-building and policy formulation (Box 5.12).

Box 5.12. A horizon scan of the illegal trade in wild species

To help inform proactive policy responses in the face of uncertainty, Esmail et al. (2020) conducted a horizon scan of significant emerging issues for the illegal trade in wild species. This covers the hunting and gathering practices discussed above, with a focus on international trade. Building upon existing iterative horizon scanning methods, they used an open and participatory approach to evaluate and rank issues from a diverse range of sources. The top 20 issues fell under three overarching themes: (i) Geographic (political, demographic and socio-economic) shifts and influences; (ii) Scientific and technological innovation, and (iii) Changing trends in demand and information (see Figure 5.15).

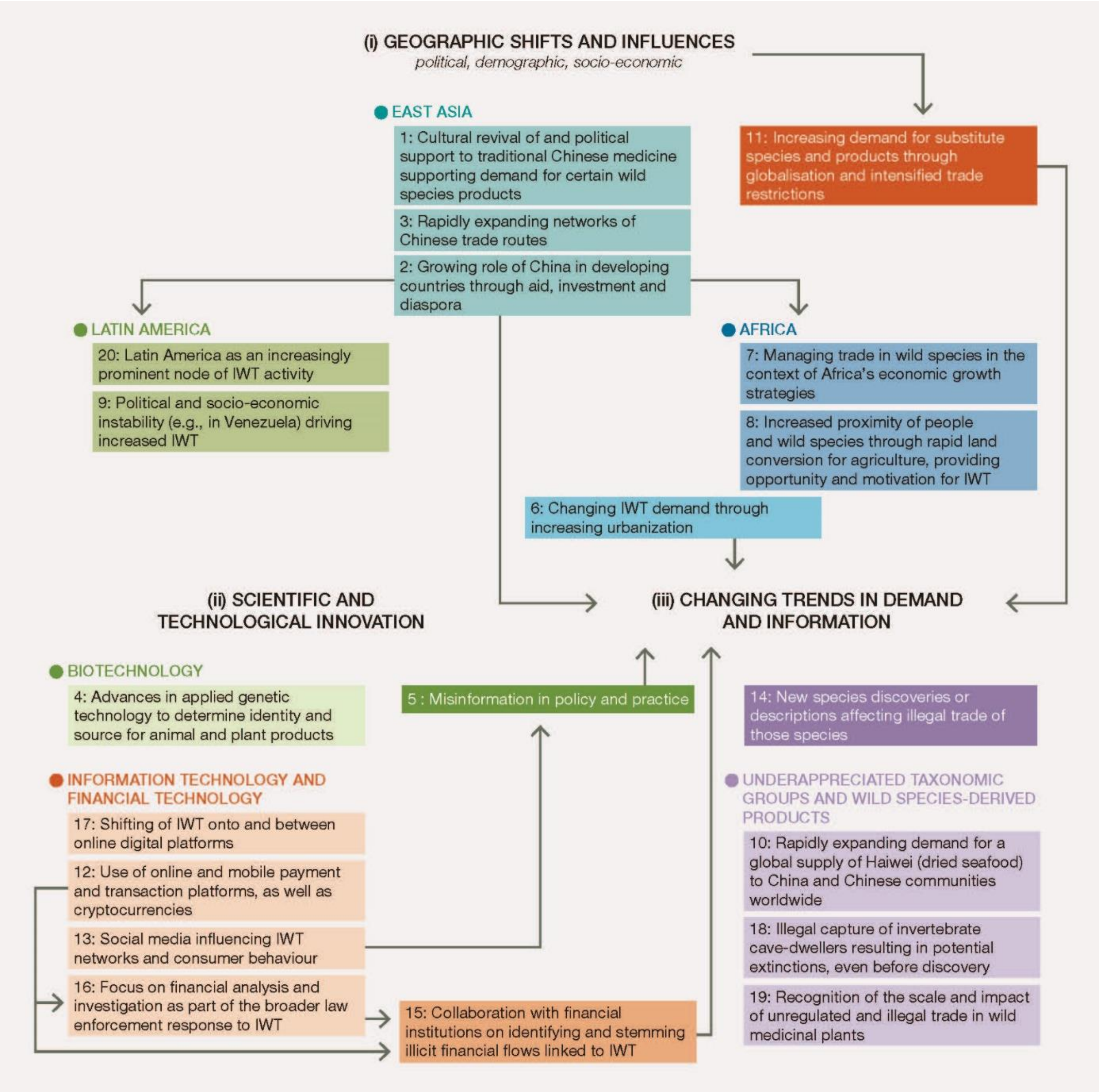

Figure 5.15 The top 20 emerging illegal wild species trade issues, illustrating linkages between them. Numbering represents the rank order of the issues (referred to in the text as Horizon scan issues 1-20). Those outlined in black are cross-thematic issues. Abbreviations: IWT: International wild species trade. Source: Esmail et al. (2020) under license CC-BY 4.0.

Issues under the first theme include changing geopolitical processes and the rising global influence of East Asia. Political, demographic and economic changes could facilitate greater access to wild species and stimulate growing demand for wild species products, but also opportunities for sustainable use. For example, the political and cultural revival of traditional Chinese medicine, the increasing role of China in developing countries, and the rapid expansion of new international trade routes, particularly in the context of the Belt and Road Initiative, could bring both new threats and new opportunities for sustainable wild species trade (Esmail et al. 2020).

Issues under the second theme fell into two broad categories: biotechnology and information technology. For example, genetic technological advancements could enable rapid, cost-effective assessments and traceability of product identity and source at the species and individual levels. This could lead to better enforcement of regulations, and potentially promote sustainable sourcing. Cross-thematic issues which touch on the vicious-virtuous cycle of Figure 5.15 included that, in the modern age of networked communication, misinformation (from market participants, intergovernmental bodies, non-governmental organizations, policymakers and/or the media) can rapidly influence policy and practice. This can be difficult to correct and can undermine conservation efforts by skewing policy responses and potentially misdirecting scarce resources. Horizon scans are meant to be repeated at regular intervals or when circumstances have changed. A post-COVID-19 scan would pick up some of the same issues (potentially intensified) as well as bringing in new ones (Esmail et al. 2020).

5.10 A critical reflection on inequality issues with respect to the sustainable use of wild species

Rising inequality is a major concern for the sustainability of economies, societies, and communities and necessitates an urgent research agenda to improve understanding of and responses to inequality (UNDESA, 2020). The sustainable use of wild species also requires particular attention to social inequalities, as was highlighted in each of the sectoral scenarios and pathways illustrated in this chapter and the vision for transformative change (section 5.8). Inequalities can be of opportunity, income, food access or other issues, and can be both within countries and between countries. They may also reflect gender and intergenerational issues. Inequality is one of the main drivers of social tension. The direct and indirect effects of the COVID-19 pandemic are strongly conditioned by inequality between countries and within countries, and as such, COVID-19 will likely worsen these inequalities (Naidoo & Fisher, 2020; Dasgupta, 2021b).

A critical reflection on social equity issues is crucial for the interpretation of the different types of scenarios that explore the future of wild species use and the trajectories that are proposed to move society towards more sustainable uses. Overall, vulnerable groups that depend on wild species have not been properly addressed in integrated assessments, models and forecasts (Gasalla, 2011, 2015; Martins & Gasalla, 2020). Although there are numerous studies that explore high-level, aggregate economic and environmental data, there is still a need for an examination of the specific underlying pathways linking different kinds of inequalities to behaviors that affect the sustainable use of wild species positively or negatively (Berthe & Elie, 2015; Hamann et al., 2018).

As an example, natural capital stocks as a whole are shrinking and the consequent social costs of these changes have not yet been well assessed (Dasgupta, 2021a). When wild species resources are overexploited, people in vulnerable situations who depend on them for their livelihoods are usually disproportionately affected. The loss of earnings and opportunities also feeds into rising inequality within countries, as illustrated by Figure 5.16, where the mechanisms of transmission of wild species degradation into inequality within countries is shown.

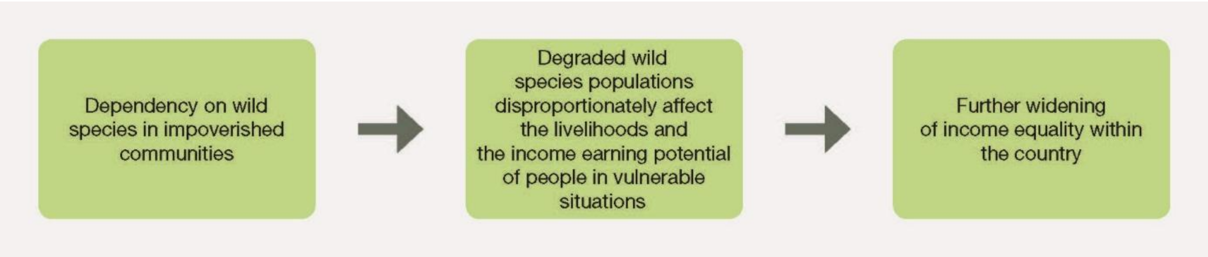

Figure 5.16 A conceptual scenario chain for the relationship between poverty, inequality and wild species dependence

Inequality is also characterized by social marginalization and exclusion. Social exclusion manifests primarily through unequal access to resources, limited political participation and voice and the denial of opportunities (UNDESA, 2016). Pastoral and fishing livelihoods have been severely undermined by decades of marginalization from policy and investment decision-making processes, violence and displacement, as well as insecure tenure rights and access (Gasalla, 2011). The lack of alternatives to the use of wild species has been critical, despite the human right to food being considered as a universal value and accepted as an international ethical standard (A. Sen, 2004; D'Odorico et al., 2019).

Markets play a critical role in the demand for wild species. Scenarios showing market concentration, i.e., the dominance of a few actors within a specific natural resource management system, suggest that the consequences for marginalized groups can be severe. As the status of natural resources improves (e.g., healthier fish stocks), higher profits allow for further accumulation of capital, as well as investment in improving extraction or harvest technologies (Hamann et al., 2015). When such investments allow firms to exploit cost advantages due to an increased scale of production, they further reinforce the trend towards market concentration (Martin et al., 2012). This concentration of wealth and influence also leads to higher lobbying power, which can be used to sway policy decisions, thus strengthening the feedbacks between market concentration, capital accumulation, and management of the resource. In resource management systems with a high level of market concentration, a small number of powerful firms or actors therefore tend to dominate the total production of a certain resource (Hamann et al., 2015). High market concentration thus implies a high level of inequality between firms or actors that use and manage the resource. Whether such inequality results in actions that are beneficial or detrimental to the sustainability of the use of wild species is highly context-dependent.

As an example, the implementation of certification schemes, such as the Marine Stewardship Council, can promote the sustainable harvest of marine wild-species through the implementation of rules and monitoring (Gómez Tovar et al., 2005), but can also exclude marginal actors given the cost of compliance with the certification regime (Bush et al., 2013; Cumming, 2007; Jacquet et al., 2010). Hence, certification can directly influence resources and promote sustainability, but it can also reinforce market concentration and increase social and economic inequalities.

In a globalizing world, wealth will inevitably be appropriated by a very small fraction of the population unless effective wealth-equalizing institutions emerge at the global level (Scheffer et al., 2017). Wealth inequality may have emerged as far back as the Neolithic era but the relative amount of wealth appropriated by the richest has increased as societies have scaled up. It happens due to the scale effect itself, and because installing effective institutions to dampen inequality becomes more challenging as scale increases (Scheffer et al., 2017). Excessive concentration of wealth is widely thought to hamper economic growth, concentrate power in the hands of a small elite and increase the chance of social unrest and political instability (Piketty & Saez, 2014). Whether the pathways for effective governance can now be achieved at the global level and, if so, what this new form of governance might look like, remain unclear (Scheffer et al., 2017).

Nevertheless, several studies suggest that the reduction of inequality will have an important role in achieving environmental sustainability as a whole, including the use of wild species. Reduction of inequality is challenging. Within a country, the national government can take various fiscal and asset redistribution policies to reduce inequality. Fiscal policies involving taxes and cash transfers are more politically feasible than asset redistribution policies are. In most developed countries a significant portion of the national income (sometimes exceeding fifty per cent) is indeed taxed and redistributed, so that the distribution of "net" (or disposable) income is much less unequal than the distribution of "market" (or gross) income. Such extensive and deep redistribution of income however is yet to be instituted in most developing countries (Islam, 2015). Reduction of inequality at the international level is difficult to achieve, because there is no "global government" with redistributive power similar to that of a national government. However, the international inequality situation is changing as a result of the operation of spontaneous economic forces. The "rise of the South" and formation of "the Group of Twenty (G20)" are manifestations of these changes. An important task for the future is therefore to harness these changes and consider how to apply them towards the sustainable use of wild species.

All these considerations are critical to improving social justice and human rights issues and incorporating them into future scenarios of the sustainable use of wild species, especially with consideration of the roles of indigenous peoples and local communities. Hamann et al. (2018) explains the interactions between inequality and the use of wild species in social-ecological systems. These pathways of interaction represent a subset of possible interactions and a starting point for further research on inequality issues in scenarios.

5.11 Knowledge gaps and priorities for future research and action

Critical knowledge gaps have arisen from evaluating the literature around scenarios of sustainable use of wild species. These include gaps for specific practices, scenarios types, and social-ecological aspects.

Beginning with individual practices, across almost all practices there is a deficit of scenarios that explore cultural aspects. The scenario literature on sustainable use predominantly pertains to fisheries and logging, and the impacts of climate change and/or management interventions and interactions with climate change. Other practices are under-represented, particularly for non-business-as-usual scenarios, as are scenarios and projections of cultural aspects, the role of indigenous peoples and local communities and rights-based approaches, and the intersection of broad top-down management and governance regimes with equity issues.

In addition to these gaps, there are specific gaps for each practice. For fishing, projections of climate change impacts are relatively common, but the translation of climate impacts coupled with governance and equity storylines to quantitative projections is limited, though scenario narratives exist at global scales (Maury et al., 2017). Thus there is a need for more holistic scenarios. Projections for aquaculture and freshwater systems also remain more limited. Furthermore, scenarios of recreational fisheries in the future remain less common.

For gathering, many species have limited empirical data on production, trade volumes and revenues, making future projections of use challenging. In general, there is a lack of projections, scenarios and generalizations, though there are numerous studies on community-based management, which could perhaps be evaluated using a scenario-based approach.

For hunting, few scenario studies exist at all and they are difficult to generalize. A further exploration of comparative studies may help in building the evidence base necessary to produce more scenarios (e.g., Dobson et al. 2019). Other specific gaps are scenarios on the effects of environmental change, particularly climate-driven change, as a driver of changes in hunting practice, and on the role of hunting, including trophy hunting, in conservation.

For logging, as with fishing, there are a number of studies on the challenges of sustainable use brought about by climate change. However, these can be fairly narrow and need to be more integrative, suggesting the need for scenarios on the sustainable use of natural forests given the interactions between climate change, development, biodiversity, and poverty, and how differing contextual factors such as biomes can affect these interactions. Furthermore, as for all practices, projections of cultural aspects remain sparse.

For non-extractive practices, there are few scenario studies at all, and even fewer focused on a non-extractive practice in isolation. There is also almost nothing on economic aspects beyond tourism.

Going beyond individual practices, broadly speaking, there are numerous scenarios and projections on environmental sustainability writ large, biodiversity conservation and climate change, but wild species use is not often explicitly considered within these. There needs to be a greater focus on sustainable use within the context of more integrated solutions, and consideration of how sustainable use interacts with conservation and other elements of a broadly sustainable society. Furthermore, when sustainable use is considered, it is less frequently under archetype scenarios corresponding to fortress world and inequality. Broad studies on these scenario types do exist, but again need to explicitly link to the sustainable use of wild species.

Finally, vulnerable groups who depend on wild species are not well represented in scenarios and projections, nor are issues around inequalities more generally, and how these inequalities affect the sustainable use of wild species.

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