Not One Biodiversity Loss, But Many: Unveiling the Scientific Discourse of Biodiversity Loss Through Drivers, Solutions, and Responsibilities

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Abstract

Biodiversity loss is considered a major global issue. At the same time, scientific actors identify different drivers, solutions, and responsibilities for the same issue of biodiversity loss. These identifications shape the storylines of scientific actors, which have varying degrees of impact on policy, depending on their roles within the biodiversity science-policy interface. Yet, a contemporary global overview of these narratives within biodiversity literature is currently lacking. This article offers an overview through a systematic literature review of global contemporary biodiversity literature and a discursive network analysis employing a framework based on drivers, solutions, and responsibilities. Through this approach, seven scientific storylines centered around drivers, solutions, and responsibilities are identified. These storylines represent an overview of the scientific discourse on biodiversity loss. The results highlight how the various storylines identify different key problems and how some storylines neglect social dimensions. Moreover, this research shows that the commonly used categorization of direct drivers of biodiversity loss by IPBES (2019) is represented by only one storyline, thereby indicating its limited prevalence across the literature. This study aids biodiversity researchers in composing a more holistic narrative by recognizing blind spots within their own narrative. Additionally, it assists policymakers in identifying relevant storylines for policy that may be less prevailing within the biodiversity science-policy interface.

Introduction

Biodiversity is widely considered one of the major global issues of our time. Biodiversity has decreased rapidly in the past decades due to human activities (IPBES, 2019; Popescu, 2015). The broad scope of biodiversity is discussed in various contexts. It interfaces with ecological, social, political, and economic dimensions. Consequently, various scientific actors have different representations and focal points regarding the same issue of biodiversity loss. This creates diversity and contingency in how the topic of biodiversity loss is understood, leading to a range of different biodiversity loss representations. Some representations of biodiversity loss prioritize its economic, social and political dimensions, such as the blue economy, environmental injustices, or a neoliberal critique on conservation (Amodu, 2019; Bax et al., 2022; Fletcher, 2020). Other representations of biodiversity loss focus more on its ecological dimensions, such as the effects of climate change on island systems or ecosystem collapse (Macinnis-Ng et al., 2021; Nicholson et al., 2021).

The term biodiversity underscores the contingency of its meaning and demonstrates how it can change in different times and contexts. While biodiversity has become a common concept, it was only introduced in 1986 at the national forum of biological diversity and gained momentum in the 1990s (Gustafsson, 2014; Väliverronen, 1998). Despite, systematic literature reviews within the environmental discourse field conducted by Arts et al. (2010) and Leipold et al. (2019), systematic reviews overseeing the contingency of global biodiversity literature are currently lacking. However, various studies have offered their perspective on diverse

biodiversity frames across different contexts. (Arts et al., 2010; Louder & Wyborn, 2020; Mace, 2014). Mace (2014) outlines the temporal contingency of biodiversity discourse with four temporal frames within a conservation context. The 1960s and 1970s are framed as "nature for itself", prioritizing natural habitats mostly excluded from people. The 1980s and 1990s are represented as "nature despite people", sparked by the increase of human activities and awareness of its effects. The 2000s are framed as "nature for people", highlighting the valuable and declining goods and services that nature provides for humans. The 2010s are represented as "nature and people", moving away from the purely utilitarian perspective of "nature for people", emphasizing the two-way and pluralistic relationship between humans and nature. These temporal frames highlight a fundamental debate: the balance between human-centric and nature-centric perspectives. This tension is further explored by Louder & Wyborn (2020): The human-centric perspective represented within the anthropocentric narrative highlights that nature sustains the economy and society, and should therefore be protected. Its counter narrative, a nature-centric perspective, critiques the anthropocentric narrative for potentially undermining the value of nature beyond its utility to humans. Besides these, Louder & Wyborn (2020) identified several other narratives and counter narratives within the conservation context. The economic narrative and its counter narrative focus on the tension whether to include economic powers. The inclusion of economic powers can aid in conserving nature according to the economic narrative. Its counter narrative claims this inclusion as paradoxical, as this narrative recognizes capitalism as fundamentally destructive. Another narrative and counter narrative revolves around the inclusion of technology for biodiversity solutions. The techno-optimist narrative advocates the possibilities of technological innovation to resolve environmental issues, while maintaining modern consumption levels. Conversely, the nature-based solutions narrative favors solutions outside technology, moving with the forces of nature. Arts et al. (2010) present a literature review of several forest discourses offering different perspectives on biodiversity than Louder & Wyborn (2020) and Mace (2014). For instance, the deforestation discourse, which initially focused on tropical deforestation, has broadened to include temperate forest, social issues and climate change. Additionally, currently prevailing forest discourses relate to common biodiversity themes such as traditional knowledge, illegal logging, and sustainable management.

Scientific biodiversity discourse and narratives can influence policy through the science-policy interface (SPI) by providing knowledge for problem-solving or legitimizing policy decisions (Matsumoto et al., 2020; Metzner, 1998). The science-policy interface refers to social processes encompassing the relations between scientists and actors in the policy process (Van den Hove, 2007). These processes mostly entail academia and governments, but also include other stakeholders as noted by Matsumoto et al. (2020), who describe five features of the biodiversity SPI: the goal, the structure, the process, the output, and the outcomes. This research focusses on the key question how the storylines of biodiversity loss in the scientific discourse shape these five features and eventually translate into actual policy and biodiversity impact. Matsumoto et al. (2020) identify three main challenges in the biodiversity SPI: participation, trust and capacity building, and policy relevance. One of the leading biodiversity SPIs is the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem services (IPBES). The IPBES is an intergovernmental body established by member states of the United Nations. It serves as a platform for bridging the gap between scientific knowledge and policy-making in the realm of global biodiversity. Although the IPBES aims for inclusive participation, it still exhibits participatory biases within the global assessment (2019) favoring certain narratives, primarily from scientific actors, while marginalizing other narratives (De Donà & Linke, 2023; Wiegleb & Bruns, 2023). Additionally, trust and capacity were identified as key obstacles for maintaining a strong relation between scientists and actors in the policy process (Matsumoto et al., 2020). Overcoming these obstacles requires continuous dialogue, mutual comprehension, and trust within interactions. Lastly, there is the challenge of policy relevance,

relating to the question whether biodiversity knowledge is actionable for policymakers, fits within their scope, and aligns with political agendas (Matsumoto et al., 2020). However, providing policy relevant knowledge also introduces the struggle between scientific objectivity and utility for policy, as exemplified by Wiegleb & Bruns (2023) within the IPBES.

The scientific narratives, frames, and discourses within the biodiversity SPI and biodiversity loss literature partly vary because they identify different drivers, solutions, and responsibilities. Pascual et al. (2021) identify the lack of multiple perspectives within the conservation movement, particularly from marginalized communities, as a key driver of biodiversity loss. They criticize governments, conservationists, and scientists for exacerbating this lack of multiple perspectives. Conversely, Jaureguiberry et al. (2022) present five direct drivers: land/sea-use, resource extraction, pollution, climate change, and invasive alien species, as the dominant reasons for biodiversity loss. The concept of direct drivers was first introduced by the Millennium Ecosystem Assessment (2005) and further reinforced by the IPBES (2019). These direct drivers are the aggregated impacts of diverse human activities that physically affect nature bundled into the categorization of the five direct drivers. Jaureguiberry et al. (2022) propose ambitious targets and policies to remedy biodiversity loss and strongly recommend "urgent transformative change (p. 5)" to tackle the root causes of biodiversity loss. Any articulations of responsibilities associated to drivers or solutions are absent (Jaureguiberry et al., 2022). The absence of explicit responsibilities for proposed solutions or drivers creates ambiguity about who should take action and who is responsible, potentially hindering effective implementation of prescribed solutions.

Jaureguiberry et al. (2022) and Pascual et al. (2021) show how factors like drivers, solutions, and responsible actors are used as reference points in scientific discussions about biodiversity loss. Veland et al. (2018) describes that stories within environmental discourse are shaped by a subset of reference points. Therefore, the interplay of these drivers, solutions, and responsibilities may represent reference points for specific narratives in which scientific actors articulate biodiversity loss within scientific literature. However, whether narratives within biodiversity discourse are structured around drivers, solutions, and responsibilities is uncertain. Hajer (2006) refers to a "storyline" as a specific type of narrative. Storylines have a beginning, middle, and end, and are a simplification of reality to make a phenomena manageable (Hajer, 2006; Mammadova et al., 2020). If the interplay of drivers, solutions, and responsibilities does articulate distinct storylines within literature, then multiple storylines could be identified by examining the drivers, solutions, and responsibilities. These storylines would represent the discourse of biodiversity loss literature. This type of discourse is defined as "an ensemble of ideas, concepts, and categories through which meaning is given to social and physical phenomena, and which is produced and reproduced through an identifiable set of practices" (Hajer & Versteeg, 2005., p. 175).

Fonseca et al. (2021) and Mazor et al. (2018) examined scientific discourse on biodiversity through a frame of drivers and solutions. Fonseca et al. (2021) found that most articles in conservation literature focus on problems, categorized by direct drivers, but also noted an emerging trend towards solution-oriented research. Mazor et al. (2018) compared the prevalence of direct drivers in biodiversity literature with their actual impact. Interestingly, climate change was the most prevalent in literature, while climate change is not the top contributor to biodiversity loss. Conversely, resource extraction and pollution were less represented in literature relative to their impact.

Three knowledge gaps have been identified. Firstly, there is currently no global overview of the scientific discourse on biodiversity loss. Secondly, it is uncertain whether storylines can be centered around drivers, solutions, and responsibilities. Thirdly, Fonseca et al. (2021) and Mazor et al. (2018) exclusively examine scientific discourse on biodiversity loss for solutions, and direct drivers, and not responsibilities or complementary drivers. The aim of this study is to create the currently lacking global overview of the contemporary and dominant biodiversity

loss discourse within the context of scientific literature. Moreover, this study seeks to identify potential storylines centered around drivers, solutions, and responsibilities. In addition, this research aims to expand the driver and solution framework of Fonseca et al. (2021) and Mazor et al. (2018) by adding responsibilities and complementary drivers beyond direct drivers. This approach allows to identify blind spots within these potential storylines and investigate their implications for policy. Consequently, biodiversity scientists can gain insights into their blind spots and narratives, enabling a more holistic narrative. Policymakers can benefit by being informed about the range of storylines present within biodiversity loss discourse, enabling them to evaluate whether they are ignoring or adhering to certain scientific storylines or frames. The global overview is accomplished through a quantitative and qualitative approach combining a systematic literature review and a discursive network analysis, as is explained below.

Methods

Systematic literature review

This article employs a systematic literature review to identify the storylines within contemporary scientific discourse of biodiversity loss. This is done within the context of the most dominant articles and within a framework of global drivers and solutions of biodiversity loss. A search strategy is implemented using the key words: “biodiversity loss”, “biodiversity decline” or “biodiversity change” coupled with “worldwide” or “global”. The articles were retrieved from Scopus between 24th of October and 2nd of November in 2023. The literature review included ninety articles (Supplementary 1) to strike an informed balance between exhaustiveness and manageability (Randolph, 2019). Fifteen articles per continent were selected to compensate for the dominance of biodiversity science by the global North, thereby ensuring a more representative and balanced global discourse (Isbell et al., 2023). To only select contemporary literature, articles before 2021 were excluded.

After conducting the search, the articles were sorted based on citation count. Subsequently, articles were included or excluded from the literature review following specific inclusion and exclusion criteria (Figure 1), starting from the most highly cited articles and moving downwards. These criteria aim to ensure that the literature encompasses global perspectives on biodiversity loss, focusing on drivers and solutions of global significance without being overly narrow in scope. An overly narrow scope refers to articles that discuss only specific dynamics of drivers and solutions not suitable for studying global biodiversity discourse. The inclusion of the articles was determined by reviewing their titles and abstracts. The inclusion and exclusion criteria were validated through a second evaluator similar to Meline (2006) to increase reliability of the literature selection. This was done through a pilot of fifteen articles. Disagreements were discussed and the exclusion and inclusion criteria were adjusted if regarded necessary (Meline, 2006). The articles were examined reiteratively if the exclusion and inclusion criteria were adjusted. The inclusion and exclusion criteria were organized into a flow chart, depicted in Figure 1, involving a yes or no decision at each step. Every box in the flow chart presents a yes or no decision, where the blue arrow represents yes and the purple arrow no. Inclusion of the article is represented by green-filled circles. Conversely, exclusion of the article is represented by red circles featuring a diagonal stripe.

Article analysis

The selected literature was fully read, and the drivers, solutions, and associated responsibilities were qualitatively coded using Atlas.ti. Drivers refer to statements about the reasons for biodiversity loss, while solutions entail statements about possible actions to increase

biodiversity or reduce the impact of the drivers. Responsibilities always entail an actor connected to a driver or a solution. The categories of actors used for coding of the responsibilities were retrieved from the list of decision-makers of the IPBES global assessment (IPBES, 2019) (Table 1). Actors responsible for drivers are identified as partly or fully accountable for past actions related to biodiversity loss within an atmosphere of criticism. Actors responsible for solutions are either recommended, often with the use of the modal verb "should", or required, typically with the modal verbs "must" or "need", to actively engage in a specific solution (Hinkel, 1995). An association between an actor and a solution expressed as a possibility often with the use of the modal verb "can" or "may", is not categorized as a responsibility. Every driver, solution or responsibility is only coded once per article.

Figure 1 Flow chart with the inclusion and exclusion criteria of the article selection

The three main categories, drivers, solutions, and responsibilities, were deductively selected. The rest of the subcategories were inductively established to remain close to the data, which is fitted for an exploratory study (Graebner et al., 2012; Linneberg & Korsgaard, 2019). In practice this created a three layered hierarchy of codes. An exemplary hierarchy is structured as follows:

1. Drivers
    1.9. Socioeconomic factors
        1.9.1. Consumption
        1.9.2. Demographics
        1.9.3. Economy, Trade & Globalization
        1.9.4. Technology

During the coding process it was attempted to balance between capturing the complexity of the literature, having a manageable set of codes, and identifying codes that connect across different papers (Linneberg & Korsgaard, 2019). When any of the codes were adjusted, the codes were iteratively examined if they still met the adjusted code or necessitated a change in codes. Furthermore, if codes were refined specific search terms were applied to the selected literature to detect possible undiscovered drivers, solutions, and responsibilities if regarded necessary. Drivers and solutions that were not assigned a specific code, were coded as "unidentified". At the end of the coding process, the unidentified codes were examined, and frequently occurring drivers and solutions were provided with a new code. Thereafter, specific search terms related to the new code were applied to identify remaining drivers or solutions not included in the unidentified category. It was considered valuable to separate the responsibilities for drivers and solutions because the literature assigns responsibility to actors differently regarding past criticism of drivers and future engagements with solutions. To divide the responsibilities into responsibilities for drivers and solutions an extensive set of synonyms for each actor (Table 1) was produced. This set of synonyms were used as search terms to extract all the sentences of a particular actor from the selected literature. Hereafter, it was evaluated if the actor was assigned a responsibility for a driver or solution within a specific article.

Table 1 The eight distinct actors, categorized as decision-makers according to the IPBES report, were directly retrieved from the IPBES global assessment report (2019)

	Decision maker
1	Global and regional (inter)governmental organizations (UN, MEA secretariats etc.)
2	National, sub-national and local governments
3	Private sector
4	Civil society, including: • Citizens (households, consumers), community groups, farmers • NGOs (e.g., environmental, human development, consumer, trade unions)
5	Indigenous Peoples and Local Communities (IPLCs)
6	Donor agencies (public and private)
7	Science and educational organizations

Theoretical framework

The scientific representation of biodiversity loss within this study is situated within a post-structuralist ontology (Glynos & Howarth, 2007). This ontology asserts that reality is socially constructed, meaning that reality can't be directly observed and always depends on discourse (Arts et al., 2010). Scientific discourse is no exception: it is also socially constructed and thereby context-dependent. This supports a context-dependent exploration suited to the variable nature of biodiversity loss discourse also demonstrated by Gustafsson (2014) and Louder & Wyborn (2020).

Discourse analysis varies from studying specific language to exploring sociocultural meaning structures, where this study focuses on the latter (Leipold et al., 2019). The definition of this type of discourse is as follows "an ensemble of ideas, concepts, and categories through which meaning is given to social and physical phenomena, and which is produced and reproduced through an identifiable set of practices" (Hajer & Versteeg, 2005., p. 175). Following this definition, the phenomenon explored in this article is the dominant contemporary scientific discourse of biodiversity loss in a global context. As the critical practice of scientific discourse is the writing of articles, the scope is placed on the biodiversity loss literature. The investigation of the scientific biodiversity loss discourse is directed through identifying drivers, solutions, and responsibilities and their relationship to determine how scientific actors conceptualize drivers, solutions, and responsibilities. This is particularly interesting because scientific actors partly construct environmental problems such as biodiversity loss (Metzner, 1998; Taylor & Buttel, 2005).

Within the broader post-structuralist ontology of this study, the chosen analytical framework entails individual articles articulating biodiversity loss through narrative storylines (Hajer, 2006; Mammadova et al., 2020). This study adopts a storyline approach with the aim to identify the various ways in which scientific articles articulate the contingent reality of biodiversity loss. Key characteristics of a storyline are that it has a beginning, middle, and end, and contain cause-and-effect relationships, where various actors have distinct interpretations of the same story (Hajer, 2006; Louder & Wyborn, 2020). A storyline is a simplification of reality, consequently, does not necessarily align with reality, and serves as a means to navigate a complex contingent reality (Hajer, 2006; Louder & Wyborn, 2020; Mammadova et al., 2020).

Driver-solution-responsibility network

A social network analysis is performed on the coded drivers, solutions, and responsibilities to explore the relational interplay of drivers, solutions, and responsibilities within the scientific biodiversity loss discourse. A social network analysis is the analysis of a network containing social components, consisting of nodes and ties (Otte & Rousseau, 2002). In this analysis, a node is identified as a driver, solution or responsibility associated to either a driver or a solution, where the size of the node corresponds to the total occurrences within the selected literature. The ties correspond to the co-occurrence of drivers, solutions, and responsibilities within the same article. The ties are weighted as the strength of the relationship is the essential element of analysis (Kadushin, 2004). The weight of the tie corresponds to the total co-occurrences in the literature review. Drivers, solutions, and responsibilities with an occurrence of less than five were excluded to reduce the influence of less relevant nodes. The nodes, ties, and weights enabled the construction of a driver-solution-responsibility network (Figure 2) of the scientific discourse of biodiversity loss.

Community detection

Storylines of the scientific discourse of biodiversity loss were identified through detecting communities within the driver-solution-responsibility network. A community is a group of drivers, solutions, and/or responsibilities which are more densely connected with each other compared to connections outside the community (Smith et al., 2020). To identify communities the Louvain community detection algorithm is applied. The Louvain method is an iterative algorithm that optimizes network community detection. The algorithm moves nodes between communities to maximize modularity within two phases, resulting in a partition of the network into cohesive groups (Traag et al., 2019). Modularity is a measure that quantifies the density of links within communities relative to connections between communities, where a high modularity has dense connections within communities and sparse connections between communities (Bedi & Sharma, 2016). In the first phase of the Louvain algorithm, individual nodes are relocated to different communities until modularity stops increasing. In the second phase the formed communities of phase one are merged into one node. Hereafter, the newly formed nodes are relocated similarly as in phase one. These phases are repeated until no further gain in modularity is achieved (Traag et al., 2019). The Louvain algorithm is selected for several characteristics described by Smith et al. (2020). Firstly, the emphasis is on the detection of communities, instead of the flow of information or the identification of essential nodes. Secondly, it includes a resolution parameter, allowing for the adjustment of the number of communities, which is valuable for identifying the appropriate number of communities needed to reveal distinct storylines. Lastly, the algorithm is stochastic, meaning that communities vary slightly for different runs, which is valuable for identifying the predominance of drivers, solutions, and responsibilities across different communities.

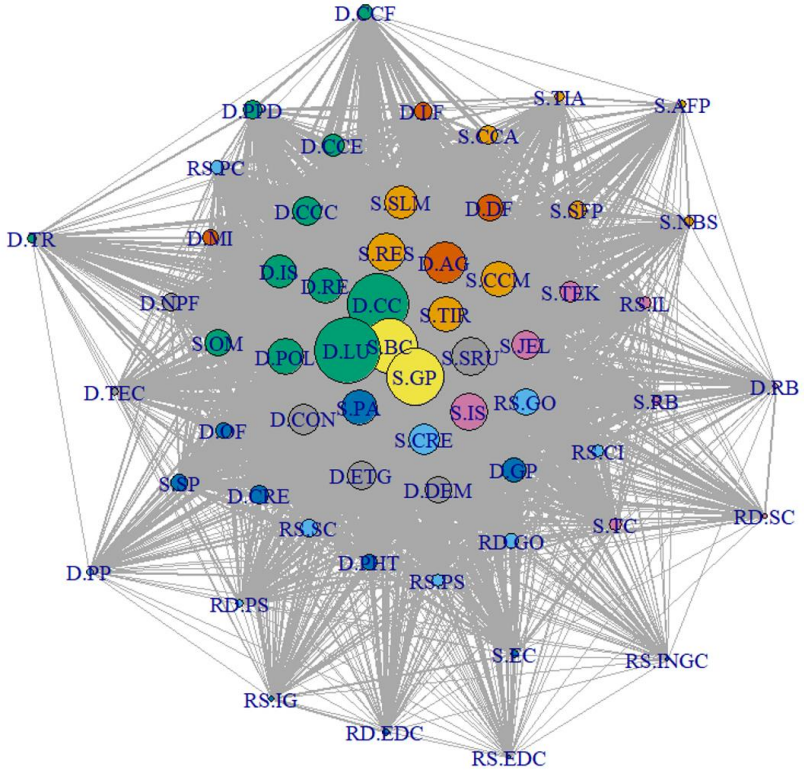

Figure 2 The driver-solution-responsibility network, where the nodes represent the drivers (D.XXX), solutions (S.XXX) and responsibilities associated with a driver (RD.XXX) or solution (RS.XXX). The colors represent the communities attained with the Louvain algorithm with a resolution parameter of 1.1.

Consensus clustering and storyline identification

The variability in community of the drivers, solutions, and responsibilities for different runs are examined by means of consensus clustering to identify clusters that represent storylines. In consensus clustering a matrix is constructed from the number of co-occurrences of nodes within a similar community over iterative runs of a particular stochastic algorithm, in this case the Louvain algorithm (Betzel, 2023). To carry out consensus clustering the driver-solution-responsibility network is run 10.000 times for every resolution. The examined resolutions were 1.0, 1.05, and 1.1, where a higher resolution gives more communities. The resolution parameter was set on different levels. To examine the different levels a consensus matrix was created by grouping drivers, solutions, and responsibilities that show a high level of co-occurrences. This resulted in a consensus matrices, enabling the identification of clusters. The resolutions of 1.0, 1.05, and 1.1, revealed three, five, or eight clusters. The resolution of 1.1 was considered most fitted for identifying storylines. This is because the formation of eight groups, each containing three to eleven drivers, solutions or responsibilities, best captured individual storylines of biodiversity loss within scientific discourse. This resolution prevents combining multiple storylines into a single cluster, unlike resolutions of 1.0 and 1.05 with lesser clusters. Furthermore, it does not contain many clusters with fewer than three drivers, solutions, or responsibilities, which are insufficient to form a complete storyline, unlike higher resolution parameters. The consensus matrix with a resolution of 1.1 is visually presented with a heatmap (Figure 3). Red represents a high frequency of co-occurrences, purple a medium frequency, and blue a low frequency.

Storylines are visually detected by means of the heatmap, where the presence of reddish squares indicates a specific storyline. To be included in a single storyline, all drivers, solutions, and responsibilities must exhibit a relatively high frequency of co-occurrences with each other within their cluster. Drivers, solutions, and responsibilities with a purple color are included in the storyline if they co-occur at least 4000 times with all the drivers, solutions, and responsibilities of the specific cluster. At this level the storylines can entail a rich diversity of drivers, solutions, and responsibilities, while being sufficiently clustered. The reddish square must include sufficient drivers, solutions, and responsibilities to form multiple arguments and create a cohesive storyline. The storylines can be validated in three ways. Firstly, the validation of storylines involves assessing the presence of clusters of drivers, solutions, and responsibilities within the consensus clustering, thereby affirming their emergence from the underlying relationships within the literature. Secondly, the storylines exhibit robustness across different resolution parameters of 1.0, 1.05, and 1.1 as most maintained their connection at different resolutions. Thirdly, the identified storylines demonstrate qualitative alignment derived from the observations of the reviewed literature.

Storyline formulation

To formulate a coherent storyline with a beginning, middle and end with cause-and-effect relationships, five to six articles containing the most drivers, solutions, and responsibilities of the storyline were selected (Hajer, 2006; Louder & Wyborn, 2020). If articles of the particular storyline contained an equal number of drivers, solutions, and responsibilities, the study with the highest proportion relative to the total number of drivers, solutions, and responsibilities was selected. The storylines were firstly more broadly structured by arranging the drivers, followed by the responsibilities associated with the drivers, thereafter the solutions, followed by the responsibilities associated with the solutions. This structure is selected as the construction of the problem often guides the solutions that ought to be taken (Hajer, 2006; Sharp & Richardson, 2001). The specific arrangement was determined by reviewing the sections of the articles containing the coded drivers, solutions, and responsibilities. The reviewing of the codes enabled the identification of successive associations, thereby facilitating

the specific arrangement of drivers, solutions, and responsibilities within the storylines. Hereafter, the character of the storyline was identified. The character was used for the introductory paragraph of the storyline. The rest of the storyline was formulated with the specific order of the drivers, solutions, and responsibilities, the reviewed sections and the identified associations. Lastly, a concluding sentence was formulated to capture the entire storyline.

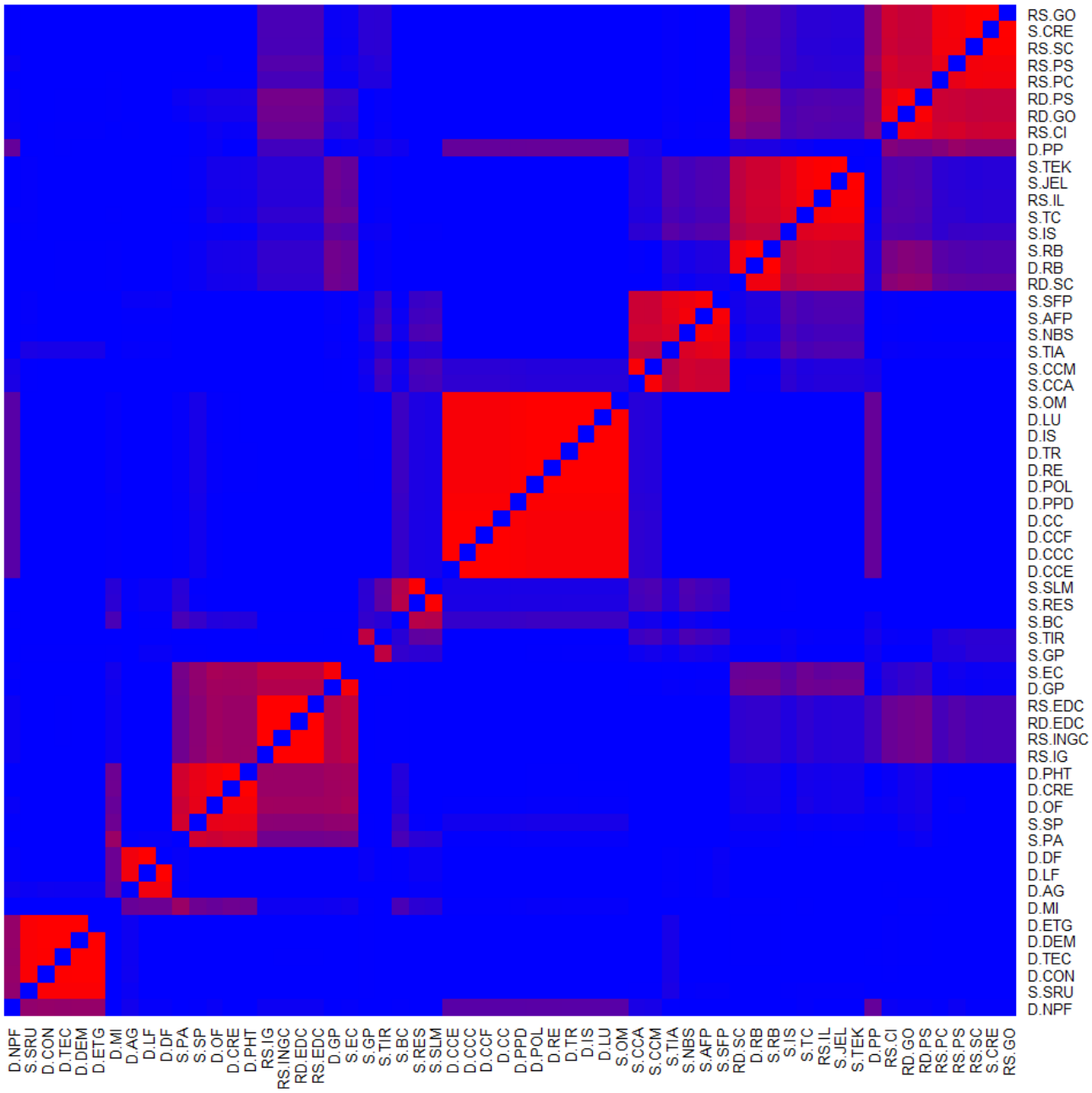

Figure 3 A heatmap of the consensus matrix of co-occurrences of drivers, solutions, and responsibilities associated to drivers or solutions of 10.000 runs of the Louvain algorithm with a resolution of 1.1. Red indicates a high level of co-occurrences, purple a medium level, and blue a low level.

Results

Through means of the driver-solution-responsibility network and the consensus matrix seven storylines were identified. These storylines are as follows:

1. *Ecological Footprint*
2. *Global Deforestation*
3. *Direct Drivers*
4. *Eco-smart*
5. *Environmental Justice*
6. *Global Governance and Marine Exploitation*
7. *Global Shared Responsibility*

Underneath are the seven distinct storylines individually described:

Ecological Footprint

Table 2 Drivers and solutions of *Ecological Footprint* (Figure 3)

D.TEC	Technology
D.DEM	Demographics
D.ETG	Economy, Trade & Globalization
D.CON	Consumption
S.SRU	Sustainable Resource Use
D.NPF	Nitrogen, Phosphorous and fertilizer

Ecological fooptrint represented by Albert et al. (2021), Dulvy et al, (2021), Montalván-Burbano et al. (2021), Rehman et al. (2021), Song et al. (2021), and Wu (2021), predominantly focuses on drivers, portraying humans as the agents exerting pressures on the environment, resulting in environmental degradation and biodiversity loss. These pressures are increasing and penetrating the carrying capacity of the earth. The fundamental causes of the deterioration of biodiversity are grounded in the socioeconomic fabric of human society.

The drivers of biodiversity loss within the socioeconomic fabric are presented in four dimensions: demographics; consumption; economy, globalization and trade; and technology (Albert et al., 2021; Dulvy et al., 2021; Montalván-Burbano et al., 2021; Rehman et al., 2021; Song et al., 2021; Wu, 2021). Demographics are mostly displayed as rapid population growth that necessitates more food production (Albert et al., 2021; Song et al., 2021). These population pressures are identified as an indirect driver of biodiversity loss (Wu, 2021), and, for example, associated with extinction risks in the ocean (Dulvy et al., 2021) or land-use patterns in the Amazon (Montalván-Burbano et al., 2021). Consumption represented as a driver of biodiversity loss expresses the idea that humans use too much in general or of a particular resource. The footprint metaphor is frequently used in this storyline, symbolizing various consumption patterns, such as a country's footprint (Rehman et al., 2021), the freshwater footprint (Albert et al., 2021) or the energy footprint (Montalván-Burbano et al., 2021). These large footprints and growing consumption patterns require the growth of the economy, trade, and globalization and are portrayed as "chilling global economic expansion yields" (Albert et al., 2021, p. 1). Similarly, trade and globalization are applied as parameters for countries' footprint (Rehman et al., 2021) or refer to the relationship between international markets and deforestation (Montalván-Burbano et al., 2021). Meanwhile, technology is indirectly driving biodiversity loss by fueling and accelerating the industrialization of the economy (Rehman et

al., 2021). The industrializing economy opened up the possibility for extractive activities such as the intensification of industrial fishing (Dulvy et al., 2021) or the increased utilization of machinery, fertilizers, and agrochemicals during the intensification of agriculture (Song et al., 2021). One consequential biodiversity loss driver of this phenomenon is the increase in nutrient load, due to increased fertilizer use (Albert et al., 2021; Song et al., 2021).

The presented solution of *Ecological Footprint* to decrease human impact is the sustainable use of resources (Albert et al., 2021; Dulvy et al., 2021; Montalván-Burbano et al., 2021; Rehman et al., 2021; Song et al., 2021; Wu, 2021). This solution prescribes that resources should be used with minimal biodiversity loss effects, such as the sustainable use of biodiversity (Wu, 2021) or targeting zero-deforestation in supply chains (Song et al., 2021). The execution of this solution is in the form of management of natural resources (Albert et al., 2021; Montalván-Burbano et al., 2021), limits on resources use (Dulvy et al., 2021) or investments in sustainable resource practices and sustainable growth (Rehman et al., 2021). This storyline identifies the socioeconomic fabric of society as the underlying driver of biodiversity loss, with minimal focus on solutions and none to responsibilities.

Global Deforestation

Table 3 Drivers of *Global Deforestation* (Figure 3)

D.DF	Deforestation
D.AG	Agriculture
D.LF	Logging & Forestry
D.MI	Mining

Global Deforestation encompasses solely drivers and presents deforestation as a critical threat to biodiversity, especially tropical deforestation. It is represented by Di Sacco et al. (2021), Hoang & Kanemoto (2021), Kyere-Boateng & Marek (2021), Meyfroidt et al. (2022), and Montalván-Burbano et al. (2021). Deforestation is described as interconnected across the globe, intertwined with other threats, and influenced by socioecological factors, which indicates the interconnectedness of social and ecological systems. Direct human activities are presented as the main drivers of deforestation, fueled by commodity demand.

Deforestation is described by Meyfroidt et al. (2022) as a process of regime shifts, where international socioecological fluctuations can rapidly alter deforestation trends. These processes translate to various human activities, where agricultural expansion is the most common human activity that drives deforestation (Kyere-Boateng & Marek, 2021; Montalván-Burbano et al., 2021). The underlying cause of this expansion is explained through the international demand of agricultural commodities (Hoang & Kanemoto, 2021). Moreover, agricultural intensification, while theoretically sparing land, can induce deforestation due to rebound effects entangled within commodity chains (Meyfroidt et al., 2022). Mining is another direct human activity linked to deforestation by way of resource extraction for the provisioning of commodities and often involves illegal practices (Hoang & Kanemoto, 2021; Kyere-Boateng & Marek, 2021; Montalván-Burbano et al., 2021). Lastly, logging and forestry are frequently portrayed as drivers of deforestation, especially illegal logging (Kyere-Boateng & Marek, 2021; Montalván-Burbano et al., 2021).

Added together, human activities inducing land-use are described as the biggest driver of deforestation (Montalván-Burbano et al., 2021). The dynamics of deforestation are explained in different ways, for example, through socioecological dynamics within a national context (Kyere-Boateng & Marek, 2021), as interconnected with global challenges like climate change and poverty (Di Sacco et al., 2021) or as internationally telecoupled footprints of nations

(Hoang & Kanemoto, 2021). In conclusion, this storyline emphasizes direct human activities located within a complex global socioecological context as drivers for deforestation without presenting solutions or responsibilities.

Direct Drivers

Table 4 Drivers and solutions of *Direct Drivers* (Figure 3)

D.CCE	Climate Change - Extreme events
D.CCC	Climate Change – Continuous Climate Change
D.CC	Climate Change
D.CCF	Climate Change - Fire
D.PPD	Pathogens, Pests, & Diseases
S.OM	Other Management
D.IS	Invasive Species
D.LU	Land-Use
D.TR	Tourism & Recreation
D.RE	Resource Extraction
D.POL	Pollution

The direct drivers of biodiversity loss are the central theme of *Direct Drivers*. This storyline consists predominantly of drivers. It is represented by Bergstrom et al. (2021), Heino et al. (2021), Kyere-Boateng & Marek (2021), Macinnis-Ng et al. (2021), and Ricciardi et al. (2021). The identified storyline demonstrates the institutionalization of the direct drivers of biodiversity loss in scientific discourse. This storyline is the most dominant in conservation articles as conservation articles categorize the threats to biodiversity by means of the direct drivers.

The direct drivers are often presented together to give an overview of the biodiversity threats in a particular context (Bergstrom et al., 2021; Heino et al., 2021; Kyere-Boateng & Marek, 2021; Ricciardi et al., 2021). As such Bergstrom et al. (2021) and Heino et al. (2021) displayed both six of the drivers of this storyline in one sentence such as climate change, wildfire, pollution, resource extraction, invasive species, and habitat loss in the global context of lakes and ecosystem collapse. In addition, the drivers are presented to threaten biodiversity synergistically (Macinnis-Ng et al., 2021; Ricciardi et al., 2021). For example, climate change exacerbates other drivers (Macinnis-Ng et al., 2021), and invasive species are enhanced by a myriad of direct drivers and trade patterns (Ricciardi et al., 2021). Furthermore, both pests, pathogens and diseases, as well as tourism and recreation are often identified as synergizing with invasive species, possibly due to their shared invasive character (Heino et al., 2021; Kyere-Boateng & Marek, 2021; Macinnis-Ng et al., 2021; Ricciardi et al., 2021).

The only solution present in this storyline is management. This solution is phrased to be applied adaptively and with consideration, articulated in terms such as strategic, adaptive or appropriate management (Bergstrom et al., 2021; Heino et al., 2021; Macinnis-Ng et al., 2021). This solution might follow to strategically mitigate the complex mix of direct drivers, but is also regularly coupled as the solution for invasive species alone (Macinnis-Ng et al., 2021; Ricciardi et al., 2021). To conclude, this storyline reveals that direct drivers have institutionalized as a framework for identifying biodiversity loss threats, particularly within conservation articles, but *Direct Drivers* has limited emphasis on potential solutions and none to responsibilities (Bergstrom et al., 2021; Heino et al., 2021; Macinnis-Ng et al., 2021; Ricciardi et al., 2021).

Eco-smart

Table 5 Solutions of *Eco-smart* (Figure 3)

S.CCM	Climate Change Mitigation
S.CCA	Climate Change Adaptation
S.NBS	Nature-Based Solutions
S.SFP	Sustainable Farming Practices
S.AFP	Alternative Farming Practices
S.TIA	Agricultural Technological Innovation

Eco-smart highlights the utility of working with nature to attain societal goals and consists solely of solutions. It is represented by Di Sacco et al. (2021), Duarte et al. (2022), Langemeyer et al. (2021), Muluneh (2021), and Selaledi et al. (2021). There is a tendency to seek innovative strategies for nature-based solutions that fulfill both societal and environmental goals. These solutions are prominently featured in the combination of climate and agricultural solutions, where various agricultural practices are formulated as a tool for global sustainability (Duarte et al., 2022; Langemeyer et al., 2021; Selaledi et al., 2021).

A nature-based solution is explicitly linked to alternative and innovative agricultural practices, such as see-weed farming (Duarte et al., 2022), urban agriculture (Langemeyer et al., 2021) or insect production (Selaledi et al., 2021). These nature-based solutions leverage ecosystem services to address both societal and environmental purposes, and are frequently proposed optimistically to mitigate a range of issues (Duarte et al., 2022; Langemeyer et al., 2021). Additionally, it is desired that these more innovative solutions are merged with traditional ecological knowledge (Duarte et al., 2022; Muluneh, 2021; Selaledi et al., 2021).

Climate mitigation and adaptation play a dominant role in this storyline and are often linked to nature-based solutions situated in an innovative alternative agricultural context (Di Sacco et al., 2021; Duarte et al., 2022; Langemeyer et al., 2021; Muluneh, 2021; Selaledi et al., 2021). Climate mitigation measures like reforestation and land restoration, along with climate adaptation solutions, such as climate resilient irrigation or crops, can be characterized as aligning with the forces of nature (Di Sacco et al., 2021; Duarte et al., 2022; Langemeyer et al., 2021; Muluneh, 2021; Selaledi et al., 2021). To conclude, this storyline emphasizes the benefit of aligning societal goals with the forces of nature to find smart climate and agricultural solutions with no emphasis on any drivers or responsibilities.

Environmental Justice

Table 6 Drivers, solutions, and responsibilities of *Environmental Justice* (Figure 3)

S.RB	Rights & Benefits - Solution
D.RB	Rights & Benefits - Driver
RD.SC	Scientists & Academia - Responsibility Driver
S.TEK	Traditional Ecological Knowledge
S.JEL	Justice, Equity & Livelihoods
RS.IL	Indigenous & Local Communities - Responsibility Solution
S.TC	Transformative Change
S.IS	Intersectionality: Integrating Socioeconomic, Biodiversity, Climate Change, and/or Health Solutions

Environmental Justice contains mainly solutions, two responsibilities and one driver. It is situated around the theme of environmental justice. It is represented by Brondízio et al. (2021), Di Sacco et al. (2021), Ellis et al. (2021), Meyfroidt et al. (2022), and Pascual et al. (2022). It tries to tackle the injustices related to rights, benefits and burdens in the biodiversity loss context, principally related to indigenous and local communities. The proposed solutions necessitate the alignment of biodiversity goals with environmental justice.

Environmental justice underscores the deficiency of rights for particularly local and indigenous communities. This includes critique about the removal of indigenous people (Ellis et al., 2021) or instances where conservation actors gave legitimacy to corrupt states which violated local communities (Pascual et al., 2021). Therefore, the storyline urges that biodiversity loss should be situated within social dimensions of rights, equity, and livelihoods, where conservation is equitable and open to multiple perspectives (Brondízio et al., 2021; Di Sacco et al., 2021; Ellis et al., 2021; Meyfroidt et al., 2022; Pascual et al., 2021).

Of critical importance is the acknowledgement of indigenous stewardship and traditional ecological knowledge (TEK) (Brondízio et al., 2021; Di Sacco et al., 2021; Ellis et al., 2021; Pascual et al., 2021). Natural scientists have especially aided in the overshadowing of traditional ecological knowledge. Meaningful collaboration are halted by the lack of investment from scientists or by a failure to account for the diverse expressions of values and justice (Brondízio et al., 2021; Ellis et al., 2021; Meyfroidt et al., 2022; Pascual et al., 2021). This is portrayed as inappropriate as TEK is characterized as critical for biodiversity (Ellis et al., 2021) and is recognized as local situated knowledge (Pascual et al., 2021). Moreover, this knowledge can be combined with scientific knowledge to reach greater understanding (Pascual et al., 2021). Therefore, Indigenous and local communities should be given responsibility to sustain and restore nature (Brondízio et al., 2021; Di Sacco et al., 2021; Ellis et al., 2021; Pascual et al., 2021).

The solutions within the storyline of *Environmental Justice* combine various purposes such as food security, poverty alleviation, and biodiversity conservation (Meyfroidt et al., 2022) to achieve "effective and socially just conservation outcomes" (Pascual et al., 2021, p. 1). Fundamentally, the problems arise from both a flawed conservation movement and an unjust neoliberal economic system. Therefore, these structures should be cracked open through transformative change (Brondízio et al., 2021; Meyfroidt et al., 2022; Pascual et al., 2021). This transformative change is articulated by Brondízio et al. (2021) as a call for "deep transformations in our relationships to nature" (p. 498). Moreover, Meyfroidt et al. (2022) highlight that apart from developing new transformative pathways, one must also focus on "weakening the forces that resist change" (p. 6). In conclusion, this storyline presents a mix of solutions, drivers, and responsibilities, embodying the call for environmental justice for Indigenous and local communities and against unjust societal and conservation structures.

Global Governance and Marine Exploitation

Table 7 Drivers, solutions, and responsibilities of *Global Governance and Marine Exploitation* (Figure 3)

S.EC	Economic Change
D.GP	Government Policy Failure
RS.IG	Intergovernmental Organizations - Responsibility Solution
RD.EDC	Developed Countries - Responsibility Driver
RS.EDC	Developed Countries - Responsibility Solution
RS.INGC	Developing Countries - Responsibility Solution
D.PHT	Poaching, Hunting & Wildlife Trade
D.CRE	Capacity, Resources & Enforcement - Driver

D.OF	Overfishing
S.SP	Species Protection
S.PA	Protected Areas

Global Governance and Marine Exploitation consists of a mix of drivers, solutions, and responsibilities, and presents government failure as a key driver of biodiversity loss. It is represented by Bax et al. (2022), Brondízio et al. (2021), Cochrane (2021), Harris et al. (2022), and Xu et al. (2021). The storyline is situated in a global governance context, emphasizing the roles of both developing and developed countries. Marine exploitation is a dominant theme in this storyline and is often linked to government failure (Cochrane, 2021; Harris et al., 2022; Xu et al., 2021). In addition to marine exploitation, this storyline addresses other topics within the context of global governance such as missing biodiversity targets (Xu et al., 2021) or the disregard of Indigenous knowledge (Brondízio et al., 2021).

Exploitative industries, involved in overfishing, are presented as expanding and encroaching (Bax et al., 2022; Brondízio et al., 2021). These marine exploitative industries are grounded in poor objectives desiring short-term economic gain above long-term sustainability exacerbated by the prevalence of illegality in unregulated fisheries (Xu et al., 2021) and the trade of CITES-listed species (Cochrane, 2021). Governments are seen as the main driver behind the unsustainable fishing, poaching, hunting, and wildlife trade due to shortcomings in their institutions (Cochrane, 2021), capabilities, legislation (Harris et al., 2022), and law enforcement (Bax et al., 2022), alongside inadequate targets and investments (Xu et al., 2021). Especially, developed countries are identified as responsible as these countries consume too much for global equity (Bax et al., 2022), transfers their problems to developing countries (Cochrane, 2021), and insufficiently invests in conservation (Xu et al., 2021).

The solutions within this narrative are closely tied to governmental authority and encompass spatial, legal, and economic interventions, such as establishing protected areas, species protection, and promoting a sustainable blue economy (Bax et al., 2022; Brondízio et al., 2021; Cochrane, 2021; Harris et al., 2022; Xu et al., 2021). The protected areas should ensure social justice, address social well-being (Bax et al., 2022), and involve local communities (Brondízio et al., 2021). The blue economy, on the other side, should aspire to balance local economic growth with ocean sustainability (Bax et al., 2022; Brondízio et al., 2021; Cochrane, 2021; Harris et al., 2022).

Both developing and developed countries within global governance share responsibility for the solution, although with different roles (Bax et al., 2022; Cochrane, 2021; Harris et al., 2022). Developing countries ought to place action on the shortcomings of their fisheries (Cochrane, 2021), where developed countries should redistribute wealth and offer financial and technical assistance to developing countries (Bax et al., 2022; Xu et al., 2021). Intergovernmental organizations hold the responsibility to connect governments of developing and developed countries through intergovernmental bodies (Bax et al., 2022; Harris et al., 2022). This storyline presents a mix of drivers, solutions, and responsibilities and underlines the role of government failure and the responsibilities of global governance in the context of international biodiversity loss and marine exploitation.

Global Shared Responsibility

Table 8 Drivers, solutions, and responsibilities of *Global Shared Responsibility* (Figure 3)

RD.PS	Private Sector - Responsibility Driver
RD.GO	Government - Responsibility Driver
D.PP	Plastic Pollution

RS.CI	Citizen - Responsibility Solution
RS.GO	Government - Responsibility Solution
S.CRE	Capacity, Resources & Enforcement - Solution
RS.PS	Private Sector - Responsibility Solution
RS.SC	Scientists & Academia - Responsibility Solution
RS.PC	Private sector - Responsibility Solution

Global Shared Responsibility consists mostly of responsibilities and conveys a spirit of shared responsibility addressing a wide range of complex global environmental issues, such global pollution (Fuller et al., 2022), invasive species (Ricciardi et al., 2021), unsustainable fisheries (Cochrane, 2021), pluralistic biodiversity perspectives (Pascual et al., 2021), and infectious diseases (Ellwanger et al., 2021). It is represented by Cochrane (2021), Ellwanger et al. (2021), Fuller et al. (2022), Pascual et al. (2021), and Ricciardi et al. (2021). Although acknowledging a collective duty, this storyline emphasizes the accountability of both the private sector and governments, with the latter expected to take a central role in the solution.

Governments are often depicted as neglecting important global issues, such as foreign infectious diseases (Ellwanger et al., 2021) and pollution problems (Fuller et al., 2022). Additionally, the government is identified as corrupt (Cochrane, 2021) and holding narrow conservation viewpoints that do not conflict with economic growth (Pascual et al., 2021). Similarly, the private sector is seen as indifferent to health and biodiversity issues (Cochrane, 2021; Ellwanger et al., 2021; Fuller et al., 2022; Pascual et al., 2021; Ricciardi et al., 2021). Fisheries drive ecosystem damage (Cochrane, 2021), pharmaceutical companies ignore unprofitable diseases (Fuller et al., 2022), corporations outsource pollution (Fuller et al., 2022), exploit corrupt institutions (Pascual et al., 2021), and introduce invasive species (Ricciardi et al., 2021). This storyline also encompasses the societally induced issue of plastic pollution (Cochrane, 2021; Ellwanger et al., 2021).

Governments are identified as the key responsible actor in these complex global domains such as pollution (Fuller et al., 2022), biosecurity (Ricciardi et al., 2021) or sustainable development goals (SDGs) (Cochrane, 2021). Proposed governmental actions to mitigate these negative effects include enhancing capacities, investments, and enforcements. For example, enhancing capacities of unsustainable fisheries (Cochrane, 2021), increasing investment into an One Health perspective or payments for ecosystem services (Ellwanger et al., 2021; Fuller et al., 2022; Pascual et al., 2021), and strengthening enforcement to manage biological invasions (Ricciardi et al., 2021) are proposed as mitigations.

Although governments hold the largest responsibility in this storyline, a necessity of shared responsibility and cooperation is urged, as these complex societally immersed global issues require the collaboration of a wide range of actors. The storyline includes the involvement of citizens, scientists, practitioners, and the private sector and highlights the importance of creating new alliances and collaborations (Cochrane, 2021; Ellwanger et al., 2021; Fuller et al., 2022; Pascual et al., 2021; Ricciardi et al., 2021). To conclude, this storyline emphasizes the requirement for collaborative action for complex global issues, while placing governments as the central actor in the solution.

Discussion

This study identified seven distinct storylines overarching the biodiversity loss literature, facilitating an examination into possible blind spots of these storylines. When examining the results, it is notable that storylines either entail dominantly drivers, or solutions, or responsibilities. In other words, a mixture of drivers, solutions, and responsibilities within one storyline appears to be uncommon. *Ecological Footprint*, *Global Deforestation*, and *Direct Drivers* mostly contain drivers. *Eco-smart* solely consists of solutions. *Global Shared Responsibility* encompasses predominantly responsibilities. In contrast to *Environmental Justice* and *Global Governance and Marine Exploitation*, which demonstrate a combination of drivers, solutions, and responsibilities. Moreover, the solutions of biodiversity conservation and government policy are shared across all storylines, while other solutions are more exclusive to individual storylines. These encompass nature-based innovation within agricultural and climate contexts for *Eco-smart;* social justice and system transformations for *Environmental Justice;* global governance for *Global Governance and Marine Exploitation*; and integrated action across stakeholders for *Global Shared Responsibility*.

The differences within biodiversity discourse

Significant differences within problems, solutions and responsibilities are continuously present in the biodiversity literature. Storylines identify different key problems of biodiversity loss. These encompass socioeconomic factors for *Ecological Footprint*; deforestation and human activities for *Global Deforestation*; direct drivers of biodiversity loss for *Direct Drivers*; environmental injustice for *Environmental Justice*; government failure and marine exploitation for *Global Governance and Marine Exploitation*; and public and private failure for *Global Shared Responsibility*. Variability of the central problem within the storylines will lead to different conceptualizations of the solutions and responsibilities (Hajer & Versteeg, 2005). E*nvironmental Justice,* for instance, gravitates to addressing social inequalities, injustices, and capitalistic economy and advocates environmental justice through stewardship of indigenous and local communities (Brondízio et al., 2021). While *Global Governance and Marine Exploitation* addresses marine exploitation and weak global governance and encourage government regulation and sustainable development (Tafon, 2018). These significant differences are potentially invisible under the uniform banner of biodiversity loss. This can hide the discursive struggle of which scientific biodiversity articulations reach the biodiversity science-policy interface, and eventually guide the policy-making process (Sharp & Richardson, 2001). With this insight Sharp & Richardson argue that in addition to questioning whether certain problems, solutions, or responsibilities are valid, it's important to consider why validity is assigned to these specific issues and not to others.

One dominant problem framing in biodiversity loss is the interconnectedness of climate change and biodiversity loss. For example, Arts et al. (2010) specifically identify climate change as a distinct forest discourse, the World Wide Fund (WWF) presents climate change and biodiversity loss as “the global double emergency” (WWF, 2022, p. 12.), and climate change is the most prevalent driver in the biodiversity literature (Mazor et al., 2018). However, the current impact of climate change on biodiversity is substantially smaller relative to resource extraction and land/sea-use, although expected to increase (Jaureguiberry et al., 2022). The danger of the large emphasis on climate change is that it may reduce the focus on drivers more damaging to biodiversity (Caro et al., 2022). This can create a bias that mitigating climate change is effectively mitigating biodiversity loss, while biodiversity loss mostly consists of other drivers.

Divergence in marine and terrestrial discourse

The global biodiversity literature relates differently to the marine and terrestrial realm. While the terrestrial realm is spread across the different storylines, the marine realm is clustered within *Global Governance and Marine Exploitation*. This entails that marine biodiversity topics are discussed in a similar fashion with spatial management, global governance, and sustainable development as central pillars (Bax et al., 2022; Cochrane, 2021; Germond-Duret, 2022; Harris et al., 2022). The scientific marine biodiversity narrative could become more integrated by incorporating other storylines. For example, incorporating perspectives from *Ecological Footprint* could expand the focus beyond managerial sustainability to include underlying socioeconomic factors such as fish consumption.

Blind spots and diversity in social dimensions storylines

Storylines relate differently to the social dimensions of biodiversity loss, as various storylines often neglect social aspects of biodiversity loss. *Ecological Footprint*, for instance, identifies the entirety of humanity as the driver of biodiversity loss, thereby neglecting social discrepancies across actors and nations. Similarly, Mace (2014) uses the term "people" in her temporal narratives of biodiversity conservation. The universality of the framing of "humanity" or "people" gives little recognition to the considerable differences in cause, impact, and power inequities (Malhi, 2017). The absence of acknowledgement regarding power inequities is evident within *Ecological Footprint*. Paradoxically, it maintains the status quo, as it doesn't propose solutions to its own identified issues of the socioeconomic system, related to consumption, demographics and the economy. Instead, *Ecological Footprint* identifies sustainable resource use as a solution, which holds a contradiction, as sustainable resource use requires technology, while technology is also identified as a driver.

In contrast to the other storylines, *Eco-smart* and its nature-based solutions doesn't identify any drivers. This creates ambiguity and opportunities for actors to pursue their own agenda. In this manner, nature-based solutions are critiqued as a "dangerous distraction" (Melanidis & Hagerman, 2022, p. 1.) serving the status quo, and the current neoliberal political climate, while not addressing the fundamental drivers (Kotsila et al., 2021). *Global Governance and Marine Exploitation* face similar critique by Germond-Duret (2022) and Tafon (2018). They argue that under the banner of sustainability and development, managerial global governance is pursued for expanding marine resource extraction, and "blue-grabbing" of territories for economic or conservation pursuits, while ignoring local populations. Both these storylines and their critique exemplify the tension between incorporating economic powers into biodiversity efforts and criticizing the fundamental destructive nature of the neoliberal economy (Louder & Wyborn, 2020). The storylines are situated within a discourse of sustainable development, which omit discussions on resource conflict and limits to growth (Dryzek, 2022). Although, Bax et al. (2022) who represent *Global Governance and Marine Exploitation* did articulate the necessity for reduced consumption. Yet, their lack of critique to the current socioeconomic system might facilitate broad collaboration among governments, the private sector, and citizens, which provides practical opportunities to mitigate biodiversity loss. More radical or system change solutions might mitigate biodiversity loss more fundamentally, however, are not often adopted by policy in the science-policy interface, as these solutions are often conflicting with current political agendas.

Global Deforestation can overlook biodiversity beyond (tropical) forests and discount broader socioeconomic systems. Although the storyline has broadened since the emergence of the deforestation discourse including national footprints, and socioecological dynamics, the various stages of the deforestation supply chain are underexposed (Arts et al., 2010; Mammadova et al., 2022). Mammadova et al. (2022) highlight this bias on human activities in the supply chain production areas, instead of attributing deforestation responsibility across

the whole spectrum of the supply chain. In this way *Global Deforestation* identifies human activities such as agriculture, logging, and mining which are related to the production sector, instead of the manufacturing, service, and control sector (Mammadova et al., 2022).

Contrastingly to the storylines neglecting social dimensions of biodiversity loss, the large emphasis of *Environmental Justice* on the social dimensions might neglect the physical dimensions of biodiversity loss. This focus on the social dimension can create a bias that solving environmental injustices and enabling Indigenous and local stewardship is a substitute for mitigating biodiversity loss. However, such a perspective risks overlooking the biophysical subtleties of biodiversity loss.

Policy-science gap: direct drivers

The presence of the *Direct Drivers* storyline indicate the influence of IPBES (2019) and the Millennium Ecosystem Assessment (2005) in categorizing drivers within scientific discourse, especially the "big five": land/sea-use, pollution, climate change, resource extraction, and invasive species. The direct drivers of biodiversity loss are considered to encompass all of biodiversity science, which makes these drivers appear as natural, thereby limiting debate (Louder & Wyborn, 2020). However, the results of this study show that the direct drivers are clustered within the literature, presenting a singular perspective that does not represent all the biodiversity literature. Interestingly, because direct drivers play prominent role in the international biodiversity science-policy interface (SPI), as the IPBES has an authoritative voice as the prominent boundary organization between policy and science (Wiegleb & Bruns, 2023). While IPBES (2019) offers comprehensive explanations of the drivers and its deeper socioeconomic roots, direct drivers probably retain a central role within the biodiversity SPI. This centrality contrasts with global biodiversity literature, where the direct drivers are strongly clustered in one storyline and play a less central role. Consequently, the emphasis placed by IPBES on the direct drivers, introduces a bias within the biodiversity SPI towards a direct drivers narrative relative to its occurrence within the biodiversity literature.

The adoption of the *Direct Drivers* storyline, potentially has sociopolitical implications. Pascual et al. (2021) criticize this categorization for oversimplifying and appearing apolitical, thus neglecting the complex sociopolitical context underneath. This categorization obscures these underlying contexts and emphasizes the effects on biodiversity instead of the source of these effects. For example, biodiversity loss can be attributed to the direct driver of pollution, yet this single indicator is a consequence of a complex mixture of anthropogenic sources and systems. The little reference of this categorization to the underlying human activities, socioeconomic system, and responsibilities gives stage for ambiguity. This ambiguity tends toward solutions that do not delve into the complex anthropogenic roots of biodiversity loss but into protecting biodiversity against the direct drivers. Protected areas and management are the main solution of this tendency because these solutions try to shield biodiversity against the drivers, instead of mitigating the complex anthropogenic roots of biodiversity loss drivers. In this way, *Direct Drivers* is situated within a narrative of protection against the current socioeconomic system, such as the "half earth" for nature narrative, rather than advocating for a change in the existing system (Durán et al., 2023). Concerningly, direct drivers are sometimes, especially within a conservation context, presented with limited linkage to other drivers (Fonseca et al., 2021; Jaureguiberry et al., 2022; Mazor et al., 2018). The detachment of direct drivers from the underlying socioeconomic explanations of biodiversity loss can overshadow more complex explanation of biodiversity loss, and obscure necessary messages for policy and science (Turnhout & Purvis, 2020).

Methodological reflections and considerations

Several reflections on the methods can be made. The storylines are rigidly separated in this

study, although in reality "overlap, come into conflict and harmonize in complex ways" (Louder & Wyborn, 2020, p. 256). This is also evident within the results of this study as many articles are present in multiple storylines (c.f. Brondízio et al., 2021; Cochrane, 2021; Di Sacco et al., 2021; Kyere-Boateng & Marek, 2021; Meyfroidt et al., 2022; Montalván-Burbano et al., 2021; Pascual et al., 2021; Ricciardi et al., 2021). Although the drivers, solutions, and responsibilities are clustered within the literature, individual articles adopt elements of multiple storylines as they present a range of drivers, solutions, and responsibilities. For example, Pascual et al. (2021) address issues of justice within conservation in accordance with *Environmental Justice* but they also call for collective action consistent with *Global Shared Responsibility*. Moreover, Meyfroidt et al. (2022) discuss elements of deforestation in line with *Global Deforestation*, while arguing the social complexities of land use sustainability compliant with *Environmental Justice*.

Selecting articles for the storyline formulation with the most drivers, solutions, and responsibilities of the storyline leads to the tendency of excluding articles with relatively less broad topics from the formulation of storylines. Additionally, the employed framework of drivers, solutions, and responsibilities gives other discursive elements such as rhetoric, visual representations or metaphors, less consideration, as these are not coded. This can erase discursive elements relevant for identifying and enriching the storylines. However, this framework makes it easy to identify blind spots and ambiguities as one can examine which drivers, solutions, and responsibilities are omitted, thereby providing a "helpful heuristic for reflection" (Louder & Wyborn, 2020, p. 3). Lastly, the aim was to ensure a balanced representation of global scientific discourse, but this was only partially achieved. Many papers included authors from multiple continents, with Latin American and African first authors often collaborating with Western co-authors. This collaboration likely skewed the continental discourse towards a more Western perspective. This bias was also exacerbated by solely incorporating articles in English. The selection of solely the highest cited articles per continent further decreased the participation of more marginalized storylines, as they were possibly left unidentified.

Conclusion

The combination of a systematic literature review and a discursive network analysis facilitated a global overview of the contemporary biodiversity loss literature and the identification of seven distinct storylines. Several blind spots have been identified, such as the lack of integration of drivers, solutions, and responsibilities or the neglect of social dimensions within several storylines. In addition, the presence of the *Direct Drivers* storyline indicates that direct drivers are less widespread within the biodiversity loss literature, contrary to the international biodiversity science-policy interface (SPI) (IPBES, 2019). The translation of biodiversity scientific discourse into policy depends on what storylines, with what drivers, solutions, and responsibilities are articulated within the biodiversity SPI, and which are not. Which storylines, and to what degree, participate in the SPI influences how the storylines are translated into policy. This global overview of biodiversity loss literature provides a useful tool to identify which storylines of the scientific discourse are participating within the biodiversity SPI and participation has been identified as one of the key issues within the biodiversity SPI. Evaluating participation based on storylines offers a new approach, as participation is commonly evaluated on disciplines, stakeholders, or geographic ranges (Stokland et al., 2022; Vadrot et al., 2016; Wiegleb & Bruns, 2023).

This study has several implications for scientists and policymakers. Scientists will remain dependent on personal judgements and are vulnerable to their personal frames, decreasing the legitimacy of the knowledge the biodiversity scientists are providing (Wiegleb & Bruns, 2023).

This decreases the legitimacy of the knowledge the biodiversity scientists are providing. However, the scientific legitimacy can be enhanced if biodiversity scientists have an opportunity to increase their awareness of the particular problems, solutions, responsibilities and narratives they are articulating and those they are not. This reflection can provide insight into their own subjectivity and facilitate the formation of a richer and more objective frame or narrative. Furthermore, the overview can assist scientific actors within the biodiversity field with structuring the scientific discourse on biodiversity loss with help of several storylines. On the other hand, policymakers commonly possess less scientific knowledge on biodiversity. An overview of storylines and a structuring of biodiversity loss into distinct drivers, solutions, and responsibilities can make this knowledge more accessible. Insight into the variations in scientific discourse on biodiversity provides the opportunity to assess and compare the presented knowledge of the scientific actors involved within the biodiversity SPI with scientific narratives outside the biodiversity SPI. This study can thereby aid in critically scrutinizing and integrating the addressed drivers, solutions, and responsibilities more effectively. Integrating drivers, solutions, and responsibilities together, contrary to most storylines within the biodiversity literature, would likely enhance the effectiveness of policies.

Biodiversity loss is a highly complex issue, where every articulation represents a different frame, with different problems identified, solutions sought or responsibilities assigned. Therefore, trying to integrate drivers, solutions, and responsibilities together and acknowledging that there is not *one* biodiversity loss but *many*, can achieve a more nuanced, socially just, and effective understanding and mitigation of biodiversity loss.

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