Aquaculture and Nature-based Solutions

Identifying synergies between sustainable development of coastal communities, aquaculture, and marine and coastal conservation

R. le Gouvello, C. Brugere and F. Simard

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Cover photo: Women harvest seaweed for soap, cosmetics and medicine, Zanzibar, Tanzania (© Shutterstock)

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Foreword

The AquaCoCo project

The Aquaculture, Coastal Communities and Conservation (AquaCoCo) project falls within the implementation of the Aichi Biodiversity Target 11 on marine biodiversity protection and Aichi Biodiversity Target 6 on sustainable fisheries (SCBD, 2010), and SDG 2 on food security and SDG 14 on ocean, seas and marine resources. AquaCoCo aims at strengthening the sustainable development and social-ecological resilience of coastal and island communities, by providing the means to improve food security and socio-economic stability, particularly in tropical areas (including coral and mangrove ecosystems).

The AquaCoCo project extends and enriches the work started by IUCN in 2014 on the topic of aquaculture and marine protected areas (MPAs), which has so far resulted in two main outputs,[1] i.e., exposing the challenges of reconciling aquaculture projects with MPA conservation objectives, and proposing an approach that is based on case studies and scientific expert reports.

The AquaCoCo project aims at further exploring the potential synergies between mariculture (Box 1) and marine conservation. The project is funded by the French Development Agency (AfD), under the framework of the France-IUCN Partnership and implemented by the IUCN Global Marine and Polar Programme, and the Ecosystem-based Aquaculture Group (E-bAG) of the IUCN Commission on Ecosystem Management (CEM). AquaCoCo includes a pilot case study on Zanzibar seaweed culture conducted in 2018–2019 as well as other ongoing case studies.

Box 1: Definitions of aquaculture and mariculture

According to FAO (Troell, 2013), aquaculture is the farming of aquatic organisms, including fish, mollusks, crustaceans and aquatic plants. Farming implies some sort of intervention in the rearing process to enhance production, such as regular stocking, feeding, or protection from predators. Farming also implies individual or corporate ownership of the stock being cultivated ... FAO (2020) explains: "Mariculture, or marine aquaculture, is conducted in the sea, in a marine water environment. For some species whose production relies on the naturally occurring seed in the sea, the production cycle is entirely in the sea. For those species that rely on seed produced from hatchery and nursery facilities even in freshwater, mariculture represents the grow-out phase of the production cycle. Because countries usually combine production from coastal aquaculture and mariculture for data reporting to FAO, it is difficult to separate mariculture from coastal aquaculture figures... It is practised in completely or partially artificial structures in areas adjacent to the sea, such as coastal ponds and gated lagoons."

1 - Booklet: https://portals.iucn.org/library/sites/library/files/documents/Rep-2017-003.pdf
- Scientific publication: le Gouvello, R. et al. (2017). "Aquaculture and marine protected areas: Potential opportunities and synergies". *Aquatic Conservation. Marine and Freshwater Ecosystems* 27(51): 1–13. https://doi.org/10.1002/aqc.2821

The Zanzibar case study led to various specific deliverables including:

- reports of the work conducted in Zanzibar (Brugere et al., 2019; Brugere et al., 2020a);
- a document presenting Aquaculture and Marine Conservation in Zanzibar (IUCN, 2020b) as the first case study of an IUCN collection of case studies illustrating the topic of Aquaculture and Marine Conservation;
- a documentary film: “A common challenge, Aquaculture and Marine conservation”; and
- and a specific evaluation of coastal aquaculture as a Nature-based Solution (NbS) in Zanzibar.[2]

New case studies of the collection Aquaculture and Marine Conservation were released in 2021. They describe situations in:

- Tunisia: Monastir Bay, finfish farming and the MPA of the Kuriat Islands,
- Indonesia: Berau Regency, brackish water pond extensive polyculture, including shrimps, Coastal and Small Islands Conservation Area (KKP3K) of the Derawan Islands and Surrounding Waters (KDPS),
- French Polynesia: Reao atoll, cultivation of the giant clam and the Reao’s MPA.

Complementary to the pilot study in Zanzibar and the other case studies of Aquaculture and Marine Conservation, this synthesis intends to discuss the connection between aquaculture and NbS. The documents produced in the framework of this project will be used to promote aquaculture and conservation issues at global, national, and regional levels. In particular, the results of the AquaCoCo project were presented at the IUCN World Conservation Congress in 2021 in Marseille, France, a major event for conservation issues (session on September 6, 2021).

Woman producer of sea cucumber in Zanzibar (Photo credit: © R. le Gouvello)

2 The short evaluation report of seaweed farming in Zanzibar as an NbS, using the IUCN NbS Global Standard framework, is being reviewed, and will become available under a specific hyperlink (see Box 7).

Executive summary

The present report examines the emerging concept of Nature-based Solutions (NbS) and the IUCN Global Standard (IUCN, 2020a) when applied to social-ecological systems that include aquaculture production.

Aquaculture production has very significantly increased in tonnage and value over the last decades. It is seen as a potential solution to replace the declining wild fishery stocks, therefore addressing SDG 2, food safety, and many other SDGs (FAO, 2018; Hambrey, 2017; FAO, 2020; Costello et al., 2020; Stentiford et al., 2020). However, this impressive growth in worldwide aquaculture production has also been associated with critical environmental and social drawbacks (Aubin et al., 2019; Edwards, 2015; Weitzman et al., 2019), highlighting the need for new approaches reconciling aquaculture with conservation and societal benefits (Le Gouvello et al., 2017).

Section 1 of the report reviews the critical contextual situation, highlighting major issues related to climate change, biodiversity losses and endangered marine ecosystems. It stresses the need for new approaches, such as the concept of NbS, to improve human ability to implement Sustainable Development and to reach the UN Sustainable Development Goals (SDGs) (UN, 2015).

The discussion about NbS in the next sections is inspired by the IUCN definition, principles and criteria proposed by Cohen-Shacham et al. (2016 & 2019), and by the recently developed Global Standard for NbS™ (IUCN, 2020a). Section 2 briefly reviews the eight criteria in the Global Standard, which presents a strong anthropogenic connotation (IUCN, 2020a), and highlights that the central scientific concept of NbS is embedded in ecosystem-based approaches and management. Instruments for the evaluation of ecosystem services (ES), and the degree of ecological engineering, are essential parts in the NbS design and assessment.

Section 3, which focuses on aquaculture, reviews the eight criteria of the Global Standard for NbS™. These are subsequently reviewed, taking into consideration the prevailing issues in aquaculture:

- The major, central and prevailing concept of Ecosystem Approach for Aquaculture (EAA) embeds aquaculture in sustainability and appears fully in accordance with most NbS criteria.
- The seven listed societal challenges that are proposed in NbS Criterion 1 would have to be specifically addressed in aquaculture as most aquaculture projects are targeted for their food, health and income benefits, but may be detrimental to the other proposed societal challenges, such as climate change mitigation or environmental protection.
- The successive scale approach described in the EAA may specifically illustrate NbS Criterion 2 that explains how NbS should be defined with respect to one scale, but potentially integrating broader spatial and temporal scales.
- The biodiversity net gain (NbS Criterion 3) that NbS should target may be difficult to demonstrate in aquaculture, a sector often criticised for its adverse effects on ecosystem integrity. However, through the exploration and valuation of ecosystem services (ES) with aquaculture, it would be possible to point out some aquacultural systems which contribute to enhance ES, such as some bivalve or seaweed cultures,

as long as a full and robust assessment is conducted on the targeted ES in consultation with all stakeholders (Aubin et al., 2019).

- Economic viability, as explained in NbS Criterion 4, clearly refers to ongoing critical discussions around aquaculture. However, some authors are now advocating for a more equitable aquaculture (Eriksson et al., 2018), a broader vision of the value chain, and more social and inclusive aquaculture (Kaminski et al., 2020) that is community-based and well-being oriented (Ateweberhan et al., 2018; Campbell et al., 2021).
- Indeed, one key element for better sustainability in aquacultural systems is the willingness of aquaculture actors to engage in a dialogue with other stakeholders, and to promote relevant and efficient governance systems (Rey-Valette et al., 2008). This requirement is in line with NbS Criterion 5 and appears quite challenging in many aquaculture systems (Vince & Haward, 2017; Davies et al., 2019).
- In fact, most NbS criteria are interconnected and clearly share the principles of EAA, as defined by Soto et al. (2008). In addition to specific NBS Criteria 3 and 6, both NbS and EEA call for the development of aquaculture and the need for it to be mainstreamed in regional, national and supranational policies. It should be done in accordance to the SDGs, Blue Economy, Blue Growth, the protection of the marine and coastal ecosystems, and the integrated management of coastal and marine zones.

Section 4 examines the NbS framework as an opportunity to enhance the sustainability of aquacultural systems by focusing on three aspects:

- While EAA is advocated as a general framework to reach sustainable aquaculture (Figure 11), it is worth noting that it has been widely recognised as being so far disappointing in its actual implementation and expansion since its launch 10 years ago (FAO, 2018; Brugere et al., 2018). The release of the Global Standard for NbS™ could offer an opportunity in 'reinvigorating' EAA, by being more operational and combining other concepts with EAA. It will also further strengthen the IUCN World Conservation Congress (WCC) 1996 Resolution 018 advocating for a sustainable aquaculture.
- The Global Standard for NbS™ may provide opportunities to re-establish and further develop traditional local *savoir-faire* in aquaculture, as advocated by the IUCN WCC 2020 Resolution 045 for the creation of a Global Indigenous Network for Aquaculture (GINA). The restoration of traditional coastal ponds in Hawai'i illustrates this situation.
- The Global Standard for NbS™ could provide new opportunities to explore synergies between aquaculture and marine protection. Concepts, such as ES, need to be further explored in aquaculture systems as some over-interpretation and misleading results may appear in cases missing a rigorous, science-based and holistic approach (Alleway et al., 2018; Custódio et al., 2019; Aubin et al., 2019; Muir et al., 1999). An attempt to classify aquaculture systems within a scale of ecological complexity, preservation and restoration is proposed with various examples (Figure 12).

In Section 5, the discussion highlights the following facts:

- The proposed new NbS approach may participate in an overall 'reinvigorating' effect on EAA that Brugere et al. (2018) and FAO (2018) advocate, providing new opportunities to implement EAA and other concepts. The NbS approach may also contribute to reduce weaknesses that have been acknowledged in the implementation of EAA, i.e. such as the need of targeting societal and biodiversity

to target societal and biodiversity benefits within aquacultural systems, strengthen an integrated approach and a robust governance system adapted to the scale of the aquaculture-related NbS.
- One of the expected positive outcomes, when the NbS framework is applied to aquaculture, is its ability to translate the complexity of assessing the sustainability of coastal social-ecological systems, including an aquaculture component, into practical, local and specific terms.
- In this report, several examples of aquaculture systems indicate that some may be considered as potential NbS, provided that a full and holistic assessment is made on each aquaculture-related solution, in compliance with the NbS Global Standard (IUCN, 2020a). Potentially, it may be said that many kinds of aquaculture systems could be considered as NbS. This would be true as long as an aquaculture-related NbS candidate meets all NbS criteria and is documented to an acceptable level to assess benefits, impacts, trade-offs, and positive and negative externalities (IUCN, 2020a).
- However, in the context of the present discussion, the Type 3 (Eggermont et al. 2015, box 2) NbS degrees (see Box 2) of engineering and human intervention are still being debated among various authors. A discussion and clarification are therefore still needed to determine whether aquaculture-related systems are considered as acceptable NbS, considering the extent of human-based artificial inputs and actions involved in the system. It may be rather difficult in aquaculture to distinguish between a solution that is dependent on '*natural*' ecosystems, and a solution that is based upon a quite artificial aquacultural system, well managed, but decoupled from '*naturalness*'.
- Similarly, it might also be critical for some aquacultural systems to provide clear evidence of a 'net benefit' for biodiversity as required by Criterion 3 of the NbS Global Standard (IUCN, 2020a). For instance, even for seaweed farming in coastal conditions, the Zanzibari case study (Box 7) shows that precautions need to be taken in the management of aquaculture activity regarding the integrity of seagrass beds.

This publication is a first attempt to examine aquaculture systems within the recent framework of the IUCN Global Standard (IUCN, 2020a). It is concluded in Section 6 that the concept of NbS may provide new opportunities to implement existing concepts for aquaculture, such as EAA, and contribute to clarifying some critical issues in aquaculture. This finding advocates for further exploration of aquaculture-related potential NbS based on specific case studies.

In all respects, it is highlighted that the NbS concept and Global Standard applied to aquaculture systems both contribute to further support and strengthen the implementation of the full text of the two WCC IUCN Recommendation and Resolution related to aquaculture (WCC 1996 Rec 018; WCC 2020 Res 045).

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List of acronyms

AquaCoCo	Aquaculture, Coastal Communities and Conservation
AZA	Allocation Zone for Aquaculture
BE	BioEconomy
BGI	Blue Growth Initiative
CBD	Convention on Biological Diversity
CCRF	Code of Conduct for Responsible Fisheries
CE	Circular Economy
CEM	Commission on Ecosystem Management
COP	Conference of the Parties
EA	Ecosystem Approach
EAA	Ecosystem Approach for Aquaculture
EbA	Ecosystem-based Adaptation
EbAG	Ecosystem-based Aquaculture Group
EbM	Ecosystem-based Mitigation
EE	Ecological Engineering
Eco-DRR	Ecosystem-based Disaster Risk Reduction
ER	Ecological Restoration
ES	Ecosystem service
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Profit
GINA	Global Indigenous Network for Aquaculture
ICM	Integrated Coastal Management
ICZM	Integrated Coastal Zone Management
IMTA	Integrated Multi-Trophic Aquaculture
IUCN	International Union for Conservation of Nature
IPCC	Intergovernmental Panel on Climate Change
LCA	Life Cycle Analysis
MPA	Marine Protected Area
MSP	Marine Spatial Planning
NbS	Nature-based Solutions
PA	Protected Area
RSM	Restorative Shellfish Mariculture
SD	Sustainable Development
SDG	Sustainable Development Goal
SES	Social Ecological System
TEEB	The Economics of Ecosystems and Biodiversity
UN	United Nations
USD	United States Dollars
WCC	World Conservation Congress

Seaweed from aquaculture drying in Zanzibar
Photo credit: © R. le Gouvello

1. Introduction

1.1 The need to find solutions in response to ocean and coastal issues

As emphasised by the scientific community, the time has come to face the emergency of climate change and the biodiversity crisis (Eggermont et al., 2015; Steffen et al., 2015; Ripple et al., 2017; Crutzen & Stoermer, 2000). Degraded ecosystems are impacting vital functions, threatening food security, water resources, air quality, and thus affecting world populations (UN, 2019; UN, 2021a).

The role of the ocean in regulating climate and safeguarding the richness of world biodiversity has been emphasized since the COP 21 and was promoted by the Ocean & Climate Platform[3] who brought attention to the impacts of climate change and biodiversity degradation on marine ecosystems. The InterGovernmental Panel on Climate Change (IPCC) special issue reported on the impacts of climate change on ocean and coastal systems and their consequences on coastal populations (IPCC, 2019). This critical situation was further highlighted in recent United Nations ocean reports (UN, 2021a; UN, 2021b; Pörtner et al., 2019). Coastal areas[4] concentrate 23% of the world population and are deemed particularly vulnerable to climate change effects as well as biodiversity losses (Goussard & Ducrocq, 2017). In the frontline, coastal activities related to seafood production, fisheries and aquaculture are a major component of present and future nutritional food supply and of some regional coastal economies, and will be impacted by climate change (Salz & Macfadyen, 2007; Costello et al., 2020; FAO, 2020; Barange et al., 2018). In addition, in Laffoley and Baxter (2019), experts point out that significant deoxygenation is occurring in deep seas and in coastal waters due to temperature rise, among other factors, further threatening the future of marine social and ecological systems. Therefore, the need for strengthening ocean conservation, as well as an urgent need for adaptation of coastal social-ecological systems to respond to these growing threats, is pointed out in recent publications (Laffoley & Baxter, 2016; Laffoley & Baxter, 2019; le Gouvello et al., 2017).

Since the 1970s, a growing awareness of ecological issues, and the emergence of the concept of sustainable development (SD) (Meadows et al., 1972; UNGA, 1987), have been proposed to face ecological threats, and translate them into international and national policies and commitments. An example of these are the Sustainable Development Goals (SDGs), adopted by the United Nations (UN, 2015), one of which is fully devoted to the ocean (SDG 14). In addition, the Strategic Plan for Biodiversity 2011-2020 and the Aichi biodiversity targets defined Target 11 on marine biodiversity protection and Target 6 on sustainable fisheries by 2020, and proposed to increase the creation of marine protected areas (MPAs) as a key tool for achieving Aichi targets in coastal and marine ecosystems (CBD Secretariat, 2010; le Gouvello et al., 2017).

In this critical context, new concepts and approaches are being constantly proposed

3 Ocean & Climate Platform: https://ocean-climate.org

4 According to IPCC, coastal areas encompass land within 100 km from the coastline and an elevation of less than 10 meters above sea level (IPCC, 2019, Cross Chapter, Box 9)

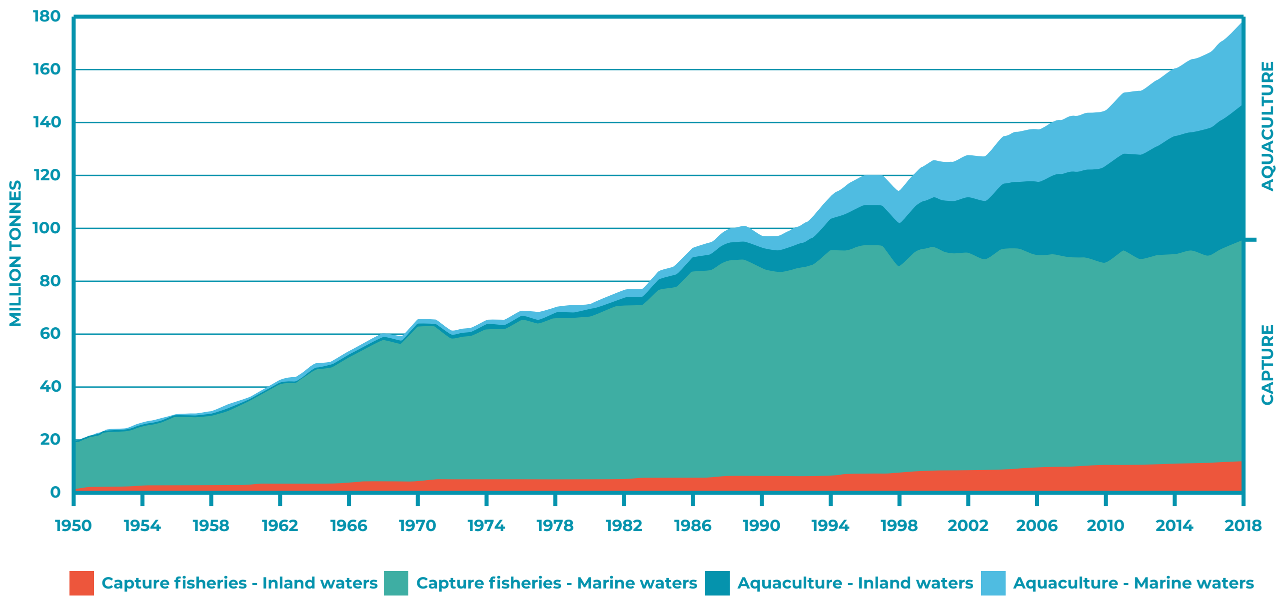
and explored to enhance the way the three pillars of SD are addressed. Nature-based Solutions (NbS) were proposed by IUCN in 2009 and quickly incorporated by the European Commission as a new approach to achieve SD (Cohen-Shacham et al., 2016; Cohen-Shacham et al., 2019; Eggermont et al., 2015). The IUCN released the IUCN NbS Global Standard in 2020 (IUCN, 2020a). Meanwhile, other concepts that are emerging to reconcile the three pillars of SD may also be related to NbS, such as circular economy, bioeconomy, regenerative economy, deep ecology, or blue economy (D'Amato et al., 2017; Loiseau et al., 2016; le Gouvello, 2019).

In addition, the present worldwide major sanitary and economic crisis is further highlighting the need to question and re-explore the pathways towards SD.

1.2 The steady rise of aquaculture

Capture fishery production has been relatively static since the late 1980s (Figure 1). More than one third of the marine fish stocks are still considered as overfished, despite all the control measures of fisheries that have been implemented (FAO, 2020). FAO (2020) recognizes that the persistence of overfished stocks is a great concern and stock rebuilding will require time and collective endeavours. As the world's population is expected to reach 9.7 billion by 2050, global fisheries will continue to be under pressure in order to meet this future demand for food fish (UN, 2015; UN, 2021b).

Attention is gradually being drawn to aquaculture as one option to meet this shortfall, as it has been responsible for the continuing impressive growth in the supply of fish for human consumption. Figure 1 shows that global fish production peaked at about 179 million tonnes in 2018, with aquaculture[5]



NOTE: Excludes aquatic mammals, crocodiles, alligators and caimans, seaweeds and other aquatic plants.
SOURCE: FAQ

Figure 1: World capture fisheries and aquaculture production

(Source: FAO, 2020)

5 Excluding aquatic mammals, crocodiles, alligators and caimans, seaweeds and other aquatic plants. Aquatic plants and seaweeds accounted for 32.4 million tonnes in 2018.

representing, respectively, 46% (82.1 million tonnes) of the total and 52%, if non-food uses (including reduction to fishmeal and fish oil) are excluded (FAO, 2020). The total first sale value of aquaculture production in 2018 was estimated at USD 263.6 billion (farm gate value). A major part of future growth in fish production is expected to originate from aquaculture, which is projected to reach 109 million tonnes in 2030 and become the main supply for food fish in the world (FAO, 2020). Recent studies by Costello et al. (2020) project that edible food from the sea could increase by 21–44 million tonnes by 2050, a 36–74% increase compared to current yields, the major increase in potential coming from mariculture.

It is now recognised that aquaculture is an important activity in terms of SD for coastal communities, playing a role in food security, poverty alleviation and economic resilience, and providing services to marine ecosystems in some cases (Alleway et al., 2018; Custódio et al., 2019; FAO, 2020). According to some authors, aquaculture is key to achieving the entire set of SDGs (Brugere et al., 2018; Hambrey, 2017). However, the question of poor sustainability of some aquaculture systems has frequently been raised over the past decades (Alleway et al., 2018; Aubin et al.; 2019, Edwards, 2015; Soto et al., 2012). In fact, the WCC 1996 Res 018 motion voted by the IUCN Congress in 1996 advocated the "need for ensure that all aquaculture within their areas of jurisdiction is responsible and sustainable". On the other hand, aquaculture might meet the requirements to help achieve both conservation and local community resilience, although solely under certain conditions and situations (Le Gouvello et al., 2017). Making the idea of reconciling nature conservation and SD possible through the implementation of aquaculture projects in MPAs, or close to MPAs, may require a further look at the conditions to permit such mutual benefits.

1.3 Report objectives and structure

As a follow-up to le Gouvello et al. (2017), this publication further looks at synergies between aquaculture, MPAs *and* coastal community livelihoods, referring to the three pillars of SD. To be successful, MPAs need to be integrated within local contexts; they need to embrace, where at all possible and appropriate, sustainable economic activities, fisheries, aquaculture, tourism and other activities, and be managed in accordance with conservation objectives (FAO, 2018; le Gouvello et al., 2017). This publication discusses potential synergies between aquaculture and marine conservation, by looking at the emerging concept of NbS as an opportunity to explore relevant/illustrative case studies. A direct link with the former work by le Gouvello et al. (2017) is made through the investigation of the NbS concept as it is applied to aquaculture. Clearly, the creation and the management of MPAs should meet the NbS Global Standard criteria by definition, if well-designed and managed with local communities (Cohen-Shacham et al., 2016; IUCN, 2020a).

In this document, Section 1 explains the general context. Section 2 introduces the NbS concept, and discusses the recent IUCN NbS Global Standard and associated criteria (IUCN, 2020a). In Section 3, focusing on aquaculture, the eight criteria of the NbS Global Standard are successively reviewed and considers the prevailing issues in aquaculture. Section 4 examines the NbS framework as an opportunity to enhance the sustainability of aquacultural systems in focusing on three aspects: i) the Ecosystem Approach for Aquaculture (EAA) re-enforced with NbS framework; ii) the opportunity to emphasize local knowledge and traditions in aquaculture, and iii) the further exploration of synergies between aquaculture and marine conservation.

In Sections 5 and 6, the discussion and conclusions open an agenda of future work in exploring aquaculture-related NbS. The findings will be tested through a detailed case study on Zanzibar seaweed culture, which will lead to the publication of a separate report (Box 7 presents preliminary findings).

This publication will therefore aim at answering the specific questions:

- How could aquaculture constitute a true, valid and relevant NbS based on the IUCN Global Standard framework for NbS?
- How could aquaculture-related NbS address societal challenges, reconcile economic and ecological targets, together with present and future needs, and well-being of stakeholders and local communities?
- How could aquaculture systems meet the recent NbS Global Standard criteria?

Scottish salmon farm on the West coast of Scotland (https://www.scottishsalmon.co.uk/)

2. Nature-based Solutions

2.1 History, definition and related concepts

The creation of the 'Nature-based Solutions' term goes back to the late 2000s, as reported by Eggermont et al. (2015). The IUCN refers to NbS in a position paper for the United Nations Framework Convention on Climate Change in 2009, after which the term has been quickly taken up by policy, viewing NbS as an innovative means to create jobs and boost green economy. In particular, the EU adopted the term in its Horizon 2020 Framework Programme (EC, 2015 & EC, n.d.).

Definition of NbS: "*Nature-based Solutions are actions to protect, sustainably manage and restore natural and modified ecosystems in ways that address societal challenges effectively and adaptively, to provide both human well-being and biodiversity benefits*" (IUCN, 2016; 2020a)

Maes and Jacobs (2017) and Eggermont et al. (2015) emphasise that the European Commission's understanding of NbS is more oriented to "offer a credible transition path of realistic incremental steps toward a sustainable economy", whereas IUCN focuses on natural ecosystems and human well-being. Nesshöver et al. (2017) advocate for a clarification of the NbS concept, as it may lead to some misinterpretation, oversimplification, etc. In response to this risk of having an NbS concept which is too vague, and not rigorous enough (Nikolaidis et al., 2017), Cohen-Shacham et al. (2019) further attempt to explain the concept of NbS, its principles and how it relates to other concepts. The IUCN Secretariat and Commission on Ecosystem

Figure 2: Conceptual framework for NbS
(Source: IUCN,2020a)

Management (CEM) has actually taken the lead to create a common understanding and consensus on NbS, and to elaborate a Global Standard for the Design and Verification of Nature-based Solutions, through a consultative process finalised in July 2020.[6] Consequently, in this publication, we rely on the IUCN definition, principles and criteria, as proposed by Cohen-Shacham et al. (2016, 2019), and in accordance to the recent released Global Standard for NbS™ (IUCN, 2020a) (Figure 2).

For the majority of authors, NbS relate to the overlapping concepts of ecological engineering and catchment systems engineering (including ecological restoration), green/blue infrastructure, ccosystem approach (EA), ecosystem-based adaptation (EbA), ecosystem services (ES), and natural capital (Nesshöver et al., 2017).

For Cohen-Shacham et al. (2016), NbS is an 'umbrella' term covering various concepts, mainly within ecosystem-related approaches. Cohen-Shacham et al. (2016) provide a useful analogy between EbA and NbS, comparing EbA to a "legal constitution", whereas NbS would be more operational, with laws or directives. NbS closely relate to all ecosystem approaches, from conservation tools up to the stages of restoration of an ecosystem which has been degraded. It includes innovations, ecological restoration,[7] and a degree of ecological engineering.

2.2 Evaluation of NbS

The evaluation of NbS remains an open field of research. Some work has been done, namely for urban NbS, providing frames for such evaluation (Eggermont et al., 2015; Maes and Jacobs, 2017; Raymond et al., 2017; van den Bosch & Sang, 2017).

Cohen-Shacham et al. (2016) adopt a narrative frame and report various NbS examples as case studies, by explaining the general background, the main activities related to the proposed NbS, as well as the results and lessons. These were expressed with quantified indicators, and an estimation of the up-scaling potential of the NbS is provided. The explored lessons deal with the level of collaborations required, the identified pitfalls, ways to go for improvement, recommendations and action plans. In addition, Cohen-Sacham et al. (2016) insist upon the fact that candidate parameters for an NbS operational framework should include ecological complexity, long-term stability, scale issues, direct societal benefits and adaptive governance.

To address the complex issues as pointed out in the previous section, Nesshöver et al. (2017) present a list of "successive questions to provide a logical approach to distinguishing unwanted or even potentially harmful aspects of the 'solutions' chosen" for NbS.

However, the present IUCN NbS Global Standard provides an opportunity to design, evaluate and monitor NbS in the near future under a clarified framework (IUCN, 2020a). The eight criteria are listed below (Table 1), each of them is detailed with guidance and indicators. The implementation of NbS is a dynamic and adaptative process — all the criteria and indicators are interconnected (Figure 3).

6 https://www.iucn.org/commissions/commission-ecosystem-management/our-work/nature-based-solutions

7 Definition of ecological restoration: "The process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed." (Cohen-Shacham et al., 2016, p. 17).

Table 1: NbS Global Standard criteria

NbS Global Standard Criterion	
Criterion 1	NbS effectively address societal challenges.
Criterion 2	Design of NbS is informed by scale.
Criterion 3	NbS result in a net gain to biodiversity and ecosystem integrity.
Criterion 4	NbS are economically viable.
Criterion 5	NbS are based on inclusive, transparent and empowering governance processes.
Criterion 6	NbS equitably balance trade-offs between achievement of its primary goal(s) and the continued provision of multiple benefits.
Criterion 7	NbS are managed adaptively, based on evidence.
Criterion 8	NbS are sustainable and mainstreamed with an appropriate jurisdictional context.

(Source: IUCN, 2020a)

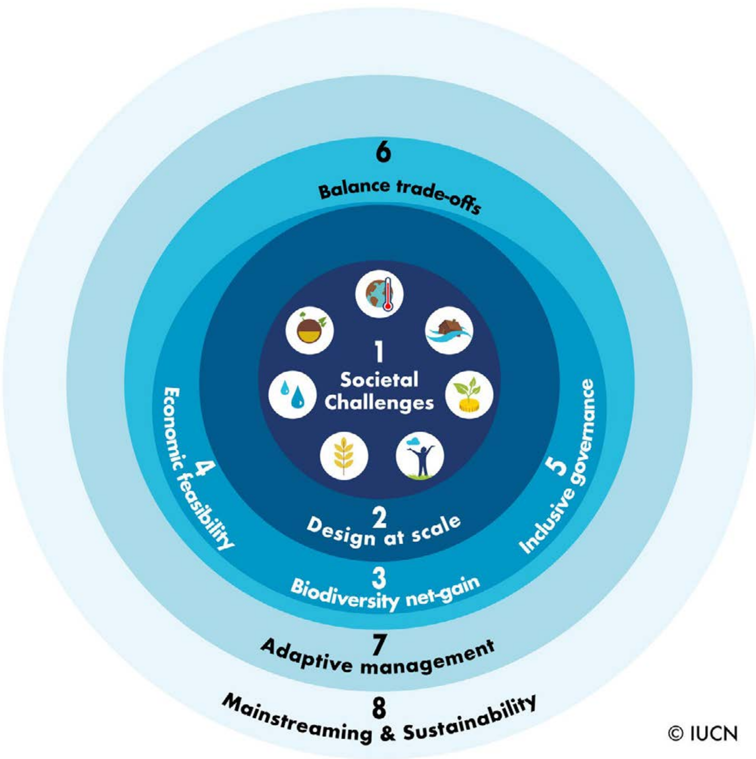


Figure 3: The eight criteria that make up the IUCN Global Standard for NbS™ are all interconnected

(Source: IUCN, 2020a)

2.3 Some key issues about NbS Global Standard criteria

2.3.1 Societal challenges

NbS are interventions aimed at solving societal challenges (Criterion 1) (IUCN, 2020a). Raymond et al. (2017) propose an NbS assessment framework considering 10 challenge areas (such as climate mitigation and adaptation, social cohesion, etc.), as well as indicators and methods for assessing NbS. Most NbS would in fact need to be multi-targeted and multi-faceted (Cohen-Shacham et al., 2016), although they may be assembled within one particular target, such as "Nature-based Solutions for food security, Nature-based Solutions for disaster risk reduction, Nature-based Solutions for climate change". The European Commission (2015) provides a list of more than 300 examples of NbS designed for various issues, such as climate regulation, coastal regulation, etc.

For Cohen-Shacham et al. (2019), NbS have the potential to substantially contribute to the 2030 SDGs, as they are directly relevant to SDG 2 (food security), SDG 3 (health and well-being), SDG 6 (clean water and sanitation), SDG 11 (sustainable cities and communities), SDG 13 (climate change), SDG 14 (conservation and sustainable use of oceans, seas and marine resources) and SDG 15 (protection, restoration and promotion of sustainable use of terrestrial ecosystems).

These targets, as well as others, should be identified, as clearly stated in Criterion 1 of the IUCN Global Standard (IUCN, 2020a), according to Figure 4, which emphasises seven major societal challenges.

2.3.2 NbS and implementation scales

Criterion 2, entitled "Design of NbS is informed by scale", is key in the IUCN Global Standard (IUCN, 2020a). In previous publications, it was emphasised that NbS would have to be designed for a defined social and ecological system, referring to the concept of social-ecological system (SES)[8] (Cohen-Sacham et al., 2016; Nesshöver et al., 2017). However, the term SES is not specifically discussed in Cohen-Shacham et al. (2019), although the authors present the 'landscape scale' as a key start for an NbS.[9] The spatialisation of ecosystem-based approaches, through SES as a spatial unit or a 'landscape', has been thoroughly

Figure 4: Major societal challenges addressed by NbS

(Source: IUCN, 2020a)
Note: "The first six challenges, from left to right, were formulated within the IUCN definition (IUCN, 2016). The seventh societal challenge, reversing ecosystem degradation and biodiversity loss, was an outcome of the second public consultation on the Standard" ©IUCN

8 Defined as: "Social-ecological systems are complex, integrated systems in which humans are part of nature." (www.resalliance.org)

9 Cohen-Shacham et al. (2019) refer to landscape, as defined by the European Landscape Convention, as a part of the land, as perceived by local people or visitors, which evolves through time as a result of being acted upon by natural forces and human beings. It is a spatial scale which is important in terms of a continuous flow of key ecosystem services (SCBD, 2011).

investigated in various works by Ostrom et al., including coastal and fishing activities (Berkes & Folke, 1998; Holling, 2001; Le Floc'h et al., 2018; McGinnis & Ostrom, 2014; Ostrom, 2009). Such approach on a limited scale is essential as a means to develop a strategy on a pilot level, while dealing with the complexity of such coastal SES (Berkes, 2006). Consequently, the implementation on a land/seascape scale and the subsequent up-scaling capacity are recognised as key in NbS Global Standard criteria.

The local and bottom-up implementation of NbS is clearly in accordance with the understanding of SD, according to Ward & Dubos, proposing the "glo-cal" "think globally, act locally" approach (Ward and Dubos, 1972). However, recommended to be implemented on a local scale, i.e. "locally-grown", NbS are intended to expand, be as inclusive as possible and integrate larger scales. The NbS capacity to extend to a larger spatial and temporal scale, i.e. its up-scaling potential, becomes a key criterion of NbS success (Keesstra et al., 2018; Raymond et al., 2017). Such up-scaling capacity is equally pointed out by Cohen-Shacham et al. (2019), who express the need for further research. Indeed, if the NbS is extended on larger scales, how are the various NbS benefits maintained in this process of up-scaling?

2.3.3 NbS and biodiversity

NbS should "result in a net gain to biodiversity and ecosystem integrity", states Criterion 3 of the Global Standard (IUCN, 2020a). Indeed, the recent NbS Global Standard insists upon ecosystem services: "NbS harness the services of ecosystems, which are complex, dynamic and self-organising systems" (IUCN, 2020a).

In other words, it means that at the core of NbS, there is the recognition of ecosystem services (ES), referring to the emergence of the concept of ES (Costanza et al., 2017; Custódio et al., 2019; MEA, 2005; TEEB, 2010).). The existing concepts, such as ecosystem services, could thereby usefully inform NbS (Keesstra et al., 2018; Nesshöver et al., 2017; Maes & Jacobs, 2017). A full comprehensive assessment of all ecosystem services should be made, requiring a holistic and systemic approach, comparing nature-based versus technical uses, and looking for locally optimal equilibriums between productivity, adaptability and resilience.

Consequently, a major issue for NbS is related to the understanding of a "truly nature-based" solution, as raised by Nesshöver et al. (2017): "The challenges of NbS as a new umbrella concept for biodiversity and ecosystem stewardship is where to draw the line as to what is considered as 'nature' or 'natural'." How do we consider the biotic and abiotic component of NbS? Are they acceptable? How far do we go into the restoration or the elaboration of a new ecosystem?

The answers to these questions are not easy, as they may very well vary among different stakeholders and communities according to various social and cultural perceptions. For instance, a perception study conducted among aquaculture salmon consumers showed that the acceptation of feeding 'natural' ingredients to the farmed fish could vary from one European country to another, from fishmeal/fish oil formulated diets, up to the case of a salmon "made vegetarian" with vegetal proteins and lipids obtained through plants, or a salmon fed with terrestrial animal proteins and lipids derived from livestock by-products (Debucquet, 2017; Vanhonacker et al., 2010).

In line with this discussion, Cohen-Shacham et al. (2019) refer to the IUCN definition of natural ecosystems as: "Ecosystems with all or most of the species and ecological interactions expected from geography and history, regenerating through natural succession."

For Eggermont et al. (2015), ecological engineering is essential in NbS as long as it complies with the ecological engineering defined by Barot et al. (2012) and reported

Seaweed farming in intertidal zones in Zanzibar (Photo credit: © Aboud Jumbe)

in their publication.[10] Three main types of NbS are identified along two gradients: i) the required level of engineering of biodiversity and ecosystems involved in the NbS ; and ii) the level of enhancement of ecosystem services achievable by the NbS (Cohen-Shacham et al., 2016; Eggermont et al., 2015) (Box 2).

Such discussion (Box 2) on the categorisation of NbS along a gradient of level of ecosystem transformation seems overlooked in the recent NbS Global Standard (IUCN, 2020a). Instead, the NbS Global Standard simply refers to the relationship between ecological complexity and ecosystem services optimisation, and the level of engineering ecosystems. As a net gain on biodiversity must be obtained in Criterion 3 of the NbS Global Standard, various potential NbS can be created, designed on the conservation of natural ecosystems, and ranging between: the highest level of ecological complexity and the lowest level of human transformation, to novel ecosystems, simplified and using the highest degree of anthropogenic transformation.

2.3.4 Participation, empowerment rules and traditional knowledge

Social innovation is important in NbS. Indeed, NbS should address social and biodiversity benefits and imply stakeholders' participation, 'good' governance rules, equity, and well-being improvement (Cohen-Shacham et

10 Ecological engineering is defined as "the development of more sustainable practices informed by ecological knowledge with the aim of protecting and restoring ecological systems, modifying ecological systems to increase the quantity, quality and sustainability of particular services they provide, or building new ecological systems that provide services that would otherwise be provided through more conventional engineering based on non-renewable resources" (Barot et al., 2012).

Box 2: Types of NbS along a degree of ecosystem preservation or restoration - A difficult assessment

As explained and commented by Eggermont et al. (2015) and Cohen-Shacham et al. (2016) three types of NbS can be identified:

- Type 1: solutions that involve making better use of existing natural or protected ecosystems (e.g. measures to increase fish stocks in an intact wetland to enhance food security). Restoring and sustainably managing wetlands and rivers to maintain or boost fish stocks and fisheries-based livelihoods, reduce the risk of flooding, and provide recreational and tourism benefits. Typically, MPAs and protected areas (PAs) are NbS Type 1 for Eggermont et al. (2015).
- Type 2: solutions based on developing sustainable management protocols and procedures for managed or restored ecosystems (e.g. re-establishing traditional agro-forestry systems based on commercial tree species to support poverty alleviation);
- Type 3: solutions that involve creating new ecosystems (e.g. establishing green buildings (green walls, green roofs).

Cohen Shacham et al. (2016) provide examples of NbS Type 2 related to marine and coastal ecosystems: "using natural coastal infrastructure such as barrier islands, mangrove forests and oyster reefs to protect shorelines and communities from coastal flooding and reduce the impacts of sea-level rise". Agro-ecological (Altieri, 2002; Eggermont et al., 2015) systems are part of NbS Type 2. Eggermont et al. (2015) note that boundaries between Types 2 and 3 are not clear. For the European Commission (Eggermont et al., 2015), Types 2 and 3 NbS are anchored in a green growth and SD.

Arguing this last point, Cohen-Shacham et al. (2019) refer to the IUCN definition and principles and indicate that IUCN NbS are strictly focused on protection and management of natural ecosystems, as described in Types 1 and 2 (Eggermont et al., 2015). Yet, the creation of "new ecosystems" as described in Type 3 would only fit in the IUCN NbS framework under some restricted circumstances: "when the purpose is to address societal challenges within a landscape, for example, in a newly constructed wetland to remove nutrients... While acknowledging the utility and need for them in specific contexts, the IUCN definition excludes the creation of interventions that are inspired by nature". In other words, a fully artificial system that is in line with "biomimicry" or "bio-inspiration" or following the principles of "industrial ecology" (as historically defined by Ehrenfeld and Erkman (Erkman, 1997; Ehrenfeld, 2004; Ehrenfeld & Gertler, 1997) is not considered an NbS according to IUCN.

al., 2016). These issues are clearly stated in NbS Global Standard Criteria 5, 6, 7 and 8 (IUCN, 2020a). New forms of public-private collaborations are required, including the need for champions and leaders, to pioneer and manage NbS. NbS may rely on local and traditional knowledge, among other interesting features, and not only exclusively on technical innovation (Eggermont et al., 2015).

2.3.5 Coping with economic viability, trade-offs, uncertainties and adaptative management

Crucial aspects are fully documented under the proposed Criteria 4, 6, and 7 of the Global Standard, such as economic viability, the need to cope with uncertainties and to search for any potential trade-offs, the resulting adaptative management (IUCN, 2020a). These criteria may answer to Cohen-Shacham et al. comments (2019), who were emphasising


Production of mussel (suspended) in Cala Iris, within a protected area, Morocco (Photo credit: © R. le Gouvello)

that risks and uncertainty have yet to be sufficiently explored in NbS.

In previous publications, Eggermont et al. (2015), Cohen-Shacham et al. (2016) and Nesshöver et al. (2017) underscores the need for NbS to deal with uncertainty, complexity and adaptive management, while ensuring that all stakeholders are involved, and that a transdisciplinary knowledge and mutual learning process are made possible through the NbS. Such implementation and evaluation framework will not be easy to follow, as potential synergies and trade-offs between ES and stakeholder's perception may be contradictory. In addition, the NbS analysis should explore all the associated risks "otherwise, NbS could generate problems instead of solutions (e.g. species introduced for pest control can become invasive, if corresponding controls are lacking)" (Eggermont et al., 2015).

Key messages from Section 2:

The central scientific concept in NbS is embedded in ecosystem-based approaches and management.

It presents a strong anthropogenic connotation, as expressed by the successive Global Standard criteria (IUCN, 2020a).

The instruments of the evaluation of ecosystem services (ES), and the degree of ecological engineering, are essential parts in the NbS design and assessment.

3. Applying the IUCN NbS Global Standard to aquaculture

The following Section 3 reviews key issues related to the application of the IUCN NbS Global Standard framework to aquacultural systems, using the eight IUCN NbS Global Standard criteria (see Table 1). In this illustrative exercise, more details are provided to Criteria 1, 2, 3, 4, 5 (discussed, respectively, from sections 3.1 to 3.5). Criteria 6, 7 and 8 are discussed together in Section 3.6, but it does not mean that they are given a lesser attention in future work as all NbS criteria are interdependent, and no hierarchy exists between them.

3.1 Criterion 1: Key societal challenges relevant to aquaculture

At first glance, as pointed out by recent FAO reports (FAO, 2018; FAO, 2020), aquaculture productions are clearly addressing major societal challenges, such as food security, economic and social development and human health (Stentiford et al., 2020). However, the way these challenges are met with aquaculture remains questionable.

For instance, if aquaculture productions are specifically designed for an export market and for a limited number of actors, depriving the local communities to an access to cheap good nutritional seafood products, these productions may contribute to the degradation of the livelihood of local communities. Indeed, seafood products (from fisheries and aquaculture) are recognised as highly exported products, about 37% of the total amounts, most of the time from emerging economies to rich industrialised ones. This trend is contributing to degrade local livelihoods (FAO, 2020; Gephart & Pace, 2015; Watson et al., 2017), although this vision may be contrasted in some cases (Belton et al., 2018).

In addition, other societal challenges, such as climate change adaptation, environmental degradation, disaster reduction and water security, would have to be specifically assessed in solutions involving aquaculture productions, which may have direct negative impacts on these societal issues (Ottinger et al., 2016; Stentiford et al., 2020; Troell et al., 2013). For instance, mangrove degradation associated with the recent development of shrimp farming in coastal areas has significantly contributed to environmental degradation, biodiversity losses, impairing the services associated with mangrove such as disaster risk reduction or climate change mitigation (Davies et al., 2019; Queiroz et al., 2013); Troell et al., 2013). Water quality and water security could be critical issues in continental regions where fish farming is practiced on large scales (Aubin et al., 2014; Aubin et al., 2019; Troell et al., 2013).

Alleway et al. (2018) acknowledge the rapid and recent growth of aquaculture in the last 50 years, as well as the significant environmental impacts, social and economic conflicts that it can create. The authors recognise the considerable progress that has been made over the past decades towards a more ecosystem-based approach for

Figure 5: How aquaculture may address the NbS societal challenges

(Adapted from IUCN, 2020a)
Note: IUCN NbS Global Standard amended with question mark; +/-: aquaculture could positively or negatively address. ?: open question that needs to be addressed

aquaculture. They emphasise that the latter could be further explored and implemented if regulatory impediments and management constraints were retrieved, and if a thorough economic valuation of the ecosystem services provided by aquacultural systems was made. Aubin et al. (2019) draw an interesting parallel between aquaculture development, its "negative trends of last decade" and agriculture development. The recent move of agri-food systems to agro-ecology (Altieri, 2002) could indicate a similar pathway to aquaculture as shown in studies in Brazil (Aubin et al., 2019; Valenti et al., 2018).

Stentiford et al. (2020) review the major challenges that sustainable aquaculture should address by 2050, using the "One Health"[11] lens, a concept that has similar societal challenges as the ones identified by NbS, although the One Health approach is more oriented to public health, in the fields of medical and veterinary sciences (Destoumieux-Garzón et al., 2018).

In addition, the potential for aquaculture mainly lies in warm, tropical areas, where there is a critical need for a "climate-smart aquaculture", specifically designed for local communities in emerging economies, as they are the most vulnerable to climate change (Dabbadie et al., 2018; Galappaththi et al., 2020; Soto et al., 2018).

Figure 5 indicates that all the NbS societal challenges will need to be addressed. None of the societal challenges that are emphasise by the IUCN NbS Global Standard could lead to a straight positive answer for aquacultural systems. Consequently, if there is a general agreement on the need for aquaculture to continue its expansion (Costello et al., 2020), the major question remains what kind of aquaculture should be promoted and what are the societal challenges facing the aquaculture solution.

Key message from Section 3.1:

The question raised in NbS Criterion 1 needs to be assessed for each NbS involving aquaculture: how can an aquaculture system fit into the NbS framework in addressing major societal challenges beyond the ones usually addressed, such as economic and social development and/or food security?

11 "The principles of One Health are defined as the collaborative, multisectoral and transdisciplinary approach to achieving beneficial health and well-being outcomes for people, non-human organisms and their shared environment".

3.2 Criterion 2: Addressing NbS multi-scalar approach in aquaculture

The Ecosystem Approach for Aquaculture (EAA) encompasses all NbS criteria and is the scientific basis for sustainable aquaculture, as discussed in detail in the IUCN guide for aquaculture site selection and management (IUCN, 2009a).

For Aubin et al. (2019), the premises leading to EAA were given in 2002 in the proposal of an "ecological aquaculture" that "not only brings the technical aspects of ecosystems design and ecological principles to aquaculture but also incorporates, at the outset, social ecology, planning for human community development, and concerns for the wider social, economic and environmental contexts of aquaculture" (Costa-Pierce, 2010). Proposed in 2008 as a response to the negative effects observed with the rapid expansion of aquaculture since the 1980s, EAA was formulated by a group of experts and promoted by FAO, in accordance with the ecosystem-based management of the Convention on Biological Diversity (CBD), and following the Code of Conduct of Responsible Fisheries (CCRF) (Soto et al., 2008):

> "*An Ecosystem Approach for Aquaculture is a strategy for the integration of the activity within the wider ecosystem such that it promotes sustainable development, equity, and resilience of interlinked social-ecological systems*".

According to most aquaculture scholars, the present key for sustainable aquaculture remains in the right understanding, interpretation and implementation of EAA.

A direct link could be found in the description of NbS Criterion 2 and EAA as defined by Soto et al. (2008). Three key principles[12] were identified as well as successive scales for implementation, i.e. aquaculture farm, water body (in which the farm is located) and its watershed/aquaculture zone as the first layers, followed by the regional, national, global and market-trade scales. Such EAA implementation and design of aquaculture systems is further described in the IUCN guides related to the Mediterranean area (ecosystem-based approach to integrated management, or EBM) (IUCN, 2007; IUCN, 2009a; IUCN, 2009b).

However, Brugere et al. (2018), Hambrey (2017) and the FAO (2018) stress the challenges that need to be answered after a 10-year period of EAA, as the adoption of EAA appears to be less disseminated than at the time it was launched. EAA is way from being fully understood and key figures to sustain aquaculture within a specific area or water body should be explored with the associated risks (Aguilar-Manjarrez et al., 2017). Spatial planning of aquaculture, the establishment of Allocated Zones for Aquaculture (AZAs) using EAA should be improved, based upon economic/productive, environmental and governance elements as shown by the example of the integrated management of the Monastir Bay in Tunisia: this case is taking into account the MPA creation, as well as other activities (see Box 3).

12 The three principles of EAA are: i) aquaculture should be developed in the context of ecosystem functions and services with no degradation of these beyond their resilience capacity; ii) aquaculture should improve human well-being and equity for all relevant stakeholders; and iii) aquaculture should be developed in the context of (and integrated to) other relevant sectors. (Soto et al., 2008 & 2012, p. xx)

Box 3: The integration of various scales and the establishment of AZAs are key issues in EAA – The example of the Monastir Bay in Tunisia

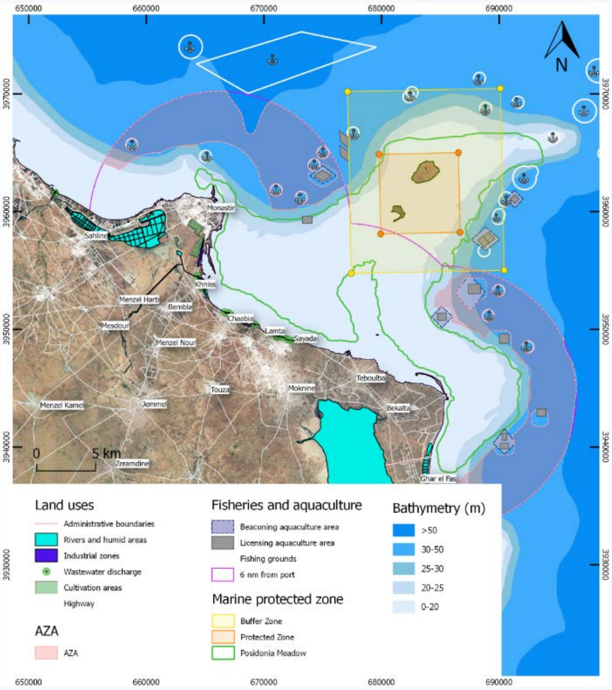
The farm level in the Monastir Bay is related to the various finfish cages in the bay, which are directly impacting the underneath seabed through the effluents from the farms, including the nearby MPA of the Kuriat Islands. The entire social-ecological ecosystem of the bay are also affected according to the currents. The carrying capacity of the whole Monastir Bay should therefore be considered for aquaculture siting and impact evaluation.

Discussed through a stakeholder platform and around the MPA creation and management plan of the Kuriat Islands, a Monastir Bay plan for the establishment of allocated zones for aquaculture has been developed and agreed with the local stakeholders in a project supported by the General Fisheries Commission for the Mediterranean (GFCM) of the Food and Agriculture Organization of the United Nations (FAO).

The broader scale of Tunisia and its aquaculture production have also been taken into account regarding the market potential and the organisation of the aquaculture commodity and value chain.

Cage finfish farms in the Monastir Bay (Photo credit: © R. le Gouvello)

Monastir Bay and the Kuriat Islands (Sallemi, 2015 & 2017)



Spatial analysis and parameters used to delineate AZA in the bay of Monastir (Source: IUCN, 2017, p. 9).

Key messages from Section 3.2:

The major, central and prevailing concept of Ecosystem Approach for Aquaculture (EAA) embeds aquaculture sustainability and appears fully in accordance with most NbS criteria.

The successive scale approach described in the EAA may specifically illustrate NbS Criterion 2 that explains how NbS should be defined with respect to one scale, but potentially integrating broader spatial and temporal scales.

3.3 Criterion 3: Aquaculture to provide a net gain to biodiversity and ecosystem integrity

A net gain on biodiversity and ecosystem integrity is clearly claimed in Criterion 3 of the IUCN Global Standard. Such criterion may contribute to discriminate some aquaculture systems versus others.

3.3.1 Most sustainable aquaculture projects are targeting an environment impact as less as possible.

For an aquaculture system to meet Criterion 3, the minimal requirement would imply that the aquaculture impacts on the environment are clearly identified, measured, and minimised inasmuch as possible, according to a robust Environment Impact Assessment (EIA), conducted with EAA (Troell et al., 2013). This assessment should be carried out considering various spatial and temporal scales, including far-field and near-field effects, and short-, mid- and long-term effects (Ottinger et al., 2016; Weitzman et al., 2019).

For instance, the discussion about the natural capital substitution that is introduced in the NbS concept may become even more critical for some aquaculture systems (Eggermont et al., 2015). Several ecological economists take the example of recent aquaculture development to illustrate how natural capital cannot be substituted by human

Coastal aquaculture ponds in Southeast Asia (Photo credit: © A. Guillaumin-Gauthier) capital (Despres & Vallée, 2014). According to these authors, aquaculture based upon the farming of carnivorous-fed finfish would not substitute the depletion of wild fish stocks as aquaculture compounded feeds could further contribute to an overexploitation of wild forage fish stocks, or "fishing down marine food webs" (Naylor et al., 2000; Pauly et al., 1998; Troell et al., 2013). Although this particular issue has been addressed by recent innovations in aquaculture feeds (Aas et al., 2019) and may represent a major brake for aquaculture future prospects (Costello et al., 2020), such statement on aquaculture remains often expressed by Western public opinion. This shows a place for debate and draws a particular attention to the scope of this report.

3.3.2 In aquaculture-related NbS, there will be the need to demonstrate a positive net gain on biodiversity using the ES framework.

In Criterion 3 related to biodiversity, there is not only the idea of reducing the impacts. The IUCN Global Standard also clearly states that a **positive net gain** on biodiversity and ecosystem integrity must be targeted and demonstrated to validate the NbS, using biodiversity assessment and monitoring tools and the framework of ES.

The valuation of aquaculture-related ES has long been seen as a promising way by aquaculture defenders, focusing on economic estimates of provisional services (Muir et al., 1999). Recently, FAO (2018) brought a direct link between Blue Growth Initiative (BGI) associated with fisheries, aquaculture and ES. For instance, FAO mentions solutions provided by aquaculture to improve ES, such as restored habitat forming essential refuges for wild fish, or the enhancement or re-stocking from aquacultural facilities to increase fishery productivity.

The valuation of ES through and with aquaculture has gained more recent attention among practitioners and scholars, as it opens new prospects for aquaculture in synergy with conservation purposes as well as local community well-being (Custódio et al., 2019; le Gouvello et al., 2017; Alleway et al., 2018; Aubin et al., 2019; Filgueira et al., 2015; Smaal et al., 2019; Weitzman, 2019) (Figure 6).

Alleway et al. (2018) provide an overview of the ES (through the classification of The Economics of Ecosystems and Biodiversity, TEEB, associated to mariculture). Smaal et al. (2019) give an extensive review of potential provisioning, regulating, and cultural services that bivalve cultivation may offer.

Some aquaculture modes of production (e.g. integrated multitrophic aquaculture) and cultured species (e.g. algae and certain bivalves, so-called extractive species by FAO, 2018) can have a positive impact on ES, by not only improving provisioning services but also providing regulating and supporting services and, potentially, cultural services. Recent work is highlighted to promote the approach of a 'restorative mariculture', associated to seaweeds or shellfish, in which the restoration of ecosystem services is targeted first (Carranza & Zu Ermgassen, 2020; Fitzsimons et al., 2020; Theuerkauf et al., 2019).

3.3.3 Such an evaluation through ES in aquaculture may lead to complex analyses and controversial, contrasted results.

However, a sole valuation of provisioning services through monetary conventional indicators may very well lead to confusing results, such as underevaluating the ES that are badly impacted by the promoted aquaculture in many cases (Muir et al., 1999). For instance, the intensive coastal shrimp farming has significantly contributed to destroy mangrove forests, and consequently disrupt all the ES that are provided by mangroves, but the exact evaluation of these

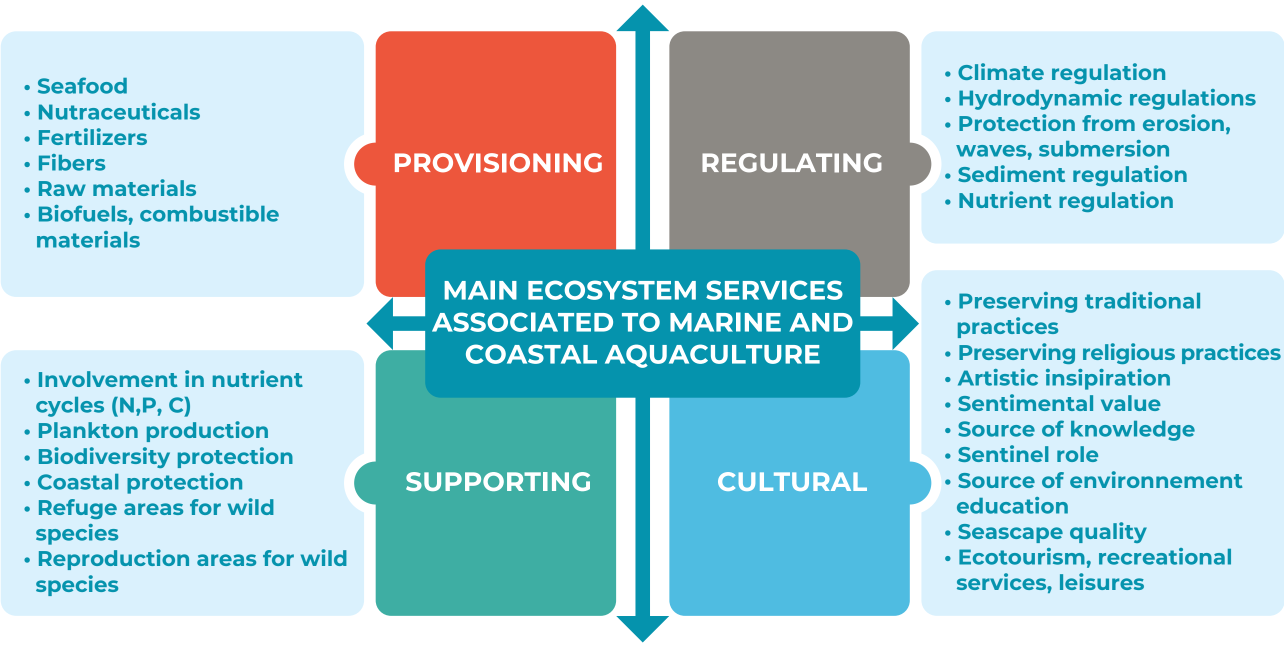


Figure 6: Major ecosystem services associated to marine and coastal aquaculture

(Source: Developed by report author, R. le Gouvello)

impacts is still under discussion (Boone Kauffman et al., 2017; Henriksson et al., 2018; Troell et al., 2013; de Souza Queiroz et al., 2017).

To illustrate the complexity of this biodiversity issue, the European Commission (2015) provides an exhaustive list of more than 300 examples of NbS classified according to the type of ES targetted. Among these, only a few include a component of aquaculture, and they are sometimes perceived as negative. For instance, for climate regulation, NbS No. 21 states: “Prohibit new aquaculture developments in intertidal areas.” However, for the same purpose, NbS No. 99 stipulates: “Encourage increased use of mangroves within and around existing extensive tropical aquaculture ponds”. For erosion regulation, NbS No. 114 proposes to “restore or create shellfish reefs in coastal locations where they may enhance sediment”, which is in line with the recent publication by Alleway et al. (2018). The ecological functions of “water purification and waste treatment” are enhanced with NbS No. 145: “Restore or create shellfish reefs to restore active filtration of suspended sediments and removal of nitrates and other pollutants.”

Indeed, many authors exploring various ES associated with aquaculture systems are expressing the need for further research work, with cultural and support services and non-tangible services that should be valued using the relevant perception approach among stakeholders (Aubin et al., 2019; Custódio et al., 2019; Smaal et al., 2019; de Souza Queiroz et al., 2017).

Box 4: Associated ecosystem services with bivalve cultures – The need for a full assessment

The range of ecosystem services enhanced by bivalve cultures and reefs are explored in detail in the recent collective book by Smaal et al. (2019) (Figure 7) investigating services, such as: habitat for wild species, protection against erosion, shoreline stabilisation and potential nutrient credits.

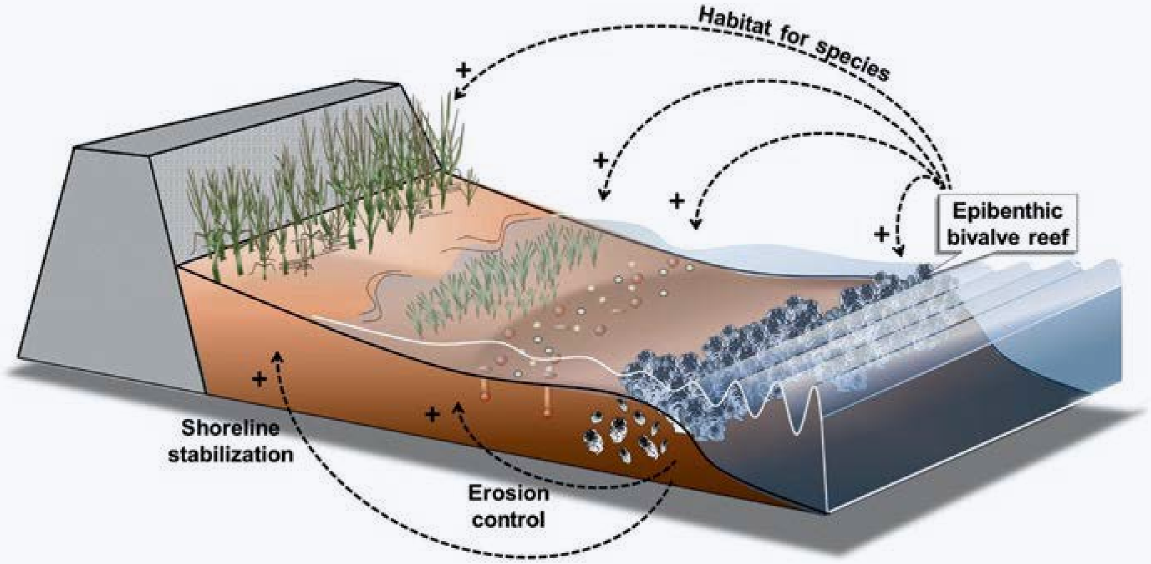


Figure 7: Visualisation of the ecosystem services delivered by epibenthic bivalve reefs

(Source: Smaal et al., 2019, p259)
Note: Reefs provide coastal protection through erosion control and shoreline stabilization, and modify the physical landscape by ecosystem engineering, thereby providing habitat for species by facilitative interactions with other habitats such as tidal flat benthic communities, sea grasses and marshes

Many studies have been conducted to further explore the services that the cultivation of shellfish and seaweeds could provide, including water quality mitigation and carbon sequestration (Aubin et al., 2018; Humphries et al., 2016). FAO (2018) now encourages the production of “extractive species” (non-fed through compounded feeds); such species include marine bivalves and seaweeds that benefit from the environment by assimilating waste materials, including waste from fed species, therefore removing these wastes, and lowering the nutrient load in the water. Recent work (Carranza & Zu Ermgassen, 2020; Fitzsimons et al., 2020; Theuerkauf et al., 2019) explores the way a shellfish restorative and enhancement mariculture can be deployed with the implantation of shellfish reefs, such as the recent SOAR project by oyster farmers in the USA.*

However, while adapting Life Cycle Analysis (LCA) assessment tools to a shellfish cultivation case, Aubin et al. (2018) were able to show the limits of such regulating service on a “bouchot”-grown mussel system in France. A higher eutrophication risk and sludge sediment accumulation may exist if hardly any good practices are in place nor adequate control measures. No significant service of carbon mitigation was found in this mussel case; such finding was mainly due to poor management practices which the farmers decided to improve after the study. Aubin et al. (2018) conclude that the

* For more information about the Supporting Oyster Aquaculture and Restoration (SOAR) in the Atlantic coast of the USA, please see: https://www.nature.org/en-us/what-we-do/our-priorities/provide-food-and-water-sustainably/food-and-water-stories/oyster-covid-relief-restoration/?vu=soar&tab_q=tab_container_copy-tab_element

ecological services of water quality nutrient mitigation should be associated with good aquacultural practices; otherwise, the expected benefits on ecosystems are lost. Similarly, establishing and modelling a nutrient budget on the broader scale of the Baltic Sea, Hedberg et al. (Hedberg et al., 2018) concluded that there clearly is a need for more research in support of the findings that blue mussel farming provides a cost-efficient nutrient uptake solution for reducing eutrophication in Baltic ecosystems (Figure 8).

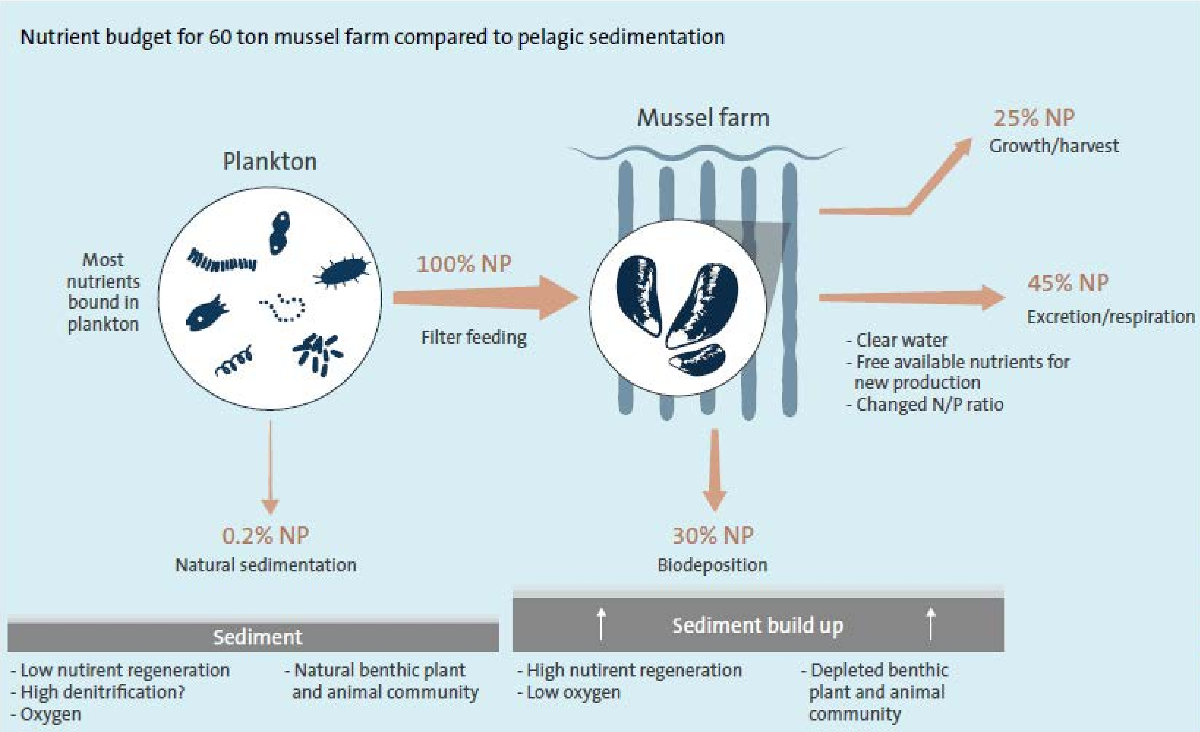


Figure 8: A schematic model of the potential impact of blue mussel farm in the Baltic proper on nitrogen and phosphorous dynamics on the local environment

(Source: Hedberg et al., 2018)
Note: The percentage roughly indicates the fate of 100 % nutrients (NP) consumed by the mussels along different pathways.

Other opportunities might be provided through the restoration and sustainable use of coastal and marine ecosystems in order to allow blue carbon to be stocked and not released to the atmosphere. Such service, according to Alleway et al. (2018), may potentially be enhanced through aquacultural systems like seaweed cultures or bivalve cultivation At the same time, these authors highlight that shellfish habitats also represent some of the most degraded marine ecosystems in the world, and traditional restoration efforts would be a long way to go, almost “impossible, given the presence of continued stressors”.

3.3.4 Controversial and opposite results on biodiversity and ES may depend on where the cursor is placed...

Some aquaculture productions may provide an opportunity to maintain or reinstate lost ES, i.e. CO_2 emissions provisioning (food, and non-food products such as cosmetics, materials, health and hygiene active ingredients, biofuels), regulating (including carbon sequestration), supporting, and cultural services. However, Alleway et al. (2018) emphasise that the relative and unique differences between mariculture and natural

Landscape and seascape view in south Brittany including mussel culture on "bouchots". (Photo credit: © R. le Gouvello)

systems must always be recognise and valued. The use of aquaculture systems as 'ecosystem engineers' should be handled methodically, examining all options and alternative actions, such as the preservation or restoration of natural habitats (seagrasses, mangrove areas, etc.), before deciding upon the implementation of an aquaculture production as a solution.

These contrasting outputs with aquaculture systems are further illustrated by the case of farmed fish in sea cages. Aggregations of transient and resident fish are often observed around these open sea facilities (Dempster et al., 2006), as they assimilate these cages to small-scale protected areas, or *pseudoreserves*, because these zones are excluding or restricting other activities. On the other hand, such sea-cage systems had often been emphasised as very detrimental for the surrounding ecosystems, in particular in the Mediterranean region such as the case of Posidonia fields (Bolognini et al., 2019). Another example of such complexity and ambiguity for the Section 3.3 is given in Box 5.

Key messages from Section 3.3:

Aquaculture systems will need to clearly demonstrate a net benefit on the overall biodiversity, as required in Global Standard Criterion 3, to be considered as NbS.

Such major criterion may in fact induce a clear discriminating cut between some aquacultural systems, excluding some of them from the NbS framework.

If aquacultural systems are designed to preserve, maintain, enhance, or contribute to restore the marine biodiversity, as proposed in the NbS framework, such approach needs to be carefully monitored and balanced with relevant biodiversity monitoring tools.

Box 5: "Ecological intensification" in aquaculture? A need for clarification...

Aubin et al. (2014; 2019) explore the concept of "ecological intensification" in a set of pilot cases of "aqua-ecosystems" as means to strengthen ES. The ecological intensification concept is applied in aquaculture using agro-ecological principles and the ecosystem services framework, "*defined as the use of ecological processes and functions to increase productivity, strengthen ecosystem services and decrease disservices*". These aquacultural systems are based upon an ecosystemic and territorial approach, biodiversity management, stakeholder active participation and the use of local and traditional knowledge. Their expected outputs lead to a greater autonomy, efficiency and better integration of the aqua-ecosystem into their surrounding territories. Such ecological intensification requires territorial governance, multi-stakeholder active platforms, similar to the land/seascape approach of NbS. They should be designed to filfil SDGs. In that understanding, the concept of 'ecological intensification in aquaculture' could very much fit within NbS principles and most Global Standard criteria.

Such ecological understanding of intensification in aquaculture may be different from the use of the term "sustainable intensification" as employed by Little et al. (2018) referring to a more conventional interpretation, less related to ecosystem services.

Sustainable Intensification is defined as: "*Producing more for less, whilst minimizing negative environmental impacts and optimizing societal benefit, has been a major objective of almost every development initiative in the sector in recent years. Indeed, a sustainable Intensification has since been promoted as a framework to focus on increasing yields as part of a broader approach to changes in the food system that meets the need of growing, urbanizing and globalizing markets.*"

Dolphins in the vicinity of sea cage farms in the Monastir Bay, in Tunisia (Photo credit: © Notre Grand Bleu)

3.4 Criterion 4: Looking for NbS economic viability in aquaculture

The economic viability of aquacultural systems has long been the major component of their sustainability. However, as proposed in the indicators of the NbS Criterion 4, the economic viability assessment must rely on the critical evaluation of how the benefits of such economic sustainability are actually shared between the involved actors, along the value chain. Positive and negative externalities must be fully identified and measured in this analysis. Such evaluation will need to go beyond the usual economic conventional indicators that are usually emphasised, on a micro- and macro levels, namely financial results expressed through gross and net economic incomes and profits, accountable added value, and Gross Domestic Profit (GDP) (Costanza et al., 2016). Indicators reflecting social benefits and population well-being must be proposed and tested. These crucial questions belong to the present research agenda in the field of social sciences applied to the aquaculture sector.

Indeed, in view of the aquaculture recent growth and subsequent critical social issues, Hambrey (Hambrey, 2017) lists the major challenges that aquaculture has to face towards 2030, such as “Poverty, hunger, health and well-being, decent work” as well as “Leaving no one behind: equity and opportunity” and better “Resource use efficiency, waste and water resources management”. Social aspects, formulated through the idea of a better equity in aquacultural systems, are advocated by the FAO (2018), referring to the existing growing gap between emerging and developed countries regarding marine resources.

To address these social issues, ongoing present work is carried out on Sustainable Global Value Chain assessment in the aquaculture sector (Bush et al., 2019), gender issues (Kruijssen et al., 2018) as well as the proposed definition and implementation of an equitable mariculture (Eriksson et al., 2018) and Community-based or Community-oriented Aquaculture (Ateweberhan et al., 2018; Campbell et al., 2021; Bradford, 2017). Equity is central in the future sustainability of aquaculture (by 2030) and to meet SDGs, as emphasised by Brugere et al. (2018), and Hambrey (2017). Kaminski et al. (2020) insist upon the need for exploring aquaculture-related global value chains with socially appropriate indicators to get true “inclusive business models” in aquaculture, noticeably in low-income countries.

NbS Criterion 4 brings up the discussion of what may be considered as a true viable economic aquacultural system. For instance, recent studies point out the controversial example of aquaculture development in Chile. Chilean salmon farming is very much criticised for its environmental negative impacts on a local level (Soto and Norambuena, 2004) but also for social negative aspects towards the local communities. However, the settlement of aquaculture salmon farms in Chilean remote area could improve the indicator of “poverty reduction” (Ceballos et al., 2018). A clear hiatus in the perception of negative or positive externalities associated to salmon farms among various kinds of stakeholders in Chile was evidenced (Salgado et al., 2015). These findings led the last authors to insist upon the need of relevant regulations and governance systems to be associated to the three pillars of sustainability in aquaculture.

Key messages from Section 3.4:

The NbS Criterion 4 is clearly in line with current discussions advocating for the need of a more inclusive, equitable, and community-oriented economic model for aquaculture development.

The implementation of Criterion 4 into the aquaculture sector may provide a new insight into projects.

3.5 Criterion 5: A relevant governance system for aquaculture

One main challenge that the aquaculture industry currently faces has been related to the capacity of aquaculture producers to be integrated in the local communities or not. If the aquaculture-related value chain is operating only with a small number of actors, disconnected from the communities, such situation may create the conditions of a rejection of the aquaculture system from the communities.

Stakeholders participation and the integration of aquaculture actors within a broader governance system has been investigated for decades, and associated with all the work made on aquaculture sustainability, namely EAA (Aubin et al., 2019; Brugere et al., 2018; Lazard et al., 2014; Rey-Valette et al., 2008; Soto et al., 2008). A relevant governance is also pointed out by recent publications, conditioning the development of aquaculture at larger scales (Costello et al., 2020; Davies et al., 2019) as well as at the local community level (Ateweberhan et al., 2018; Bradford, 2017). However, if advocated by many authors, the implementation of an "inclusive, transparent and empowering governance process" (IUCN, 2020a) involving the aquaculture sector and in compliance with NbS Criterion 5 requires specific answers on a case-to-case basis, as situations vary from one area to another.

Such governance criterion is intrinsically connected to the ones related to trade-offs, adaptative capacity, and mainstream environment (Criteria 6, 7 and 8). How is the aquaculture system fitting into a general mainstream governance system, that includes all stakeholders, that is on various scales, and that is driven by appropriate policies, regulations and control measures?

Many major failures in the development of aquaculture and associated detrimental effects on the surrounding social-ecological systems have been associated with a lack of solid governance systems and appropriate regulations (Davies et al., 2019). In addition, numerous examples exist of rather bad acceptability, poor social acceptance of the settlement of aquaculture farms in coastal areas, partly expressing a lack of a constructive dialogue between aquaculture producers, their shareholders and the other stakeholders (Mather & Fanning, 2019; Vince & Haward, 2017; Raux et al., 2021).

These conflicts around the acceptability of aquacultural projects are reflect the weak interpretation of EAA over the past decade, far from expectations (Brugere et al., 2018), and prompting the need for more consideration to be given to the concepts of 'social licence' and 'social acceptability' into the aquaculture industry (Baines & Edwards, 2018; Mather & Fanning, 2019).

Conflicts and social-ecological issues are even more prevalent in coastal areas where usages are being multiplied, thus justifying the need for a specific coastal governance system, the Integrated Coastal Management (ICM) (Stephenson et al., 2019). In fact, as emphasised by the 1992 Rio Declaration on Environment and Development (UNGA, 1992), ICM must be implemented in coastal areas, which are recognised as overly complex social-ecological systems, to address coastal sustainable development objectives and their adaptative capacity (Hagstrom & Levin, 2017; Stephenson et al., 2019). Such integrated management refers to a relevant governance system, recognising all stakeholders and giving them the means to express their needs or perceptions. But, if recognised as a general need, the implementation of ICM has been quite disappointing so far (Stephenson et al., 2019).

Among the challenges of improving ICM initiatives, it is recognised that aquaculture actors should be part of the ICM system as other stakeholders, including the fishing actors (Brugere et al., 2018; Soto et al., 2012).

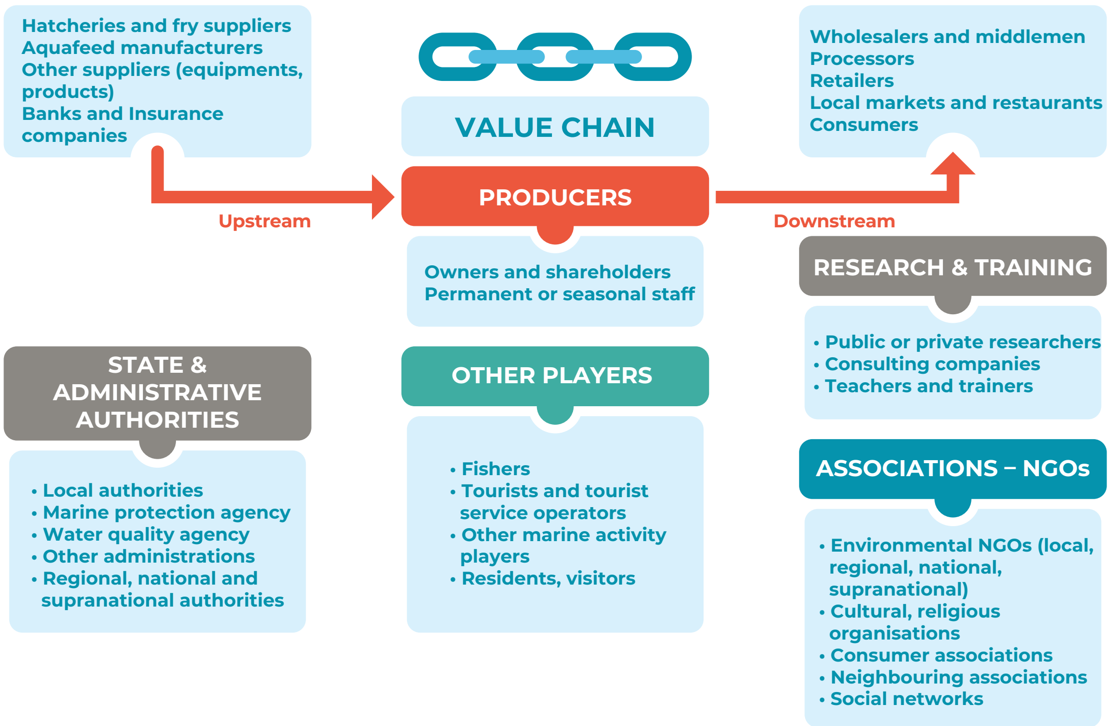


Figure 9: Mapping of stakeholders in marine and coastal aquaculture systems

(Source: Adapted from Rey-Valette et al., 2008)

Aquaculture and fisheries systems are closely interconnected (Troell et al., 2013) and should open themselves to other interlinked system. Moreover, they should consider themselves as components of coastal SES.

Numerous studies explain how a good governance system could be achieved, including an aquaculture component. However, it is not the purpose of this document to review this specific topic. Among referenced publications, it must be emphasised that EAA explicitly describes an approach including stakeholder's consultation and participation, in association with the aquaculture project. As an example, the various stakeholders associated with an aquaculture production are mapped on the following Figure 9 updated since the EVAD[13] project (Rey-Valette et al., 2008). It shows that a complete systemic vision must be taken in the exercise of such relevant governance to integrate aquaculture within a whole SES and identify all the interactions between actors.

Key messages from Section 3.5:

According to Criterion 5 and EAA, the degree of integration of the aquaculture system within the local broader system should be closely assessed.

All stakeholders should be identified and mapped, including the whole aquaculture value chain.

Interactions between the stakeholders should be described as well as governance rules.

3.6 Criteria 6–8: Trade-offs, adaptive management and mainstreamed aquaculture

The IUCN NbS Global Standard emphasised that all criteria are interconnected. In particular, Criteria 6, 7 and 8 (balanced trade-offs, adaptative management and

13 EVAD = Evaluation of aquaculture system sustainability

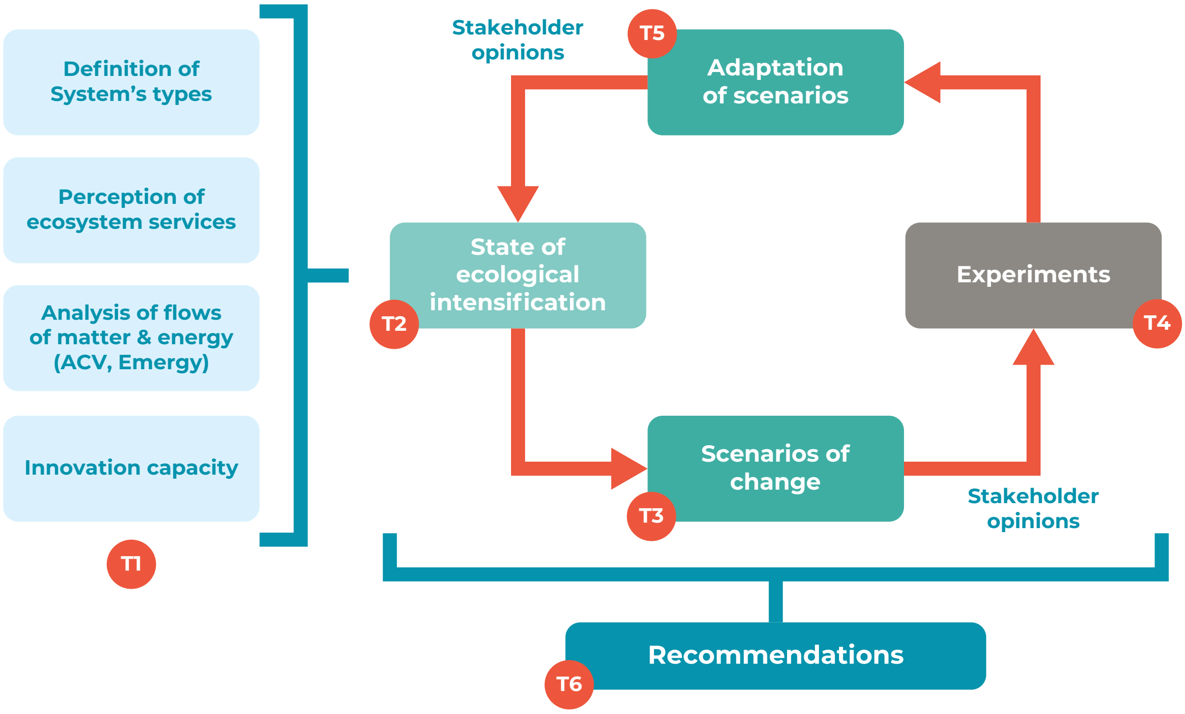


Figure 10: Adaptative capacity illustrated by a conception loop for ecological intensification of aquaculture

(Source: Aubin et al., 2019)
Note: The conception loop of adaptative capacity is based on a multidisciplinary approach. The successive steps (T) of the loop include: T1, assessment of a study site (i.e. aquaecosystem typology, analysis of the perception of ecosystem services, environmental assessment), which defines the initial state of ecological intensification; T2, co-design of improvement scenarios; T3, co-design and conducting of experiments; T4, analysis of experimental results; T5, adaptation of scenarios to define; and T6, recommendations, principles and pathways.

mainstreamed, respectively) may be associated and considered as a result of a good governance system in place (Rey-Valette & Mathé, 2012).

The capacity of adaptative management has been associated with EAA since its emergence. In its guide for aquaculture site selection and management, the stakeholder assembly gathered by IUCN insisted upon the process of an adaptative capacity that should be defined with the deployment of EAA (IUCN, 2009a). Another recent illustration of an adaptative approach, established with a stakeholder participation, is provided by Aubin et al. (2019) and was applied in various case studies of aqua-ecosystems. In these studies, trade-offs, which are adaptative management measures resulting in combined social and biodiversity benefits, could only be obtained through conception loop based on a multidisciplinary approach, involving the stakeholder community and the implementation of appropriate tools, such Life Cycle Analysis, applied to the aqua-ecosystems (Figure 10)(Box 6).

Similarly, the existence and the development of aquaculture within a SES have to be mainstreamed, and conducted in accordance with various planning tools, policy instruments that deal with water, ocean and coastal management, natural resources management and the SDGs, international and national policies. The case study explained in Box 3 provides an example of the allocation of aquaculture zones, within the Monastir Bay in Tunisia, illustrating the recommendations of marine spatial planning (MSP), allocation zones for aquaculture (AZA), integrated coastal management (ICM) and marine protection policies.

Box 6: An example of a multidisciplinary approach in aquaculture that addresses NbS criteria

As presented by Aubin et al. (2019) and reported in a methodological guide for the implementation of an "ecological intensification" (Box 5) in aquaculture (project PISCEnlit) (Aubin et al., 2014), a multidisciplinary approach was tested in various sites with aquaculture. For instance, in Catarina State in Brazil, the continental aquaculture system is based upon a polycultural farming system in earthen ponds, inspired by the Asian traditional systems. The aquaculture productions associate several species of carps and tilapia, feeding at various trophic levels in the ponds. The system is also associates pig farms, as the manure fertilizes the ponds and enhance the production of phytoplankton or macrophytes. Such agri-aquasystems can be clearly associated to agro-ecological methods. However, in Brazil, the quality of the effluents from the ponds is controversial, where new environmental regulation may ban these cultural practices from the vicinity of rivers, and therefore threaten their future. The PISCEnlit research project involved all stakeholders in this Brazilian social ecological system, and used various tools (LCA, social LCA, emergy analysis...) to identify and qualify ecosystem services associated to the system, including cultural services. Scenarios of change illustrating an adaptative management were investigated to address the specific issues identified such as the water quality problem. Plantation of onions and floating plants using the pond effluents were tested and proved to be efficient in increasing the water quality and the provisioning services as well. However, the proposed solutions are increasing the degree of complexity of this social ecological system, requiring more labour, education and training for the producers. It was therefore important to include all stakeholders in the decisions and collectively decide for the best trade-offs.

(Source: Aubin et al., 2014; Aubin et al., 2019; Valenti et al., 2018)

In other words, in the case of marine aquaculture, it is essential that aquaculture systems are mainstreamed with various jurisdictions. It means that the aquaculture system considered in association with an NbS should comply with:

- protection measures, the deployment of marine protected areas;
- the European Union directives of Marine Spatial Planning, European Marine Strategy Framework Directive, the Common Fisheries Policy;
- integrated coastal management strategies and initiatives;
- the FAO Code of practices in fisheries and aquaculture, the FAO "Blue Growth initiative"; and
- etc.

The review provided in Section 3 allows to conclude with these key messages:

Key messages from Section 3:

Most of the current research and proposed indicators currently used to monitor and assess the sustainability of aquacultural systems seem relevant to provide valid information to document aquaculture-related NbS cases.

Most of the proposed NbS Global Standard criteria seem to be in accordance with EAA.

The NbS framework may help in further exploring crucial issues such as societal and biodiversity gains, economic viability and relevant governance.

The proposed evaluation framework for NbS may provide a new and useful opportunity to further document the sustainability of aquacultural systems.

4. NbS Global Standard as an opportunity for aquaculture

4.1 A new dynamic for EAA

The NbS concept and Global Standard approach (IUCN, 2020a) may provide an opportunity to improve aquaculture sustainability and existing concepts and tools that are investigated and applied in SES with an aquaculture component. The proposed new NbS approach may participate in an overall EAA 'reinvigorating' promoted by Brugere et al. (2018) and FAO (2018).

Indeed, the preceding section's the review of proposed NbS Global Standard with current aquaculture concepts and tools indicates a clear link of all these NbS criteria with the implementation of the EAA, as it should be (Brugere et al., 2018). The EAA could be taken as an umbrella of all existing other concepts and tools as reviewed in Section 3 that are proposed to improve aquaculture sustainability. The integration of these concepts and tools under the EAA umbrella may indicate a pathway moving from 'aquaculture systems' towards cases of 'aquaculture-related NbS' (Figure 11). In both ways, under the EAA umbrella, various concepts and tools as listed in Figure 11 should be mobilised. However, this list of concepts and tools is not exhaustive and would need to be updated on a regular basis.

The constraints faced by the implementation of the EAA are related to legislative and regulatory issues (Brugere et al., 2018). Among the misinterpretations of EAA observed in

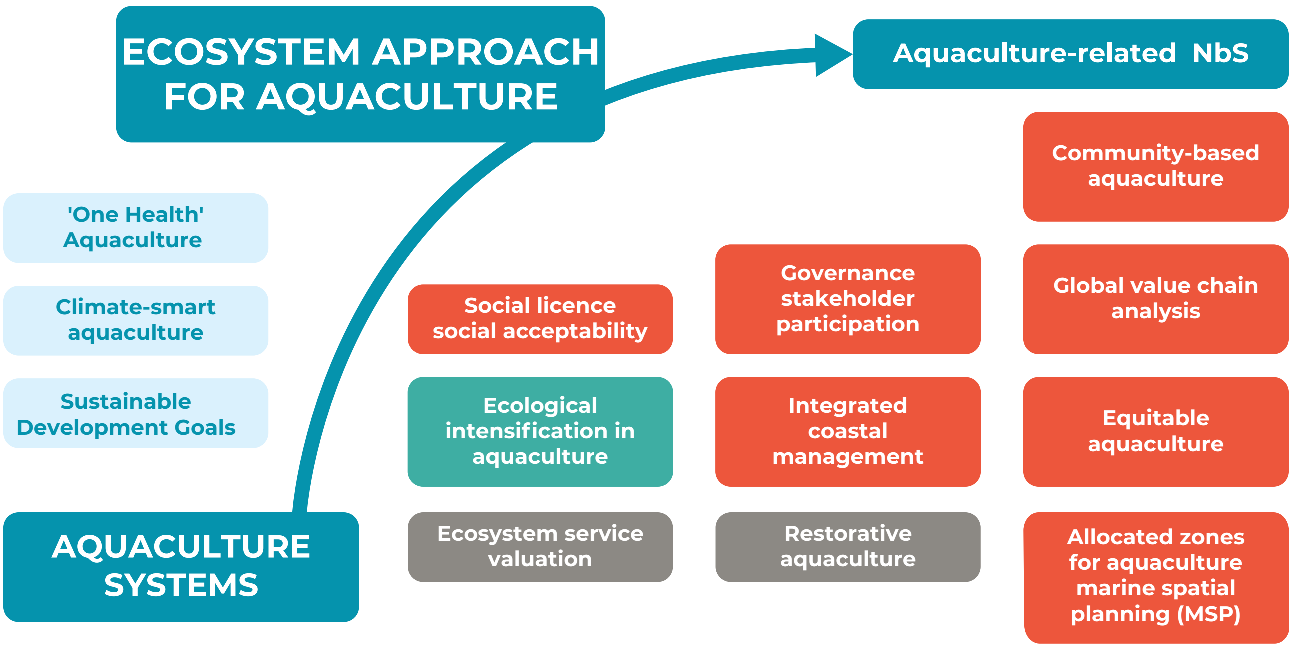


Figure 11: Concepts associated with aquaculture-related NbS within the EAA umbrella

(Source: Developed by report author, R. le Gouvello)
Note: Colours are introduced just for visibility purposes

various cases, examples of insufficient equity, stakeholder participation, governance, knowledge and capacity building are numerous. Key impediments of the EAA can be synthesised in terms of: scope, autonomy, behavioural change and internal features of the approach. The scope refers to the ambitions given to EAA, whether aquaculture is addressing multiple targets, SDG-related targets, or overcoming strict individual and industry sector objectives. The 'autonomy' of the EAA is associated with the idea that countries should create the right context for supporting an ecosystem approach, such as policy initiatives of MSP or ICM. The critical points are related to the misunderstanding and misinterpretation of the EAA concept. The broader perspective advocated for EAA should not only address the aquaculture sector, but it should also be applied by all stakeholders involved in the blue economy of the region where aquaculture takes place. In that sense, a full implementation of EAA will address other NbS criteria, such as Criterion 5 (governance), 6 (trade-offs), 7 (adaptative management) and 8 (mainstream).

Moreover, there is a need to 'reinvigorate' the EAA through the exploration of EAA links with other prevailing and emerging concepts and current stakes (Brugere et al., 2018; FAO, 2018). Among them, EAA should be associated climate change, value chain explorations, adaptive and resilience capacity of ES, ecosystem-based management, and the valuation (not only in monetary terms) of ecosystem services. Other tools applied to aquaculture, such as Life Cycle Assessment (LCA), Carrying Capacity evaluation, will participate in the documentation and risk assessment that are highlighted in the NbS Global Standard (Le Gouvello et al., 2017) and implemented in projects (Aubin et al., 2019) (Box 5 and Box 6).

This NbS approach may contribute to making some of the strategic concepts like EAA more operational and to providing new opportunities to implement them.

NbS seem strongly embedded into local approaches that would have to expand on larger scale thereafter. Although FAO (2018) recognises the importance of small-scale aquaculture and community-based management of natural resources in fisheries and aquaculture, such bottom-up deployment may be strengthened in the present implementation of EAA. This could help in taking into consideration all the work related to community-based aquaculture (Ateweberhan et al., 2018; Bradford, 2017). Similarly, Campbell et al. (2021) advocate for a reframed marine aquaculture to enhance community well-being, to serve the 'Blue Communities' while being part of the future blue economy.

Key messages from Section 4.1:

NbS approach may contribute to overcoming some weaknesses that have been acknowledged in the implementation of EAA, as well as targeting societal and biodiversity benefits with the aquacultural systems, strengthening an integrated approach, and establishing a robust governance system adapted to the scale of aquaculture-related NbS.

The NbS Global Standard framework could very well provide an operational approach to a marine aquaculture-reoriented for supporting "Blue Communities" well-being, as proposed by Campell et al. (2021).

4.2 Emphasis on local knowledge and traditions

NbS do not necessarily lead to new sophisticated technologies, but may help in digging out local knowledge and giving a new birth to traditional 'good' practices (Eggermont et al., 2015). This approach might be 'refreshing' in aquaculture, an industry that has shown more interest in pure technological and sophisticated innovations over the past decades rather than acknowledging traditional *savoir-faire*, and less sophisticated and artificial techniques (Joffre et al., 2017).

Alleway et al. (2018) refer to old aquacultural systems as comparable to traditional terrestrial agro-ecosystems with a long social-ecological history. Like Aubin et al. (2014,1019) who worked on integrated agri-aquacultural systems in Brazil (Box 5), they promote examples, such as livestock-cum-polyculture of fish in earthen fishponds that have been existing for millennia in China, and extensive integrated agriculture-aquaculture fishponds that were in place in Hawai'i between the 10th and 14th centuries. These systems, which were based on exchanges of nutrient flows, were abandoned or deeply modified in the 'modern times'. New practices, such as the replacement of natural food with compounded feeds, were introduced to intensify them but contributed its delink from natural ecosystems (Edwards, 2015; Troell et al., 2013). However, recent work has been carried out to show how such traditional activities were structuring local SES, not only in terms of food provisioning for the human community but also for their cultural significance. For example, Hawai'ian ponds are not only directed to the restoration of provisional old services, but they also serve as semi-natural barriers to waves and re-create a local community link though a collective management (Haroun & le Gouvello, 2016).[14] In fact, such traditional aquaculture Hawai'ian system could meet most NbS Global Standard criteria.

Similarly, the recent new aquaculture-related motion, WCC 2020 Res. 045, voted by the IUCN Congress is calling for a Global Indigenous Network for Aquaculture (GINA), in which aquaculture-related NbS based on best indigenous practices will be further documented and promoted.

4.3 Further exploration of synergies between aquaculture and marine conservation

Combining the NbS approach with existing concepts of EAA, aquaculture-related ES and ecological intensification in aquaculture could provide new opportunities to explore synergies between a sustainable aquaculture and conservation initiatives. Potential limitations in aquaculture and marine conservation synergies raised by Custodio et al. (2019), le Gouvello et al. (2017) and Alleway et al. (2018) may be further clarified through the NbS framework. For instance, in shellfish farming, would we consider that a production of triploid oysters is NbS-compatible? Would aquaculture systems based on the farming of high-value carnivorous-fed species for export market be compatible with the NbS principles? Why not, we may say, if this aquacultural system does not impact the environment, provides an equitable income to the local communities and contributes to conservation objectives by providing financial resources, thus adequately balancing trade-offs according to the NbS Global Standard Criterion 6 (IUCN, 2020a).

The NbS frameworks proposed by Cochen-Shacham et al. (2016, 2019) and Eggermont et al. (2015) could be adapted to sustainable aquacultural systems in order to classify aquaculture-related NbS, with reference to the various NbS concepts, types and the scale of ecosystem transformation introduced (Figure 12).

MPAs could constitute NbS Type 1 according to Eggermont et al. (2015) and Cohen-Shacham et al. 2016), relying on the marine natural ecosystems, although most of them

14 For more details, plase contacz Brenda Asuncion: Loko I'a Coordinator Kua'āina Ulu 'Auamo (KUA) Email: brenda@kuahawaii.org Kua'āina Ulu 'Auamo (KUA), www.kuahawaii.org

Restoration of traditional fishponds in Hawai'i (Photo credits, clockwise, top left: photos 1, 2, 4 and 5 © R. le Gouvello; photo 3 © R. Haroun)

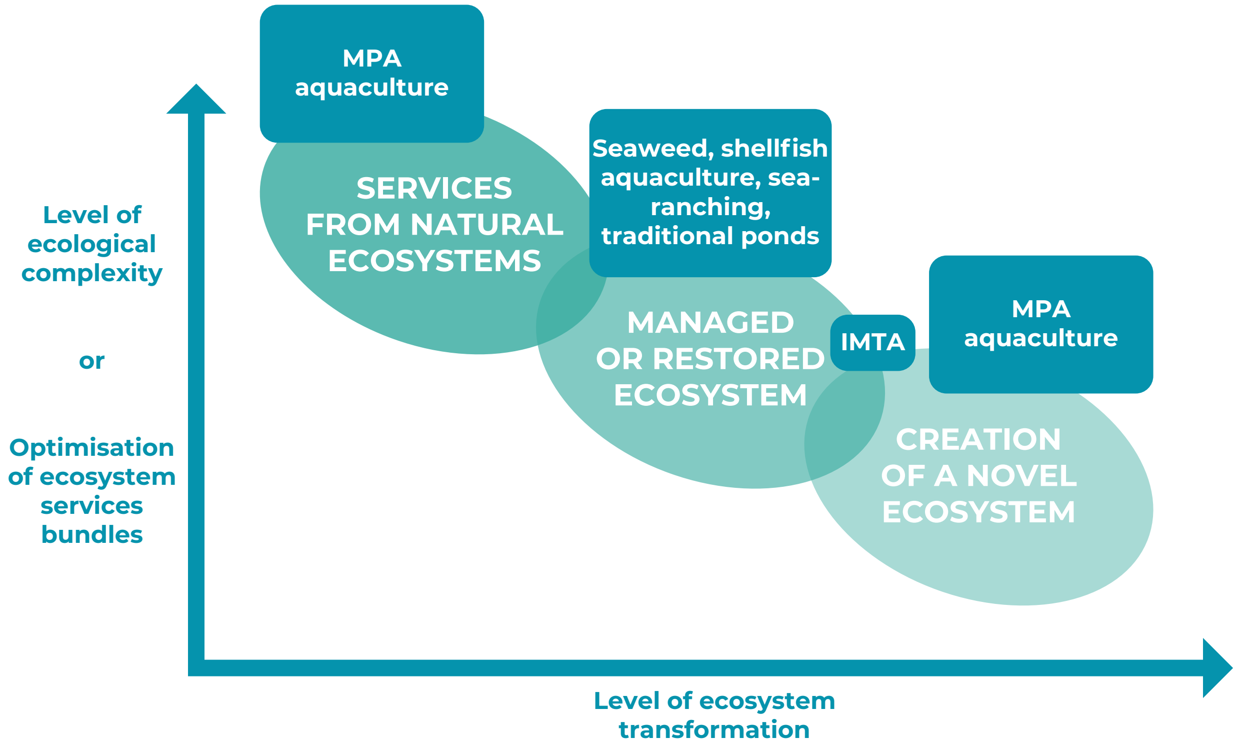


Figure 12: Aquaculture systems, ecological complexity, ecosystem services optimisation and level of ecosystem transformation

(Source: Adapted from IUCN, 2020)

may include altered ecosystems in their perimeter. Aquaculture systems developed within an MPA would a priori be in accordance with the NbS definition and Global Standard, if MPAs are well-managed (McNeill et al., 2018; Rossiter and Levine, 2014; le Gouvello et al., 2017), and if the MPAs are meeting NbS societal challenges as required in the NbS Criterion 1. For instance, many MPAs are focused on preserving fish stocks. Hence, aquaculture may play a role for fish stock regeneration or may provide an alternative income to fisheries (IUCN, 2017; le Gouvello et al., 2017; Ateweberhan et al., 2018) (Blue Venture case).

Agro-ecological systems may be part of NbS. Aubin et al. (2019) explain that a direct reference to agro-ecology in aquaculture appears in different studies. Strong similarities are found between agro-ecology and Integrated Multi-Trophic Aquaculture (IMTA), tending to prove that IMTA systems could very well fit into NbS, relying on restored or managed ecosystems. Custodio et al. (2019) highlight IMTA as endorsed by scientists as a more sustainable mode of aquaculture than intensive monocultures (Buck et al., 2018; Chopin et al., 2012; Granada et al., 2016; Marques et al., 2017) (Figure 13). In IMTA, nutrient effluents originating from artificially fed cultures (e.g. fish, shrimp), in both particulate and dissolved forms, are redirected to downstream trophic levels to nourish extractive species, thus mimicking the functioning of the 'natural' ecosystem. Consequently, the IMTA system could be assimilated to an NbS based on a restored or managed ecosystem. So could be the restoration of brackish water coastal ponds, with extensive production of bivalves, seaweeds and/or and finfish as explored in the Esteros in southern Spain (Walton et al., 2015a; Walton et al., 2015b).

The emerging concept of a restorative aquaculture (Theuerkauf et al., 2019), a **mariculture-based enhancement** and

Restorative Shellfish Mariculture (RSM) (Carranza & Zu Ermgassen, 2020)[15] may be explored under this NbS framework, as more than 500 existing cases of RSM are recorded. The proposed criteria for a definition of an RSM project appear with NbS Global Standard criteria (Table 2).

Similarly, more artificial IMTA, land-based recirculating units (Aubin et al., 2014) or aquaponic systems in urban areas, as proposed by the Paul Ricard Ocean institute,[16] may be considered within the category of NbS Type 3. However, this last point might be subject to discussion, as Cohen-Shacham et al. (2019) do not consider such artificial systems that mimic nature to be true NbS according to the IUCN definition and principles.

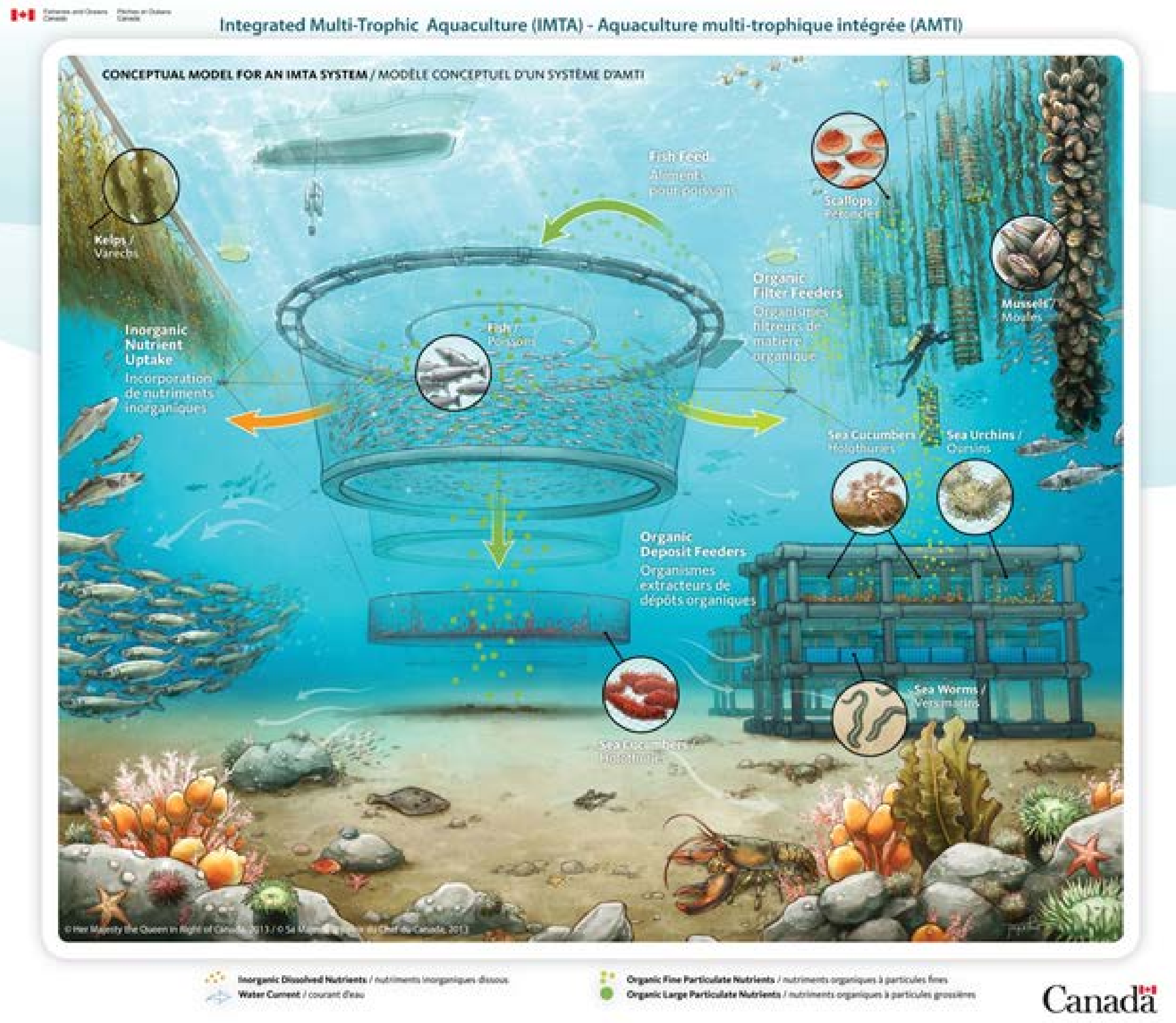


Figure 13: Conceptual model of Integrated multi-trophic aquaculture

(Source: IUCN, 2017, p. 14.)

15 This is recently applied in the project, Supporting Oyster Aquaculture and Restoration (SOAR), in the Atlantic coast of the United States. For more information, please see: https://www.nature.org/en-us/what-we-do/our-priorities/provide-food-and-water-sustainably/food-and-water-stories/oyster-covid-relief-restoration/?vu=soar&tab_q=tab_container_copy-tab_element

16 https://www.institut-paul-ricard.org/en/programmes_recherche/amti/

Table 2: Criteria used to define 'restorative shellfish mariculture', in contrast to 'non-restorative shellfish mariculture'

	Restorative shellfish mariculture	Non-restorative shellfish mariculture
Motivation	Non-exclusively financial (e.g. conservation of species, habitats)	Exclusively financial
Project seeks to maximise	Several Biodiversity and ecosystem services, including target species production, although could be long term	Target species production
Ownership of the harvest/ resources	Public and/or private	Always private
Status of the target species	Target species, native and depleted, or overfished, or locally or regionally extinct, or functionality extinct	Least concern
Type of production system	Generally artisanal, low-tech, non intensive	Generally intensive (e.g. put and take, or sea ranching)

(Source: Adapted from Carranza and Zu Ermgassen, 2020)

5. Discussion

In terms of methodological innovations, it appears that the NbS approach brings a new vision and aggregates existing concepts within aquaculture's current frame of sustainability, namely EAA and associated concepts. The proposed Global Standard for NbS™ (IUCN, 2020a) may provide a new and useful approach to further document the sustainability of aquacultural systems and contribute to "reinvigorate" EAA.

The NbS approach may also contribute to overcoming some weaknesses that have been acknowledged in the implementation of EAA, namely the need to target societal and biodiversity benefits within aquacultural systems, strengthen the integrated approach and introduce a robust governance system adapted to the scale of the aquaculture-related NbS.

Very likely, one expected positive outcome provided by the NbS framework applied to aquaculture will highlight practical, local and specific interventions that deal with the complexity of coastal SES including an aquaculture component. The bottom-up, multi-scalar and polycentric approach described in the NbS Global Standard is fully in agreement with other work using the proposed framework of sustainability of SES. This includes work implemented in coastal SES that are dependent on fisheries and recognised as quite complex and adaptive systems (Ostrom, 2008; Ostrom, 2009; Leslie et al., 2015; Hagstrom and Levin, 2017; Le Floc'h et al., 2018; McGinnis and Ostrom, 2014). The introduction of the NbS into such an SES sustainability assessment framework would have to be further explored. However, the discussion seems quite in line with current trends. As an example, there are clearly strong links between the re-orientation of marine aquaculture towards the Blue Communities well-being as advocated by Campbell et al. (2021) and the NbS Global Standard framework.

In this report, several examples of aquaculture systems indicate that some may be considered as potential NbS, provided that a full and holistic assessment is made on each solution fin one defined SES, in compliance with NbS Global Standard (IUCN, 2020a). Potentially, it may be said that all kinds of aquaculture systems could be considered as NbS (mainly Types 2 or 3). This will be true as long as the aquaculture-related NbS candidate meets all NbS principles and is documented to an acceptable level to assess benefits, impacts, trade-offs, and positive and negative externalities, all NbS criteria being informed (according to IUCN 2020a). Overall, the NbS candidate would thus be considered as a "well-practiced aquaculture system" in agreement with EAA principles. This 'open' conclusion was proposed by le Gouvello et al. (2017) in the discussion about aquaculture within MPAs. The expert group agreed that there might be only one formal objection to the presence of aquaculture production within an MPA, i.e. a badly-practiced aquaculture system.

At any rate, NbS Type 3 is still being debated among various scientisits. A discussion and clarification are therefore needed to determine whether aquaculture-related systems are considered as acceptable NbS, considering the extent of human-based artificial inputs, and actions involved in the system. It may be rather difficult in aquaculture to distinguish between a solution that is dependent on 'natural' ecosystems and a quite artificial aquacultural system that is well managed but decoupled from 'naturalness'. Most farmed aquatic animals are artificially fed now, except bivalves, sea cucumbers and some extensive systems with shrimps or fish. Would the existence of artificial feeding constitute the limit in the 'naturalness' of the NbS in aquaculture? Or is it acceptable that an aquaculture system based on sea cages, like salmon or seabass farms, can be part of an NbS or constitutes one? Regarding shellfish farming, if the NbS is based on the on-growing of triploid and genetically-selected strains of hatchery-supplied larvae of an exotic species (like Pacific oysters in Europe), is it an acceptable candidate as an NbS?

Similarly, it might also be critical for some aquacultural systems to provide clear evidence of a 'net benefit' for biodiversity, as required by Criterion 3 of the proposal of NbS Global Standard (IUCN, 2020a). Even for seaweed farming in coastal conditions, the Zanzibari case study (Box 7) shows that precautions should be taken in the management of this aquaculture activity. Seaweed farming should be implemented maintaining a proper balance with other activities and other natural habitats, such as seagrass beds (IUCN, 2020b).

Box 7: Preliminary IUCN Global Standard assessment of Zanzibar seaweed farming as an NbS

A preliminary evaluation was made using IUCN NbS Global Standard (IUCN, 2020a) to a solution that consists of seaweed farming in Zanzibar. The evaluation was carried out as a desk study by R. le Gouvello and submitted to IUCN NbS team. The information gathered through preceding AquaCoCo phases, mainly the Zanzibar case study and recent scientific publications (Brugere et al., 2019; Brugere et al., 2020a; Brugere et al., 2020b; IUCN, 2020b) were used to address each criterion and the associated indicators, under an evaluation computed table, associated with a scoring system for each indicator.

Seaweed farming in the Zanzibar islands is an activity that has been successfully initiated in the 1990s, making the Zanzibar region a main seaweed producer in Africa (IUCN, 2020b). It is practiced in the intertidal zones, mostly located in marine conservation areas, and operated by women.

Table 3: Overall result of the assessment of Zanzibar seaweed farming under the IUCN NbS Global Standard

Criterion	Your Criterion Score	Maximum Criterion Score	Normalised criterion	FINAL OUTPUT Your Criterion %age
1. Societal challenges	4	9	0,44	0,4
2. Design at scale	4	9	0,44	0,4
3. Biodiversity net-gain	2	12	0,17	0,2
4. Economic feasibility	5	12	0,42	0,4
5. Inclusive governance	5	15	0,33	0,3
6. Balance trade-offs	2	9	0,22	0,2
7. Adaptive management	3	9	0,33	0,3
8. Sustainability and mainstreaming	4	9	0,44	0,4
Total			2,81	0,4

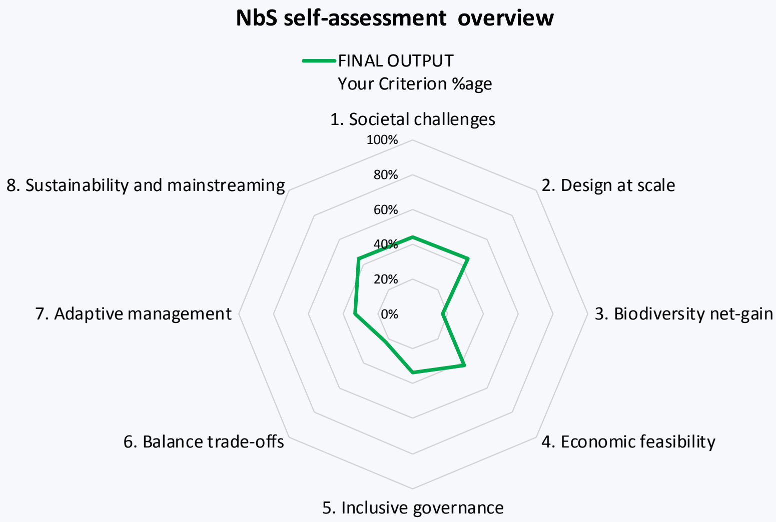


Figure 14: Radial diagram showing overall result of the assessment of Zanzibar seaweed farming under the IUCN Global Standard

(Source: Adapted from IUCN, 2020a.)

The assessment made by the AquaCoCo team (R. le Gouvello and A. Spadone) was reviewed by the IUCN Global Standard team and commented, resulting in a change of scoring or the need for additional rationale. After these successive reviews, a final score was defined for each indicator but the need for clarification was also reported when no final agreement could be found between the NbS IUCN team and the AquaCoCo team. As it is a strong requirement for the implementation of NbS, the results of this assessment can only be taken as a first indication on how an aquaculture-related NbS could be assessed and what are some critical questions emerging.

This first assessment of seaweed farming in Zanzibar as an NbS clearly places the proposed solution in the "Partial" scoring group for the general score obtained. However, the fact that some criteria 3 (Biodiversity) and 6 (Trade-offs) are estimated as "Insufficient" may imply that seaweed farming in Zanzibar is NOT considered to adhere to NbS Global Standard.

The radial diagram (Figure 14) indicates that the strengths (more than 40% adherence) of this intervention are found in social challenges (Criterion 1), and in its design in scales (Criterion 2), economic viability (Criterion 4) and the overall sustainability framing (Criterion 8). The questions of governance, adaptative management and trade-offs are to be improved, but this can only be achieved with the Zanzibar people. Not surprisingly, as discussed in this publication, the biodiversity net gain is difficult to obtain, and the resulting score severe. In this regard, the needs for improvement lie in the establishment of adequate measures to reduce, control and mitigate any impact of seaweed farming on biodiversity.

Such exercise as a desk study would need to be conducted in Zanzibar and should be collectively managed with local stakeholders. The proposed NbS frame may help in improving the solution within a general frame of sustainable development challenges, and as such consolidate the place of seaweed and aquaculture systems in Zanzibar.

Women at work in seaweed farms in Zanzibar
(Photo credit: © R. le Gouvello)

Regarding NbS Criterion 3 (biodiversity gain), the possibility exists that only a limited number of interventions that include aquaculture could comply, namely artisanal, extensive and local aquaculture productions. Furthermore, the requirements of Criteria 3 and 4 (biodiversity gain, and economic viability and equity) should exclude some aquacultural systems from NbS qualification, for instance industrial, intensive peneid or salmon farming systems. However, this intuitive assumption will require full investigation on a case-to-case basis. Clearly, regarding these issues, there is the need to further document new cases of potential aquaculture-related NbS to clarify the limits of the NbS framework in the aquaculture sector.

In conclusion, it is highlighted that the NbS concept and Global Standard applied to aquaculture systems contribute to further explain and strengthen the full text of the two WCC IUCN motions related to aquaculture (WCC 1996 Rec 018; WCC 2020 Res 045).

6. Conclusion

This report is a first attempt to use the NbS Global Standard and apply it to aquaculture. In fact, considering the proposed scope of the IUCN definition of NbS and the Global Standard framework (IUCN, 2020a), aquaculture systems may constitute true valid and relevant NbS, under specific circumstances and if they are correctly planned within a SES, and if EAA is fully implemented, in association with other sustainability-related concepts.

Potentially, aquaculture-related NbS may provide solutions to societal challenges (mainly food security, economic and social development). They could also reconcile economic and ecological targets, together with present and future needs, and the welfare of stakeholders and local communities.

The NbS framework may provide new opportunities to better implement EAA, to further emphasised local and traditional knowledge in SES involving aquaculture, as well as to strengthen synergies between aquaculture and marine protection. It will contribute to further explain and strengthen the full text of the two WCC IUCN Recommendation and Resolution related to aquaculture (WCC 1996 Rec 018; WCC 2020 Res 045).

This publication highlights the need for future research and development work on aquaculture-related NbS, as it is already the case for other NbS (Nesshöver et al., 2017), in order to clarify some critical issues. Albert et al. (2017) emphasise the lack of a precise definition for the term 'Nature-based Solutions' with its inherent risks of making the concept seem arbitrary and impractical (Albert et al., 2017). They propose short recommendations to implement NbS to stimulate cooperation between actors from science, policy and practice, and to comply with the expectations behind the NbS concept.

Undeniably, the Global Standard for NbS™ (IUCN, 2020a) will greatly help with the implementation and evaluation of NbS. Nonetheless, it is anticipated that additional work will have to be carried out on specific cases to better define the limits and relevance of the NbS approach applied to aquaculture.

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