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Nature-based solutions to freshwater fisheries: challenges and opportunities for their application in Ethiopian fisheries management

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Abstract

Nature-based solutions are a new approach to protecting and restoring ecosystems and are crucial for maintaining fish and sustaining fisheries. This review focuses on the potential role of Nature-based solutions in freshwater fisheries management and discusses the challenges and enablers of Nature-based solutions' implementation and paths in Ethiopian fisheries. Nature-based solutions simultaneously address environmental, social, and economic challenges by maximizing the benefits of nature. Wetlands, floodplains, river restoration, protected areas, and river and lake riparian buffers are the most common types of Nature-based solutions used for fisheries management. The potential pathways for applications of Nature-based solutions in fisheries management include habitat restoration and rehabilitation, water management, aquaculture development, biodiversity conservation, climate change adaptation and mitigation, and creating alternative jobs and food security sources for fishers. In Ethiopia, implementing climate resilience, a blue economy, green legacy efforts, landscape restoration programs, water resource management, and protected areas are some of the enablers for utilizing and addressing Nature-based solutions in fisheries management. Therefore, leveraging finance, creating an enabling regulatory and legal environment, creating awareness, and improving cross-sectoral collaboration are needed to respond to barriers to Nature-based solutions in Ethiopia's fisheries.

Keywords: Challenge, Fisheries, Freshwater, Nature-based solutions, Opportunity

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Introduction

Freshwater ecosystems are key natural resources that provide crucial ecosystem services for human well-being and livelihoods across the world (Acreman et al., 2019; Boelee et al., 2017; Loury, 2020). Freshwater ecosystems have extraordinary biodiversity (Oliveira et al., 2021); in particular, they support inland fish populations (Oliveira et al., 2021) and fisheries (Loury, 2020).

Freshwater ecosystems and biodiversity are under stress and rapidly disappearing worldwide (Nikitina et al., 2020; Wilkinson et al., 2019). Indeed, the 2020 Living Planet Index shows that the global average abundance of freshwater populations (mammals, birds, amphibians, reptiles, and fish) has declined by 84% since 1970. As a result, freshwater fishes are among the world's most threatened vertebrates (Arlinghaus et al., 2015), with around 35% of species vulnerable (Oliveira et al., 2021; Xie et al., 2019). They are imperiled and dramatically declining globally (Boelee et al., 2017; Loury, 2020). Human activities, including habitat degradation, overharvesting, climate change, land-use changes, invasive species, illegal activities, high water abstractions, floods, increased nutrient loads, and pollution, significantly contribute to the global decline of freshwater fish species (Iseman & Miralles-Wilhelm, 2021; Scarabotti et al., 2021).

The protection of freshwater fishes and their habitats requires comprehensive management actions. Alternatives include biologically sustainable exploitation, aquatic biodiversity protection, and fair stakeholder benefit sharing (Arlinghaus et al., 2015; Nikitina et al., 2020; Xie et al., 2019). Solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social, and economic benefits, and help to build ecosystem resilience known as nature-based solutions (NbS) (Bauduceau et al., 2015). The NbS is a new approach to protect and restore landscapes and freshwater ecosystems, including forests, grasslands, wetlands, and coastal habitats (Boelee et al., 2017; Souliotis & Voulvoulis, 2022). It aims to improve water quality, biodiversity conservation, and manage floods and droughts (Cohen-Shacham et al., 2016). NbS are crucial for maintaining fish populations and sustaining fisheries, as they contribute to biodiversity conservation (Iseman & Miralles-Wilhelm, 2021).

Ethiopia's lakes, rivers, and reservoirs are home to a diverse array of ichthyofauna. The potential fish output for the main water bodies is projected to be about 94,500 tons per year, with only around 20% being produced (Tesfaye & Wolff, 2014). Ethiopian freshwater fish biodiversity is declining due to human activities (Getahun, 2017; Getahun & Stiassny, 1998), Overfishing, wetland degradation, dam construction, deforestation, urbanization, and industrialization are all factors that contribute to low productivity (Hirpo, 2017). To potentially address the aforementioned challenges, management strategies should focus on issues such as adopting a watershed or ecosystem approach, incorporating income generation into conservation programs, and sharing responsibility and benefits among local stakeholders (Mengesha & Belachew, 2017).

In Ethiopia, a wide range of NbS are practiced in agriculture, agroforestry, wetland, forest, river, and soil and land restoration (Songwe, 2020). However, the potential application of NbS to Ethiopian fisheries and aquatic ecosystems has not been well practiced. Therefore, this review aims to provide a better understanding of NbS and their potential role as a freshwater fishery management tool in the world as well as the current opportunities and challenges of their application in Ethiopian fisheries. The specified objectives of this review paper are intended to discuss the concept and classifications of NbS, explore the current applications of NbS around the globe and success stories, raise awareness of the potential approaches and applications of NbS in fisheries management, as well as their links to freshwater ecosystems, and highlight the enablers and constraints to scaling NbS in Ethiopian fisheries.

Concepts and principles of nature-based solutions

NbS is a novel concept that was initially offered by the World Bank in 2008 (MacKinnon et al., 2008). In 2015, the European Commission formally defined NbS as "actions address environmental, social, and economic challenges simultaneously by maximizing the benefits provided by nature inspired by, supported by, or copied from nature" (Bauduceau et al., 2015). The International Union for Conservation of Nature (IUCN) provided another widely accepted definition as "actions to protect, sustainably manage, and restore natural or modified ecosystems that address societal challenges (e.g., climate change, food security, water security, disaster risk, human health, or natural disasters) effectively and adaptively, simultaneously providing human well-being and biodiversity benefits" (Cohen-Shacham et al., 2016).

NbS is an umbrella concept that brings together a varied range of stakeholders and disciplines to collaborate, resulting in cross-disciplinary work and a variety of perspectives (Cardinali

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et al., 2021; Cohen-Shacham et al., 2019; Stafford et al., 2021). NbS is a concept that aims to balance the benefits of nature, biodiversity, and society in managing natural systems (Fig. 1) (Souliotis & Voulvoulis, 2022; Sowińska-Świerkosz & García, 2022). It is based on eight principles from the IUCN Global Standard: addressing societal challenges, landscape scale of intervention, biodiversity gain, economic viability, governance capability, equitably balancing trade-offs, adaptive management, and mainstreaming within an appropriate jurisdictional context (IUCN, 2020). The European commission's SfEP (2021) offers five criteria for determining if an action is NbS: making use of nature or natural processes, providing social benefits, improving economic benefits, creating or enhancing environmental benefits, and benefiting biodiversity. As a result, NbS is defined by nature-based, solution-oriented, multifunctionality, integrative implementation, and context adaptability (Ramírez-Agudelo et al., 2022). It is important to note that any management action that has a net negative impact on climate, biodiversity, or local communities should not be considered a NbS (Stafford et al., 2021).

Eggermont et al. (2015) identified three forms of NbS: activities without significant impacts on ecosystem services, management approaches altering ecosystem functionality, and creating new ecosystems to increase ecosystem service production. ThinkNature's scheme (Somarakis et al., 2019) classifies NbS based on intervention level and engineering type, categorized into Type 1, better use of protected ecosystems; Type 2, sustainability and multi-functionality of managed ecosystems; and Type 3, design an ecosystem, such as water management, ecological restoration, and semi-natural water creation.

Types of nature-based solutions for freshwater fishery management and benefits

NbS have a wide range of uses and offers several benefits to society and the environment (Cardinali et al., 2021; Cross et al., 2021; Taylor et al., 2018). It may also provide co-benefits by tackling societal challenges as well as mitigating and adapting to climate change and environmental degradation (Price, 2021). Specifically, NbS for their fishery management functions could be permeable pavement. This section, therefore, moves from these insights on to discuss the types of NbS for fishery and water management and their benefits, as summarized in Table 1.

Wetland management

Wetlands are crucial ecosystems that serve as a buffer, mitigating storms and assimilating pollutants (Jongman et al., 2021). They are rich in biological productivity and are considered natural resources (NbS) with numerous social, economic, and environmental benefits (Sarkar et al., 2018; Thorslund et al., 2017). Wetlands offer advantages for fish production and fishery management, including increasing species richness and habitat heterogeneity (Smith & Chausson, 2021). Wetland vegetation also provides a surface for fish to attach eggs to or create nests, providing a protective cover and food source for young fish

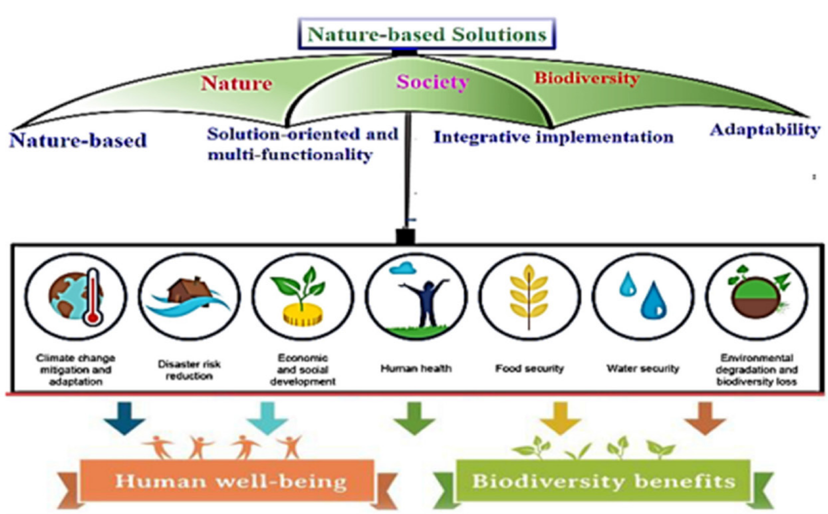

Fig. 1. Conceptual framework of nature-based solutions. Adapted from IUCN (2020) with permission of author.

Table 1. Types of nature-based solutions, their fishery and inland water management benefits and co-benefits

Types of NbS	Fishery and inland water management benefits	Co-benefits	Sources
Wetland management	· Fish farming · Sustain fisheries and aquaculture · Maintain or boost fish stocks · Provide fish habitat (spawning, feeding) · Clean water · Regulate water flow · Reuse nutrients · Water temperature control	· Biodiversity · Stimulate local economies and job creation (farming, fishing, tourism) · Carbon storage and sequestration · Provide a social amenity (recreation)	Cross et al. (2021) Iseman & Miralles-Wilhelm (2021) Jongman et al. (2021) Matthews & Cruz (2022) Price (2021) Takavakoglou et al. (2022) Taylor et al. (2018) WWAP (2018)
Reconnecting rivers to floodplains	· Maintain or boost fish stocks · Provide diverse habitats for fish · Maintain water abstractions · Water supply regulation · Food mitigation · Water purification	· Biodiversity · Recreation · Nutrient replenishment · Livelihood opportunities · Resilience to extreme · Climate events	Addy et al. (2016) Cross et al. (2021) Price (2021) Smith & Chausson (2021) Souliotis & Voulvoulis (2022) Taylor et al. (2018) WWAP (2018)
Riparian buffers	· Provide diverse habitats for fish · Migration corridor and nursery area for fish · Riverine flood mitigation · Water purification · Erosion reduction · Water temperature control	· Biodiversity · Recreation	Arlinghaus et al. (2015) Segura et al. (2018) Smith & Chausson (2021) Taylor et al. (2018)
River restoration	· Provide diverse habitats for fish · Maintain or boost fish stocks · Provide fish shelter areas during high flows · Water supply regulation · Pollution purification · Reduce habitat loss and sediments	· Water supply regulation · Flood mitigation · Aesthetic value · Biodiversity · Recreation and tourism · Food mitigation	Addy et al. (2016) Arlinghaus et al. (2016) Cross et al. (2021) WWAP (2018) Price (2021) Souliotis & Voulvoulis (2022)
Protected areas	· Provide diverse habitats for fish · Maintain or boost fish stocks · Water supply regulation · Physical modification reduction · Reduce habitat loss and sediments	· Climate change mitigation · Biodiversity	Abell et al. (2007) Kupilas et al. (2021) Loury (2020) Marselle et al. (2019)
Aquaculture	· Fish production · Reduce capture fishery · Maintain or boost fish stocks · Reduce pollution discharge	· Economic and ecological targets · Livelihood opportunities	IUCN (2022)

(Sarkar et al., 2018).

Natural wetlands, such as lake marginal wetlands and floodplain marshes, are crucial for fishery management and water treatment. They are part of larger water systems, such as headwater catchments and the littoral zones of lakes and rivers (Cross et al., 2021). Conservation of these wetlands is essential for fishery management and water treatment. For instance, the Namatala wetland in Uganda, a papyrus wetland, provides home to catfish and lungfish, treats discharge effluent, and encourages fishing and agricultural activities, reducing the main river fishery's fishing burden (Namaalwa et al., 2013).

Constructed wetlands are also the center of NbS since they constitute cost-effective solutions based on and supported by nature, able to provide multiple environmental and socioeconomic benefits (Takavakoglou et al., 2022), treat waste water, and make it suitable for reuse on the fish farm (Truijen & van der Heijden, 2013). Moreover, both types of wetlands are the most productive habitats in the world, with greater fish and other biological diversity (Jongman et al., 2021), improve water quality, reduce flooding, sustain healthy ecosystems, and stimulate the local economy (e.g., tourism potential and service jobs, harvest food and building materials) (Jongman et al., 2021;

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Metcalfe et al., 2018).

Riparian buffer zones

Riparian zones are semi-terrestrial areas, providing essential habitat for terrestrial and aquatic biota (Loos & Shader, 2016). They are biodiversity hotspots (Kupilas et al., 2021), aiming to protect fish habitats, maintain fisheries resources for public access, and protect tidal lands from natural erosion and greenhouse effects (Bavins et al., 2000). Riparian vegetation is crucial for fish as it impacts light regimes, thermal dynamics, water quality, habitat, and food availability. Establishing a management buffer zone between fish habitats and development or land use aims to protect these habitats, protect fisheries resources, and provide economic benefits (Arlinghaus et al., 2015; Kupilas et al., 2021).

River restoration

River restoration is a management approach aimed at restoring a functioning river system and supporting native biodiversity and ecosystem services like flood and drought risk mitigation, aquifer recharge, nutrient retention, and recreation (Smith et al., 2021). It involves re-establishing natural physical processes (e.g., flow and sediment movement), features (e.g., sediment sizes and river shape), and habitats of a river system, ensuring its health and sustainability (Addy et al., 2016).

River restoration projects worldwide utilize NbS to restore the natural behavior and ecosystem services of riverine systems. NbS can be implemented in various parts of the riverine system, including the river channel (e.g., meander, incise, floodplains), riparian zone, and wetlands (Keesstra et al., 2018). The goal is to restore the river's natural dynamics by creating physical structures to direct water flow and providing habitat for aquatic species (Addy et al., 2016; Jongman et al., 2021). NbS river protection and sustainable management can also sustain and enhance fish production (Smith et al., 2021), offering various shelter, breeding, and feeding habitat opportunities (Addy et al., 2016).

Floodplain restoration

A floodplain is the land area adjacent to a stream or river that is periodically inundated by water from an adjacent river and formed and influenced by river flows and sediment (Loos & Shader, 2016; Serra-llobet et al., 2022). Floodplains are some of the most biodiversity-rich and productive lands on Earth (Loos & Shader, 2016). Floodplain restoration is a means to return a river-floodplain system to a healthy, functioning state (Loos & Shader, 2016). It is an example of NbS that can make a significant contribution to more effective flood risk management, strengthen the multifunctionality of the river landscape, and increase the supply of ecosystem services (Jongman et al., 2021; Serra-Lobet et al., 2022).

Floodplains provide abundant food resources and underpin some of the most productive fisheries (Serra-llobet et al., 2022). Floodplains are essential for maintaining the health and productivity of fish populations in riverine ecosystems (Cornelius & Pérez-Cirera, 2021). Floodplain rehabilitation and river-floodplain reconnection can improve attenuation, provide diverse habitats for fish (nursery grounds and feeding; Arlinghaus et al., 2015), increase food availability (Serra-llobet et al., 2022), and facilitate changes in conditions (e.g., fish moving to sheltered areas during high flows) (Addy et al., 2016). These practices also enhance fish reproductive success and growth rates (Loos & Shader, 2016), play a crucial role in recruiting fish populations (Sarkar et al., 2018), and restore metapopulation dynamics (Arlinghaus et al., 2015).

Aquaculture development

The NbS concept and global standard approach for aquaculture systems constitute true, valid, and relevant NbS (IUCN, 2020). Potentially, aquaculture-related NbS may provide solutions to societal challenges (mainly food security and economic and social development). They could also reconcile economic and ecological targets with present and future needs and the welfare of stakeholders and local communities (IUCN, 2022). For example, different types of wastewater treatment ponds are typically less energy-intensive units. The ponds have a positive impact owing to their ability to support biodiversity and improve aquatic ecological conditions. As a result, they can provide habitat for fish and other fauna and flora. Therefore, fishing is recovered in rivers or lakes beyond pollution discharged, since its water quality has improved after the wastewater treatment ponds project implementation (Cross et al., 2021). In addition to fish farming, the ponds are also used by local fishermen to grow vegetables and crops (Zhu et al., 2018).

Protected areas

One of the cornerstones of global efforts to conserve biodiversity in NbS is the establishment of protected areas (Marselle et al., 2019; Xie et al., 2019). The establishment of freshwater protected areas (FPAs) is a crucial part of global efforts to conserve biodiversity in the Northern Hemisphere. FPAs are defined geographical spaces recognized, dedicated, and managed to achieve long-term conservation of nature, ecosystem services, and cultural values (Bower et al., 2015). They have played a significant role in the rehabilitation and conservation of various freshwater fish and other species. Additionally, the presence of an FPA on a water body minimizes human disturbance, benefiting freshwater environments at multiple levels (Marselle et al., 2019).

Fish conservation zones (FCZs), heritage or wild rivers, inland fishery reserves, and riparian buffer zones are FPAs that aim to protect fish or other freshwater life (Loury, 2020). FCZs are FPAs where communities play a significant role in their establishment and management. Heritage or wild rivers are examples of traditional protected area ideas adapted to fit the freshwater environment (Abell et al., 2007). Inland fishery reserves, also known as harvest reserves, are spatially defined areas of water managed by technical regulations to sustain or increase fish yield from natural fish stocks for fishers. Within a protected area, all fishing may be prohibited, certain types and amounts of gear or storage equipment may be regulated, and access by specific types of fishers might be controlled. Riparian zones are characterized as biodiversity hotspots (Kupilas et al., 2021), with plants and animals uniquely adapted to living with flood disturbance and creating biotic assemblages (Abell et al., 2007; Loos & Shader, 2016).

Potential pathways for applying nature-based solutions in freshwater fisheries

NbS enhance aquatic ecosystems and species by increasing habitat diversity, restoring ecosystems and improving the quality and reliability of water (Grace et al., 2021). It encompass a broad range of practices that can be deployed directly in the context of the production fishes (including fisheries and aquaculture) (Iseman & Miralles-Wilhelm, 2021) and management (Grace et al., 2021). The implementation strategies of NbS are also diverse (Fig. 2). Taking this into account, the following sections of this review explores the potential pathways, and the nature of interventions and applications of NbS for fisheries and inland water management.

Habitat restoration and rehabilitation

Habitat change and loss pose significant threats to freshwater fish (Arlinghaus et al., 2015). Sustainable restoration and rehabilitation strategies based on natural processes and cycles are sustainable, as they utilize natural flows of matter and energy, local solutions, and seasonal changes (Keesstra et al., 2018). NbS

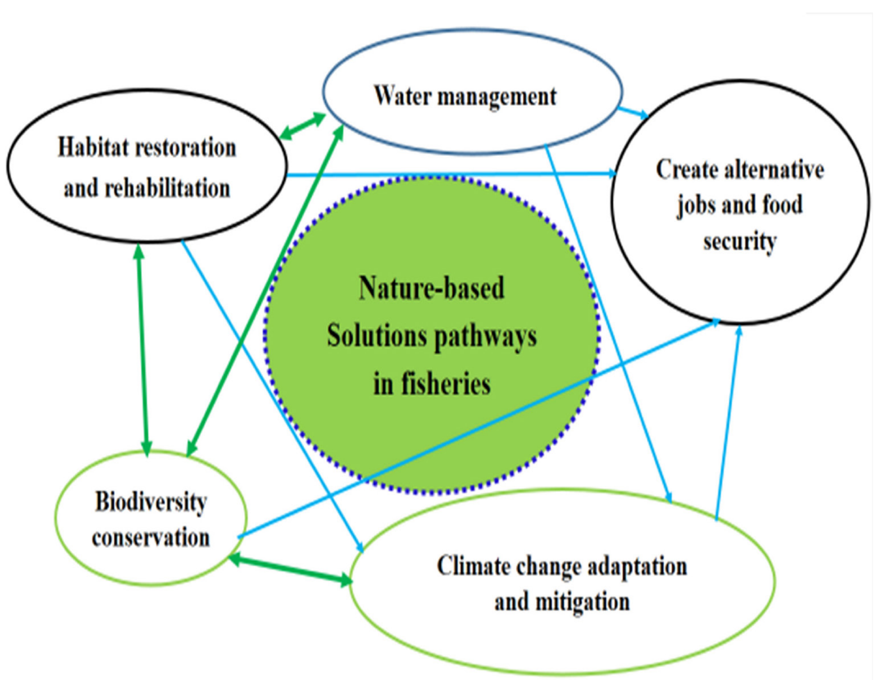

Fig . 2. Implementation strategies and pathways of nature-based solutions in fisheries.

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can be a successful strategy for fisheries, involving conserving or rehabilitating natural ecosystems and/or enhancing natural processes in modified or artificial ecosystems (WWAP, 2018). The typical approach assumes that rehabilitation of physical habitats ensures ecological functions, increasing fish biomass (Albertson et al., 2018).

Restoring freshwater habitats is crucial for biodiversity, as it provides diverse habitats for aquatic organisms like fish. NbS river restoration, which slows floodwater flow, introduces gravel banks and riffles, facilitating the restoration of critical aquatic ecosystems like wetlands and watersheds (Smith & Chausson, 2021). Many NbS projects aim to restore degraded stream habitats for fish by restructuring channel morphology, planting riparian forests, and reducing fine sediment inputs (Albertson et al., 2018; Iseman & Miralles-Wilhelm, 2021).

Water management

Freshwater fisheries face significant pressures due to water quality and water level perturbations (Arlinghaus et al., 2015). NbS can improve water management by improving availability and quality, reducing water-related risks like flooding and drought, and generating additional social, economic, and environmental benefits (Cardinali et al., 2021; Taylor et al., 2018; WWAP, 2018). The three main ways NbS can be harnessed by water managers are protection, restoration, and extension. Protection involves using and protecting natural ecosystems; restoration involves rehabilitating degraded ecosystems; and extension involves creating new ecosystems. By harnessing NbS, water managers can enhance overall water security and generate additional benefits (Taylor et al., 2018). NbS is a method used to manage water availability and ecosystem services by moderating water in catchments. It can provide benefits like reduced surface runoff, increased surface water storage, and improved water quality by reducing pollutant loads (Cardinali et al., 2021). NbS focuses on managing precipitation, humidity, and water storage, infiltration, and transmission. Buffer strips are used to mitigate pollution, protect biodiversity, and reduce river bank erosion. These practices aim to protect water quality and ecosystem services (Souliotis & Voulvoulis, 2022; WWAP, 2018).

Aquatic restoration aiming to return water bodies to a status that provides a higher volume of ecosystem services (WWAP, 2018). Natural infrastructure such as wide river floodplains with connected biodiversity-rich wetlands can be a cost-effective alternative to natural embankments for flood protection (Boelee et al., 2017). In the context of water and sanitation, constructed wetlands for wastewater treatment can be a cost-effective NbS that provides effluent of adequate quality for several non-potable uses, including irrigation, as well as offering additional benefits, including energy production (WWAP, 2018). There is also growing evidence that NbS can be more cost-effective than engineered alternatives, at least when it comes to less extreme hazard scenarios. For example, across 52 coastal defence projects in the USA, NbS were estimated to be two to five times more cost-effective at lower wave heights and at increased water depths compared to engineered structures (Seddon et al., 2020).

Aquatic restoration aims to restore water bodies to a higher volume of ecosystem services (WWAP, 2018). Natural infrastructure like river floodplains with biodiversity-rich wetlands can be cost-effective alternatives to natural embankments for flood protection (Boelee et al., 2017). Constructed wetlands for wastewater treatment can provide adequate quality effluent for non-potable uses, including irrigation, and offer additional benefits like energy production (WWAP, 2018). NbS can be more cost-effective than engineered alternatives, especially in less extreme hazard scenarios. For example, in 52 coastal defense projects in the USA, NbS were estimated to be two to five times more cost-effective at lower wave heights and increased water depths compared to engineered structures (Seddon et al., 2020).

Biodiversity conservation

Strategic and well-executed NbS will simultaneously provide significant additional public goods and biodiversity conservation (Stafford et al., 2021). Biodiversity underpins fishers' and fish farmers' livelihoods and ability to produce food (FAO, 2021). Biodiversity is relevant to NbS in two ways. Firstly, biodiversity has a functional role in NbS, whereby it underpins ecosystem processes and functions and, therefore, the delivery of ecosystem services. Secondly, biodiversity is relevant to NbS in the sense of achieving biodiversity 'conservation' objectives, irrespective of its functional role regarding water (WWAP, 2018). The implementation of NbS for wastewater treatment in aquatic habitats and ecological systems contributes to the co-benefits of fisheries (Cross et al., 2021), as it aligns with the IUCN definition and the Global Standard for NbS (Cohen-Shacham et al., 2016; IUCN, 2020). Fish diversity positively impacts biomass and productivity (Bower et al., 2015), while reductions in soil biodiversity negatively impact organic carbon, moisture, infiltration, runoff, erosion, and groundwater recharge (WWAP, 2018).

Climate change adaptation and mitigation

Freshwater ecosystems and fisheries are largely vulnerable to climate change (Stafford et al., 2021). Reducing vulnerability in fisheries and aquaculture urgently requires the application of adaptation and mitigation options at appropriate scales. In nature-based climate adaptation, the goal is to preserve ecosystem services that are necessary for human life in the face of climate change and to reduce the impact of anticipated negative effects of climate change (e.g., more intense rainfall, floods, heat waves and droughts) (Naumann et al., 2014).

There is already a growing evidence base for NbS to climate change adaptation and mitigation for effective fishery management (Malhi et al., 2020). Climate change adaptation via NbS includes wetland restoration and re-naturalization of water courses to provide natural flood management in river systems, and cooling the urban environment, e.g., green spaces (Stafford et al., 2021). However, in nature-based climate change mitigation, ecosystem services are used to reduce greenhouse gas emissions and to conserve and expand carbon sinks (Naumann et al., 2014). According to Stafford et al. (2021), climate change mitigation can be achieved via NbS by reducing carbon emissions (e.g., avoiding deforestation and restoring wetlands and rivers) and by increasing carbon sequestration in ecosystems (e.g., reforestation, wetland restoration and agroforestry and urban tree planting. Moreover, NbS enable nature to help resolve the problems of climate change, and currently it considered as a key means to meet the challenges of climate change (Herrmann-Pillath et al., 2022), both in reducing atmospheric greenhouse gas concentration and adapting our infrastructure (Stafford et al., 2021).

Create alternative jobs and food security for fishers

The adoption and implementation of NbS has the potential to create new economic opportunities and jobs and socially inclusive economic growth (Cardinali et al., 2021). NbS can be used to sustain or enhance the jobs and productivity of those working in farming, fisheries, forestry and tourism sectors (Kopsieker et al., 2021; Lieuw-Kie-Song & Pérez-Cirera, 2020). In the current context, with an urgent need for immediate job creation, the potential of NbS to quickly create direct jobs is of particular interest. There is a considerable body of experience of putting NbS into practice around the world (Cardinali et al., 2021). NbS, such as restoring water catchments, can increase water availability and reduce soil erosion, contributing to increased agricultural productivity. Similar benefits can be found in sectors such as fisheries and forestry, where the use of NbS can sustain or enhance the jobs and productivity of those working in these sectors (Lieuw-Kie-Song & Pérez-Cirera, 2020).

The state of NbS is a key enabler of the tourism sectors. NbS such as reforestation and wetland restoration interventions planned for disaster risk reduction promise to create opportunities for employment at relatively large scale and over longer time frames. These approaches can reduce the risk of erosion, landslides and flooding, and also increase the resilience of ecosystems to climate change and fishery management (Lieuw-Kie-Song & Pérez-Cirera, 2020).

Challenges implementing nature-based solutions in Ethiopian fisheries

Despite the growing attention and evidence base for NbS (Price, 2021), NbS faces a numerous barriers and enabling factors to wide adoption and implementation (WWAP, 2018), to their use and scale-up (Grace et al., 2021; Pacetti et al., 2022; Price, 2021) and to influence the successful governance (Smith et al., 2021). The major challenges of NbS in Ethiopian fisheries are also discussed in the next sections.

Low institutional capacity, and lack of stakeholders' follow-up, collective action and governmental support

Indeed, NbS should address social and biodiversity benefits and imply stakeholders' participation, 'good' governance rules, equity, and wellbeing improvement NbS (Cohen-Shacham et al., 2016; IUCN, 2020). A key barrier to increasing NbS adoption has been a lack of political commitment as well as institutional and technical capability (Pacetti et al., 2022). In Ethiopia, involvement of the central government to issuing nationwide fisheries laws is limited and provision of technical support and professional advice is low (Kebede & Gubale, 2016). The constraints and vulnerability of fisheries communities are mainly due to lack of stakeholders support, remote locations and poor services, low literacy and innumeracy and weak organization capacity are other factors that expose fishing communities to poverty (Meko et al., 2017).

NbS requires cooperation among multiple institutions and stakeholders to ensure benefits flow to those most in need (Nelson et al., 2020). Fishery sectors have been undervalued compared to other agricultural sectors, leading to uneven efforts in Ethiopian fishery management (Kebede & Gubale, 2016). In Lake Tana, stakeholders lack awareness of existing fishery laws and federal regulations. There is a lack of understanding of the

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critical role of natural assets in social and economic development (Daniel, 2013). NbS involves people collaborating with nature to develop comprehensive solutions that enhance biodiversity and human well-being. However, low participation of fishing communities in fisheries management is a major factor affecting the implementation of fisheries management in Ethiopia (Kebede & Gubale, 2016). Developing strong, transparent, and fair institutions that empower the vulnerable can ensure the benefits of NbS reach those most in need (Cardinali et al., 2021; Smith & Chausson, 2021).

NbS often involve multiple actions taking place over broad landscapes and seascapes, crossing jurisdictional boundaries. For example, effective management of storm-water drainage across watersheds using NbS requires joint decision-making across different local, regional or even national governments and among multiple ministries (agriculture, forestry, and environment, finance, development, transport; Songwe, 2020). Nevertheless, the fishing sector of the economy has various problems in Ethiopia, among others, mismanagement of the resource, inappropriate policies and institution, inadequate technical and material backup to the sector are also other NbS challenges in the country fisheries. NbS typically result in a mix of economic and social benefits for multiple sectors and stakeholders in the water basin (Taylor et al., 2018). Similarly, improving and reinforcing technical capacities in fisheries and aquaculture management institutions, especially at decentralized levels, and is essential to the effectively implementation of the NbS in freshwater ecosystems facing multiple anthropogenic stressors (Iseman & Miralles-Wilhelm, 2021).

Moreover, implementation of the national and regional proclamations is lacking in Ethiopia (Gebremedhin et al., 2018). To be successful, governance of NbS requires active cooperation and coordinated action between stakeholders (Songwe, 2020). However, lack of proper policy implementation, participation of the local communities and institutional collaborations are leading to ineffective fisheries management in Ethiopia (Gebremedhin et al., 2018).

Improper water-land use near fish habitats

Most of the Ethiopian lakes, rivers, and reservoirs are presently facing serious ecological problems due to development activities such as agriculture expansion, sand mining, river water pumping, dam construction for both irrigation and hydropower purposes undermine the biodiversity of the fish and alter natural ecosystem (Gebremedhin et al., 2018). Therefore, these activities are potentially affecting water quality and finally threat fishery resources (Kebede & Gubale, 2016). Moreover, the Ethiopian lakes, on which the inland fishing is mainly practiced, are threatened by catchment's deforestation, shore damage, water pollution, siltation and eutrophication and overfishing (Meko et al., 2017). In Ethiopia wetland, river and floodplain destruction and conversion to agricultural areas are still widely accepted in the national context and annually a campaign is organized by 'ill-advised' development agents, who are responsible for agricultural development (Gebremedhin et al., 2018). In Ethiopia, the land-use change affects watershed runoff, microclimatic resources, groundwater levels, and landscape-scale biodiversity (Elias et al., 2018). As in many parts of the world, population growth, agricultural development, and industrialization are contributing to the loss of Ethiopian freshwater fish biodiversity (Getahun & Stiassny, 1998). Today, fisheries resources are declining due to different environmental conditions, illegal fishing practices, habitat changes, and the extraction of gravel and sand for development activities. These indirectly affecting the NbS implementation or the spawning, nesting and feeding site of fish species.

Lack of accessible funds and economic factors

Lack of accessible funds to invest in and scale-up NbS (Grace et al., 2021; Pacetti et al., 2022; Price, 2021), the increasing gentrification, the limited availability of land due to ownership issues and to urban planning limitations, and lack of technical guidance, tools and approaches to determine the right mix of NbS (Pacetti et al., 2022) are barriers of NbS implementation. Perhaps, allocation of budget for fishery sector at the federal and regional levels is very small (Tesfaye & Wolff, 2014). Limitation of institutional, technical, and financial capacity in the resource monitoring, control and surveillance, planning, and coordination are observed as a major challenge in Ethiopian fisheries management (Kebede & Gubale, 2016). Although NbS can offer more cost-effective solutions than alternatives in the long term, when all public and private costs and benefits have been taken into account, governments and other funding agencies may need to provide practical and financial support to enable the transition to NbS in a way that meets local needs (Smith et al., 2021).

Lack of awareness

NbS confront challenges similar to other paradigm shifts including: limited awareness; knowledge gaps surrounding applications and their effectiveness; insufficient understanding of costs and benefits; diverse stakeholder values and perceptions; and limited policy and economic instruments (Nelson et al., 2020). The literature consulted suggest a number of knowledge gaps in the evidence base for NbS effectiveness including lack of: robust and impartial assessments of current NbS experiences; site specific knowledge of field deployment of NbS; timescales over which benefits are seen and experienced; cost-effectiveness of interventions compared to or in conjunction with alternative solutions; and integrated assessments considering broader social and ecological outcomes (Chausson et al., 2020; Price, 2021). Lack of public understanding, unclear definitions and concepts of NbS is one of the major challenge (Nelson et al., 2020). Lack of awareness of the community in fisheries management is also challenged in water bodies of Ethiopia (Desalegn & Shitaw, 2021).

Despite the recent significant increase in research and peer-reviewed papers on NbS, there are still gaps in our understanding of the ideas and procedures for actually planning NbS. There are still gaps in our understanding regarding the reliability and objectivity of assessments of current NbS experiences, as well as site-specific knowledge of planning NbS. There are still gaps in our understanding regarding the reliability and objectivity of assessments of current NbS experiences, as well as site-specific knowledge of NbS experiences, the length of time it takes for benefits to be felt, the cost-effectiveness of interventions when compared to or used in conjunction with alternative solutions, and integrated assessments that take into account broader social and ecological outcomes (Chausson et al., 2020). Local knowledge is particularly important for NbS, especially from indigenous communities that have adaptive capacity embedded in their traditional knowledge systems (Price, 2021).

Opportunities and enablers of nature-based solutions in Ethiopian fisheries

A wide range of NbS are being implemented in Ethiopia, including protection and restoration of forests, rivers, wetlands; agriculture; agro-forestry and participatory forest management. In the following subsections NbS enablers, opportunities, and harnessing of fishery management in Ethiopia are discussed.

Climate resilient green economy and green legacy initiative

In 2011, Ethiopia enacted a green growth strategy based on a net zero increase in greenhouse gas emissions from 2010 years. These figures are set out in the climate resilient green economy (CRGE) strategy that seeks to promote climate change adaptation and mitigation measures. As part of its commitments to a green growth strategy nationally and to support climate and biodiversity action globally, the government of Ethiopia in 2014 pledged to restore 15 million hectares of degraded landscapes by 2030 (Pedercini et al., 2021). Ethiopia has shown both conservation and policy responses to combat climate change. Protected area systems, afforestation and reforestation programmes are feasible strategies for mitigating and adapting climate change (Zegeye, 2018).

Ethiopia reformed forest laws in 2018 and has launched the green legacy initiative (GLI) as of 2019. The GLI is a campaign that mobilizes millions of citizens during the rainy season to plant billions of seedlings and saplings on mountains, or watersheds, or any land. Ambitiously planned to plant 20 billion seedlings from 2019–2024 (Jalleta, 2021; Songwe, 2020); of which 5 billion seedlings are being planted in 2020. In the context of fishery, these NbS commitments involve forest establishment and landscape restoration provide a promising approach to reverse the widespread land and aquatic ecosystem degradation, which could improve fisheries management and enhance fisheries production (Pistorius et al., 2017).

Fishery laws, policies and strategies for fish resource development

Appropriate water management system is needed for fishery management in Ethiopia (Mengesha & Belachew, 2017). NbS that improve soil and water, such as vegetative hedgerows, contour farming, cover crops and area closure, have been particularly successful in Ethiopia (Gumma et al., 2021).

The Ethiopian water resources strategies undertake proper assessment, preservation, and enrichment of aquatic resources in rivers and lakes; and incorporate aquatic resource development in large scale water resources master plan studies, such as taking actions to develop and maintain the potential of aquaculture; enhancing development of capture fisheries in existing and future reservoirs; and installing fish breeding stations in the reservoirs to enhance fish production. According to FDRE (2020), water conservation should be promoted to maximize water availability and quality and promote NbS strategy to manage water availability and water quality in the country. Buffer zones, wetlands management, watershed management and integrated water resources management also other strategies that should be delineated, demarcated and legally protected along water bodies to sustain and maximize environmental, social and eco-

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logical benefits (FDRE, 2020).

Today, fishery legislation is available at federal and in some at regional levels is the top responsible party. The Ethiopian government has ratified fishery legislation in 2003, FDRE Fisheries Development and Utilization Proclamation No.315/2003 with a view to ensure the conservation, development and utilization of fishery resources in the country (FDRE, 2003). The main objectives of the proclamation are: for the prevention and control of over-exploitation of fish resources, conservation of fish biodiversity and its environment; for the attainment of food security by sustainably producing good quality fish products; and for the expansion of aquaculture development (FDRE, 2003). Therefore, it indicated support of NbS fisheries management.

Similarly the Amhara National Regional State fisheries development, protection and utilization proclamation has basic similarity with FDRE Fisheries Development and Utilization Proclamation No. 315/2003. Therefore, the Amhara fisheries proclamation is given the appropriate attention in water bodies where fish potential is present since the legislation of exploiting fisheries resources does not yet exist in order to effectively prevent, develop, and transform the resource for the next generation (Daniel, 2013). The preamble to the rule indicates that a proclamation has been made about the development, protection, and usage of the fisheries' resources to be applicable across the regional state (ANRS, 2007).

Ethiopia has a history of watershed management initiatives dating back to the 1970s (Chimdesa, 2016). Currently, watershed management is following holistic approach targeting sustainable natural resource management and utilization for the improvement of the livelihood of the community in the watershed (Negasa, 2020). There is a massive movement in watershed management in almost all regions of the country (Chimdesa, 2016). This NbS approach has brought success across the areas where watershed management measures applied in Ethiopia at some extent and fisheries management. For example, NbS Eco-hydrological demonstration project in the Gumara catchment of Lake Tana includes implementation of ecotone/buffer zones for reducing point and non- point sources of pollution and recovery of degraded ecosystems and soils; and optimized fish-based aquaculture in the Lake Tana littoral zone as a measure for preventing the on-going process of encroachment in the lake littoral zone.

Available environmental conditions for nature-based solutions

NbS are fundamental to the ecosystem approach, a method for the integrated management of land, water, and living resources that promotes equitable conservation and sustainable utilization (Boelee et al., 2017). Ethiopia is endowed with several water bodies that contain a high diversity of aquatic fauna. Major rivers and lake systems, together with their associated wetlands, are fundamental parts of life interwoven into the structure and welfare of societies and natural ecosystems (Meko et al., 2017). Ethiopia has diverse wetlands of various origins that distributed in many parts of the country which includes land covered by shallow water encompassing lakes, rivers, swamps, marshes, floodplains, natural or artificial ponds, high mountain lakes and human made wetlands. They provide with various benefits to local communities and as biodiversity conservation devices which are prominent habitat fishes and other fauna (Menbere & Menbere, 2018).

Protected areas

Protected areas such as national parks and biosphere reserves are the cornerstones of almost all national and international nature-based conservation strategies (Marselle et al., 2019; Xie et al., 2019). In order to conserve biodiversity and combat climate change, Ethiopia has given due attention for establishment and management of protected areas (Zegeye, 2018). In Ethiopia Gebe Sheleko, Nech Sar, Bale Mountains, Awash, Aibijatta-Shalla and Alitash national park are supporting fish species. For example, in the Gebe Sheleko national park, 10 fish species are identified (Mekonen & Hailu, 2021), and 43 fish species identified in the Alitash national parks (Eyayu, 2019).

Areas of terrestrial and marine ecosystems known as "biosphere reserves" work to find ways to balance the conservation of biodiversity with its sustainable usage (Ayalew & Alemu, 2021). There are now 5 internationally certified biosphere reserve areas in Ethiopia that protect biodiversity, including fish, by a natural manner (Zegeye, 2018) as NbS. Kafa with Yayo, Sheka, Lake Tana, and Majang were nominated in 2010, 2012, 2015, and 2017, respectively (Ayalew & Alemu, 2021; Tadese et al., 2021). The management of our fisheries is made possible by all the biosphere reserves that house a variety of fish (Tadese et al., 2021).

For example, Lake Tana biosphere reserve is a hotspot of biodiversity and a potential home for different fishes and other aquatic fauna and flora (Ayalew & Alemu, 2021). Lake Tana fishes have many natural habitats includes tributary rivers (over 60 rivers and streams), natural vegetation (i.e., riverine, swamp, floodplains and lake shore vegetation), wetlands and flood plains (Mengistu et al., 2017), which are the NbS as mentioned above (Section 2.2). Majority of the wetlands distributed along the tributaries and around the lake shores and estimated to cover 2.14% of its total surface area which support many endemic and globally threatened fish species, and provided various goods and services to many people (Mohammed & Mengist, 2018). More than 90% of the catch in Welala and Shesher wetlands of Lake Tana contributed by Clarias gariepinus and other endemic species. This implies that these wetlands are ideal spawning and nursery habitats for fishes (Anteneh et al., 2012). In Lake Tana three biosphere reserve zones (potential core zones, buffer areas and transition zones) were already identified. These zones are very important and can be the solution to minimize the risk of wetlands and the lake ecosystem as a whole (Dejen et al., 2017; Mohammed & Mengist, 2018). Therefore, implementation of biosphere reservation could be one of NbS for fishery management.

The fisheries management plan for Lake Tana has been developed and adopted by the local government on September 2015 (Dejen et al., 2017). To promote fish recruitment, it is important to reduce the fishing pressure on the breeding populations. To achieve this, fishing in the inflowing rivers of Lake Tana and 5 km of the river mouths will be closed for fishing every year from July to October. Wetlands around Lake Tana like Welala and Shesher will be closed from any fishing activities during the rainy season (Dejen et al., 2017).

Different management options appropriate for the Lake Tana catchment also were identified and broken-down to different levels, introduced in the drivers-pressure-state-impact-responses (DPSIR) framework. The adopted DPSIR framework, therefore, provides a conceptual understanding of the interactions between anthropogenic pressures, state changes and potential management options in the lake catchment and stimulates efficient communication among policy makers, scientists and the public, improving the cooperation among them (Gebremedhin et al., 2018). As a result, among the suggested management options, policy revision and proper implementation, stop flood recession agriculture, limitation of fertilizer and pesticides, build waste treatment plant, waste recycle, soil and water conservation, afforestation, buffer zone delineation, proper policy implementation, wetland restoration, provide alternative livelihood could be NbS for Lake Tana fisheries. There are also various soil and water conservation programs implemented in Guna-Tana watershed, within past 17 years and there is tendency of increasing vegetation regeneration, productivity and maintenance of ecosystem health in a watershed (Gella, 2018).

Blue economy initiative

The concept of the blue economy, introduced in 1992, refers to activities originating from or reliant on marine and aquatic ecosystems, including oceans, coasts, seas, rivers, lakes, and groundwater. It was later referenced in the African Union's Agenda 2063 in 2014, aiming to transform Africa's socio-economic development (Nagy & Nene, 2021). The Blue Economy promotes a multispectral and integrated approach towards sustainable management of these activities for socioeconomic transformation and sustainable development (UNECA, 2016). It aims to promote economic growth, social inclusion, and livelihood preservation while ensuring the environmental sustainability of oceans and coastal areas (World Bank & UNDEA, 2017). The concept acknowledges that healthy freshwater and ocean ecosystems can lead to aquatic and maritime economies, benefiting both islands and landlocked states (UNECA, 2016).

The Africa Blue Economy Strategy aims to guide African Union member states and regional institutions in formulating national and regional blue economy strategies that promote socio-economic transformation and growth (Nagy & Nene, 2021). It outlines key drivers of change shaping the continent's blue economy development, strategic and technical challenges, and priority areas for sustainable development. One of the strategy's consolidation thematic areas is fisheries, aquaculture, conservation, and sustainable aquatic ecosystems (AU-IBAR, 2019). Ethiopia, one of the 13 African Union member state, has provided projects related to the blue economy, demonstrating its commitment to marine and coastal ecosystems (AU-IBAR, 2019; UNECA, 2016).

Conclusion and Recommendations

NbS is an integrated approach to addressing societal challenges like climate change and biodiversity loss while supporting sustainable development. NbS involves actions to protect, sustainably manage, and restore natural or modified ecosystems. Wetlands are considered NbS due to their richness in fish species and habitat variability, as well as their vegetation providing protective cover and feeding areas. Riparian vegetation plays a critical role in the life cycles of many fish species, providing physical habitats and supplies for breeding, spawning, growth, feeding, and predation protection. Natural river protection and restoration can sustain and enhance fish production. NbS in fisheries can be managed through FCZs, heritage or wild rivers,

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inland fishery reserves, and riparian buffer zones.

NbS are cost-effective interventions that can improve fishery management and production by enhancing resilience, restoring and rehabilitating fish habitats, mitigating climate change, conserving biodiversity, and creating income and jobs for fishers. They have the potential to outperform end-of-pipe solutions for freshwater fishery protection. Despite challenges, recent progress in Ethiopia shows promise for implementing NbS in aquatic habitat restoration, rehabilitation, and fishery management.

Ethiopia's NbS practices, such as restoring and reforestation of landscapes, sustainable land, water, and forest management, and a climate-resilient green economy, are enabling opportunities for NbS in Ethiopian fisheries. However, there is potential for improvement in its effectiveness and contribution to fisheries and freshwater management. Academics and investors must resolve barriers to ensure that NbS is treated equally with other choices for fisheries and water resource management.

The review highlights several promising Nature-based solutions initiatives in the world's inland fisheries and Ethiopia. However, more benefits can be achieved by scaling these actions across the country and adopting best practices. Recommendations include strengthening NbS into fisheries management policies, promoting awareness-creation among local people and stakeholders, fostering proactive collaboration among sectors to leverage funding sources, adhering to available standards and guidelines, leveraging financing, creating an enabling regulatory and legal environment, improving cross-sectorial collaboration, and improving the knowledge base. Further research, including social and economic perspectives, is needed to assess NbS more comprehensively and develop a more robust evidence base to support NbS implementation practice.

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