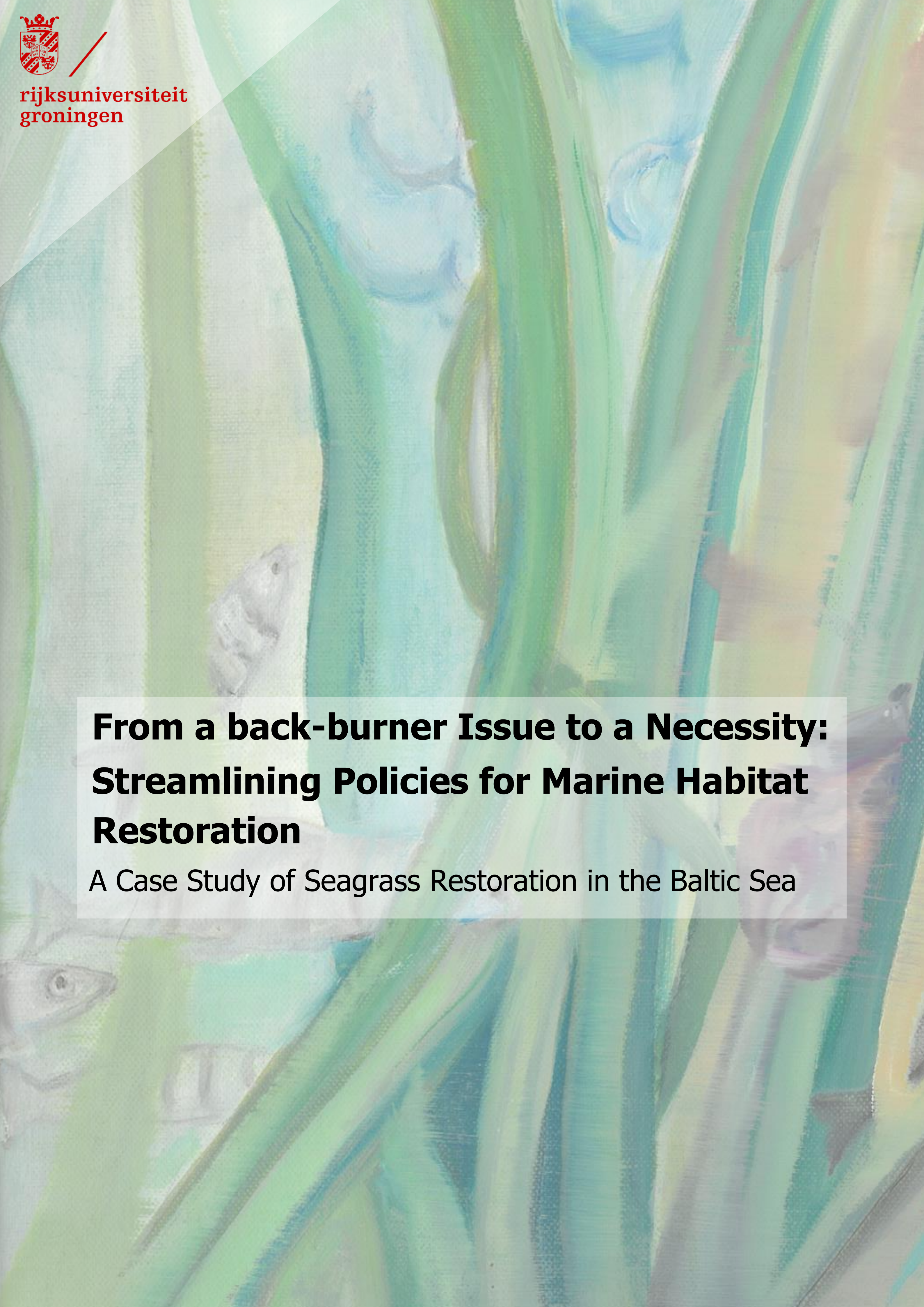

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From a back-burner Issue to a Necessity: Streamlining Policies for Marine Habitat Restoration

A Case Study of Seagrass Restoration in the Baltic Sea

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Science & Policy Report of the SBP Internship 2024

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Prologue

The oceans cover more than 70% of our planet and are the lifeblood of Earth. They regulate climate, provide food, and support various life forms. For humanity, the oceans are an indispensable resource, promoting economic prosperity, cultural heritage, and environmental stability. Despite their immense value, marine ecosystems face many threats from human activities and climate change.

Among these critical ecosystems, seagrass beds play a vital yet often overlooked role. Seagrass meadows are essential for supporting marine biodiversity, maintaining water quality, protecting coastlines, and storing carbon, thus mitigating climate change.

A rapid deterioration of seagrass ecosystems is occurring due to increasing temperatures, pollution, coastal development, and other anthropogenic pressures. Effective nature restoration policies and their implementation are paramount to reverse this trend and ensure the resilience of seagrass habitats. This report was developed to contribute to the vision of supporting a sustainable future where marine ecosystems thrive, benefiting both nature and humanity.

"Restoring natural ecosystems is not only about bringing back lost species or habitats; it's about rebuilding the resilience of our planet and securing a future for all forms of life."
- Dr. Jane Goodall

Acknowledgments

I would like to express my gratitude to Carla Langsenkamp and Stella Nemecky for their supervision and for providing me with the opportunity to pursue this internship. It was inspiring talking to them which created an atmosphere that allowed me to explore and find out. Thank you for your time and effort in understanding and answering my (sometimes unclear) questions.

I also wish to extend my thanks Jorien Zevenberg my supervisor at the University of Groningen, for offering many insightful ideas and invaluable advice as well as for asking the right questions at the right moments, which often provided the exact direction I needed.

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Lastly, I extend my thanks to all my colleagues here at WWF. I especially appreciated working with many knowledgeable, intelligent, and assertive women at WWF. I am thankful for the opportunity to learn from them and gain a deeper understanding of how the "real world" functions. It was a great pleasure!

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Acronyms

AI	Artificial Intelligence
ANK	Aktionsplan Natürlicher Klimaschutz
BfN	Bund für Naturschutz
BMUV	Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz
BSAP	Baltic Sea Action Plan
BSH	Bundesamt für Seeschifffahrt und Hydrographie
CBD	Convention on Biological Diversity
CDR	Carbon Dioxide Removal
CFP	Common Fisheries Policy
EC	European Commission
EU	European Union
EEZ	Exclusive Economic Zone
GES	Good Ecological Status
HD	European Habitats Directive
HELCOM	Helsinki Convention
MER	Marine ecosystem restoration
MPA	Marine Protected Area
MSFD	Marine Strategy Framework Directive
MSP	Maritime Spatial Plan
MV	Mecklenburg-Vorpommern
NGO	Non-Governmental Organization
NRL	European Nature Restoration Law
NRP	National Restoration Plan
OSPAR	Oslo-Paris Convention
PAR	Photosynthetically active radiation
POC	Particulate Organic Matter
SAC	Special Area of Conservation
SER	Society for Ecological Restoration
SH	Schleswig-Holstein
SI	Surface irradiance
SPM	Suspended Particulate Matter
SWOT	Strengths, weaknesses, opportunities, and threats
UN	United Nations
WFD	Water Framework Directive
WWF	World Wide Fund for Nature

Glossary

Biodiversity - The variety of living organisms on Earth from all sources including terrestrial, marine, and other aquatic ecosystems, and the ecological complexes of which they are a part. Biodiversity includes diversity within species, between species, and of ecosystems.

Citizen Science - Work undertaken by civic educators together with citizen communities to advance science, foster a broad scientific mentality, and/or encourage democratic engagement, which allows society to deal rationally with complex modern problems.

Conservation – Nature conservation aims to protect and preserve the natural environment, including ecosystems, wildlife, and natural resources by encompassing various strategies and actions, such as establishing protected areas, implementing sustainable practices, and promoting awareness and education.

Ecological restoration – The process of actively or passively assisting the recovery of an ecosystem towards a good condition of a habitat type to the highest level of health attainable and its favorable reference area, of habitat of a species to a sufficient quality and quantity or of species populations to satisfactory levels, as a means of conserving or enhancing biodiversity and ecosystem resilience.

Ecosystem – A dynamic complex of plant, animal, and microorganism communities and their non-living environment, interacting as a functional unit and including habitat types, habitats of species, and species populations.

Ecosystem degradation- A level of harmful human impact that results in the loss of biodiversity and simplification or disruption in its composition, structure, and functioning, and generally leads to a reduction in the flow of ecosystem services.

Ecosystem functions – The biotic and abiotic processes that occur within an ecosystem and may contribute to ecosystem services either directly or indirectly.

Ecosystem services – The benefits people obtain from ecosystems.

Governance - The rules of collective decision-making in settings where there is a plurality of actors or organizations and where no formal control system can dictate the terms of the relationship between these actors and organizations.

Habitat - A habitat of a species is an environment defined by specific abiotic and biotic factors, in which the species lives at any stage of its biological cycle.

Indicator – A component or measure of environmentally relevant phenomena used to depict or evaluate environmental conditions.

Seagrass – Specialized marine flowering plants that have adapted to the nearshore environment of the world's continents.

Executive Summary

In times of a warming planet and the loss of many species, it is crucial to actively restore habitats as a measure to secure the structure and functioning of ecosystems. Resilient ecosystems are crucial for stable economies and providing food security. In the past, policies that aim at conserving and restoring habitats and ecosystems have proven to be only sparsely implemented resulting in unmet targets and further degradation.

This report dissects the factors that play into the successful implementation of marine habitats with the case study of seagrass restoration in the Baltic Sea by WWF. Generally, seagrass meadows are crucial habitats functioning as carbon sinks, coastal protectors, fish nurseries as well as shelters for many more species. Despite their immense value, populations worldwide are declining. Efforts to restore seagrass meadows have been conducted in the past with only little success in most cases.

By examining conservation policies and current practices, identifying barriers to success, and proposing strategic improvements, this report aims to improve the implementation of conservation and restoration policies for seagrass beds in the Baltic Sea. The rise of the currently adopted Nature Restoration Law was long overdue. It will be critical for the restoration success in German waters, as EU member states are now obligated to develop national restoration plans in which marine habitats such as seagrasses should be included.

Another policy focusing on the protection of the Baltic Sea, the Baltic Sea Action Plan partly targets lowering eutrophication. If fully implemented, it has been identified as an important tool to reach the targets and lay a path for the right environmental conditions for seagrass. Recently, the Aktionsplan Ostseeschutz an action plan for the protection of the Baltic Sea coast of Schleswig-Holstein was published with restoration targets for seagrass. This policy might be on a regional level and is non-binding but comes with high engagement of the state to be implemented as this was the proposed alternative to a nature reserve. The policy is also a good example of a marine conservation tool and could potentially be an inspiration for further federal states as Mecklenburg-Vorpommern. WWF is currently planning on conducting seagrass restoration in this state and starting the first approaches to map the occurrence of seagrass meadows on the coastal waters in this state.

A guideline to support WWF gathers all relevant elements that are needed to succeed with such a project. These elements include necessary ecological factors for a successful restoration project, decision support for finding the suitable restoration site, method & donor material as well as mentioning bottlenecks that must be overcome. The guideline also discusses challenges like stakeholder engagement, unharmonized data, the incoherence of policies, and the lack of governance.

Finally, this report delves into how Germany's restoration efforts can be optimized through advice on the implementation of WWF to achieve meaningful, long-lasting outcomes for seagrass conservation. The focus lies on planning steps to develop a suitable site model, finding collaborators, and necessary outreach to increase awareness of the worth of seagrass protection.

Contents

01 Shifting Currents for Nature Conservation

1.1. Introduction

Nature is the foundation of all life on earth and provides many essential ecosystem functions and services (Cornell et al., 2002). However, severely rapid biodiversity loss is occurring leading to the so-called sixth "mass extinction" (Ceballos et al, 2015) and is coupled to increasing temperatures (Fig. 1). This can be attributed to the ecologically poor status of several habitats, habitat loss, and habitat fragmentation due to global warming and other contributing factors like pollution, exploitation of resources, industrialization, among other human interferences (Heinrichs et al., 2016; Scanes, 2018). Climate change only be mitigated by functioning ecosystems with a stable biodiversity to provide food security, higher resilience against natural disasters, less vulnerable communities, and overall sustainable and secure economies (Asmamaw et al., 2015). Contracting parties of the UN Convention on Biological Diversity (CBD) adopted a Strategic Plan for Biodiversity to conserve species diversity and strengthen habitats by targeting the restoration of a minimum of 15% of degraded ecosystems by 2020 (CBD, 2010). The same target was adopted by the EU Biodiversity Strategy established to rebuild degraded habitats listed in the Natura 2000 network (EC, 2011).

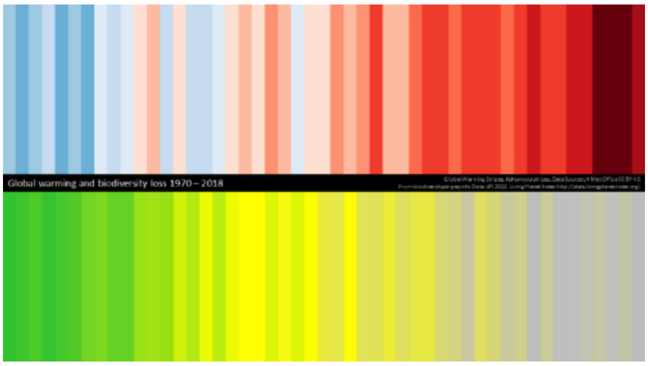


Figure 1: Global warming (top; red = warmer temperatures, blue = colder temperatures) in correlation with biodiversity loss (bottom; grey = biodiversity loss, green = higher biodiversity) between 1970-2018 (from left to right) (https://biodiversitystripes.info/global).

It was assessed whether there was an improvement in the ecological status of the habitats listed in the Natura 2000 EU's Birds Directive (EC, 2009) and Habitats Directive (EEC, 1992) in 2013-2018. European habitats did not show improvement in the overall conservation status as 81% of all habitats are in unfavorable conditions (Fig. 2) For example, more than 80% of the coastal habitats in Europe are in a poor or bad state (EEA Report No 10/2020). In 2022, the CBD published new targets in the Fifteenth Conference of the Parties (CBD, 2022). Amongst others, they issued the "30x30 target", with the goal of protecting 30% of terrestrial and 30% of marine ecosystems until 2030 (UN Environment program, 2022). The EU adopted the "30x30 target" in the EU Biodiversity Strategy for 2030 (EC, 2020) as a key element of the European Green Deal (EC, 2019). Another addition to the European repository of conservation tools is the Nature Restoration Law (NRL) which is part of the European Green Deal to restore more than 20% of degraded marine and terrestrial habitats protected until 2030. The addressed habitats are listed in the Natura 2000 network and are aimed to be restored to a 'good ecological status' (GES) (EC, 2022a). The watered-down version of the law with fewer targets than originally intended was adopted by the EU Council in June 2024 (Dimopoulou, 2024). Many hopes lay on this policy to bring back nature that encompassed binding targets, clear timelines, effective tools together with implementation strategies. The next step is the development of national restoration plans for each country to implement the policy (Hering et al., 2023).

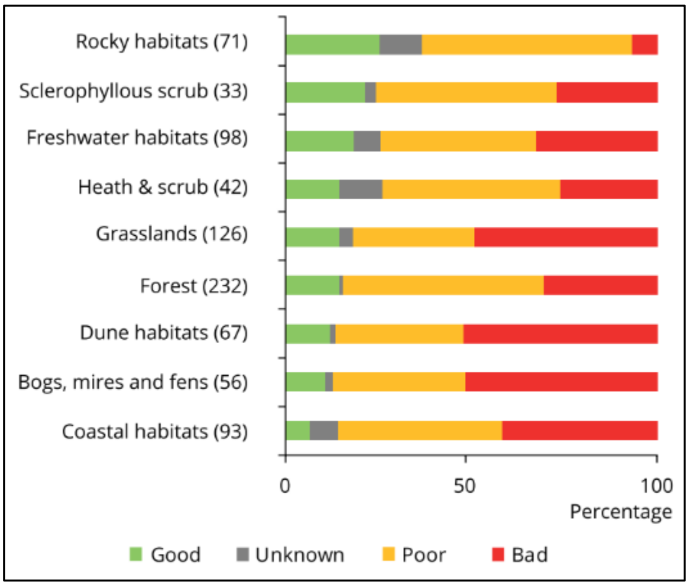


Figure 2: Conservation status per habitat group at the EU level in the reporting period 2013-2018 of Natura 2000 habitats. More than 80% of coastal habitats are in an unfavorable conservation status (EEA Report No 10/2020).

The implementation of conservation- and restoration plans can be challenging due to multiple factors such as lack of stakeholder engagement by exclusion of socioeconomic aspects (Baker & Eckerberg, 2016), lack of objectives with later monitoring & evaluation (Leslie & McLeod, 2007), incoherent policies (Hering et al., 2023), lack of enforcement (Rife et al., 2013), or insufficient funding (Cortina-Segarra et al., 2021). Marine restoration was not as prevalent in the past compared to terrestrial restoration, potentially leading to less experience in the practice (Fig. 3) (Blignaut et al., 2013; France, 2016). Figure 3 gives an overview of the root causes of the policy problem. Much required awareness of certain ecosystems is low due to the limited visibility of underwater life. Seagrass meadows are often less known than other ecosystems and therefore less protected (Cullen-Unsworth et al., 2014). Currently, seagrass meadows worldwide are facing a rapid decline (Waycott et al., 2009).

It was shown that degrading ecosystems have a strong correlation with the loss of ecosystem services and functions (Worm et al., 2006). Seagrasses provide many ecosystem services and functions like food and shelter for several species (Plummer et al., 2013; Unsworth et al., 2019), carbon uptake (Fourqurean et al., 2012), and coastal protection (Dinu et al., 2023; Infantes et al., 2022). In the Baltic Sea, the domiciled common eelgrass *Zostera marina* is threatened by fisheries, eutrophication, and increasing temperatures (Schubert et al., 2015). As a response to decreasing fish stocks in the Baltic Sea, it might be beneficial to emphasize the protection of juvenile fish. This can be achieved by focusing on seagrass meadows as nursery grounds for many commercial fish species. Effective large-scale restoration along the German coast of the Baltic Sea has the potential to eventually revive this ecosystem.

The Client

The World Wide Fund for Nature (WWF) is a non-governmental organization with the primary aim of nature conservation. They focus on the preservation of biodiversity and protection of terrestrial and marine ecosystems as well as reducing humanity's footprint on this planet. They do this by implementing conservation projects, political lobbying, working tightly together with other environmental organizations, publishing recommendations as well as raising awareness through campaigns. Additionally, WWF is involved in cooperations and partnerships with further organizations and businesses with the main goal of strengthening conservation (WWF, n.d.). Seagrass restoration could be a comprehensive response to achieve policy and conservation goals for marine ecosystems and biodiversity together with strengthening socioeconomic aspects. WWF-Hamburg is planning to conduct seagrass restoration on the western Baltic Sea coast of Mecklenburg-Vorpommern (MV, from here on called 'area of interest') a federal state of Germany.

1.2. Goal & Scope of the Report

The overall aim of this report is to overcome the problem that *policies supporting marine restoration are poorly implemented and therefore sparsely effective*. A root cause flow chart (Fig. 3) analyzes the underlying causes of the situation. The goal of the report is to elaborate on the primary and secondary root causes leading to the policy problem and the consequential symptoms.

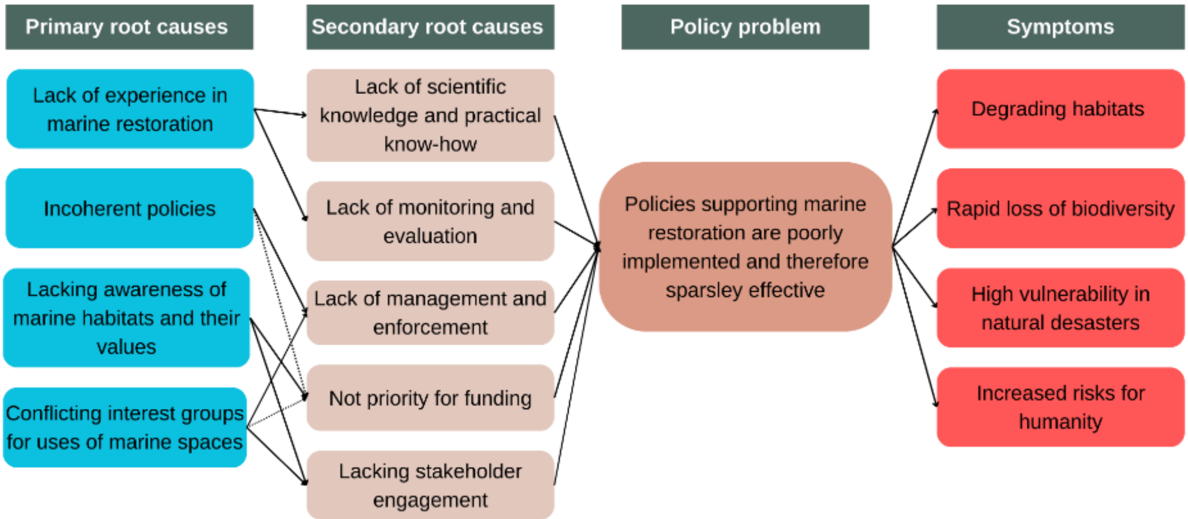


Figure 3: Root cause flow chart of the policy problem. Primary and subsequential secondary root causes led to the policy problem and the consequential symptoms. Dotted lines indicate a less strong connection compared to solid lines.

The first goal of this report therefore is to gather scientific contributions about the relevant ecosystem and the most important criteria that need to be considered for general restoration of marine habitats. The intended outcome is harmonized data and support experience in marine restoration. Secondly, nature conservation and management policies are compared and analyzed for different criteria to determine the supportiveness and effectiveness of the policies for marine habitat restoration with a focus on eelgrass in the western Baltic Sea on the German coast. The third goal is to identify challenges in the effective implementation of policies and planned projects and how to overcome them. Finally, a guideline for WWF summarizes the most important steps for a project together with advice on the implementation to follow with concrete actions. This leads to the following **research question**:

How can marine habitat restoration (here seagrass meadows in the Baltic Sea) be more effective in its implementation?

The following **sub-questions** were tackled in this report to develop recommendations on how to effectively restore Seagrass meadows in the area of interest:

Scientific research sub-questions:

- *What is ecological (marine) restoration?*
- *What is the state of the Baltic Sea?*
- *What is the ecosystem seagrass meadow?*
    - *Why does it need to be restored?*
    - *How can it be restored?*

Policy research sub-questions:

- *Which policies are relevant for marine restoration?*
    - *Why are conservation policies not effectively implemented?*
    - *How can these policies be implemented more effectively, specifically regarding seagrasses in the Baltic Sea?*
- *What does the environment look like regarding marine restoration?*
- *What are the internal structures of WWF?*

Integrated research sub-questions:

- *Which elements are important in a guideline for seagrass restoration?*
- *How can WWF implement this guideline?*

The report was developed in the context of an internship of the master's track 'Science, Business, and Policy' of the University of Groningen that was conducted at WWF Germany and took place under the supervision of experts in scientific and policy fields of both the University of Groningen and WWF Germany (Tab. 1).

Table 1: List of supervisors involved in this internship.

Name	Institute	Function	Role in supervision
Carla Langsenkamp	WWF	Policy Advisor	Daily supervisor
Stella Nemecky	WWF	Senior Policy Advisor	Daily supervisor
Jorien Zevenberg	University of Groningen, Science Business and Policy master's track	Lecturer	SBP supervisor
Prof. Dr. Laura Govers	University of Groningen, Marine Biology department	Associate Professor	Science supervisor

1.3. Reading Guide

This report deals with analyzing information about ecological, social, and political aspects that must be considered for marine restoration. The information is gathered as guidelines for WWF for the effective restoration of seagrass meadows along the German coast of the Baltic Sea. A summary of the contents of each following chapter is given below.

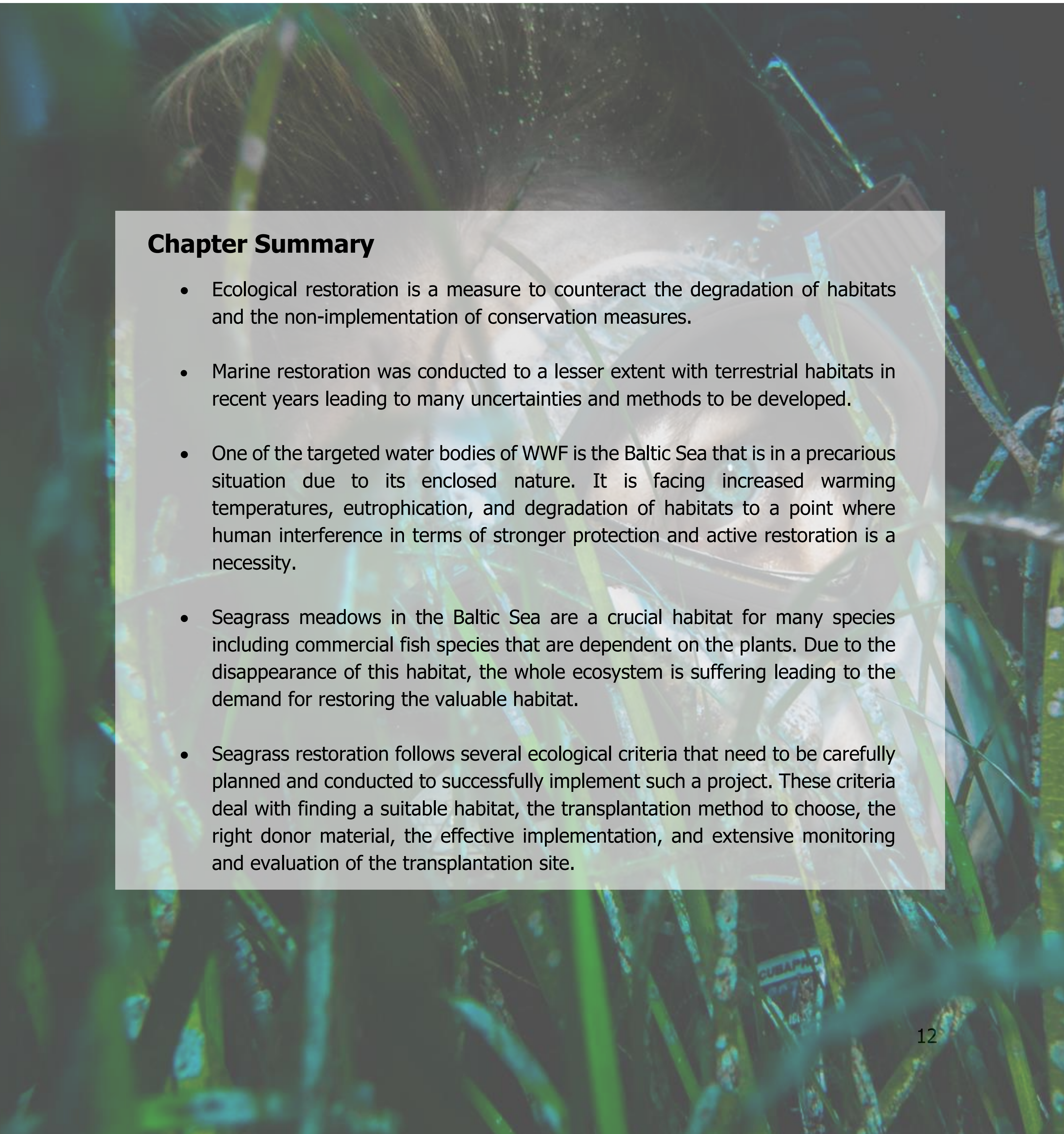
Chapter 2 focuses on the scientific aspects of ecological restoration by explaining terms and describing how marine restoration differs from terrestrial as well as presenting an overview of the Baltic Sea, as the case study. Moreover, this chapter explains the ecology of seagrasses, and emphasizes their meaning for underwater life and the atmosphere. It also describes their threats which led to a threatened status and summarizes the steps of seagrass restoration and the most relevant criteria.

Chapter 3 analyzes the importance of policy aspects in marine restoration. Relevant policies were assessed through a multi-criteria analysis and represented with a focus on how they can support seagrass restoration in the Baltic Sea. General challenges in the implementation of effective restoration policies are outlined, together with strategies on how to overcome them. Additionally, this chapter explores the external environment for marine restoration with a PESTEL analysis and which stakeholders are relevant. Lastly, a SWOT Analysis provides information about the strengths, weaknesses, opportunities, and threats of WWF to develop a strategy tailored to the organization.

Chapter 4 integrates the scientific aspects from Chapter 2 and the policy aspects from Chapter 3 and discusses how this information can help to develop the strategy on how to effectively conduct seagrass restoration in the Baltic Sea. In addition to that, this chapter describes the potent policy window of opportunity and the momentum for marine restoration.

Chapter 5 summarizes all information in a guideline for WWF on how to tackle seagrass restoration in the Baltic Sea. It lists all criteria that need to be considered and points toward crucial information. The subsequent advice on the implementation is the last element of the report. It assists with the planning of required actions to proceed with the project, by informing about information that needs to be collected and assessed and possible contacts to reach out to exchange knowledge and learn from experience to effectively restore seagrass ecosystems in the future.

02
Diving into unseen Worlds



Chapter Summary

- Ecological restoration is a measure to counteract the degradation of habitats and the non-implementation of conservation measures.

- Marine restoration was conducted to a lesser extent with terrestrial habitats in recent years leading to many uncertainties and methods to be developed.

- One of the targeted water bodies of WWF is the Baltic Sea that is in a precarious situation due to its enclosed nature. It is facing increased warming temperatures, eutrophication, and degradation of habitats to a point where human interference in terms of stronger protection and active restoration is a necessity.

- Seagrass meadows in the Baltic Sea are a crucial habitat for many species including commercial fish species that are dependent on the plants. Due to the disappearance of this habitat, the whole ecosystem is suffering leading to the demand for restoring the valuable habitat.

- Seagrass restoration follows several ecological criteria that need to be carefully planned and conducted to successfully implement such a project. These criteria deal with finding a suitable habitat, the transplantation method to choose, the right donor material, the effective implementation, and extensive monitoring and evaluation of the transplantation site.

2.1. Ecological Restoration

81% of EU-protected habitats are in poor condition mostly due to non-implementation of conservation policies (EEA, 2020). Many scientists therefore stressed the need to adopt the NRL to not only protect habitats but also to actively restore them to climate resilience and food security in the future (Pe'er et al., 2023). Ecological restoration is defined as: "[…] *the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed*" with the addition that "an ecosystem has recovered - and is restored - when it contains sufficient biotic and abiotic resources to continue its development without further assistance or subsidy. It will sustain itself structurally and functionally. It will demonstrate resilience to normal ranges of environmental stress and disturbance. It will interact with contiguous ecosystems in terms of biotic and abiotic flows and cultural interactions" (SER, 2004). Active restoration meaning the active re-introduction of species doesn't necessarily show more results than passive restoration meaning solely tackling the enhancement of environmental conditions. Active restoration might however be the solution if passive restoration proceeds too slowly to achieve conservation targets (Jones et al., 2018; Perrow & Davie, 2002).

"Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed." (SER, 2004)

Rohwer & Marris (2016) however argue that erroneous ecological restoration is commonly thought to bring back the state of a specific historical timeline whereas the goal should rather be to re-establish a new state. Climate change and the dynamic nature of ecosystems as well as the lack of knowledge of the exact historical state, also referred to as the 'shifting baseline' phenomenon (Pinnegar & Engelhard, 2007) hinder or prevent the return to the "original" state. To bring back ecosystem functionality and a self-sustaining state, it is important to be aware of the phenomenon. It needs new goals for restoration that consider the historical baseline but also the needs of the associated local community and their livelihoods (Higgs et al., 2014). Higgs et al. (2014) therefore developed a new version of ecological restoration which "uses historical knowledge as a guide and not as a template, accepts multiple potential trajectories for ecosystems, emphasizes process over structure, and embraces pragmatic goals for human well-being". This is also reflected in *Key Concept 1* of the guideline 'International Standards for the Practice of Ecological Restoration' by the Society for Ecological Restoration (SER). The concepts serve as a framework for fundamental ideas of ecological restoration (Fig. 4) (McDonald et al., 2016).

However, so far, the status quo of restoration success is low, for various reasons (see introduction). Jones & Schmitz (2009) analyzed that one-third of several reviewed global habitats showed full recovery. Aligning with Key Concept 2 (Fig. 4), oftentimes clear goals and objectives are lacking leading to unclear assessments of whether restoration targets were achieved as previously stated (Abelson et al., 2020). It was shown that when applying both passive and active restoration measures after one another, eliminating stressors first, restoration of marine habitats worldwide can be more successful (Duarte et al., 2020). The

Figure 4: Key concepts of the guideline International Standards for the Practice of Ecological Restoration by the SER (McDonal et al., 2016).

MERCES pressure catalog can be used for examples of stressors for marine habitats and active as well as passive restoration measures to mitigate and remove those stressors (Bekkby et al., 2017). According to *Key Concept 4* (Fig. 4) of the SER "Restoration seeks 'highest and best effort' progression towards full recovery" (McDonald et al., 2016), yet oftentimes, the scientific foundation for nature restoration is insufficient for a successful re-establishment leading to the need to gather information and find best-practice examples (Gann et al., 2019). The practical implementation of nature restoration projects is not only challenging due the lack of scientific knowledge but also due to the lack of experience as well as evaluation and monitoring (Cortina-Segarra et al., 2021). It is therefore important to include a wider community as a knowledge network, also to improve implementation as suggested in *Key Concept 5* (Fig. 4).

Some policies and project plans were rarely successfully implemented because stakeholders had conflicting interests and because of the low political priority (Cortina-Segarra et al., 2021; Hermoso et al., 2022) which is addressed in *Key Concept 6* (Fig. 4). Additionally, restoration can be hindered due to high costs for ecological restoration and lacking funding (Holl & Howarth, 2000). According to the NRL, every invested euro in the ecological restoration was calculated to have a benefit equally of 8-38€ of output in ecosystem services (EC, 2022a), yet due to the enormous value of the ecosystem services the long-term benefits are estimated to be higher than the investment (Li et al., 2021).

2.2. Restoring Marine Habitats

The oceans are in a dire state, though crucial to buffering symptoms of the climate crisis (Laffoley et al., 2020). Marine Protected Areas (MPAs) are thought to be an oasis for marine life by regulating or prohibiting human activities defined as "a clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values" (Dudley, 2008). However, due to no enforcement of the rules and no controls, illegal activities are oftentimes still occurring and MPAs are designated mostly just on paper giving them the name ‘paper parks’ (Rife et al., 2013). No-take zones, areas in which strict regulations forbid any kind of exploitation, are the most effective MPAs in terms of ecosystem functionality and health (Sala & Giakoumi, 2018). However, fishing in the world’s oceans is still allowed in 94% of the MPAs and less than 1% of the world’s MPAs are no-take zones (Costello and Ballantine, 2015). The rest of the world’s seas are mostly left to their own devices which invites exploitation by humanity. Overfishing, illegal fishing, bycatch, and bottom trawling have a huge negative impact on the health of the oceans (Bradshaw et al., 2021; Hall et al., 2000; Canyon et al., 2022).

Additionally, Eutrophication as a result of decades of high nutrient input in the seas and the growth of algae lead and still leads to increased turbidity and less light penetration (Clarke et al., 2006; Andersen et al., 2017). Dredging, for commercial sand extraction or to clear channels for ships stirs up sediments and reduces the visibility even more (Lednicka et al., 2022). Further crucial threats for marine coasts and waters are the growing offshore wind sector, bottom trawling, elevated maritime traffic, and pollution (Korpinen et al., 2012; Eigaard et al., 2017; EEA, 2017). The deterioration of marine ecosystems does not only impact the functionality and resilience of ecosystems but also directly threatens human well-being through algae blooms and microbial and chemical contamination of water and seafood (Sandifer and Sutton-Grier, 2014; Fleming et al., 2006). Humanity relies on the many services marine ecosystems provide, e.g., living resources (food), resources, coastal protection, carbon uptake, and oxygen production (Heckwolf et al., 2021).

The number of restoration projects of marine habitats like kelp, seagrasses, oysters, and corals drastically increased with the beginning of the 21st century (Duarte et al., 2020; see Appendix 1, Fig. 14). Marine restoration, especially of corals and seagrasses is associated with very high costs and only little success (Bayraktarov et al., 2016). It was shown that the restoration of marine habitats can result in higher success when increasing the scalability and monitoring efforts as most marine restoration projects occur on a very small scale (Saunders et al., 2020). Abelson et al. (2020) therefore suggest four processes for more effective implementation of coastal marine ecosystem restoration (MER): (1) development of effective, scalable restoration methods, (2) incorporation of innovative tools that promote climate adaptation, (3) integration of social and ecological restoration priorities, and (4) promotion of the perception and use of coastal MER as a scientifically credible management approach. Europe is one of the fastest-warming regions worldwide (Wang et al., 2022) and the oceans are not detached from global warming. German water bodies, the North Sea and Baltic Sea nowadays face many threats and are increasingly degrading due to coastal development and exploitation by humans. One water body in Europe is in a very challenging situation due to its isolated location and is currently experiencing rapid warming - The Baltic Sea.

2.3. The Case of the enclosed Sea

The Baltic Sea (Fig. 5) is a water body closed off by many bordering countries with only a little saltwater input from the North Sea. The bathymetrical characteristics and its closed-off nature result in many different basins with varying conditions. Salinity levels fluctuate between up to 30‰ in the very west in the so-called “Belt Sea” at the entrance to approximately 1‰ in the northern part of the sea (Andersen et al., 2017). The temperature of the brackish sea in winter is 0-4°C and in summer 18-24°C (Worm & Reusch, 2000). Due to global warming, the overall temperature of the sea rose by +1.35 °C between 1982 and 2006 (Dutheil et al., 2023). Due to the low water exchange rate, the residence time of the water -meaning the exchange time of all water of the Baltic Sea- is approximately 33 years (Elken & Matthäus, 2008). For the same reason and due to years of high nutrient input in the Sea from mostly agriculture, eutrophication is still one of the most severe stressors of the water body (Fig. 5) even though overall improvements were detected (Andersen et al., 2017). Low oxygen levels up to hypoxia threaten the Baltic Sea resulting in a dead zone within the sea where no oxygen occurs and bottom-living organisms mostly don't survive (Conley et al., 2011). The Baltic Sea is home to

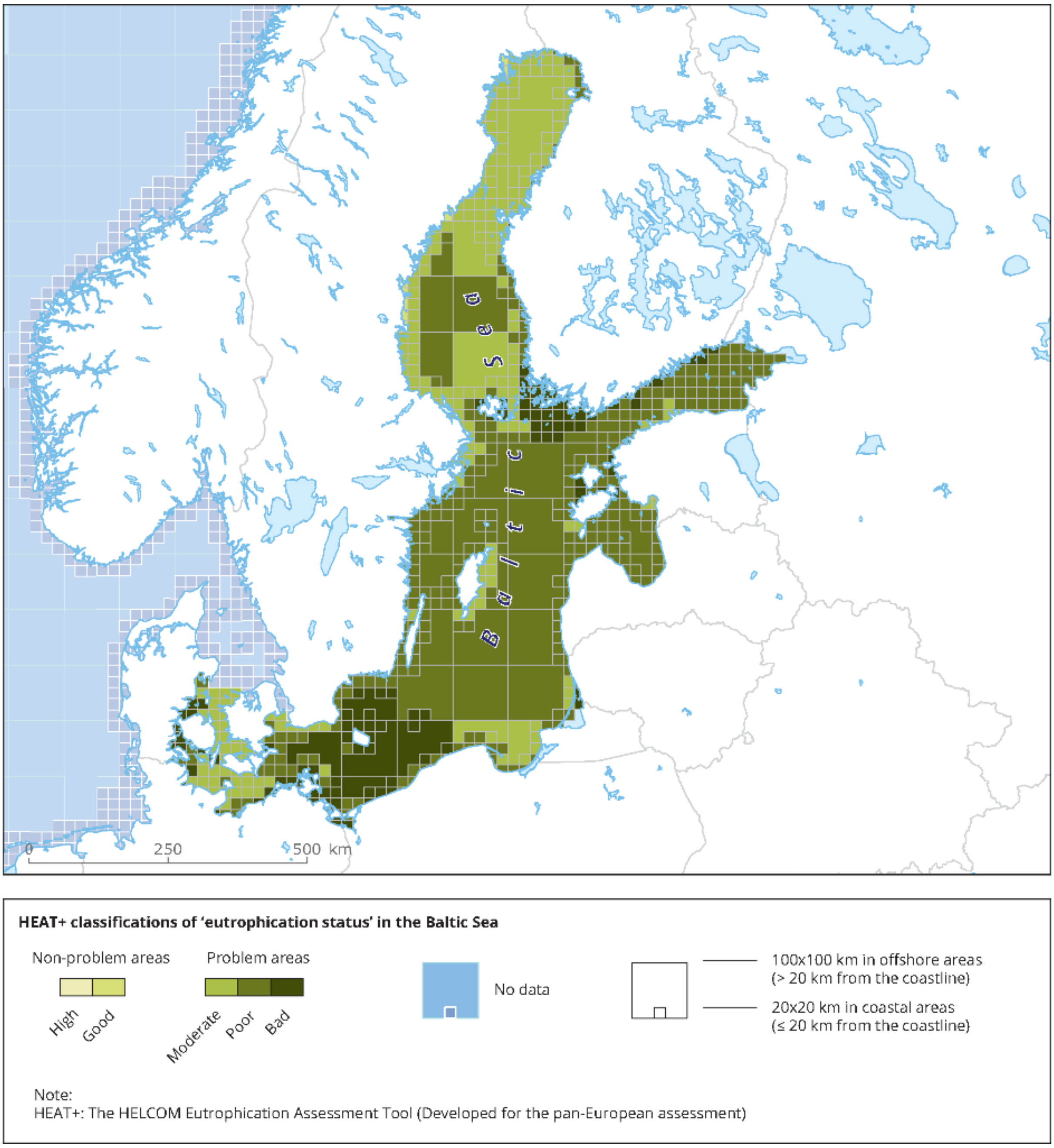


Figure 5: Map of the Baltic Sea indicating the eutrophication status by using the assessment tool HEAT+. The intensity of the coloring indicates the grade of eutrophication (adapted from EEA, 2019: https://www.eea.europa.eu/data-and-maps/figures/heat-classifications-of-eutrophication-status/heat-classifications-of-eutrophication-status).

many associated species (Ojaveer et al., 2010). Economically important fish species like Hering, sprat, and cod could be found in higher biomass than other fish species but were decreasing in the 20th century partially due to shifts in the climate and unsuitable hydrographic conditions in the spawning areas. Overfishing depleted fish stocks (Aps & Lassen, 2010), and bottom trawling led to slow or non-recovery of the fish stocks (MacKenzie et al., 2007). Bottom trawling is considered one of the most significant threats to the Baltic Sea (Bradshaw et al., 2021). Other activities such as dredging also lead to the resuspension of sediment particles and deposition of Particulate Organic Carbon (POC) in the water column (Suspended Particulate Matter, SPM). This causes increased turbidity and more algae growth due to nutrient release (Kari et al., 2017; Lednicka et al., 2022; Bradshaw et al., 2021). That leads to less penetration of light which many of the benthic macrophytes need for photosynthesis (Lee et al., 2007). Ghost nets from the increased commercial fisheries are furthermore a problem for many species, mostly fish but also habitat-building species (Stolte et al., 2022).

Those stressors result in degraded habitats that many species depend on, leaving uncertainty about how it will affect the whole ecosystem in the long run. The connectivity and interdependencies in complex food webs are still not completely understood but it was shown that stressors simplify those food webs and decrease their resilience (Heleno et al., 2020). 'Fair Oceans', 'Slow Food' and 'Brot für die Welt' claimed February 29th this year to be the "End of fish"-Day, the day on which Germany exhausted all their national fish stocks so that additional fish to cover demands must be imported from that day on (Zimmermann et al., 2024).

The Baltic Sea is also a habitat for small mammals, namely three seal species and the harbor porpoise (Phocoena phocoena) with the latter nowadays classified as a "critically endangered" species (HELCOM Red List of Species). Furthermore, the water body is home to many macrophytes that can be found close to the coast, mainly macroalgae and seagrasses but also other aquatic vascular plants that can be found in the shallow coastal waters. These are however, impacted by changing nutrient loads, weather patterns, and increased turbidity leading to the decrease of many underwater plants (Boström et al., 2014; Kovtun et al., 2009).

2.4. Underwater Meadows

Seagrasses, like other flowering angiosperms, have leaves, roots, and flowers, only that they grow submerged in estuarine and marine waters (Green and Short, 2003; Larkum et al., 2006). There are approximately 60 seagrass species worldwide that are commonly adapted to grow in a fully submerged environment (Arber, 1920). Seagrasses are worldwide abundant on the coasts of all continents except for Antarctica (Short et al., 2007).

Common Seagrasses (eelgrass) like *Zoster marina* and *Zostera noltii* are widely abundant in Nordic climates and can be found in intertidal and subtidal coastal locations (Park et al., 2016; Short et al., 2007). The optimal temperature for eelgrasses is 10-20°C with higher mortality rates at temperatures above 25°C and the salinity optimum is between 10-25‰ (Nejrup & Pedersen, 2007). Seagrasses in general require large amounts of light hence they are bound to the shallow coast in water depths of approximately 1m down to 40m of depth (Duarte et al., 2007). With 2-37% of Surface Irradiance (SI) grasses require large amounts of light compared to macroalgae and phytoplankton with only 1-3% of the SI (Lee et al., 2007). In the Western Baltic Sea on the German coast, seagrasses are exposed to salinities of 10-18‰ (frequently 8-28‰) in muddy and sandy sediments in a depth of approximately 2.5 m sometimes in more shallow waters and in sandy areas also in deeper waters (Boström et al., 2003).

Seagrass can reproduce both by pollination and seed formation and vegetatively via horizontal growth of the rhizomes and the formation of new shoots which in turn means that clones of the mother plant are formed (Phillips et al., 1983). For this reason, it can happen that a vast seagrass meadow genetically consists of only one individual (Reusch et al., 1999). In a worldwide comparison between seagrasses Yu et al. (2024) found a seagrass in the Baltic Sea with a calculated age of up to 1400 years. It was found that pollen limitation leads to an allee effect in seagrasses meaning that the larger the population the more positive effects there are for each individual and vice versa. This is also a bottleneck for seagrass restoration since the success is dependent on the recruitment of seeds. With global warming, more plants have the strategy of clonal reproduction which results in smaller genetic variance and even less resilience. This mostly seems to be happening in fragmented habitats. The patchier the meadow, the relatively fewer seeds are produced by the plants (van Tussenbroek et al., 2016; Reusch, 2003).

2.5. Ecosystem Services & Functions

Ecosystem services are defined as "the benefits people obtain from ecosystems" and encompass ecological processes like ecosystem functions and additional goods from ecosystem resources that are valuable for humans (Danely & Widmark, 2016).

Seagrasses are considered ecosystem engineers as they are "organisms that directly or indirectly modulate the availability of resources to other species, by causing physical state changes in biotic or abiotic materials" (Jones et al., 1994). The underwater meadows are a hotspot for many associated species. Along the Gulf Coast of Florida, USA for instance seagrass restoration led to an increased biodiversity of 43-64% more species compared to unvegetated areas and provided habitat and feeding ground (McHenry et al., 2021).

Seagrass meadows function as a fish nursery by offering sheltered structures to attach eggs and protect juvenile fish from predators. For that reason, seagrass meadows are crucial for the growth of fish populations and therefore the livelihood of many fishers. (Bertelli & Unsworth, 2014; Unsworth et al., 2019). Additionally, seagrass meadows are feeding grounds for some coastal bird species like the redhead whose primary food source is seagrass when wintering in the beds (Michot et al., 2008). Marine mammals (Dugong and Manatee) and turtles feed on seagrass (Hays et al., 2018; Lefebvre et al., 2017) and some shark species like the Tigershark are highly connected to this ecosystem to forage (Gallagher et al., 2021).

Due to its abilities to store large amounts of carbon, Seagrasses work as a carbon sink (Oreska et al., 2020; Duarte, 2017) by taking up CO_2 from the water for photosynthesis (Stevenson et al., 2023; Röhr et al., 2018). While covering less than 0.2% of ocean surface seagrass is responsible for at least 10% of the annual carbon capture of the seas (Fourqurean et al., 2012). Not only is the natural climate enhancer taking up the greenhouse gases, but the so-called *blue carbon* also has a longer lifespan of up to hundreds of years. Plants do not only store carbon in the plants themselves but also bury it in the sediment through their roots. If stored in the sediment and not physically resuspended it is much more stable than buried terrestrial carbon (Röhr et al., 2018; Fourqurean et al., 2012). A new study demonstrates that seagrass has the lowest technical requirements of all habitats and other technical and natural carbon dioxide removal (CDR) techniques (Borchers et al., 2024). Terrestrial peatlands for example have an enormous capacity to store carbon, yet there are not many possible areas where peatlands can be successfully restored (Borchers et al., 2024).

Next to taking up carbon, seagrasses are strongly associated with filtering water which then allows seagrasses themselves to maintain a beneficial environment for the whole population. By trapping particles and nutrients from the water column more sun can penetrate the water, hence the seagrass has higher light availability for photosynthesis (Lamb et al., 2017; Richir et al., 2013). Sensibility to environmental changes like the degradation of the water quality and less light availability, seagrasses are used as bioindicators for environmental assessments (Dennison et al., 1993; Richir et al., 2013). The seagrass meadow, able to dampen wave and current energy creates a calmer environment within the meadow (Dinu et al., 2023). Seagrasses act as a natural coastal protection through their rhizomes and fine roots which create networks that stabilize the sediment and prevent erosion. In times of climate change and increasing climate catastrophes, it is more important than ever to have an ally in coastal protection (Infantes et al., 2022; Dinu et al., 2023).

Because of these so-called "positive feedback loops" that create a more beneficial environment for the whole meadow, the health of seagrass populations is density dependent (see Appendix 2, Fig. 15). The turbidity and hydro energies at one point become too high as a result of lack of plants that do not allow the establishment of new plants (Van der Heide et al., 2007; Maxwell et al., 2017). The positive feedback loops were shown to play a major role in the Baltic Sea leading to higher numbers of plants when recolonizing eelgrass shoots; the higher the initial density the higher the shoot growth after 6 months. Positive feedback loops from the plants due to higher density are therefore more important than the resulting competition for nutrients and light between plants in the Baltic Sea in the establishing phase of a restoration in contrast to other species (Worm & Reusch, 2000). All ecosystem services are gathered in Appendix 3, Table 3.

2.6. Threats & Status

Most seagrass meadows nowadays are declining with a current rate of approximately 7% per year worldwide (Waycott et al., 2009). It started when in the 1930s a majority of the seagrass meadows in the North Atlantic died off due to the 'wasting disease', caused by the slime mold *Labyrinthula Zosterae Sp. Nov.* (Muehlstein et al., 1991) which presumably led to mortality rates of more than 90% of the seagrasses worldwide (Orth et al., 2006). Due to increased eutrophication together with industrialization many of the populations could not recover (Boström et al., 2014; Bull et al., 2012; Schubert et al., 2015). Heatwaves caused by climate change increase the mortality of seagrasses as was shown in the western Baltic Sea (Reusch et al., 2005). Physical disturbances due to changing hydrodynamics, bottom-trawling, propellers, anchors, and dredging additionally challenged the recovery of seagrass beds (Kenworthy et al., 2002; Short & Wyllie-Echeverria, 1996). Along the shallow coast, increasing temperatures make it impossible for seagrass to grow. Bottom trawling and eutrophication increase turbidity and lead to low amounts of light reaching the seafloor. That excludes deeper waters as suitable sites for seagrasses. The pressure is coming from both sides so to speak (Fig. 6) (Krause-Jensen et al.,

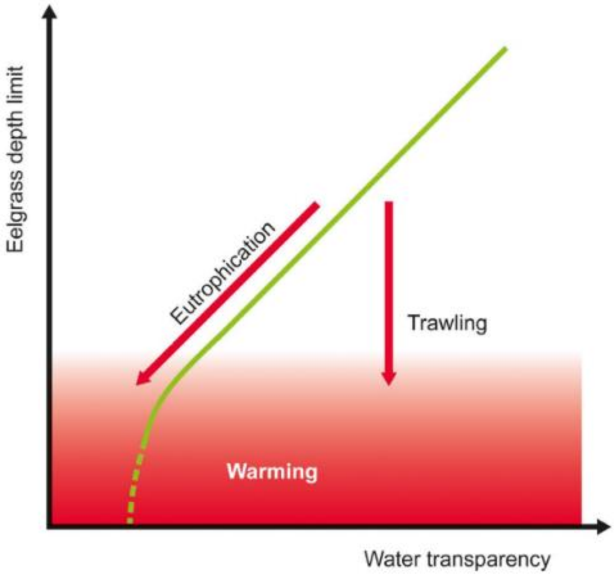


Figure 6: Current threats for eelgrass recovery and the relation of eelgrass depth limit and the water transparency. Eutrophication and trawling push eelgrass towards the coast due to less light availability where the waters are warming up and additionally threatening eelgrass (adapted from Krause-Jensen et al., 2021).

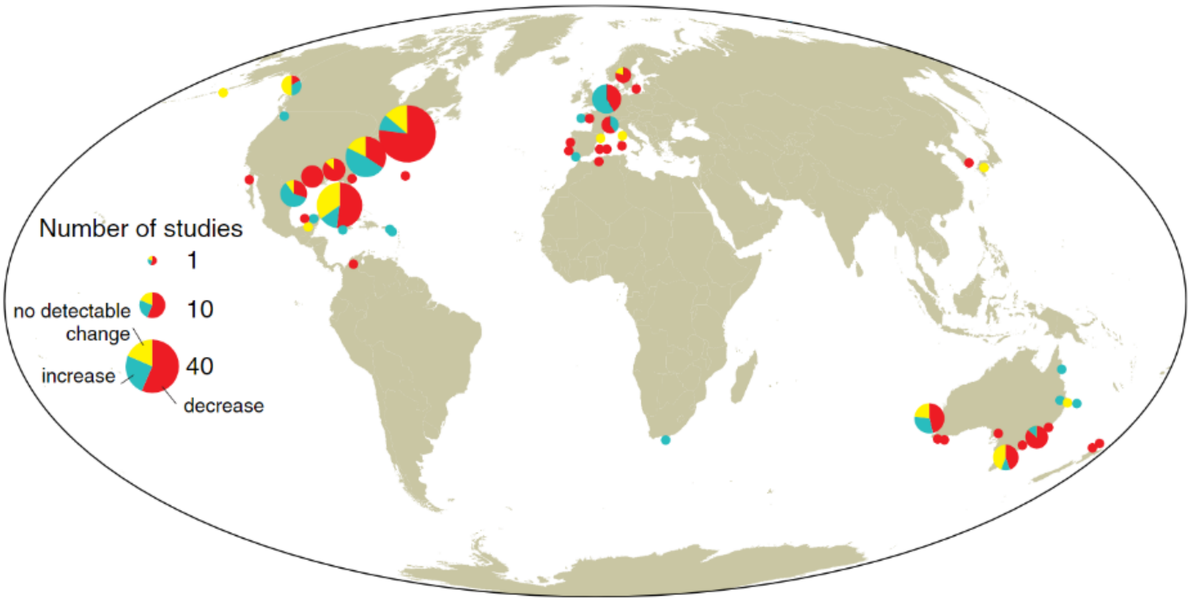


Figure 7: Status of seagrass population worldwide. Even though some populations do recover, the overall decline of seagrass meadows is approximately 7% per year since 1990 (adapted from Waycott et al., 2009).

2021). Seagrasses in Europe are on the red list of marine ecosystems with 8 out of 10 seagrass habitats in European seas of conservation concern (NE; Near Threatened in the Baltic Sea – CR; Critically endangered on North-East Atlantic) (Gubbay et al., 2016). Even though some populations are recovering, degradation is predominated worldwide (Fig. 7) (Waycott et al., 2009) and especially *Zostera marina* in Europe shows an overall decline (de los Santos et al., 2019; see Appendix 4, Fig. 18). Yet seagrasses receive little attention in social media, the news, and the least number of articles out of all marine ecosystems due to its less appealing appearance and perceived lack of charisma (Duarte et al., 2008). Slowly the focus shifts towards the neglected ecosystems and arises in the increase of restoring degraded marine habitats (Duarte et al., 2020) (see Appendix 1, Fig. 14).

2.7. Seagrass Restoration

Seagrass restoration efforts have been made worldwide with occasionally promising results (Tan et al., 2020). Yet, despite some populations that are increasing again, there was only little success in seagrass restoration so far (Cunha et al., 2012; van Katwijk et al., 2016). Long-term performances after habitat restorations are rare due to short monitoring periods even though some seagrass meadows have been shown to be persistent after up to 32 years post-restoration (Rezek et al., 2019).

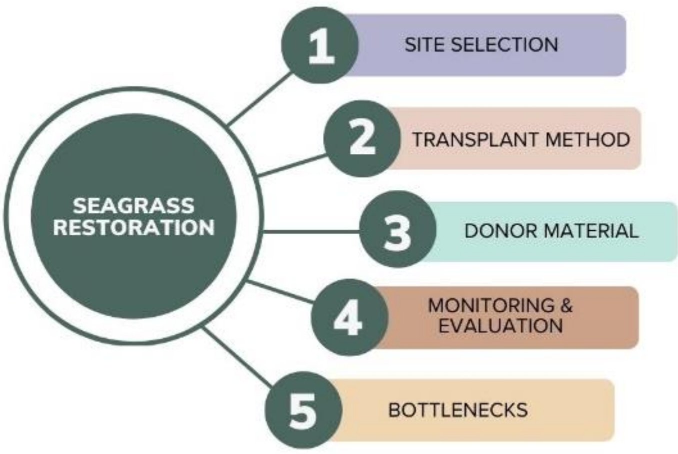


Figure 8: Ecological factors for seagrass restoration that this report deals with.

For an ecological restoration project, several factors need to be elaborated that are crucial for the success of the seagrass survival and growth. It was shown in previous attempts that the site selection and the methods for transplantation are two of the most significant criteria for the restoration success (Short et al., 2002; van Katwijk et al., 2009; Tan et al., 2020). It is furthermore important to carefully assess where the donor material will be taken from and when the restoration will be conducted. Additionally, it has to be evaluated how effective the measures were to adapt if necessary. This is done by monitoring different parameters and comparing those to a reference site. Lastly, bottlenecks from previous restoration projects might be considered to adapt the management plans (Fig. 8).

Where - Site Selection

As the selection of the unsuitable transplanting site is one of the major reasons for unsuccessful restoration (Abelson et al., 2020) it needs to be tackled with care. The extent of seagrass meadows is often not clear, leaving a big knowledge gap in management plans for seagrass conservation (Unsworth & Cullen, 2010). To conduct seagrass restoration, it is important to first find out where seagrasses could be found historically as a reference. The exact historical baseline, however, is difficult to establish due to a lack of information and the shifting baseline that was mentioned earlier. Seagrass areas of the Baltic Sea coast in the German federal state Schleswig-Holstein (SH) are quite well mapped and were used for potential restoration sites for restoration efforts conducted by the project SeaStore (Schubert et al., 2015).

Many factors affect the suitability of a restoration site. Restoration does not aim to bring back the historical state but rather targets areas with optimal conditions for the species that is to be restored. Ideally, restoration occurs in protected areas with no disturbance. The closer the donor site is to the transplantation site, the higher the survival of the transplants because of faster acclimatization in the same environment (van Katwijk et al., 2009). Many projects failed due to the selection of a non-suitable site it is crucial to utilize an extensive model for predictions of seagrass occurrence (Fonseca, 2011). Several other biotic and abiotic factors were shown to affect the growth and survival of the transplants. Short et al. (2002) included the historical presence of seagrasses, the current occurrence of seagrasses, the proximity to the natural seagrass bed, water quality, water depth, hydrodynamic energies, and sediment composition in the model for finding a suitable site for seagrasses in the USA. Salinity was not included in the model of Boström et al. (2014) due to the high tolerance of the salinity range of *Z. marina* and no significant impact on the model. For adequate site selection, a test transplant should be performed prior to the main restoration (Moksnes et al., 2021).

How - Transplant Methods

There are many methods to restore seagrass meadows (Eriander et al., 2016; Fishman et al., 2004; Flindt et al., 2022; Tan et al., 2020; Orth et al., 2006). The biggest distinction between transplantation methods is *shoots vs. seeds*.

For the shoot-based method whole adult plants are carefully taken out of the mother meadow. They need to be stored in suitable water with the right salinity until the shoots are transplanted in the restoration site. Especially in water bodies with higher velocities, whole shoots can potentially be uprooted. Iron nails or other anchoring structures are used in high hydrodynamic waters to prevent the rhizomes from being flushed out. More methods fall in the category of introducing materials like additional sediments through so-called cores and hemp mats as an anchoring system. In a seagrass restoration project in Estonia, anchoring the shoots with a rope system seemed to be promising (Pajusalu et al., 2023). Oftentimes shoots are transplanted in a chess pattern for optimal expansion through vegetative reproduction and the benefits of the positive feedback loops, as it was done in Horses Fjord, Denmark for instance (Steinfurth et al., 2022; see Appendix 4, Fig. 19).

In general, seeds are used for transplanting when the impact of harvesting donor material and transplanting should be kept low (Orth et al., 2006). This is accomplished by collecting the seeds of matured plants at the end of May into early June by manually collecting the tips of flowering shoots holding the seeds (Orth et al., 2006). Seed-based methods are less practiced regarding upscaling seagrass restoration since harvesting of seeds is done through picking by hand (Tan et al., 2020). It was shown, however, that especially in the future seed-based restoration efforts can be more beneficial due to higher genetic diversity (Williams, 2001), which is explained in the next section.

A common practice is to spread restoration efforts to not only one but several areas to minimize risks of random events like storms or heat waves (van Katwijk et al., 2009; Cunha et al., 2012; Moksnes et al., 2021).

With consideration of the transplant method comes the scalability/cost-effectiveness as methods that ecologically and legally work might be difficult in the implementation because of logistics and high costs. The time per planting unit (as a cost criterion) is an additional factor for the decision of the right transplantation method as it was analyzed by Orth et al. (2006, Table 2).

In fine sediment habitats, sand capping was shown to be a successful method for re-introducing seagrass. A coarse sand layer (approximately 10cm) is added to a muddy marine area to provide suitable sediment and enhance light availability for the plants (Flindt et al., 2022; Steinfurth et al., 2024). It should therefore be considered as a method if the grain size of sediments in otherwise suitable habitats is too small and/or turbidity is too high. All ecologically possible methods therefore need to be identified and verified with further requirements.

What - Donor Population

For the selection of suitable donor material, it must be looked at traits of the plants for them to survive in the new environment in the long-term (van Katwijk et al., 2009). It was proven to be beneficial if the donor site was as comparable to the restoration site as possible (Tan et al., 2020). On the other hand, the genetic characteristics of seagrasses play an increasingly important role nowadays. A high genetic diversity in the seagrass population ensures increased resilience to environmental influences. Suitable genetic variants for restoration in increasingly warming seas can be found by identifying more temperature-tolerant plants (Jueterbock et al., 2016). A higher genetic diversity in seagrasses is therefore desirable and could play a more important role in the future. Since vegetative reproduction of seagrasses results in clones it is recommended to focus more on the dispersal of seeds which might increase the genetic diversity. It is furthermore recommended to collect donor material from several donor sites to increase the potential genetic diversity (Williams, 2001).

Monitoring & Evaluation

To assess and evaluate the success of the restoration it is crucial to monitor the health of the transplanted meadow and compare the data to a reference site. The reference site should be a natural meadow that is located close to the transplantation site and was not manipulated (Moksnes et al., 2021). Following the *Handbook for restoration of eelgrass in Sweden*, test transplants conducted in May should be monitored 1, 2-3, and 11 months after planting (Moksnes et al., 2021). The gathered data together with the suitability index of geospatial parameters might confirm the suitability of a habitat. Short et al. (2002) included light measurements, bioturbation of species that occur locally and are known to disturb seagrasses, survival of the plants, and nitrogen content in the leaves in the model together with the suitability index of the geospatial parameters. Variables to monitor the plants could also be growth of the plants, shoot density, biomass, and areal- and depth distribution of the meadow. Also, seagrass ecosystem services such as carbon storage could potentially be monitored (Moksnes et al., 2021). In the past monitoring of the main restoration site was mostly conducted over short periods, less than 1 year which most possibly gives a wrong impression of the outcome (Cunha et al., 2012). In general, it is useful to conduct monitoring for a long period as seagrass recovery can take more than 7 years and initial performances give wrong insights into the health of the restored meadow (Bell et al., 2014).

Notable Bottlenecks

As failures are mostly not published, it is important to stay connected to the broader community to receive insights and learn from peers in the field. Talking about the experience of bottlenecks of another seagrass restoration project in the Baltic -SeaStore- pointed out that the decision for the right restoration site seemed to be the most important consideration for the planning of this particular project (personal communication with Dr. Maike Paul from SeaStore, 18.05.2024).

Trawling effects hindered seagrass recovery along Danish coasts due to the resulting resuspension of sediments and reduced light availability but also due to direct physical disturbance resulting in the uprooting of shoots (Krause-Jensen et al., 2021).

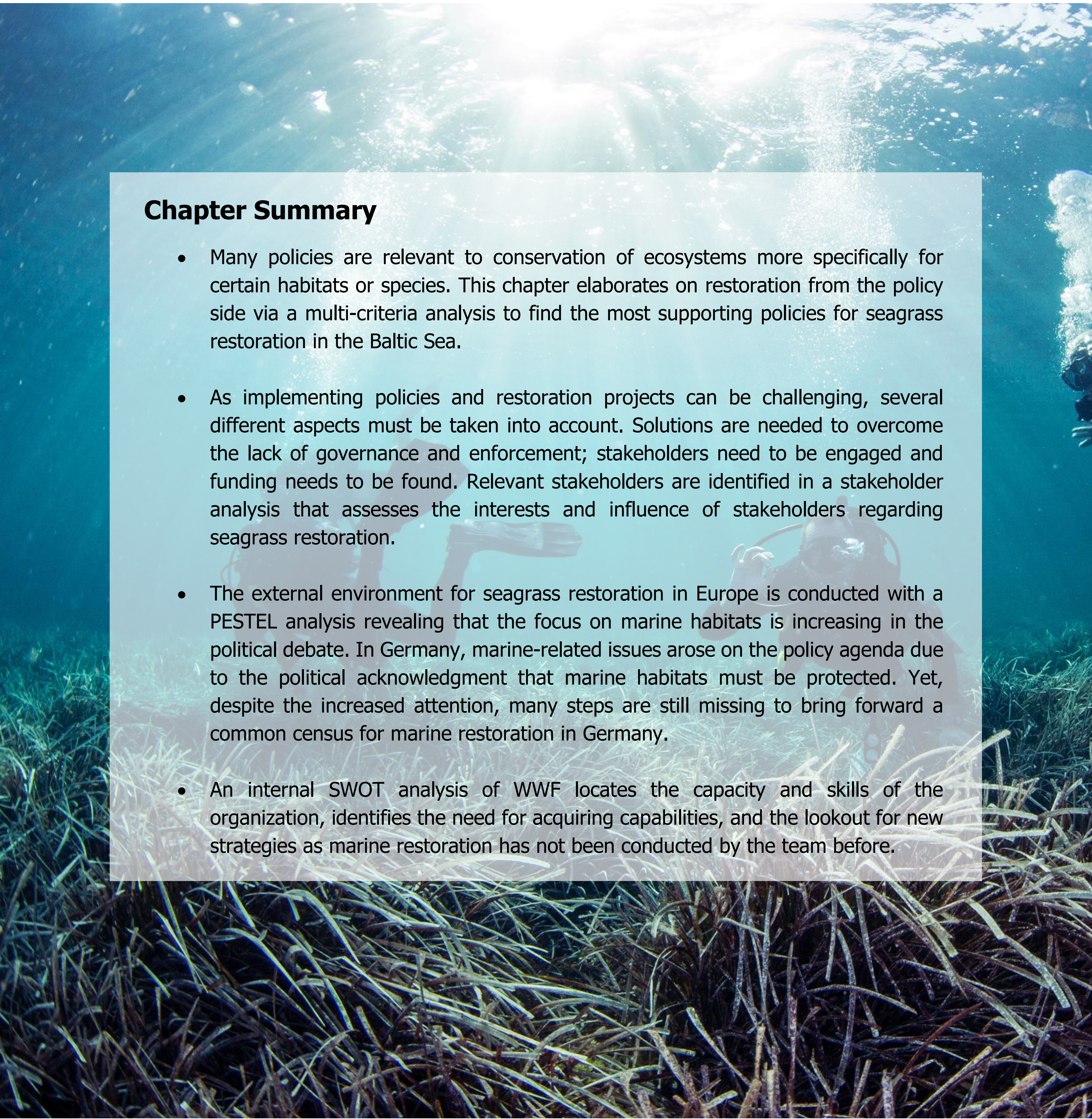
Problems with positive feedback loops should not be underrated as the chances of the survival of transplants are much higher if the meadow reaches a critical size and density. Yet, most of the seagrass restoration projects were conducted on a smaller scale (van Katwijk et al., 2016) (see Appendix 2, Fig. 16). In areas that are not as sheltered, the hydrodynamic energies might be too high and sparse meadows might not establish in the sediment.

Legal considerations like the ownership of the land, permits for transplanting seagrass in an area and regulations for introducing other materials (like iron nails and hemp mats to anchor the transplants) might not align with ecological conditions. For that reason, it is indispensable to firsthand identify relevant regulations and authorities to address.

Especially large-scale restoration with long-term commitment results in many uncertainties that arise as the development of some factors is not foreseeable. It is recommended to institutionalize adaptive management. In this approach, it has to be assessed whether measures were successful and adjust efforts accordingly to the developments over time (Ebberts et al., 2018; Murray & Marmorek, 2003).

03

Governing Habitat Revival



Chapter Summary

- Many policies are relevant to conservation of ecosystems more specifically for certain habitats or species. This chapter elaborates on restoration from the policy side via a multi-criteria analysis to find the most supporting policies for seagrass restoration in the Baltic Sea.

- As implementing policies and restoration projects can be challenging, several different aspects must be taken into account. Solutions are needed to overcome the lack of governance and enforcement; stakeholders need to be engaged and funding needs to be found. Relevant stakeholders are identified in a stakeholder analysis that assesses the interests and influence of stakeholders regarding seagrass restoration.

- The external environment for seagrass restoration in Europe is conducted with a PESTEL analysis revealing that the focus on marine habitats is increasing in the political debate. In Germany, marine-related issues arose on the policy agenda due to the political acknowledgment that marine habitats must be protected. Yet, despite the increased attention, many steps are still missing to bring forward a common census for marine restoration in Germany.

- An internal SWOT analysis of WWF locates the capacity and skills of the organization, identifies the need for acquiring capabilities, and the lookout for new strategies as marine restoration has not been conducted by the team before.

3.1. Relevant Policies for Marine Restoration

Policies and governmental actors on different levels directly or indirectly impact marine restoration. This led to a complex policy puzzle (Fig. 9). Many conservation and management policies (especially the most recent ones) in the European Union (EU) and Germany mention restoration as a crucial measure to protect nature and ensure healthy ecosystems for security and food production. All policies that deal with nature restoration (sometimes mentioning seagrass) are shortly elaborated in this paragraph. Due to the inconsistency of wording, it was not trivial to identify the best policies. Some policies specifically mention seagrass, while others refer to them as macrophytes or angiosperms, some more generally had references to plants or flora. Sometimes habitats are not directly mentioned but linked to for example via the Natura 2000 network.

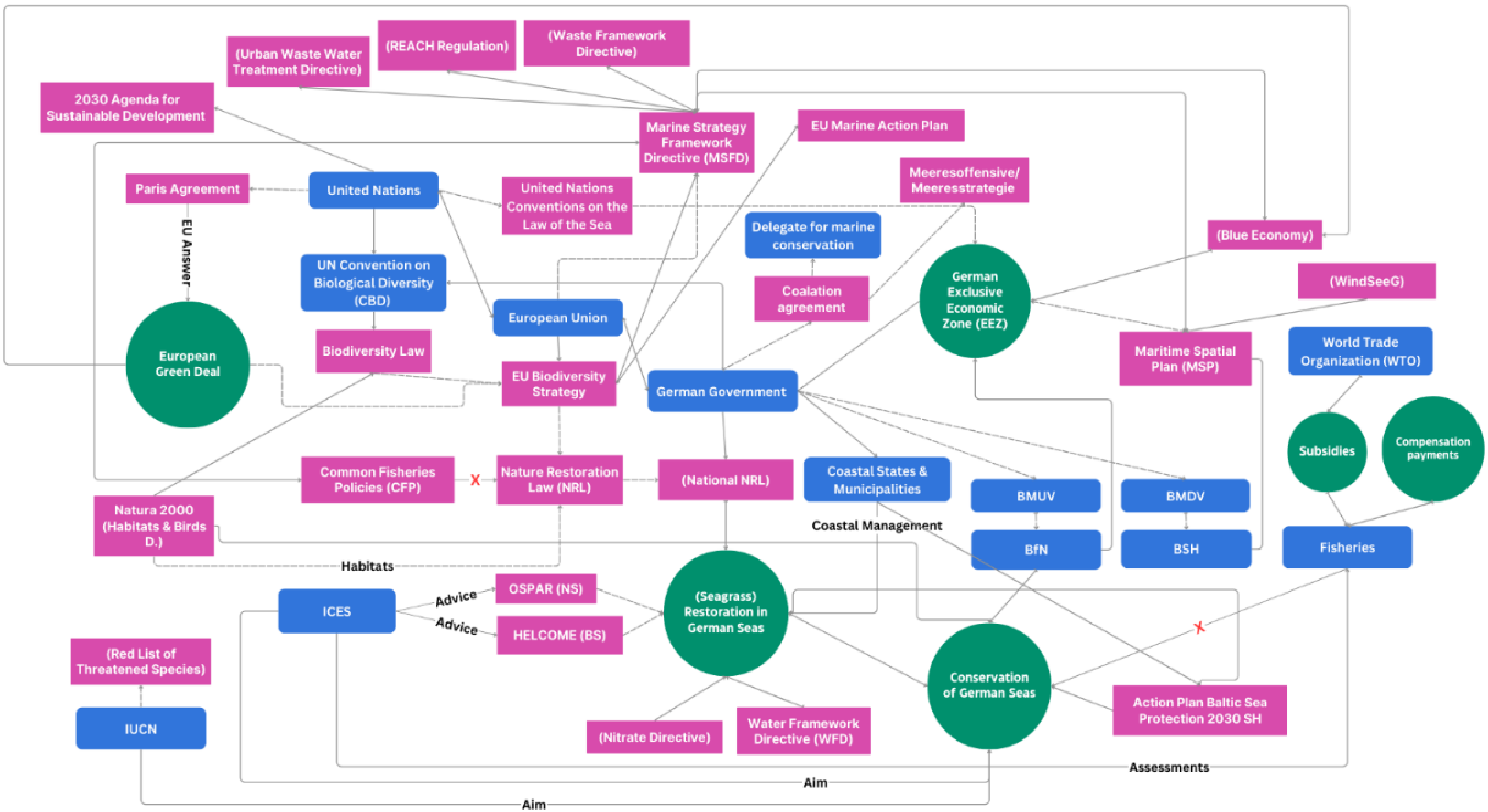


Figure 9: Policy Puzzle of marine restoration on different levels which analyzes possible relevant policies and political stakeholders and how they are connected. Blue indicates different stakeholders and governmental bodies; pink indicates policies and green indicates specific topics. Policies in brackets were considered of lower priority for the report and are therefore not elaborated. A red X indicates a negative relationship or impact. Dotted lines indicate a more passive relationship or derivation than solid lines. In some cases, the connections of the boxes are specified with explanations.

Water Framework Directive

The EU Water Framework Directive (WFD) tackles the management and protection of inland surface waters, transitional waters, coastal waters, and groundwater. The regulative legally binding directive demands restoration as a measure to keep or bring back 'good quality water for all purposes' (EEC, 2000). As the WFD presents biological indicators for water bodies that can be adapted to marine ecosystems, the directive could be used as an example for the NRL on how to implement a Europe-wide monitoring system based on those indicators (Hering et al., 2023). While seagrass itself is not mentioned in the WFD, macrophytes are described as a biological indicator for assessing the ecological status of lakes and rivers. In this group, Seagrass falls under the category "angiosperms" as a biological quality element for coastal and transitional waters for indicating the quality status of the water bodies (EEC, 2000).

Marine Strategy Framework Directive

The Marine Strategy Framework (MSFD) is a European directive dealing with the management of resources and conservation of the seas. It was adopted in 2008 and entered into force the same year. The legally binding directive intended to bring European seas back to a "good environmental status" (GES) "[…] which means the environmental status of marine waters where these provide ecologically diverse and dynamic oceans and seas which are clean, healthy and productive within their intrinsic conditions, and the use of the marine environment is at a level that is sustainable, thus safeguarding the potential for uses and activities by current and future generations […]. Good environmental status shall be determined at the level of the marine region or subregion […] on the basis of the [11] qualitative descriptors in Annex I" (extract from the MSFD, EEC, 2008). The GES should have been achieved for all descriptors by 2020 which however was not succeeded due to a lack of effective implementation (EC, 2020b). In the implementation report, it says: "The Directive has notably improved the knowledge of the state of the Union's marine waters (SWD(2020) 61), although integrating and harmonizing that knowledge at EU level remains a challenge.". Compared to the WFD, this policy covers additional aspects in coastal waters such as underwater noise and marine litter (EC, 2020b). The MSFD does mention restoration as one of the goals and as a supportive measure. While mentioning "angiosperms" as one characteristic "biological feature" in Annex III the directive does not acknowledge seagrass as a key ecosystem. Seagrass beds are not directly listed under the characteristic 'habitat types' only indirectly linking to the Birds- and Habitats Directives considered as a 'special habitat' for determining GES (EEC Council, 2008). The MSFD is less suitable for the support of seagrass restoration as many targets were not met in the many years while it was consulted in further policies despite its legally binding character.

Common Fisheries Policy

The Common Fisheries Policy (CFP) was originally adopted in 1983 but most recently reformed in 2013 with 17 targets to manage fisheries and aquaculture in the EU (EC, 2013). Belschner et al. (2019) categorized the indicators of the policy in the criteria of fisheries management and assessed if they were met on a member-state level. The authors found out that all criteria were either neutral or negative outcomes which is thought to be because the objectives of the CFP were not phrased precisely enough (Belschner et al., 2019). While seagrass meadows are vital as nurseries for many commercial fish stocks, they are not explicitly mentioned in the policy as a key feature to keep fish populations in a healthy state. Merely the need for habitat protection of the fishes is stated. Other policies have a more holistic approach of ecosystem protection in order to reach the goals of fishery management plans. The need for the protection of seagrasses and further underwater plants is mentioned for example in the Fisheries Act of Queensland (1994).

The updated version of the CFP emphasizes the need for higher coherence with other conservation and management directives such as the MSFD, the HD, and BD. Restoring marine environments is part of the updated CFP as the coherence of the biodiversity strategy is aimed to be higher (EC, 2023). The CFP could furthermore support implementing the NRL by providing funds for measures that are targeted in both policies such as the restoration of seagrass meadows as the CFP states in Article 2 Paragraph 1 that "the CFP shall ensure that fishing and aquaculture activities are environmentally sustainable in the long-term […]." (EC, 2013). The in-EU Action Plan for the CFP suggested funding programs "The European Maritime, Fisheries and Aquaculture Fund" (EMFAF) and "LIFE" can be used as financial instruments (EC, 2023) for seagrass restoration, under both the CFP but also further conservation policies as the NRL.

German Maritime Spatial Plan

The German Maritime Spatial Plan (MSP) is a policy developed by the Bundesamt für Seeschifffahrt und Hydrographie (BSH). It designates and coordinates maritime spaces for the users of the German EEZ in the North and the Baltic Sea. This policy does not specifically mention restoration but stresses the importance of connected functional spaces – i.e., the connectivity of for example MPAs. (AWZ-ROV, 2021). In the future, areas specifically designated for conservation and restoration are needed as a measure to ensure resilient habitats in offshore waters. The German MSP could be a useful tool to ensure these spaces. Leverage could be reached by lobbying the BSH and the federal ministry for the interior and community as they are the responsible ministry for spatial planning (Bundesministerium des Inneren und für Heimat, BMI).

Habitats and Birds Directive

The Habitats Directive (HD) (EEC, 1992) for the protection of habitats and the Birds Directive (BD) (EC, 2009) are the foundation for the Natura 2000 network of protected habitats. Both policies aim to achieve a favorable conservation status for wild birds and animals as well as habitats. The HD was adopted in 1992 and entered into force in 1994. Next to the protection of species, the policy objectives are the conservation of degraded habitats listed in the Annexes. Member states are asked to designate Special Areas of Conservation (SACs) regarding Annex I and II (EEC, 1992). Seagrass habitats are listed in Annex I of the Habitats Directive. Yet, the directive struggled with reaching the targets as most of the Natura 2000 habitats were still in unfavorable conditions in 2020 (see Chapter 1; EEA Report No 10/2020).

Restoration is mentioned in both policies as a measure to return to a favorable conservation status, which also supports the EU Biodiversity Strategy (see below) to be implemented. The Habitat Directive does show gaps in restoration as the lack of robust restoration norms with a historical baseline and the lack of climate adaptation norms in natural habitats for instance (Hoek, 2022).

EU Biodiversity Strategy 2030

The EU Biodiversity Strategy is the EU-adopted policy from the CBD of the UN. The non-binding European Strategy presents strategies for the worldwide protection of species after the rapid decrease in biodiversity (EC, 2020a). It holds targets for the protection of species and habitats (Natura 2000 network) to counteract biodiversity loss by protecting 30% of EU habitats until 2030. National Biodiversity Strategies and Action Plans (CBD, n.d.) are central instruments to meet international goals nationally. In the mid-term report of the EU Biodiversity Strategy for 2020 (EC, 2015) it was shown that targets were not met because of insufficient funding, incomplete implementation, small-scale measures, and too little enforcement. One of the new strategies of the EU is the development of a Nature Restoration Plan to accelerate the reaching of the goals (EC, 2015).

EU Nature Restoration Law

Taking on a leadership role in the world, the EU developed a policy specifically designated to restore degraded habitats. The Nature Restoration Law (NRL) focuses solely on nature restoration. The law acknowledges that this is the only way of halting and reversing biodiversity loss and mitigating the climate crisis as well as securing (food) security and resilient ecosystems in times of a quickly changing planet and increasing nature catastrophes. In June 2024, after many rounds of amendments and step-backs it was eventually taken up in the agenda of the European Council. This policy is a holistic document with clear targets, ways of funding, and the inclusion of further directives and laws such as the Birds- and Habitats Directives (Natura 2000 network), the MSFD, and the CFP (EC, 2022b). The goal of the policy is the development of National Restoration Plans (NRPs) by each member state indicating specific restoration measures to ensure the directive is implemented as effectively as possible. These NRPs must be submitted to the European Commission within the upcoming two years.

HELCOM Baltic Sea Action Plan

The Helsinki Convention (HELCOM) published the Baltic Sea Action Plan (BSAP) in 2007 with measures to reach the goal to achieve a Baltic Sea in good environmental status by 2021. (HELCOM, 2007). To counteract against human-induced stressors, and enhance habitat quality and species abundance, measures were predefined in action plans. However, the latest HELCOM assessment showed no improvement in the ecological status of this water body in the years 2016-2021 (HELCOM, 2023). The main supporting tool for this policy is the MSFD with its integrated approach to reaching the GES of European waters (HELCOM, 2021). When looking at different scenarios of climate change and the measures for the conservation of the

Baltic Sea, the best results align with the implementation of the BSAP and when nutrient loads are kept low (Saraiva et al., 2019).

Indeed, the nitrogen and phosphorous input have been reduced at the turn of the millennium (Eurostat., 2022). However, the nutrient concentrations are still not sufficiently reduced in most of the water basins of the Baltic Sea (HELCOM, 2018). One reason for that is the long residence time of nutrients in the water and sediments which leads to a slow response rate (Savchuk, 2018). Iho et al. furthermore suggest adapting the metric of the BSAP for the phosphorous values in the Baltic Sea leading to new measures that could accelerate the phosphorous reduction (Iho et al., 2023). Still, a more holistic and effective policy for enhancing the quality of the Baltic Sea was needed. The BSAP was therefore updated in 2021 with new targets to reach the GES for the Baltic Sea (HELCOM, 2021). The updated version has an integrated approach to reach its vision: "A healthy Baltic Sea environment with diverse biological components functioning in balance, resulting in a good ecological status and supporting a wide range of sustainable economic and social activities." (HELCOM, 2021). An assessment of Gaia Consulting Oy for WWF identified challenges in the implementation of national implementation programs for the implementation of the BSAP. These were suggested to be non-compliance with the schedule and too vague targets. This leads to lacking momentum of stakeholders and an unclear monitoring system on whether implementation measures and targets were met, and progress was made (Ahvenharju et al., 2010).

Aktionsplan Ostseeschutz 2030

On a local level in SH, the first plans to open a nature reserve along the coast of the Baltic Sea of the state were presented in 2021 (Schumacher, 2022). Due to a lack of acceptance by relevant stakeholders like fisheries and tourism the plans for the nature reserve were discarded and replaced with the so-called "Aktionsplan Ostseeschutz 2030" (APOS, Action Plan for Baltic Sea Protection 2030) (Boerger, 2024). Measures of the HELCOM BSAP or the MSRL cannot be implemented on a federal-state level and have to be tackled in national and international committees. These measures are linked to international shipping or the use of resources for instance (Schleswig-Holstein, 2024a). The action plan is meant to be initiated and implemented by the federal state SH with measures for the conservation of the Baltic Sea coast in the state. After plans for a nature reserve in the Baltic Sea in SH were not approved by many stakeholders, the stated targets of the APOS are meant to be a compromise for Baltic Sea protection and the demands of stakeholders (Schleswig-Holstein, 2024b).

The targets include to lowering eutrophication, reducing bottom trawling, and improving fisheries. Three new MPAs shall be set up and together with established Natura 2000 areas a total of 12,5% of the MPAs should be under strict protection. This goal is leaning toward fulfilling the targets of the EU Biodiversity strategy (30% of protected areas and 10% of strictly protected areas). To lower eutrophication, nutrient levels of nitrate and phosphate in SH waters are targeted to be reduced by 10% until 2030 and by another 10% until 2035, respectively. Farmers can decide individually how the reduction measures are carried out. One of the measures suggested in both action plans for the Baltic Sea (this policy and the BSAP) is enhancing the environmental status through restoration. The policy also aims to include fisheries in conservation measures as well as expand both public involvement as well as environmental education as measures to engage more people to create a common sense of responsibility. The policy also aims to introduce an integrated station for tourism, environmental education, and conservation of the Baltic Sea (Schleswig-Holstein, 2024a).

Koalitionsvertrag

The "Koalitionsvertrag" (coalition contract) although not a policy describes the focus areas and goals of the German Government. The document is the written and agreed collection of ambitious aims of the three coalition parties SPD, Bündnis90/Die Grünen, and FDP for the legislative period 2021-2025. It is the task of this current "Bundesregierung" to implement the commitments into strategies and action plans (Koalitionsvertrag; Bundestag, 2021). In the case of marine conservation, a national marine strategy is currently being developed. From a nature conservation point of view, this process is relevant as it allows to define and safeguard long-term measures for marine protection and restoration when being adopted with the current legislation (Personal communication Carla Langsenkamp). The first sign towards marine protection in Germany was the appointment of a representative for marine conservation topics in the German parliament, Sebastian Unger (BMUV, 2022).

3.2. Finding the best Fit

The conservation and management policies of the previous section were filtered for their relevance for the Baltic Sea as WWF is planning to conduct seagrass restoration in this water body. The German Koalitionsvertrag was not included in the table, due to the ongoing process of developing the strategy for implementation. The contract and its outcomes in the form of a national marine strategy are potentially important as they should include restoration targets.

The filtered policies were compared in a multi-criteria analysis in Table 2 based on different criteria. The criterion *Active restoration targets* means the policy includes specific targets for active restoration. *Seagrass mentioned* looks at whether the respective policy includes a specification of seagrass habitats for either conservation or restoration purposes in the policy (sometimes described in other terms, such as "macrophytes" or "angiosperms"). *Policy implemented* stands assesses if the policy is implemented, hence the overall goal was reached. Due to the infancy of some of the policies, their implementation could not have been reached and is therefore not assessed. The *topicality* refers to whether the policy is fitting to actual demands and or into the political debate, i.e., whether there is a (high) political momentum that enables to put certain topics on the political agenda and have discussions about it. Lastly, the *feasibility for restoration* is an amalgamation of whether a) clear targets and goals are stated, (b) an implementation plan is remarked, (c) ways of funding were discussed and (d) strategies for effective execution are suggested, such as e.g., sanctions for non-compliance. Each category was evaluated with different scores from 'not applicable' (0 points, red) over 'somewhat applicable' (1 point, light green) to 'applicable' (2 points, green). The sum of the points gives an idea about the supportive character of the policy towards marine restoration. Arising from this analysis, the three policies with the highest score are elaborated in the following section.

Table 2: List of identified both national and international supporting policies on seagrass restoration in the Baltic Sea. General categories (dark green) describe policy structures. Five criteria (dark grey) were evaluated with different scores from 'not applicable' (0 points, red) over 'somewhat applicable' (1 point, light green) to 'applicable' (2 points, green). The sum of the points gives an idea about the supportive character of the policy towards marine restoration.

Policy	Official Name	Geographical Scope	Region	Policy Area	Policy Type	Degree of Compulsion	Year of Adoption	In Force since/updated	Active restoration targets	Seagrass mentioned
HD	Habitats Directive	Supranational	EU	Nature conservation	Directive	legally binding	1992	1994	restoration to GES, mostly conservation	yes
WFD	Water Framework Directive	Supranational	EU	Water management	Directive	legally binding	2000	2000	shortly mentioned	under Macrophytes (only for freshwater habitats)
BSAP	**Baltic Sea Action Plan 2021-2030**	Supranational	Baltic Sea	Marine conservation	Plan of Action	non-binding	2007	NA	includes restoration as important measure	no
MSFD	Marine Strategy Framework Directive	Supranational	EU	Marine management	Directive	legally binding	2008	2008	shortly mentioned, restoration to GES until 2020	under Angiosperms in Annex III
MSP	German Maritime Spatial Plan	National	Germany	Marine management	Regulation	legally binding	2021	NA	no	no
APOS	**Aktionsplan Ostseeschutz 2030**	Federal	Schleswig-Holstein	Marine conservation	Plan of Action	non-binding	2024	2024	habitats mentioned; objectives for N and P reduction	yes
NRL	**Nature Restoration Law**	Supranational	EU	Nature restoration	Regulation	legally binding	2024	2024	yes, main topic	yes; different seagrass habiats

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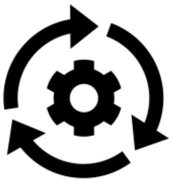
Policy	Policy Implemented	Topicality	Feasibility for Restoration*	Supportive**	Notes e.g., for relevance
HD	no	no novelty	no clear restoration targets, no implementation plan, or funding, outdated habitat list	4	Many polices refer to protect habitats from Natura 2000 network which includes degraded habitats from the HD
WFD	partially	no novelty	Indicators listed, but no clear targets and funding	4	indicators for deconstructed single elements of system; up to 1nm of coast
BSAP	partially	relatively new	clear targets and deadlines, financing included	7	focuses on eutrophication which is one of most crucial factors of seagrass decline
MSFD	no	no novelty	imprecise measures and targets	3	indicators for the whole system: qualitative descriptors in Annex I; starting from 1 nm from coast
MSP	NA	relatively new	no restoration targets are mentioned	1	could be interesting for restoration in MPAs and outside in the future (in specifically no-take zones) when the plan includes stipulations for restoration
APOS	NA	was just published	vague targets and sources of funding	7	action plan instead of nature reserve; includes 12,5 % strict protection of MPAs
NRL	NA	was just adopted	clear targets	8	best policy for (marine) restoration, also very specific for seagrass habitats, and expands to more than just the Natura 2000 habitats

applicable	**2**
somewhat applicable	**1**
not applicable	**0**

*Includes objectives/targets, funding and enforcement (e.g., sanctions for noncompliance)

** Sum of scores of each row for the supportiveness or environmental effectiveness for seagrass restoration

1. Baltic Sea Action Plan (supranational, Baltic Sea) – Implementation



Eutrophication and the associated light reduction have been identified as the biggest threats to seagrasses in the Baltic Sea. Under the premise that the goals of the **Baltic Sea Action Plan** will be accomplished Bobsien et al. (2021) showed that nutrients might presumably decrease, with light penetration increasing, and then ultimately widen the scope of suitable habitats for seagrasses to greater depths. It was shown that this presumably led to a significant increase in the seagrass area of the SH coast in the Baltic Sea until 2066 (Bobsien et al., 2021). Under the premise that the BSAP will be implemented, and the stressors will be removed, the success of active seagrass restoration will be elevated. Additionally, if the measure of protecting 30% of the marine sea with one-third of strict protection adapted from the CBD (HELCOM, 2021) is implemented in this policy lays a path for more connected MPAs with a higher potential of eelgrass to recover.

2. Aktionsplan Ostseeschutz (regional, Schleswig-Holstein) - Inspiration

The **Aktionsplan Ostseeschutz** is a regional example of how marine conservation can be realized due to its topicality and emphasis on seagrass restoration and including a few criteria that have been considered in this context. Once the policy is implemented, it will be prohibited to anchor in seagrass beds. More strict enforcement and control of the protected sites is planned potentially increasing the success of re-establishing seagrass if restoration occurred in strictly protected areas. As a policy for the federal state of SH, it is a pioneer that can be used as inspiration and a relevant example for future lobby work for a similar policy in MV.

3. Nature Restoration Law (supranational, EU) – Adaptation

The national Restoration Plans developed under the **Nature Restoration Law** are now an essential next step to many restoration measures. However, measures are of a non-deterioration nature meaning that plans are assessed through the effort and not about the outcomes after monitoring. As the law complements the nature directives such as the Habitats Directive, MSFD, and WFD, the implementation of the NRL might bridge the implementation gaps of these policies. Monitoring indicators need to be more harmonized for that matter. For marine restoration, the MSFD indicators could be consulted (Hering et al., 2023). Even though the focus is primarily on the protected habitats under the Natura 2000 network, restoration sites can also be outside of SACs. As the Habitats Directive is relatively old, new developments lead to more species on the red list. The policy is therefore limited to only certain species and habitats. For seagrasses solely the species *Posidonia Oceania* occurring in the Mediterranean Sea is directly mentioned as a SAC. Consequentially, the NRL too does not cover the necessary restoration of all degraded habitats. For that reason, more adaptive management is needed to be more flexible with changing biodiversity (Hoek, 2022).

3.3. Implementation Hurdles of Conservation Policies

Many policies aim to conserve and restore nature and well are projects in the planning with similar aims. However, some challenges hinder the effective implementation of policies and restoration plans and therefore reaching the targets. The improvement of the status of the ecosystem is therefore very slow or nonexistent. In the following paragraphs, relevant implementation hurdles and possible solutions are being discussed.

Lack of Governance

For the effectiveness of the implementation of conservation policies, it is important to follow with streamlined implementation plans, enforcement, and monitoring. For this, strong governance and management are needed (France, 2016). The lack of governance and conjugated responsibilities leaves room for misunderstanding, no clear objectives, and goals as well as slow proceeding. Richardson & Lefroy (2016) suggest aligning governance with scales, improving biological feasibility (scientific knowledge), sociocultural acceptability, financial viability, and institutional tractability as measures for successful habitat restoration. A governing body is needed to take on the responsibility and promote marine restoration. Without the dedication to guiding the implementation processes of a leadership role, the implementation of projects oftentimes fails. These leaderships can keep the overview of the whole process, organize the personnel and the resources, and plan it accordingly, and are dedicated to successfully finishing the project (Walters, 2007). It was shown that it was useful to integrate top-down and bottom-up approaches. For example, combining biophysical characteristics of the area that policymakers use for making decisions (top-down) with the inclusion of socioeconomic factors on stakeholder behavior (bottom-up) to lower implementation conflicts (Ding et al., 2023). Shifting from top-down towards bottom-up approaches and finding an integrated middle ground of both strategies is therefore recommended. For this, it is advised to learn from terrestrial restoration as it has been practiced longer and can give guidance especially focusing on social-ecological aspects (France, 2016).

Inaction of Stakeholders

Oftentimes the approval and support for habitat restoration of stakeholders are missing (Lundquist & Granek). For marine habitats this would include possible landowners of the restoration site (if near shore), fishers if this area is a fishing site, and further collaborators as well as the tourism sector. In the offshore area, this could include talking to actors from the offshore wind industry as potential restoration sites could be linked to the wind parks (Bos et al., 2023). If linked to socio-economic development, especially in developing countries where many biodiversity hotspots are located there could be a higher general acceptance of the need for marine restoration. Examples are the increase in social benefits due to jobs being created and improving livelihoods, as well as involving local users for direct support (Aronson et al., 2006). It is furthermore important to not only express the ecological functionality and the monetary value of ecosystem services but also emphasize how these ecosystems contribute to the well-being of people by increasing health, and safety and providing resources (Díaz et al., 2019). In a poll by Sapience for Oceana and Seas at Risk about 'public attitudes towards ocean protection and fishing practices in the EU' it was shown that the majority of European and German citizens are in favor of a higher priority of marine conservation in political decisions and support the ban of bottom trawling and the need for MPAs (Oceana, 2024).

Absence of Enforcement

A lack of compliance leads to resistance to measures and consequentially non-implementation of policies. An underlying reason is the absence of enforcement such as fines, prison terms, and social sanctioning (Keane et al., 2008). There is an increasing trend nowadays towards soft policies meaning policies, i.e., not legally binding (Cappellina et al., 2022). Legally binding does not necessarily mean policies are being enforced. Usually, enforcement means that sanctions are the consequence of not implementing the policies to increase compliance. It was also shown that the legal obligation to implement a policy positively influences compliance, more than just the political commitments but independently of enforcement (Bodansky, 2015). In the Netherlands the sea ranger service partially surveys illegal activities working as the "eyes and ears at the sea" (sea ranger Jan van den Bos). This innovative program enables more presence at sea and next to those inspections several monitoring services (Sea Rangers, n.d.). A similar program is currently starting in the state of MV. The first trained 'Sea Rangers' will support research projects and conduct environmental education (NDR, 2024). This program could be expanded to more surveillance of the waters and securing enforcement of certain regulations. It is recommended to assess the reason for non-compliance to find out a suitable enforcement method (Keane et al., 2008).

Incoherence of Policies

Another big challenge is the incoherence of policies that work against each other and have different levels of priority, e.g., the CFP that interferes with nature conservation. Here, it might be useful to point out the strengths and weaknesses of this interplay. The goal should be to align policies by sharing the same goals, so they have the potential to boost restoration if implemented correctly (Hering et al., 2023). But also, the management of fisheries must be adapted to conservation standards. For example, seagrass protection needs to be included in fishery management policies like the CFP to secure healthy ecosystems and stable fish populations. While Article 8 of the CFP states to protect "areas where there is heavy concentration of fish below minimum conservation reference size and of spawning grounds" the wording leaves leeway for interpretation as the habitat seagrass meadow and specific species are not targeted (EU, 2013).

Hindrance by Fisheries

The status of the fisheries at the moment is hindering marine restoration. Bottom trawling for example has devastating consequences for the seabed and environment such as increasing the turbidity and physically destroying habitats (Bradshaw et al., 2024). Instead of decreasing fisheries that are harmful to marine habitats, existing subsidies for fishers make it attractive for entrepreneurs to enter the market. These are mostly companies with sizable vessels that have more negative impacts on the environment. Small fishing companies or families on the other hand are more threatened with losing their livelihood since they usually have less access to (high amounts of) subsidies which adds socio-economic injustice and decreases understanding of nature conservation (Schuhbauer et al., 2017). The point of intervention here could be to find a solution for small fishers and involve them in marine restoration for instance in the mapping and monitoring processes. In the long term, subsidies have to be canceled to make it less attractive for big fishing companies to invest. Lastly, the CFP should be properly implemented and used as an ally in conservation as the policy strives for the same goal for fisheries and conservation which are healthy ecosystems and therefore stable fish populations.

Unharmonized Data & Monitoring Methods

Limited or unharmonized data hinders analyzing and comparing restoration outcomes of different projects. This could be a result of non-streamlined data collection from different projects or member states. Good models are needed especially for mapping and site selection of habitats hence mainstreamed data sets with the same parameters are crucial. In general, there are huge knowledge gaps for marine and coastal habitats. For 26% of marine habitats, the conservation status is unknown for Member States of the EU whereas it is only 4% of terrestrial habitats (EC, 2020c). Long-term monitoring of marine and coastal habitats is required but has not been conducted in many cases. Without this data, it is difficult to prove the significance of the results and the effectiveness of measures which is also of importance for funding stakeholders. Silo thinking, isolated working of different sectors but also policies could hinder the progression of methods. For example, do the indicators for monitoring habitats in the HD and the NRL not align. Policies with the same goals, building up on each other have to be aligned in their technical requirements such as monitoring indicators. Seagrass restoration still stumbles upon a lot of unanswered questions. This results in experimental small-scale restoration efforts for research purposes looking at the effects of e.g., suitable transplanting sites or methods. With the development of best practice frameworks, it can be possible to effectively upscale the efforts (Moksnes et al., 2021). If we think about monitoring specific data that are harmonized within the seagrass community worldwide the outcome would be an extensive comparable data set that can give many insights into effectiveness of methods. Collaborations of different institutes, organizations, and citizens for better data gathering and exchange and combined efforts could therefore lead to higher success. For this, guidelines are needed that are commonly accepted and followed by the scientific community. This could be achieved for example by reaching out to Seagrass-Watch, a global network of experts and conservationists to monitor seagrasses, partially through citizen science and educating (Seagrass-Watch, n.d.).

Tides of Change in Offshore Habitat Restoration

In Germany, restoration got more awareness with the emergence of the Action Plan for Natural Climate Protection (Aktionsplan Natürlicher Klimaschutz, ANK). The Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz, BMUV) of Germany has planned to spend 4 billion € on restoration projects that enhance habitats with natural carbon sequestration abilities (BMUV, 2023). This money is amongst others managed by the BfN which is also planning restoration projects in the offshore waters of the German Seas. The money of the ANK however is not planned for marine restoration (Interview with Kevin Dietz and Linda Westphal, 30.05.2024).

Marine habitat restoration is mostly done close to the coasts where the biodiversity is higher than in offshore waters because more light reaches the seafloor in shallower waters. Due to the many uses of the German offshore waters and the associated challenges finding suitable areas, and the access, restoration is still in its infancy in these areas. BfN takes care of nationwide nature conservation affairs of the German Exclusive Economic Zone (EEZ) of the North Sea and the Baltic Sea. The federal authority is inferior to the BMUV and accomplishes scientific and administrative tasks like data gathering and processing, project supervision and funding, nature conservation law, and advising politicians based on the German Federal Nature Conservation Act (Bundesnaturschutzgesetz) (BfN, n.d.).

The following exerts derive from an interview (see Appendix 5 for the whole interview) that was held with Kevin Dietz and Linda Westphal who both work for BfN (Division II, department 3: marine conservation) and deal with restoration matters in the German EEZ. The interview was held to get insights into the possibility of restoration projects in offshore waters in the EEZ and the role of the BfN in these undertakings as well as challenges in restoration in general. Linda Westphal explained that "in the German North Sea, the European oyster was present over large parts of continuous oyster reefs that have been completely lost through bottom trawling. Another habitat is the geogenic reefs, i.e., the natural stone deposits" (personal communication, Linda Westphal, 30.05.2024). Looking back at what was 100 years ago however might not be the best solution as a historical reference for restoration, as it could prove unachievable.

The shifting baseline and uncertainty of knowledge of the historical state result in many uncertainties (Klein & Thurstan, 2016). Another question is whether it makes sense to restore a habitat to its (unclear) original state as the needed services from an ecosystem nowadays change as well as the conditions of the system (Rohwer & Marris, 2016). Restoration efforts in the German EEZ have just started and need to mature as the degradation is not only happening along the coasts. With the industrialization of the oceans (the increasing installations of infrastructures such as wind turbines and LNG Terminals), marine ecosystems need to become more resilient and complex to adapt to changes and buffer climate gases. One solution could be natural structures mimicking habitats with associated species in areas of industrialized parts of the seas such as offshore wind parks.

Restoration in Germany is however not taking place within offshore wind parks at the moment. This "would all fall under the heading of multi-use, i.e., how the wind farms could be used in further ways. This is difficult to handle for nature conservation because multi-use assumes usage, and it is always better for nature conservation if there is less usage" as Kevin Dietz explained (personal communication, Kevin Dietz, 30.05.2024). Linda Westphal complemented that "in Germany, this is currently the state of play because we don't have a clear dismantling or repowering strategy yet. We don't know what will be repowered and where. You probably can't drive in the same place where a pile was driven, but you will drive next to it, in the spaces in between. And if there are other restored habitats, they will be destroyed" (personal communication, Linda Westphal, 30.05.2024).

Oftentimes the push to accelerate green energy is very strong and puts nature conservation on the back burner. Even if nature conservation leads to natural climate protection it does not mean that climate protection is always in favor of nature conservation. The fast rise of wind turbines, their installation, and operation in the sea can be challenging since nature needs spaces of no disturbance. Kevin Dietz explained that "the site development plan and maritime spatial plan are submitted to us by BSH, and we can comment on them. We can then bring in the nature conservation aspects, which would then speak in favor of an area or not. Ultimately, however, BSH has the greater decision-making power. They also have to comply with the implementation requirements set by politicians. This is also one of the biggest problems for marine nature conservation, namely that climate protection is not equated with marine nature conservation, but marine nature conservation includes climate protection. It is difficult for nature conservation to manage the balancing act because, of course, conservationists also want to promote climate protection. The question is at what price" (personal communication, Kevin Dietz, 30.05.2024).

For that reason, it is important to balance the industrialization of the EEZ by increasingly restoring habitats. It is difficult to find suitable areas due to the spatial pressure that occurs in the highly used waters. As conservation showed to be the most effective in no-take MPAs due too little to no disturbance, marine restoration could potentially be more effective in MPAs too. But only a few areas are designated MPAs, and barely any of them have no-take zones. Activities like fisheries are threatening the re-establishment of species as bottom contacting fishing methods that destroy reefs on the seafloor. Kevin Dietz explained that "bottom-contact fishing was only recently excluded from the [MPA] "Borkum Riffgrund". This was previously still possible and therefore no possibility for us to carry out restoration measures there. You have fewer users within the MPAs. We now hope that the 30/10 goal - i.e., 30% of the seas under protection and 10% under strict protection - will continue to be enforced and that this will make even more area available where there is no form of use at all" (personal communication, Kevin Dietz, 30.05.2024).

The changes here must be structural, by developing new maritime spatial plans with the prioritization of conservation and designation of strictly protected areas. With the implementation of the 30/10 goal, stated in the EU Biodiversity strategy (EC, 2015) more areas for restoration, as in no take-zones might be an option. Linda Westphal explained that "at the moment, restoration measures are completely limited to the MPAs in the EEZ, and we are currently unable to plan measures outside of these protected areas" (personal communication, Linda Westphal, 30.05.2024). Kevin Dietz elaborated that "the biggest problem is finding areas where restoration can be introduced and then have a long-term effect. There is no point in establishing something somewhere if it is immediately destroyed again by fishing" (personal communication, Kevin Dietz, 30.05.2024). However, also fisheries are carrying a burden, according to Linda Westphal, since "with every wind farm, also lose areas that were previously used for fishing. The wind farms are fishing exclusion zones and, as a result, fishing is becoming increasingly concentrated outside the wind farms. If you look at the site development plan, you can see that a large and significant part of the EEZ is planned for offshore wind. Then there is the infrastructure, i.e., all the power lines, converter platforms, submarine cables, and shipping routes. We have a lot of interest and user groups in the EEZ, and space is limited" (personal communication, Linda Westphal, 30.05.2024). For that reason, ecological restoration in German offshore waters will most probably be accelerated by finding suitable areas where the targeted species can re-establish without being disturbed.

3.4. Navigating through Unknown Waters

A PESTEL Analysis was carried out to explore the landscape for marine restoration (Fig. 10). The overall aim is to scan the environment around the organization WWF to develop strategies to find the right (political) momentum for seagrass restoration. For example, are the 2020s both the UN Decades for Ecological Restoration and the UN Decade for Ocean Science for Sustainable Development. In Germany, the upcoming elections of the German Bundestag in 2025 will result in a new coalition agreement. Until then, the national marine strategy has to be developed and set in place which should include concrete marine restoration plans. Also, for the new legislation, marine restoration must be emphasized to be taken up on the agenda and be part of the new focus areas and goals of the German Government in the new legislative period from 2025.

The PESTEL analysis integrates the rather scientific topic into society and indicates factors that have to be considered in the planning process. Each category describes factors on how marine restoration, specifically seagrass restoration is to be classified in the external landscape with aspects discussed in previous paragraphs of this report. Many sectors have a stake in seagrass restoration due to their ecosystem services and the potential of climate regulation while also aligning with political regulations.

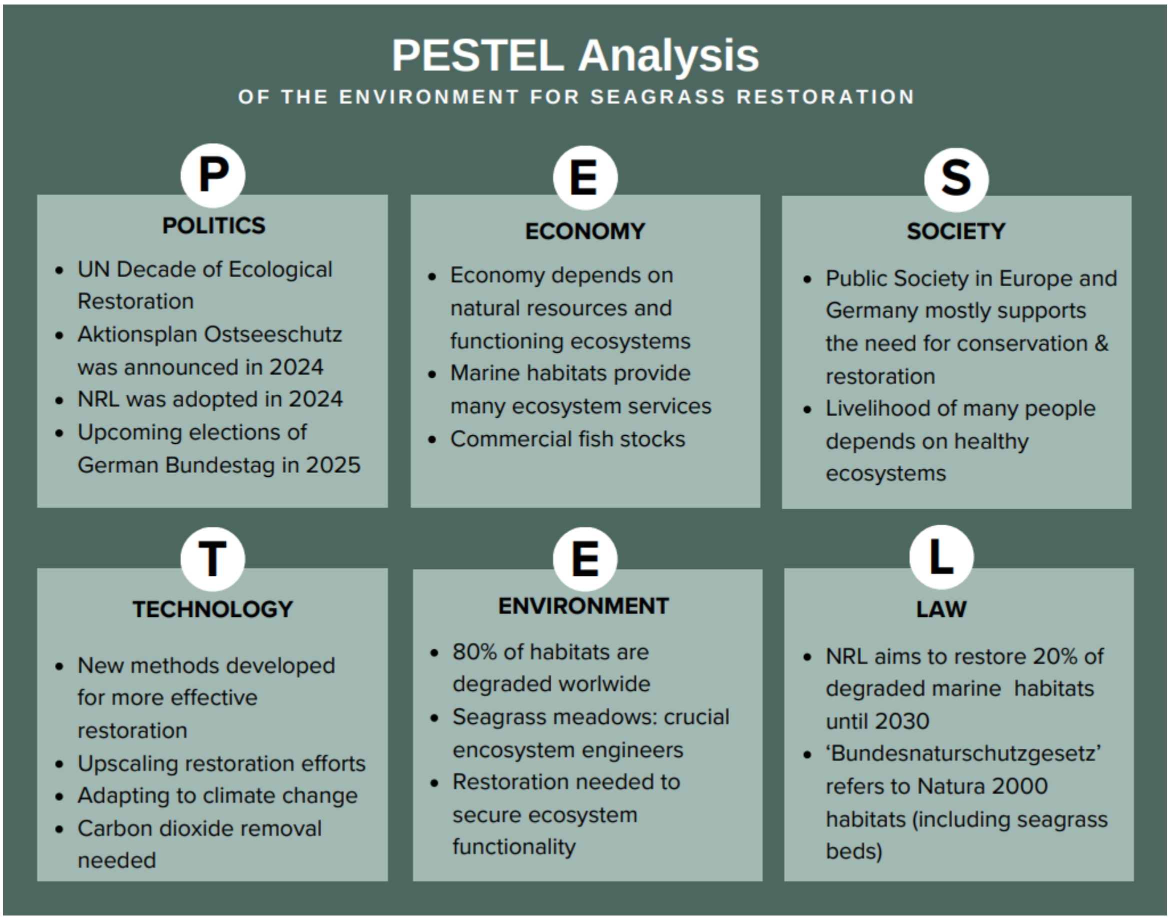


Figure 10: PESTEL Analysis for Seagrass Restoration in Germany. For each dimension, current events and developments concerning seagrass restoration in Europa are assessed.

3.5. Getting Everybody on Board

Due to the many sectors that affect seagrass restoration (Fig. 10) it is crucial to identify all stakeholder with potential interest and influence. As WWF is planning to restore Seagrass in the state of MV, stakeholders in this region were assessed in Figure 11. One element of proceeding with the project planning is getting the approval of all stakeholders. For that reason, it is important to understand what the intentions of all stakeholders are to find arguments that align with their needs or to discuss compromises. Depending on where each stakeholder can be found in the matrix they have to be managed differently. Stakeholders with *High Influence – Low Interest* (yellow) must be kept satisfied as they normally have a lot of power while not using that power in favor of the project. On the contrary, those with *Low Influence – Low Interest* (light green) have to be monitored with only minimal effort as they are the least relevant for the project. Stakeholders with *Low Influence – High Interest* (dark green) have to be kept informed as spreading awareness and education are potentially valuable tools. Those with *High Influence – High Interest* (red) must be kept close as they are the ones who can move the project forward the most efficiently. The possible stakeholders relevant to a seagrass restoration project in MV and more details are listed in Table 4 (see Appendix 6).

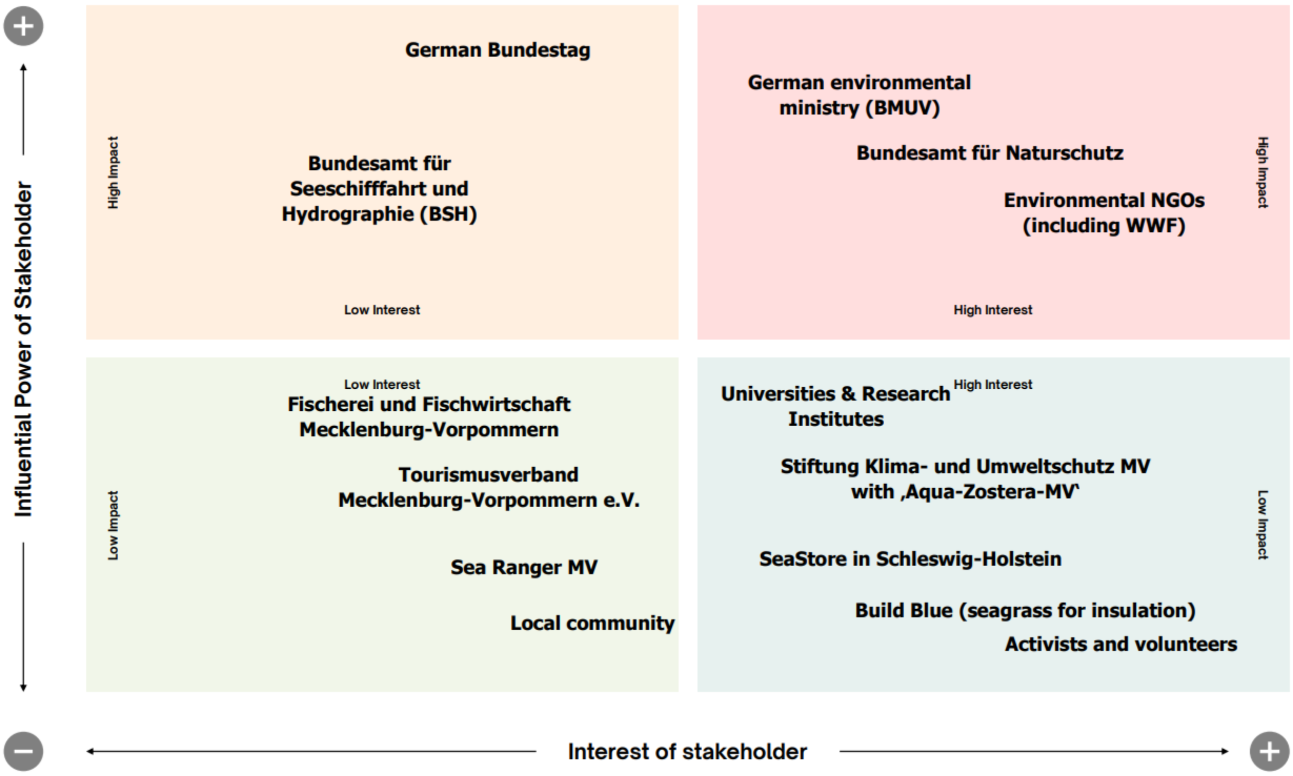


Figure 11: Stakeholder map with interests and influence.

3.6. Exploring internal Flows

As one of the worldwide leading environmental non-governmental organizations, WWF stands up for nature conservation. The organization is highly involved in economic and political topics and operates in more than 100 countries (WWF Germany, Intranet, n.d.). One of the German offices is located in Hamburg is the International Centre for Marine Conservation. As parts of the team seeks to conduct seagrass restoration, information on internal structures is needed. A McKinsey 7S Analysis (Fig. 12) gives insights into the internal structures of WWF Germany and deals identifies (1) Strategy, (2) Structure, (3) System, (4) Shared Values, (5) Skills, (6) Style, and (7) Staff of the organization. Information was gathered in weekly team meetings, personal communication with colleagues, and the intranet of WWF.

Strategy
- conservation efforts of landscapes and biodiversity
- transformation efforts of politics, economy and society
- through conservation projects, cooperations, lobbying and outreach
- by working closely with network & eNGO alliance
- WWF takes role as financier & pioneer, activator, advocate and advisor

Structure
- worldwide network
- board of several members taking care of each department in Germany
- overall flat hirarchy

Systems
- work tasks on own initative with internal coordination
- lobbying in conferences and calls
- office workflows

Shared Values
- courage, collaboration, integrity, respect, responsibility

Skills
- many years of project and lobbying experience
- many collaborators
- high influence

Style
- transparence and integrity of staff in many decisions
- horizontal structure
- appreciating atmosphere

Staff
- worldwide 8500+ employees in 100+ countries
- high intrinsic motivation of employees
- employees experts in their fields

Figure 12: McKinsey 7S Analysis of WWF Germany.

A SWOT Analysis (fig. 13) shows the strengths and weaknesses of WWF Germany as well as the opportunities and threats. Information was gathered from the McKinsey 7S Analysis (Fig. 12) through the same methods. A SWOT analysis gathers points of leverage to develop a strategy on which capacities to exploit, where to improve and what to look out for. The general strength of WWF is being well positioned in a network of internal offices and other environmental non-governmental Organizations (eNGOs). Despite highly motivated employees with expertise in their fields, a weakness of the organization is that the capacities of people and time are low, and especially policy work can have low impacts compared to the high amount of invested work. Most crucial external threats boil down to missing initiatives and proceeding too slowly to act instead of reacting. In the way WWF is lined up, it is an opportunity to create synergies within the network but also collaborate with more external stakeholders.

Figure 13: SWOT Analysis of WWF that indicates the Strengths, Weaknesses, Opportunities and Threats of the organization.

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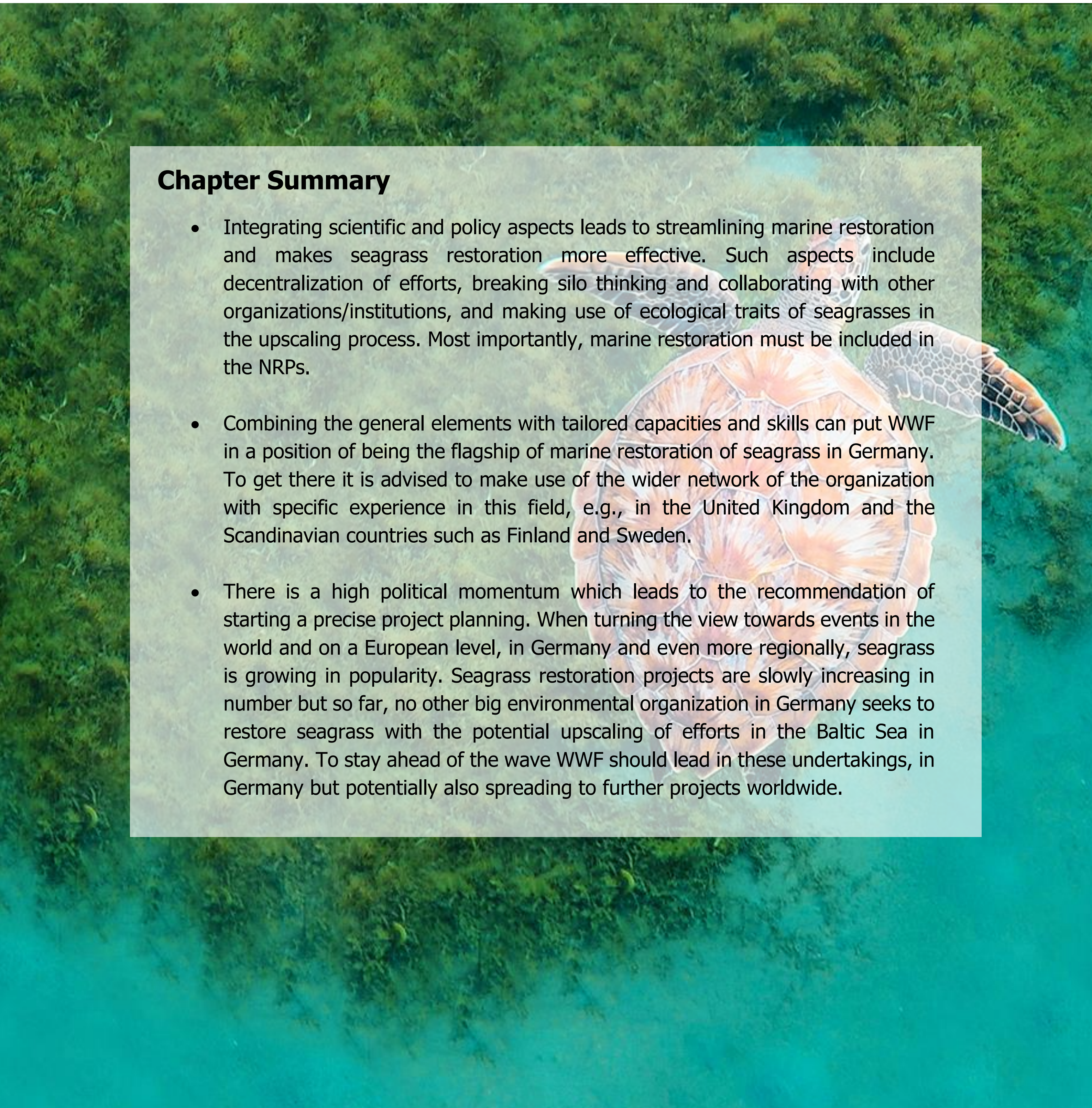
04

The bigger Picture



Chapter Summary

- Integrating scientific and policy aspects leads to streamlining marine restoration and makes seagrass restoration more effective. Such aspects include decentralization of efforts, breaking silo thinking and collaborating with other organizations/institutions, and making use of ecological traits of seagrasses in the upscaling process. Most importantly, marine restoration must be included in the NRPs.

- Combining the general elements with tailored capacities and skills can put WWF in a position of being the flagship of marine restoration of seagrass in Germany. To get there it is advised to make use of the wider network of the organization with specific experience in this field, e.g., in the United Kingdom and the Scandinavian countries such as Finland and Sweden.

- There is a high political momentum which leads to the recommendation of starting a precise project planning. When turning the view towards events in the world and on a European level, in Germany and even more regionally, seagrass is growing in popularity. Seagrass restoration projects are slowly increasing in number but so far, no other big environmental organization in Germany seeks to restore seagrass with the potential upscaling of efforts in the Baltic Sea in Germany. To stay ahead of the wave WWF should lead in these undertakings, in Germany but potentially also spreading to further projects worldwide.

4.1. Discussion & Strategy

Ecological, political, legal as well as social factors must be considered when planning to restore marine habitats. Elements of this chapter summarize the political, legal, and social challenges and factors that build up on ecological considerations. These are strategies and how policies have to be adapted, points of interference, and influencing decision-makers in the light of long-term visions. Following elements are foundation of the guideline and advice in Chapter 5.

Due to the lack of **aligning clear structures** of national restoration plans, marine restoration especially seagrass restoration was not prioritized in the past. Seagrasses are aimed to be protected in many European policies as in the Natura 2000 network and used as indicators for the ecological state under the MSFD and WFD, so far seagrass was however not in the center of focus. This is currently changing as the Koalitionsvertrag mentions seagrass restoration as a carbon sink measure and the Aktionsplan Ostseeschutz 2030 aims to restore seagrasses in SH. Yet, at this point in time, there is no nationwide regulation targeting the protection and restoration of seagrass meadows in German waters. Seagrass could for instance also be managed in a European regulation as is the case with the Council Regulation (EC) No. 1967/2006 which protects seagrasses in the Mediterranean Sea from aggressive fisheries (Cunha et al., 2012). The focus on lobby work should now lay on the NRL as the NRPs have to be worked out now and it could be a strategy to influence decision-makers by emphasizing restoration efforts increasingly for marine habitats by pointing out the many benefits and beforehand inducing stakeholders and public citizens to act in protecting the seas. The NRL does need more considerations in adapting the habitats to be tackled need to expand from those included in Natura 2000. Here lobbying for more adaptive management in the quick change of developments and altering biodiversity is required.

Offshore restoration should also be considered as the measure might increase in importance due to the rise of the NRL and the plans under the ANK. It is advised to look further into offshore restoration and develop first drafts. That could help WWF to keep the flagship role in case of new developments regarding multi-use plans of the German EEZ. This is an interesting opportunity considering the focus on accelerated and expanded installations of wind turbines at the sea and the organization's interest in the topic.

To keep all structures aligned, it has been shown that integrating bottom-up and top-down governance should be used for effective management (Ding et al., 2023). The lack of effective governance was identified to be one of the main hurdles to marine restoration of the REST-Coast projects to scale them up (Aljinovic, 2022). In the light of effective upscaling of restoration projects, it was shown that the inclusion of socio-ecological in the project is beneficial in the long run (Ounanian et al., 2018). A **decentralization of governance** would lead towards a multi-level and -actor governance with non-state actors, communes, and citizens being involved and taking responsibility and contributing to the management. By involving stakeholders in the binning, they gained a feeling of ownership which helps to commit in the long-term to protecting ecosystems (Lundquist et al., 2005).

Ecological restoration success can be measured with different approaches, for instance, by focusing more on **social criteria** (Baker & Eckerberg, 2016). Seagrass provides many health benefits like water purification from pathogens like vibrions which is beneficial for the local citizens and the tourism sector. More than that seagrass is now more and more valued for its properties like functioning as isolation material. For example, the company Baltic Materials (Baltic Materials, n.d.) located in Kiel, creates blankets and pillows with old, dried seagrass that was flushed ashore and sorted with the help of AI-supported detection of seagrass. It can also be used as an isolation material e.g., houses (Build Blue, n. d.) and creates direct job opportunities from the increased biomass that is washed ashore. The image shift from "bothering plant at the beach" towards a valuable material that creates jobs should be spread out and a become the norm. Social norms play a big role in decision-making regarding conservation as humans tend to follow decisions of collective ideas and preferably invest in those. Social capital, the "idea that social bonds and norms are important for people and communities" is therefore a powerful tool (Pretty, 2003). Pretty (2003) suggests conducting collective resource management programs to build trust and norms as well as form groups to have a common understanding of conservation. This is reached by reaching out and educating people, preferably in workshops that allow participants to gain a feeling of tackling a problem as a group effort and having shared responsibility.

A strong **collaboration** to support a restoration project and implement the plans can be found in SeaStore as the project group is starting with the second phase of the project (IOW, n.d.) and is planning to find effective upscaling methods and seed-based restoration methods to develop an extensive guideline on seagrass restoration (Ocean Summit, n.d.).

Adapting to a Warming World

Under the premise of climate change, restoration efforts need to be adapted to re-build resilient ecosystems. Millar et al. (2007) mention the "neo-native" forests with the historical baseline of the state several thousand years ago. The state of the ecosystem at that time is supposed to be similar to future predictions with the restored tree species being resilient and outlasting despite harsh conditions of the future climate (Millar et al., 2007). The focus in restoration so far was mostly on terrestrial habitats but with the fast-changing oceans, we have to shift it towards marine habitats. This includes longer time frames -as especially seagrass may need up to 30 years to reach its fully functional state-, the consideration between taking local donor plants or such that already adapted to warmer temperatures, as well as thinking in the longer term when it comes to restoration. Starting to restore a population that won't survive after a few years may not make sense to re-establish in the first place (Wood et al., 2019). The authors additionally emphasize that the most important stressors of macrophyte restoration in the future will most probably be climate change and its consequences as the increase in temperature and frequency of storms. To counteract against future stressors Wood et al. (2019) therefore suggest maintaining high genetic diversity in the seagrasses and even looking for strains of seagrasses that are more heat resilient (Jueterbock et al., 2016). Adaptive management was shown to be an effective tool that leads to fewer uncertainties that can hinder large-scale restoration projects over long-term periods (Ebberts et al., 2018).

The Flagship in Marine Restoration

Since many actors will be included in a seagrass restoration project in MV it is beneficial to understand the potential role of WWF in this undertaking. I advise WWF to become the flagship for marine restoration in Germany. For marine restoration projects, it is important to be aware of environmental and political developments and stay connected to the network. WWF-FI conducted a successful seagrass restoration pilot study in 2021 (personal communication with Iiris Kokkonen, WWF-FI, 16.02.24) and WWF-UK is expanding its experience in several seagrass restoration projects together with Project Seagrass on the coast of the United Kingdom (personal communication with Daisy Durden, WWF-UK, 12.03.24). It is currently an increasingly conducted practice to govern and manage different marine habitats on a large scale through an integrated seascape approach (Murphy et al., 2021). WWF Germany is planning seagrass restoration together with mangroves and corals in Belize to make use of the benefits of connected management. Murphy et al. (2021) discuss the need for a "backbone" organization for this undertaking which could eventually be the role of WWF Germany.

Better Together: Seagrass – Mangroves – Coral reefs

The three joint habitats in tropical waters exchange nutrients and function together as an interconnected refuge and feeding ground for juvenile fish (Unsworth et al., 2008). This is of great importance for small-scale fisheries in the tropics, as fish stocks are heavily dependent on seagrass beds (La Torre-Castro et al., 2014; Nordlund et al., 2018). The network complex gives seagrass in tropical waters enormous value that often is underrated in management plans regarding coral health and fish stocks (Unsworth & Cullen, 2010). Not only fishes that thrive in seagrass meadows and corals but many more species like sea urchins, sea stars, and shrimps adapted to both habitats (Du et al., 2020). By supporting each other in coastal and erosion protection, the network of the three ecosystems gives every single one a higher resilience (Guannel et al., 2016). It was shown that seagrass reduced up to 50% of bacterial pathogens that threaten corals (Lamb et al., 2017). Combined restoration efforts therefore increase the impact on a larger scale and can be beneficial for a higher number of species and the overall conservation of each habitat (Guannel et al., 2016).

Now is the Time to bring back Seagrass

The political will for marine-related issues and their conservation and restoration seem to increase and create an optimal moment to push marine restoration. The UN Decade on Restoration and the UN Decade of Ocean Science 2021-2030 are a worldwide symbol to not only emphasize the conservation of marine ecosystems but also actively tackle the restoration of degraded habitats (United Nations, International Decades). The elevated awareness and acceptance of nature conservation and restoration and the demand for actions by many eNGOs, scientists, companies, and citizens put pressure on the government to react with strong policies and their implementation. In Germany, 2024 was dedicated to being the year of *shallow coastal waters of the Baltic Sea* after one of the many categorizations of water types in the MSRL that are also habitats for macrophytes such as seagrasses (Umwelt Bundesamt, 2024). Seagrass restoration as a measure to mitigate climate change is mentioned in the coalition agreement (Koalitionsvertrag) of the current government (Bundesamt, 2021). One of the actions tackling solutions for natural carbon uptake is the *Natural Climate Protection Action Plan* (Aktionsplan Natürlicher Klimaschutz, ANK) which was published in 2023 and lays a solid foundation for nature restoration in Germany. The originally planned 4 billion $ project aims to regenerate terrestrial and coastal ecosystems that can work as a natural carbon sink (BMUV, 2023). Many coastal ecosystems like salt marshes, kelp forests, and seagrass beds can store enormous amounts of carbon if in a healthy state (Uhl et al., 2024). For example, the BMUV is interested in Seagrass ecosystems as it supported a subproject of seagrass watch (Seagrass-Watch, n.d.) to identify ecosystem services of seagrasses in the Indo-Pacific. Finally, the EU Council recently adopted the NRL in Brussels on 17.06.2024. It is now the task of the BMUV, further ministries, and federal states to sit at a table and discuss the consequential actions and NRPs in Germany. To take on this momentum, lobbying for the rise of augmented marine restoration is therefore advised now.

05

Guidance toward Restored Seas

Chapter Summary

- Seagrass restoration is essential to preserve valuable ecosystem functions and services and is vital for numerous species and humanity. Following the guidelines establishes the foundational steps for effective restoration.

- The 5 guiding principles for seagrass restoration are (1) the assessment of the area, (2) planning of the project with clear goals & objectives, (3) good and thorough implementation of the plans, (4) ongoing management to ensure the survival and growth of seagrasses with (5) continued monitoring and evaluation to adapt with an improved strategy if necessary.

- To implement the guideline for WWF, a comprehensive model should be developed to identify suitable habitats for transplants, considering ecological parameters and legal requirements. Collaborating with research institutes and other projects already in place can streamline the process, avoid bottlenecks, and facilitate knowledge sharing.

- Early outreach is crucial to spread information about seagrass value, attract sponsors, and involve stakeholders. This can be promoted through workshops, citizen science, and community groups managing restoration sites. This approach can then lead to cost savings, increased commitment, and decentralized efforts. The goal should be to empower stakeholders to increase engagement.

5.1. Guideline for Seagrass Restoration & Advice on Implementation

The following guideline structure is adapted from the five principles of ecosystem restoration by the SER Standards of Practice to guide ecosystem restoration, 2024 (see Appendix 7, Fig. 20). Connecting to the 5 principles of restoration in the guideline there are different actions of implementation for WWF. The goal of the project is to understand the steps that WWF needs to take to ensure successful seagrass restoration in the Baltic Sea. I emphasized the first two phases, (1) assessment and (2) planning & designing since I considered them to be the most crucial and chronologically the first ones to tackle. This decision was also made because a solid plan as a foundation will eventually result in more effective (3) implementation, (4) management, and (5) monitoring & evaluation.

1. Assessment

The first step of successful restoration is to assess all stakeholders, the site conditions, the seascape context, to conduct baseline monitoring, and to find a reference model (Nelson et al., 2024). This was also a recommendation pointed out by the participants in a seagrass restoration workshop in 2012 (Cunha et al., 2012). The initial step is the mapping of seagrasses in MV thereby defining areas where seagrass could potentially be restored. WWF is currently developing a pilot project to achieve this via a project called "Wo bist du Seegras" (eng: where are you seagrass), funded by Civic Coding & the initiative "KI-Ideenwerkstatt" (from the BMUV) where AI shall be used for environmental protection. The goal is a prototype of a camera installation and sonar on boats to generate GPS-tagged and AI-analyzed mapping of seagrass meadows on the sea floor. Involving the aforementioned Sea Rangers to gather the data can provide the needed information on potential restoration- as well as reference sites. "Ecological restoration practice is based on an appropriate local native reference ecosystem, taking environmental change into account" (McDonald et al., 2016). For that reason, it is important to develop a model for eelgrass occurrence probability that includes further variables and parameters, which were adapted from eelgrass restoration of the Baltic Sea Coast in SH (Bobsien et al., 2021) and successful eelgrass restoration in the United States by Short et al. (2002). Prior to restoration, it is then important to eliminate local threats like the reduction of nutrients, or regulations of less pollution and other disturbing stressors at the suitable sites respectively (Cunha et al., 2012). Recommended parameters for a suitable site model are the following:

- **Water quality** with light measurements is the most important factor for spatial seagrass distribution. These could be a combination of turbidity and eutrophication.

- **Water depths** with spatial maps to find the optimal depth in which the specific seagrass species can grow.

- **Hydrodynamic exposure**, i.e., current velocity and wave velocity as physical damage was one of the most destructive stressors recorded for seagrasses, both naturally occurring and restored.

- **Sediment composition** and grain size as well as content of sand, silt, clay, and organic content due to the correlation to turbidity and the chances of the roots establishing in the sediment in different hydrodynamic energies.

With this information suitable sites can be located, and test transplantation gives more data about the success. Here monitoring data like the growth and survival of the transplants, and the SI could be added to the original suitable site maps and create a score system for a regional best practice of a suitable site for seagrass restoration (Short et al., 2002). Once the area is more defined it is crucial to reach out to the local stakeholders that would be affected by the project. A solution for more effective communication could be to organize workshops that are open for casual discussions and a transparent conveying of ideas. Here it is immensely important to not only invite stakeholders, that are on board but especially invite those that need to acknowledge the value of seagrass restoration. Visually appealing presentations can be a powerful tool for communication in this case. It is therefore advised to develop posters that give an overview of the ecosystem but also the plan of the project itself. To engage with the stakeholders, make sure to keep the expectations low, give reasons for possible failures, and educate them about the results. Make sure to also engage with the public to increase the appreciation of seagrasses and give updates (Cunha et al., 2012).

Advice for WWF: ACTION

- It needs to be assessed and precisely put on paper what the status quo, the problem is. Next to defining it for the project team itself to eventually find solutions, it is also beneficial for communication purposes later with other stakeholders. In this case, a brief explanation about the status of the Baltic Sea, the degradation of seagrass beds, and the resulting consequences for fish must be elaborated. This overview will deplete confusion and provide guidance and a common understanding of the project by the team and can function as the introduction for a funding proposal.

- The first steps of WWF were already initiated with the start of the seagrass mapping project. From there on, it is important to think about what is going to happen as soon as the data is gathered, and maps are developed. The following action is finding a suitable site for the restoration for which a model needs to be developed. The model should not only consider the presence or non-presence of seagrasses in the relevant Baltic Sea area but also the most relevant parameters described in the guideline. As WWF is not a scientific institute, this task could potentially be outsourced and developed by a research institute or further collaborating organizations. Consider the discussed parameters frame from the previous paragraph *assessment.*

- Currently an event for seagrass restoration in November 2024 is in the planning to gather all relevant stakeholders. For the planning, one of the next important steps is the consideration who to invite. It is advised to consider stakeholders of Table 4 (Appendix 6) to not only get their approval but also for potential financial support, spreading awareness but also for involvement in the implementation. Mainly of importance here is to discuss the issue with municipalities to find the right areas where seagrass restoration can be realized and won't be refused by stakeholders that are active in the same area, like the tourist sector and fisheries. Here it is advised to ask for each stakeholder's needs and to be transparent about all steps of the planning.

- Following up on the new website that was published in July 2024 educating about the ecosystem seagrass meadow (Seegraswiesen – Mikrokosmos im Meer (wwf.de)), it is advised to publish additional information in formats such as a blog entry and social media content to increase outreach.

2. Planning and Designing

This step of working out a restoration project might be the most important of all steps as all actions depend on extensive and thought-through planning and designing of the project also with regards to *Key Concept 2* (Fig. 4) of the SER guideline "Identifying the target ecosystem's key attributes is required before developing longer-term goals and shorter-term objectives" (McDonald et al., 2016). These could be the many ecosystem services and functions that seagrass provides as mentioned in Chapter 2 and listed in Table 3 (see Appendix 3). This is a crucial step for later being able to have clear and measurable outcomes. Project goals could be ecological like increased biomass or carbon and nutrient uptake as was shown in previous highly successful restoration projects of eelgrass (Orth et al., 2020; see Appendix 3, Fig. 17). A socio-economic goal could be job creation as large-scale projects do provide many job opportunities (Keenleyside et al., 2012). The following general elements must be considered for the planning of a marine restoration project in the Baltic Sea:

Legal and Socio-Ecological Frame

- Support marine restoration by lobbying decision-makers through consulting the three policies that were elaborated on in Chapter 3.

- Make sure that these policies will be implemented by supporting strong governance, learning lessons from terrestrial habitats (France, 2016), and making sure that all stakeholders involved in the process (Keulartz, 2009).

Ecological Criteria

- Assess which area and transplant method are the most suitable for the species and are feasible within the legal frame.

- Then start with small-scale test runs to ensure the effectiveness before increasing to a large-scale restoration effort. However, large-scale efforts might be crucial sometimes to ensure positive feedback loops for the survival of for instance seagrasses (van Katwijk et al., 2009).

Upscaling

- Only upscale when a best practice model is found. Beforehand, conduct small-scale test-restoration to decide on the most suitable site and method.

- Be aware of positive feedback loops in seagrasses as it is worth initially planting more shoots/seeds to increase the survival and growth of transplants. Communicate this aspect to stakeholders as a crucial argument to invest in big-scale restoration.

- Orth et al. (2020) showed that large-scale seagrass restoration can be successful when combining efforts of academic, nonprofit, and citizen groups. It took however a reasonable number of years (here 20 years of re-seeding and management). This was done with seed plots which presumably initiated positive feedback loops. Therefore, make this project a community project and keep up the idea of slow ecosystem recovery and the need for long-term monitoring.

- Upscaling can create job opportunities which needs to be communicated to stakeholders. Yet, to save money, it might be essential to find diving volunteers to help with the labor-intensive implementation of restoration.

Advice for WWF:

ACTION

- ➢ As WWF is currently in a process of internal structural rearrangements it is considered crucial to develop long-term goals of marine restoration and follow up with objectives on how to reach them. As this is the first step of the planning, all the following information needs to build up on the objectives. Consider the discussed points about the legal and socio-ecological frame from the previous paragraph *Planning & designing.*

- ➢ As for the seagrass restoration project planning, it may be beneficial to attend to workshops of the upcoming 14th European Conference on Ecological Restoration on the 26-30.08.24. As SER Europe will be one of the organizers it will be gathered beneficial information from many experts and a possibly vital exchange of many scientists and politicians (SERE2024, n.d.).

- ➢ Work out a concept for the restoration which includes the responsibilities, the work that needs to be carried out, locations, dates and timelines, a list with all required materials, budget, supervision, and safety issues (IUCN, 2012). A weather forecast right before the implementation ensures that the implementation takes place in a suitable time frame, so the first settling phase of the plants won't be disturbed by for instance storms.

- ➢ Even though it is recommended to initially focus on a small-scale test project, cooperate with for instance Project Seagrass and SeaStore to learn about their developments in large-scale seagrass restoration. Consider the discussed points about upscaling and ecological criteria from the previous paragraph *planning & designing.*

- ➢ Start planning the monitoring, by determining indicators/variables (Chapter 1), the methods, and resources that are needed.

3. Implementation

After thought-through planning, it is important to stick to the plan for the implementation of seagrass restoration. While it is recommended to outsource the implementation to an experienced party, it is beneficial to be partly present at the restoration site and use the event for outreach. Gather volunteers to support the implementation and expand the project from an internal and solely science project to a community project. This opportunity invites people to learn about seagrass and the need for its protection.

Advice for WWF:

ACTION

- Find a collaboration partner with the infrastructure and resources for the practical part of the project. It is advised to contact SeaStore due to their experience and nearby location in SH with the most similar environment to MV.

- Together with the collaboration partner, organize events for harvesting donor material such as seed-picking events where volunteers can help, as large amounts of seeds are needed for restoration. WWF-UK is very knowledgeable in this field and could give more detailed information on how to plan these activities.

4. Ongoing Management

After the planting is before the actual growth season begins. It is advised to install devices that detect temperature, light intensity, and if possible, wave velocity. This information is crucial for effective management and evaluation of seagrass health. Enforcement of the regulations is a bottleneck of non-compliance for instance anchoring in seagrass meadows or illegal fishing. It is therefore recommended to designate people for the protection of the plants. In Portugal, women of the fishing community are designated for the protection of seagrasses (Ocean Alive, n.d.). It is advised to involve the Sea Rangers as they could provide resources like boats and are additionally trained to support data gathering at sea.

Advice for WWF:

ACTION

- Collaborate with the Sea Rangers in MV to help with surveillance, management, and monitoring.

- Use the network structures and outreach skills to designate a volunteering local community for seagrass restoration that is trained by WWF for the management, monitoring as well as spreading knowledge.

- Keep the involved stakeholders informed about developments and organize events to keep up awareness of the program.

Monitoring and Evaluation

Seagrass meadows should be monitored regularly, starting from shortly after transplantation, but also during the ongoing management for at least 10 years. This is done by gathering the same harmonized parameters as mentioned in Chapter 1 to effectively compare data points in the evaluation. The recommended idea is to build a community-based monitoring program in the long-term (McKenzie et a., 2000), to raise awareness, save resources, engage citizens, and to create a common census for the need to protect seagrasses.

Advice for WWF:

ACTION

- Consistently monitor the indicators that are stated in the plan for the whole monitoring phase (approx. 10 years).
- Consult the designated local community for seagrass restoration for monitoring.
- Collaborate with the Sea Rangers in MV to help with management and monitoring.
- Evaluate the outcome and in the light of adaptive management adjust the measures. Develop an internal guideline.

5.2. Planting the Seeds for Tomorrow

It is time to bring back the pivotal marine ecosystems that over the many years degraded as a result of human-induced stressors. From the past, we learned that the more carefully prepared and thought through, the higher are chances for a restoration success. Concluding with answering the sub-questions, marine restoration is an essential measure of assisting marine ecosystems to reach a good ecological status and self-sustaining functioning. Due to the many stressors of the Baltic Sea, like the warming of the water, eutrophication, and seabed disturbing practices, seagrass meadows are slowly degrading. The flowering plants are however crucial for carbon storage, providing habitat for commercial fish, and reducing coastal erosion. Restoration can be successful if a suitable restoration site is modeled, and the method aligns accordingly to the species and the water body. It has been shown that more heat-resilient plants might be the better choice keeping adaptive management in mind. For this, extensive monitoring and gathering harmonized data over many years are crucial.

Many conservation policies in the past were not implemented. Focusing not only on influencing NRPs for the NRL but also implementing policies like the BSAP and keeping a close look into developments of the Aktionsplan Ostseeschutz are therefore recommended. I again emphasize not only developing clear goals and objectives, filling out all necessary information for a restoration plan but also staying in close contact with the community that deals with marine restoration to learn from each other about successes and failures. By working with the best intentions and the inclusion of the public in volunteering programs it is possible to clear the path for many more marine restoration projects to come. WWF is experienced and capable of taking the role of the "backbone" organization and governing marine habitat revival. The humanity relies on lush underwater ecosystems that clean the oceans and atmosphere, protect our coasts, and are home to many creatures. Finally, I want to finish with a quote by Sylvia Earle a marine researcher, who perfectly outlines to not only judge science but to also take a step back sometimes and acknowledge the simple beauty of underwater life.

"Marine life is a world of vibrant colors and intricate dances, each creature playing a vital role in the ocean's grand ballet."

– Sylvia Earle

Bibliography

Abelson, A., Reed, D. C., Edgar, G. J., Smith, C. S., Kendrick, G. A., Orth, R. J. et al. (2020). Challenges for Restoration of Coastal Marine Ecosystems in the Anthropocene. *Front. Mar. Sci. 7*, 40. DOI: 10.3389/fmars.2020.544105.

Ahvenharju, S., Halonen, M., Rinne, P. (2010). Analysis of the status of implementation of the Baltic Sea Action Plan for WWF. Gaia Consulting Oy. https://www.pdf.lv/uploads/dokumenti/wwf_bsap_implementation_analysis_17052010_final.pdf

Aljinovic, B. (2022). Report mapping the governance status quo in pilot sites. Deliverable D5.1. EU Horizon 2020 REST-COAST Project, Grant agreement No 101037097

Andersen, J. H., Carstensen, J., Conley, D. J., Dromph, K., Fleming-Lehtinen, V., Gustafsson, B. G., et al. (2017). Long-term temporal and spatial trends in eutrophication status of the Baltic Sea. *Biological reviews of the Cambridge Philosophical Society, 92*(1), 135‐149. DOI: 10.1111/brv.12221.

Aps, R., & Lassen, H. (2010). Recovery of depleted Baltic Sea fish stocks: a review. *ICES Journal of Marine Science, 67*(9), 1856‐1860. DOI: 10.1093/icesjms/fsq118.

Arber, A. (1920). Water plants. A study of aquatic angiosperms. Cambridge: Univ. Press.

Aronson, J., Clewell, A. F., Blignaut, J. N., & Milton, S. J. (2006). Ecological restoration: A new frontier for nature conservation and economics. *Journal for Nature Conservation, 14*(3-4), 135‐139. DOI: 10.1016/j.jnc.2006.05.005.

Asmamaw, M., Ambellu, A., Tiku, S. (2015). Resilience of Ecosystems to Climate Change. *American Journal of Environmental Protection, 4*(6), 325-333. DOI: 10.11648/j.ajep.20150406.19.

AWZ-ROV. (2021). Verordnung über die Raumordnung in der deutschen ausschließlichen Wirtschaftszone in der Nordsee und in der Ostsee (AWZ-ROV) vom 19. 8. 2021 (BGBl. I S. 3886). https://www.bgbl.de/xaver/bgbl/text.xav?SID=&tf=xaver.component.Text_0&tocf=&qmf=&hlf=xaver.component.Hitlist_0&bk=bgbl&start=%2F%2F*%5B%40node_id%3D%271033497%27%5D&skin=pdf&tlevel=-2&nohist=1&sinst=ABE5FD84

Baker, S., & Eckerberg, K. (2016). Ecological restoration success: a policy analysis understanding. *Restoration Ecology, 24*(3), 284‐290. DOI: 10.1111/rec.12339.

Baltic Materials. (n. d.). *Bauen und Dämmen*. https://www.balticmaterials.de/bauen-und-daemmen/

Bayraktarov, E., Saunders, M. I., Abdullah, S., Mills, M., Beher, J., Possingham, H. P. et al. (2016). The cost and feasibility of marine coastal restoration. *Ecological applications*, *26*(4), 1055–1074. DOI: 10.1890/15-1077.

Bekkby, T., Gerovasileiou, V., Papadopoulou, K-N., Sevastou, K., Dailianis, T., Fiorentino, D., McOwen, C., Smith, C. J., Amaro, T., Bakran-Petricioli, T., Bilan, M., Boström, C., Carreiro-Silva, M., Carugati, L., Cebrian, E., Cerrano, C., Christie, H., Danovaro, R., Eronat, E. G. T., Fraschetti, S., Gagnon, K., Gambi, C., Grehan, A., Hereu, B., Kipson, S., Kizilkaya, I. T., Kotta, J., Linares, C., Milanese, M., Morato, T., Ojaveer, H., Orav-Kotta, H., Pham, C. K., Rinde, E., Sarà, A., Scharfe, M., Scrimgeour, R. (2017). State of the knowledge on European marine habitat mapping and degraded habitats. Deliverable 1.1, MERCES Project. 137 pp, incl. 4 Annexes.

Bell, S. S., Middlebrooks, M. L., & Hall, M. O. (2014). The Value of Long-Term Assessment of Restoration: Support from a Seagrass Investigation. *Restoration Ecology, 22*(3), 304‐310. DOI: 10.1111/rec.12087.

Belschner, T., Ferretti, J., Strehlow, H. v., Kraak, S. B. M., Döring, R., Kraus, G., et al. (2019). Evaluating fisheries systems: A comprehensive analytical framework and its application to the EU's Common Fisheries Policy. *Fish and Fisheries, 20*(1), 97‐109. DOI: 10.1111/faf.12325.

Bertelli, C. M., & Unsworth, R. K. F. (2014). Protecting the hand that feeds us: seagrass (Zostera marina) serves as commercial juvenile fish habitat. *Marine pollution bulletin, 83*(2), 425–429. DOI: 10.1016/j.marpolbul.2013.08.011.

BfN. (n.d.). *Nationale Meeresschutzgebiete*. https://www.bfn.de/nationale-meeresschutzgebiete

BfN. (n.d.). *Über das BfN.* https://www.bfn.de/thema/ueber-das-bfn

BMUV. (2022, September 14). *Neuer Meeresbeauftragter der Bundesregierung nimmt seine Arbeit auf.* https://www.bmuv.de/pressemitteilung/neuer-meeresbeauftragter-der-bundesregierung-nimmt-seine-arbeit-auf

BMUV. (2023). Aktionsprogramm Natürlicher Klimaschutz - Kabinettsbeschluss vom 29. März 2023. https://www.bmuv.de/fileadmin/Daten_BMU/Pools/Broschueren/ank_publikation_bf.pdf

Bobsien, I. C., Hukriede, W., Schlamkow, C., Friedland, R., Dreier, N., Schubert, P. R., et al. (2021). Modeling eelgrass spatial response to nutrient abatement measures in a changing climate. *Ambio, 50*(2), 400–412. DOI: 10.1007/s13280-020-01364-2.

Bodansky, D. (2015). Towards a workable and effective climate regime: Chapter 11: Legally binding versus nonlegally binding instruments. London: Centre for Economic Policy Research. 155-165- VoxEU.org. ISBN: 978-1-907142-95-6.

Boerger, F. (2024). *Aktionsplan statt Nationalpark: So soll die Ostsee geschützt werden.* NDR. https://www.ndr.de/nachrichten/schleswig-holstein/Aktionsplan-statt-Nationalpark-So-soll-die-Ostsee-geschuetzt-werden,ostseeschutz104.html

Borchers, M., Förster, J., Thrän, D., Beck, S., Thoni, T., Korte, K., et al. (2024). A Comprehensive Assessment of Carbon Dioxide Removal Options for Germany. *Earth's Future, 12*(5), 92. DOI: 10.1029/2023EF003986.

Bos, O. G., Kamermans, P., Tonk, L., Schutter, M., Maathuis, M., van Gool, A., et al. (2023). Eco-friendly reef restoration pilots in offshore wind farms: Report Project ECOFRIEND 2019-2023. Wageningen Marine Research. DOI: 10.18174/632058.

Boström, C., Baden, S. P., Krause-Jensen, D. (2003). World Atlas of Seagrasses: The Seagrasses of Scandinavia and the Baltic Sea. 1.1 Ostsee und Nordsee. 27-37. University of California.

Boström, C., Baden, S., Bockelmann, A.-C., Dromph, K., Fredriksen, S., Gustafsson, C., et al. (2014). Distribution, structure and function of Nordic eelgrass (Zostera marina) ecosystems: implications for coastal management and conservation. *Aquatic conservation: marine and freshwater ecosystems, 24*(3), 410‑434. DOI: 10.1002/aqc.2424.

Bradshaw, C., Iburg, S., Morys, C., Sköld, M., Pusceddu, A., Ennas, C., et al. (2024). Effects of bottom trawling and environmental factors on benthic bacteria, meiofauna and macrofauna communities and benthic ecosystem processes. *The Science of the total environment, 921*, 171076. DOI: 10.1016/j.scitotenv.2024.171076.

Bradshaw, C., Jakobsson, M., Brüchert, V., Bonaglia, S., Mörth, C.-M., Muchowski, J., et al. (2021). Physical Disturbance by Bottom Trawling Suspends Particulate Matter and Alters Biogeochemical Processes on and Near the Seafloor. *Frontiers in Marine Science, 8*, 127. DOI: 10.3389/fmars.2021.683331.

Build Blue. (n. d.). *Dämmung aus der Ostsee*. https://www.buildblue.de/

Bull, J. C., Kenyon, E. J., & Cook, K. J. (2012). Wasting disease regulates long-term population dynamics in a threatened seagrass. *Oecologia, 169*(1), 135‑142. DOI: 10.1007/s00442-011-2187-6.

Bundestag. (2021). *Koalitionsvertrag* https://www.bundestag.de/resource/blob/870238/cf3d58c538b983e957d459ec6c7baee9/koalitionsvertrag-data.pdf

Canyon, D., Allen, E., Long, M., and Brown, C. (2022). Policy recommendations for combatting overfishing and fisheries crime.

Cappellina, B., Ausfelder, A., Eick, A., Mespoulet, R., Hartlapp, M., Saurugger, S., & Terpan, F. (2022). Ever more soft law? A dataset to compare binding and non-binding EU law across policy areas and over time (2004‑2019). *European Union Politics, 23*(4), 741‑757. DOI: 10.1177/14651165221111985.

CBD. (2010). COP 10 Decision X/2, Strategic Plan for Biodiversity 2011-2020.

CBD. (n.d.). *National Biodiversity Strategies and Action Plans (NBSAPs).* https://www.cbd.int/nbsap

Ceballos, G., Ehrlich, P. R., Barnosky, A. D., García, A., Pringle, R. M., & Palmer, T. M. (2015). Accelerated modern human-induced species losses: Entering the sixth mass extinction*. Science advances, 1*(5), e1400253. DOI: 10.1126/sciadv.1400253.

Clarke, A. L., Weckström, K., Conley, D. J., Anderson, N. J., Adser, F., Andrén, E., et al. (2006). Long-term trends in eutrophication and nutrients in the coastal zone*. Limnology and Oceanography, 51*(1part2), 385‑397. DOI: 10.4319/lo.2006.51.1_part_2.0385.

Conley, D. J., Carstensen, J., Aigars, J., Axe, P., Bonsdorff, E., Eremina, T., et al. (2011). Hypoxia is increasing in the coastal zone of the Baltic Sea. *Environmental science & technology, 45*(16), 6777‑6783. DOI: 10.1021/es201212r.

Cornell, T., Freeman III, A. M., Gilfillan E. S., Hawes, E. L., McMahon, S. F., Simon, L. H. (2002). Valuing Nature. A set of papers resulting from the shipman workshop. Bowdoin College.

Cortina-Segarra, J., García-Sánchez, I., Grace, M., Andrés, P., Baker, S., Bullock, C., Decleer, K., Dicks, L. V., Fisher, J. L., Frouz, J., Klimkowska, A., Kyriazopoulos, A.P., Moreno-Mateos, D., Rodríguez-González, P. M., Sarkki, S. and Ventocilla, J. L. (2021). Barriers to ecological restoration in Europe: expert perspectives. *Restoration Ecology, 29*. DOI: 10.1111/rec.13346.

Costello, M. J., & Ballantine, B. (2015). Biodiversity conservation should focus on no-take Marine Reserves: 94% of Marine Protected Areas allow fishing*. Trends in ecology & evolution, 30*(9), 507‑509. DOI: 10.1016/j.tree.2015.06.011.

Cullen-Unsworth, L. C., Nordlund, L. M., Paddock, J., Baker, S., McKenzie, L. J., & Unsworth, R. K. F. (2014). Seagrass meadows globally as a coupled social-ecological system: implications for human wellbeing. *Marine pollution bulletin, 83*(2), 387–397. DOI: 10.1016/j.marpolbul.2013.06.001.

Cunha, A. H., Marba, N. N., van Katwijk, M. M., Pickerell, C., Henriques, M., Bernard, G., Adelaide Ferreira, M., Garcia, S., Garmendia, J. M., and Manent, P. (2012). Changing Paradigms in Seagrass Restoration. *Restoration Ecology, 20*(4), 427‑430. DOI: 10.1111/j.1526-100X.2012.00878.x.

Danley, B., & Widmark, C. (2016). Evaluating conceptual definitions of ecosystem services and their implications*.* *Ecological Economics, 126*(2), 132‑138. DOI: 10.1016/j.ecolecon.2016.04.003.

de los Santos, C. B. de, Krause-Jensen, D., Alcoverro, T., Marbà, N., Duarte, C. M., van Katwijk, M. M., et al. (2019). Recent trend reversal for declining European seagrass meadows. *Nature communications, 10*(1), 3356. DOI: 10.1038/s41467-019-11340-4.

Dennison, W. C., Orth, R. J., Moore, K. A., Stevenson, J. C., Carter, V., Kolla, S., Bergstrom, P. W., and Batiuk, R. A. (1993). Assessing Water Quality with Submersed Aquatic Vegetation: Habitat requirements as barometers of Chesapeake Bay health*. BioScience, 43*, 86–94. DOI: 10.2307/1311969.

Díaz, S., Settele, J., Brondízio E.S., Ngo, H. T., Guèze,M., Agard, J., Arneth, A., Balvanera, P., Brauman, K. A., Butchart, S. H. M., Chan, K. M. A., Garibaldi, L. A., Ichii, K., Liu, J., Subramanian, S. M., Midgley, G. F., Miloslavich, P., Molnár, Z., Obura, D., Pfaff, A., Polasky, S., Purvis, A., Razzaque, J., Reyers, B., Roy Chowdhury, R, Shin, Y. J., Visseren-Hamakers, I. J., Willis, K. J., Zayas, C. N. (2019). Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. IPBES secretariat, Bonn, Germany.

Ding, Z., Zheng, H., Wang, J., O'Connor, P., Li, C., Chen, X., et al. (2023). Integrating Top-Down and Bottom-Up Approaches Improves Practicality and Efficiency of Large-Scale Ecological Restoration Planning: Insights from a Social‑Ecological System. *Engineering, 31*(9), 50‑58. DOI: 10.1016/j.eng.2022.08.008.

Dinu, I., Monclús i Bori, A., Gràcia, V., García-León, M., Lin-Ye, J., Stănică, A., & Sánchez-Arcilla, A. (2023). Assessing the coastal protection role of seagrass meadows along a barrier beach, southern Romanian coast*.* *Journal of Sea Research, 191*(9), 102329. DOI: 10.1016/j.seares.2022.102329.

Du, J., Hu, W., Nagelkerken, I., Sangsawang, L., Loh, K. H., Ooi, J. L.-S., et al. (2020). Seagrass meadows provide multiple benefits to adjacent coral reefs through various microhabitat functions. *Ecosystem Health and Sustainability, 6*(1), 6923. DOI: 10.1080/20964129.2020.1812433.

Duarte, C. M. (2017). Reviews and syntheses: Hidden forests, the role of vegetated coastal habitats in the ocean carbon budget. *Biogeosciences, 14*(2), 301–310. DOI: 10.5194/bg-14-301-2017.

Duarte, C. M., Agusti, S., Barbier, E., Britten, G. L., Castilla, J. C., Gattuso, J.-P., et al. (2020). Rebuilding marine life. *Nature, 580*(7801), 39–51. DOI: 10.1038/s41586-020-2146-7.

Duarte, C. M., Dennison, W. C., Orth, R. J. W., & Carruthers, T. J. B. (2008). The Charisma of Coastal Ecosystems: Addressing the Imbalance. *Estuaries and Coasts, 31*(2), 233–238. DOI: 10.1007/s12237-008-9038-7.

Duarte, C. M., Marba, N., Krause-Jensen, D., Sanchez-Camacho, M. (2007). Testing the predictive power of seagrass depth limit models. *Estuaries and Coasts, 30*(4), 652-656.

Dudley, N. (2008). Guidelines for Applying Protected Area Management Categories. Best Practice Protected Area Guidelines Series No. 21. IUCN.

Dutheil, C., Meier, H. E. M., Gröger, M., & Börgel, F. (2023). Warming of Baltic Sea water masses since 1850. *Climate Dynamics, 61*(3-4), 1311‑1331. 10.1007/s00382-022-06628-z.

Ebberts, B. D., Zelinsky, B. D., Karnezis, J. P., Studebaker, C. A., Lopez-Johnston, S., Creason, A. M., et al. (2018). Estuary ecosystem restoration: implementing and institutionalizing adaptive management. *Restoration Ecology, 26*(2), 360‑369. DOI: 10.1111/rec.12562.

EC. (2009). Directive 2009/147/EC of 30 November 2009 on the conservation of wild birds (Publication Office of the European Union, 2010).

EC. (2011). Our life insurance, our natural capital: an EU biodiversity strategy to 2020.

EC. (2013). Regulation (EU) No 1380/2013 of the European Parliament and of the Council of 11 December 2013 on the Common Fisheries Policy (Official Journal L354, Publications Office of the European Union, 2013).

EC. (2015). The Mid-term Review of the EU Biodiversity Strategy to 2020. Brussels, 2.10.2015 COM(2015) 478 final.

EC. (2019). Communication from the Commission to the European Parliament, the European Council, the European Economic and Social Committee and the Committee of the Regions (The European Green Deal. Brussels, 11.12.2019 COM(2019) 640 final.

EC. (2020a). EU biodiversity strategy for 2030 ‐ Bringing nature back into our lives, Publications Office of the European Union. DOI: 10.2779/677548.

EC. (2020b). Report from the Commission to the European Parliament and the council on the implementation of the Marine Strategy Framework Directive (Directive 2008/56/EC). Brussels, 25.6.2020 COM(2020) 259 final.

EC. (2020c). Report on the status and trends in 2013 - 2018 of species and habitat types protected by the Birds and Habitats Directive. Brussels, 15.10.2020 COM (2020) 635 final.

EC. (2022a). Proposal for a Regulation of the European Parliament and of the Council on Nature Restoration. Brussels, 22.6.2022 COM(2022) 304 final.

EC. (2022b). Directorate-General for Environment, Restoring nature ‐ For the benefit of people, nature and the climate, Publications Office of the European Union, 2022. DOI: 10.2779/439286.

EC. (2023). Report from the Commission to the European Parliament and the council. The common fisheries policy today and tomorrow: a Fisheries and Oceans Pact towards sustainable, science-based, innovative and inclusive fisheries management. Brussels, 21.2.2023 COM(2023) 103 final.

EEA (2017). State of Europe's seas, Publications Office of the European Union. EEA Report No 2/2015. DOI: 10.2800/0466.

EEA (2020). State of nature in the EU; Results from reporting under the nature directives 2013-2018. EEA Report No 10/2020. EEA Report No 10/2020. DOI: 10.2800/705440.

EEC. (1992). Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora (Publications Office of the European Union, 1992).

EEC. (2000). Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy (Publications Office of the European Union, 2000).

EEC. (2008). Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy. (Publications Office of the European Union, 2008).

Eigaard, O. R., Bastardie, F., Hintzen, N. T., Buhl-Mortensen, L., Buhl-Mortensen, P., Catarino, R., Dinesen, G. E., Egekvist, J., Fock, H. O., Geitner, K., Gerritsen, H. D., González, M. M., Jonsson, P., Kavadas, S., Laffargue, P., Lundy, M., Gonzalez-Mirelis, G., Nielsen, J. R., Papadopoulou, N., Paulette, Posen, P. E., Pulcinella, J., Russo, T., Sala, A., Silva, C., Smith, C. J., Vanelslander, B., Rijnsdorp, A. D. (2017). The footprint of bottom trawling in European waters: distribution, intensity, and seabed integrity. ICES. *Journal of Marine Science, 74*(3), 847–865. DOI: 10.1093/icesjms/fsw194.

Elken, J., and Matthäus, W. (2008). Baltic Sea oceanography. Assessment of ClimateChange for the Baltic Sea Basin. Unite Kingdon: BALTEX.

Eriander, L., Infantes, E., Olofsson, M., Olsen, J. L., & Moksnes, P.-O. (2016). Assessing methods for restoration of eelgrass (Zostera marina L.) in a cold temperate region. *Journal of Experimental Marine Biology and Ecology, 479*, 76‐88. DOI: 10.1016/j.jembe.2016.03.005.

Eurostat. (2022). Gross nutrient balance. https://ec.europa.eu/eurostat/databrowser/view/aei_pr_gnb/default/table?lang=en

Fishman, J. R., Orth, R. J., Marion, S., and Bieri, J. (2004). A Comparative Test of Mechanized and Manual Transplanting of Eelgrass, Zostera marina, in Chesapeake Bay. *Restoration Ecology, 12*, 214‐219. DOI: 10.1111/j.1061-2971.2004.00314.x.

Fitzsimons, J., Branigan, S., Brumbaugh, R. D., McDonald, T., zu Ermgassen, P. S. E. (2019). Restoration Guidelines for Shellfish Reefs. *The Nature Conservancy*, Arlington VA, USA.

Fleming, L. E., Broad, K., Clement, A., Dewailly E., Elmir, S., Knap, A., Pomponi, S. A., Smith, S., Solo Gabriele, H., and Walsh, P. (2006). Oceans and human health: Emerging public health risks in the marine environment. *Marine Pollution Bulletin, 53*, 545-560. DOI: 10.1016/j.marpolbul.2006.08.012.

Flindt, M. R., Oncken, N. S., Kuusemäe, K., Lange, T., Aaskoven, N., Winter, S., et al. (2022). Sand-capping stabilizes muddy sediment and improves benthic light conditions in eutrophic estuaries: Laboratory verification and the potential for recovery of eelgrass (Zostera marina*). Journal of Sea Research, 181*, 102177. DOI: 10.1016/j.seares.2022.102177.

Fonseca, M. S. (2011). Addy Revisited: What Has Changed with Seagrass Restoration in 64 Years? *Ecological Restoration, 29*(1-2), 73-81. DOI: 10.3368/er.29.1-2.73.

Fourqurean, J., Duarte, C., Kennedy, H. (2012). Seagrass ecosystems as a globally significant carbon stock. *Nature Geosci, 5*, 505–509. DOI: 10.1038/ngeo1477.

France, R. L. (2016). From land to sea: Governance-management lessons from terrestrial restoration research useful for developing and expanding social-ecological marine restoration. *Ocean & Coastal Management, 133*, 64–71. DOI: 10.1016/j.ocecoaman.2016.08.022.

Gallagher, A. J., Shipley, O. N., van Zinnicq Bergmann, M. P. M., Brownscombe, J. W., Dahlgren, C. P., Frisk, M. G., et al. (2021). Spatial Connectivity and Drivers of Shark Habitat Use Within a Large Marine Protected Area in the Caribbean, The Bahamas Shark Sanctuary. *Frontiers in Marine Science, 7*, e0184763. DOI: 10.3389/fmars.2020.608848.

Gann, G. D., McDonald, T., Walder, B., Aronson, J., Nelson, C.R., Jonson, J., Hallett, J. G., Eisenberg, C., Guariguata, M. R., Liu, J., Hua, F., Echeverría, C., Gonzales, E., Shaw, N., Decleer, K. and Dixon, K. W. (2019). International principles and standards for the practice of ecological restoration. Second edition. *Restoration Ecology, 27*, 1-46. DOI: 10.1111/rec.13035

Green, E. P. and Short, F. T. (2003). World Atlas of Seagrasses. Prepared by the UNEP World Conservation Monitoring Centre. University of California Press, Berkeley, CA. 298 pp.

Guannel, G., Arkema, K., Ruggiero, P., Verutes, G. (2016). The Power of Three: Coral Reefs, Seagrasses and Mangroves Protect Coastal Regions and Increase Their Resilience. *PLOS ONE, 11*(7). DOI: 10.1371/journal.pone.0158094

Gubbay, S., Sanders, N., Haynes, T., Janssen, J. A. M., Rodwell, J. R., Nieto, A., García Criado, M., Beal, S., Borg, J., Kennedy, M., Micu, D., Otero, M., Saunders, G., and Calix, M. (2016). European Red List of Habitats: Part 1. Marine habitats. IUCN. DOI: 10.2779/032638.

Hall, M. A., Alverson, D. L., and Metuzals, K. I. (2000). By-Catch: Problems and Solutions. *Marine pollution bulletin, 41*(1-6), 204‐219.

Hays, G. C., Alcoverro, T., Christianen, M. J. A., Duarte, C. M., Hamann, M., Macreadie, P. I., et al. (2018). New Tools to Identify the Location of Seagrass Meadows: Marine Grazers as Habitat Indicators*. Frontiers in Marine Science, 5*, 53. DOI: 10.3389/fmars.2018.00009.

Heckwolf, M. J., Peterson, A., Jänes, H., Horne, P., Künne, J., Liversage, K., Sajeva, M., Reusch, T. B. H., Kotta, J. (2021). From ecosystems to socio-economic benefits: A systematic review of coastal ecosystem services in the Baltic Sea. *Science of The Total Environment, 755*(2), 142565. DOI: 10.1016/j.scitotenv.2020.142565.

Heinrichs, J. A., Bender, D. J., Schumaker, N. H. (2016). Habitat degradation and loss as key drivers of regional population extinction. *Ecological Modelling, 335*, 64-73. DOI: 10.1016/j.ecolmodel.2016.05.009

HELCOM. (2007). HELCOM Baltic Sea Action Plan (adopted by the HELCOM Ministerial meeting, Krakow, Poland 15th November 2007).

HELCOM. (2018). State of the Baltic Sea – Second HELCOM holistic assessment 2011-2016. Baltic Sea Environment Proceedings 155.

HELCOM. (2021). Baltic Sea Action Plan: 2021 Update. https://helcom.fi/wp-content/uploads/2021/10/Baltic-Sea-Action-Plan-2021-update.pdf

HELCOM. (2023). State of the Baltic Sea. Third HELCOM holistic assessment 2016-2021. Baltic Sea Environment Proceedings 194.

Heleno, R. H., Ripple, W. J., & Traveset, A. (2020). Scientists' warning on endangered food webs. *Web Ecology, 20*(1), 1‐10. DOI: 10.5194/we-20-1-2020.

Hering, D., Schürings, C., Wenskus, F., Blackstock, K., Borja, A., Birk, S., et al. (2023). Securing success for the Nature Restoration Law. *Science (New York, N.Y.), 382*(6676), 1248‐1250. DOI: 10.1126/science.adk1658.

Hermoso, V., Carvalho, S. B., Giakoumi, S., Goldsborough, D., Katsanevakis, S., Leontiou, S., Markantonatou, V., Rumes, B., Vogiatzakis, I. N., Yates, K. L. (2022). The EU Biodiversity Strategy for 2030: Opportunities and challenges on the path towards biodiversity recovery. *Environmental Science & Policy, 127,* 263-271. DOI: 10.1016/j.envsci.2021.10.028.

Higgs, E., Falk, D. A., Guerrini, A., Hall, M., Harris, J., Hobbs, R. J., et al. (2014). The changing role of history in restoration ecology. *Frontiers in Ecology and the Environment, 12*(9), 499–506. DOI: 10.1890/110267.

Hoek, N. (2922). A Critical Analysis of the Proposed EU Regulation on Nature Restoration: Have the Problems Been Resolved? European Energy and Environmental Law Review, 31(5), 320-333.

Holl, K. D., and Howarth, R. B. (2000). Paying for Restoration. *Restoration Ecology, 8*(3), 260‐267. DOI: 10.1002/abio.370040210.

Iho, A., Valve, H., Ekholm, P., Uusitalo, R., Lehtoranta, J., Soinne, H., & Salminen, J. (2023). Efficient protection of the Baltic Sea needs a revision of phosphorus metric. *Ambio, 52*(8), 1389–1399. DOI : 10.1007/s13280-023-01851-2.

Infantes, E., Hoeks, S., Adams, M. P., van der Heide, T., van Katwijk, M. M., & Bouma, T. J. (2022). Seagrass roots strongly reduce cliff erosion rates in sandy sediments. *Marine Ecology Progress Series, 700,* 1–12. DOI: 10.3354/meps14196.

IOW. (n.d.). *SeaStore 2: SeaStore-2 - Schutz und Wiederansiedlung von Seegraswiesen in der südlichen Ostsee; Vorhaben: Integrative Betrachtung der Treibhausgasbilanz bei Wiederansiedlung von Seegraswiesen*. https://www.io-warnemuende.de/projekt/344/seastore_2.html

Jones, C. G., Lawton, J. H., & Shachak, M. (1994). Organisms as Ecosystem Engineers. *Oikos, 69*(3). DOI: 10.2307/3545850.

Jones, H. P., & Schmitz, O. J. (2009). Rapid recovery of damaged ecosystems*. PloS one, 4*(5), e5653. DOI: 10.1371/journal.pone.0005653.

Jones, H. P., Jones, P. C., Barbier, E. B., Blackburn, R. C., Rey Benayas, J. M., Holl, K. D., et al. (2018). Restoration and repair of Earth's damaged ecosystems. *Proceedings Royal Society, 285*(1873). DOI: 10.1098/rspb.2017.2577.

Jueterbock, A., Franssen, S. U., Bergmann, N., Gu, J., Coyer, J. A., Reusch, T. B. H., et al. (2016). Phylogeographic differentiation versus transcriptomic adaptation to warm temperatures in Zostera marina, a globally important seagrass. *Molecular Ecology, 25*(21), 5396–5411. DOI: 10.1111/mec.13829.

Kari, E., Kratzer, S., Beltrán-Abaunza, J. M., Harvey, E. T., & Vaičiūtė, D. (2017). Retrieval of suspended particulate matter from turbidity - model development, validation, and application to MERIS data over the Baltic Sea. International Journal of Remote Sensing, *38*(7), 1983-2003. DOI: 10.1080/01431161.2016.1230289.

Keane, A., Jones, J. P. G., Edwards-Jones, G., and Milner-Gulland, E. J. (2008). The sleeping policeman: understanding issues of enforcement and compliance in conservation*. Animal Conservation, 11*, 75-82. DOI: 10.1111/j.1469-1795.2008.00170.x.

Keenleyside, K., Dudley, N., Cairns, S., Hall, C., and Stolton, S. (2012). Ecological Restoration for Protected Areas: Principles, Guidelines and Best Practices. Best Practice Protected Area Guidelines Series No.18. IUCN.

Kenworthy, W. J., Fonseca, M. S., Whitfield, P. E., and Hammerstrom, K. K. (2002). Analysis of Seagrass Recovery in Experimental Excavations and Propeller-Scar Disturbances in the Florida Keys National Marine Sanctuary*. Journal of Coastal Research, 37*, 75-85.

Keulartz, J. (2009). European Nature Conservation and Restoration Policy—Problems and Perspectives. *Restoration Ecology, 4*, 446–450. DOI: 10.1111/j.1526-100X.2009.00566.x.

Klein, E. S. & Thurstan, R. H. (2016). Acknowledging Long-Term Ecological Change: The Problem of Shifting Baselines. Dordrecht: Springer Netherlands; Imprint: Springer. DOI: 10.1007/978-94-017-7496-3_2.

Korpinen, S., Meski, L., Andersen, J. H., Laamanen, M. (2012). Human pressures and their potential impact on the Baltic Sea ecosystem. *Ecological Indicators, 15*(1), 105-114. DOI: 10.1016/j.ecolind.2011.09.023.

Kovtun, A., Torn, K., & Kotta, J. (2009). Long-term changes in a northern Baltic macrophyte community. *Estonian Journal of Ecology, 58*(4), 270. DOI: 10.3176/eco.2009.4.03.

Krause-Jensen, D., Duarte, C. M., Sand-Jensen, K., & Carstensen, J. (2021). Century-long records reveal shifting challenges to seagrass recovery. *Global change biology, 27*(3), 563–575. DOI: 10.1111/gcb.15440.

La Torre-Castro, M. de, Di Carlo, G., & Jiddawi, N. S. (2014). Seagrass importance for a small-scale fishery in the tropics: the need for seascape management. *Marine pollution bulletin, 83*(2), 398-407. DOI: 10.1016/j.marpolbul.2014.03.034.

Laffoley, D., Baxter, J. M., Amon, D. J., Currie, D. E.J., Downs, C. A., Hall-Spencer, J. M., et al. (2020). Eight urgent, fundamental and simultaneous steps needed to restore ocean health, and the consequences for humanity and the planet of inaction or delay. *Aquatic Conservation: Marine and Freshwater Ecosystems, 30*(1), 194-208. DOI: 10.1002/aqc.3182.

Lamb, J. B., van de Water, J. A. J. M., Bourne, D. G., Altier, C., Hein, M. Y., Fiorenza, E. A., et al. (2017). Seagrass ecosystems reduce exposure to bacterial pathogens of humans, fishes, and invertebrates. *Science (New York, N.Y.), 355*(6326), 731–733. DOI: 10.1126/science.aal1956.

Larkum, A. W. D., Orth, R. J., Duarte, C. M. (2006). Seagrasses: Biology, Ecology and Conservation (1st ed.). Dordrecht: Springer Netherlands. ISBN: 9781402029837.

Lednicka, B., Kubacka, M., Freda, W., Haule, K., Dembska, G., Galer-Tatarowicz, K., & Pazikowska-Sapota, G. (2022). Water Turbidity and Suspended Particulate Matter Concentration at Dredged Material Dumping Sites in the Southern Baltic. *Sensors (Basel, Switzerland), 22*(20). DOI: 10.3390/s22208049.

Lee, K.-S., Park, S. R., & Kim, Y. K. (2007). Effects of irradiance, temperature, and nutrients on growth dynamics of seagrasses: A review. *Journal of Experimental Marine Biology and Ecology, 350*(1-2), 144–175. DOI: 10.1016/j.jembe.2007.06.016.

Lefebvre, L. W., Provancha, J. A., Slone, D. H., & Kenworthy, W. J. (2017). Manatee grazing impacts on a mixed species seagrass bed. *Marine Ecology Progress Series, 564*, 29–45. DOI: 10.3354/meps11986.

Leslie, H. M., and McLeod, K. L. (2007). Confronting the Challenges of Implementing Marine Ecosystem-Based Management. *Ecological Society of America, 5*(10), 540‑548. DOI: 10.1890/060093.

Li, M., Liu, S., Liu, Y., Sun, Y., Wang, F., Dong, S., & An, Y. (2021). The cost-benefit evaluation based on ecosystem services under different ecological restoration scenarios. *Environmental monitoring and assessment, 193*(7), 398. DOI: 10.1007/s10661-021-09188-7.

Lundquist, C. J. and Granek, E. F. (2005). Strategies for Successful Marine Conservation: Integrating Socioeconomic, Political, and Scientific Factors. *Conservation Biology*, 1771‑1778. DOI: 10.1111/j.1523-1739.2005.00279.x.

MacKenzie, B. R., Gislason, H., Möllmann, C., and Köster, F. W. (2007). Impact of 21st century climate change on the Baltic Sea fish community and fisheries. *Global change biology, 13*, 1348‑1367. DOI: 10.1111/j.1365-2486.2007.01369.x.

Maxwell, P. S., Eklöf, J. S., van Katwijk, M. M., O'Brien, K. R., La Torre-Castro, M. de, Boström, C., et al. (2017). The fundamental role of ecological feedback mechanisms for the adaptive management of seagrass ecosystems - a review. *Biological reviews of the Cambridge Philosophical Society, 92*(3), 1521–1538. DOI: 10.1111/brv.12294.

McDonald, T., Gann, G. D, Jonson, J., and Dixon, K. W. (2016). International standards for the practice of ecological restoration ‑ including principles and key concepts. Society for Ecological Restoration, Washington, D.C.

McHenry, J., Rassweiler, A., Hernan, G., Uejio, C. K., Pau, S., Dubel, A. K., & Lester, S. E. (2021). Modelling the biodiversity enhancement value of seagrass beds. *Diversity and Distributions, 27*(11), 2036–2049. DOI: 10.1111/ddi.13379.

McKenzie, L. J., Lee Long., W. J., Coles, R. G., Roder, C. A. (2000). Seagrass-Watch: Community based Monitoring of Seagrass Resources. *Biol. Mar. Medit., 7*(2), 393–396.

Michot, T. C., Woodin, M. C., Nault, A. J. (2008). Food habits of redheads (Aythya americana) wintering in seagrass beds of coastal Louisiana and Texas, USA. *Acta Zoologica Academiae Scientiarum Hungaricae, 54*, 239–250.

Millar, C. I., Stephenson, N. L., Stephens, S. (2007). Climate Change and Forests of the Future: Managing in the Face of Uncertainty. *Ecological Applications, 17*(8), 2145–2151. DOI: 10.1890/06-1715.1

Moksnes, P. O., Gipperth, L., Eriander, L., Laas, K., Cole, S., Infantes, E. (2021). Handbook for restoration of eelgrass in Sweden - National guideline. Swedish Agency for Marine and Water Management, Report number 2021:5, 111 pages (excluding appendices).

Muehlstein, L. K., Porter, D., & Short, F. T. (1991). Labyrinthula Zosterae Sp. Nov, The Causative Agent of Wasting Disease of Eelgrass, Zostera Marina. *Mycologia, 83*(2), 180–191. DOI: 10.1080/00275514.1991.12025994.

Murphy, S. E., Farmer, G., Katz, L., Troëng, S., Henderson, S., Erdmann, M. V., et al. (2021). Fifteen years of lessons from the Seascape approach: A framework for improving ocean management at scale. *Conservation Science and Practice, 3*(6), 3. DOI: 10.1111/csp2.423.

Murray, C. & Marmorek, D. (2003) Ecological Restoration of Southwestern Ponderosa Pine Forests: A Sourcebook for Research and Application, Island Press, Washington, DC, chapter 24: Adaptive Management and Ecological Restoration, 417-428.

NDR. (2024, June 24). "Sea-Ranger": Die ersten Auszubildenden sind fertig. https://www.ndr.de/nachrichten/mecklenburg-vorpommern/Sea-Ranger-Die-ersten-Auszubildenden-sind-fertig,ranger158.html.

Nejrup, L B., Pedersen, M. F. (2007). Effects of salinity and water temperature on the ecological performance of Zostera marina. *Aquatic Botany, 88*, 239–246. DOI: 10.1016/j.aquabot.2007.10.006.

Nelson, C. R., Hallett, J. G., Romero Montoya, A. E., Andrade, A., Besacier, C., Boerger, V., Bouazza, K., Chazdon, R., Cohen-Shacham, E., Danano, D., Diederichsen, A., Fernandez, Y., Gann, G. D., Gonzales, E. K., Gruca, M., Guariguata, M. R., Gutierrez, V., Hancock, B., Innecken, P., Katz, S. M., McCormick, R., Moraes, L. F. D., Murcia, C., Nagabhatla, N., Pouaty Nzembialela, D., Rosado-May, F. J., Shaw, K., Swiderska, K., Vasseur, L., Venkataraman, R., Walder, B., Wang, Z., Weidlich, E. W. A. (2024). Standards of practice to guide ecosystem restoration – A contribution to the United Nations Decade on Ecosystem Restoration 2021-2030. Rome, FAO, Washington, DC, SER & Gland, Switzerland, IUCN CEM. DOI: 10.4060/cc9106en.

Nordlund, L. M., Koch, E. W., Barbier, E. B., and Creed, J. C. (2016). Seagrass Ecosystem Services and Their Variability across Genera and Geographical Regions. *PloS one, 11*(10), e0163091. DOI: 10.1371/journal.pone.0163091.

Nordlund, L. M., Unsworth, R. K. F., Gullström, M., & Cullen-Unsworth, L. C. (2018). Global significance of seagrass fishery activity. *Fish and Fisheries, 19*(3), 399‑412. DOI: 10.1111/faf.12259.

Ocean Alive. (n.d.). *Keepers of the Sea: women of the fishing community who protect the seagrass meadows*. https://www.ocean-alive.org/en/keepers-of-the-sea

Ocean Summit. (n.d.). *SeaStore ‑ Diversity Enhancement Through Seagrass Restoration.* https://ocean-summit.de/allgemein/seastore-steckbrief/

Oceana. (2024). *Public attitudes towards ocean protection and fishing practices in the EU*. https://europe.oceana.org/wp-content/uploads/sites/26/2024/06/Sapience_SaR-Oceana_Final_Report_20240604-v3.pdf

Ojaveer, H., Jaanus, A., Mackenzie, B. R., Martin, G., Olenin, S., Radziejewska, T., et al. (2010). Status of biodiversity in the Baltic Sea. *PloS one, 5*(9). DOI: 10.1371/journal.pone.0012467.

Oreska, M. P. J., McGlathery, K. J., Aoki, L. R., Berger, A. C., Berg, P., & Mullins, L. (2020). The greenhouse gas offset potential from seagrass restoration. *Scientific reports, 10*(1), 7325. DOI: 10.1038/s41598-020-64094-1.

Orth, R. J., Bieri, J., Fishman, J. R., Harwell, M. C., Marion, S. R., Moore, K. A., Nowak, J. F., and van Montfrans, J. (2006). "A review of techniques using adult plants and seeds to transplant eelgrass (Zostera marina L.) in Chesapeake Bay and the Virginia Coastal Bays," in Seagrass Restoration: Success, Failure, and the Costs of Both, eds S. F. Treat and R. R. Lewis (Sarasota, FL: Mote Marine Laboratory).

Orth, R. J., Lefcheck, J. S., McGlathery, K. S., Aoki, L., Luckenbach, M. W., Moore, K. A., Oreska, M. P. J., Snyder, R., Wilcox, D. J., Lusk, B. (2020). Restoration of seagrass habitat leads to rapid recovery of coastal ecosystem services. *Science advances, 6*(41). DOI: 10.1126/sciadv.abc6434.

Orth., R. J., Carruthers, T. J. B., Dennison, W. C., Duarte, C. M., Fourqurean, J. W., Heck JR., K. L., Hughes, A. R., Kendrick, G. A., Kenworthy, W. J., Olyarnik, S., Short, F. T., Waycott, M., Williams, S. L. (2006). A Global Crisis for Seagrass Ecosystems. *BioScience, 56*(12), 987–996.

Ounanian, K., Carballo-Cárdenas, E., van Tatenhove, J. P.M., Delaney, A., Papadopoulou, K. N., & Smith, C. J. (2018). Governing marine ecosystem restoration: the role of discourses and uncertainties. *Marine Policy, 96*(325), 136–144. DOI: 10.1016/j.marpol.2018.08.014.

Pajusalu, L., Boström, C., Gagnon, K., Kaljurand, K., Kotta, J., Püss, T., & Martin, G. (2023). Restoration of eelgrass (Zostera marina) in Estonian coastal waters, Baltic Sea. *Proceedings of the Estonian Academy of Sciences, 72*(1), 41. DOI: 10.3176/proc.2023.1.05.

Park, S. R., Kim, S., Kim, Y. K., Kang, C.-K., & Lee, K.-S. (2016). Photoacclimatory Responses of Zostera marina in the Intertidal and Subtidal Zones*. PloS one, 11*(5), e0156214. DOI: 10.1371/journal.pone.0156214.

Pe'er, G., Daniel Hering, D., Kachler, J., Bruelheide, H., Wittmer, H., Bonn, A., et al. (2023). Scientists support the EU's Green Deal and reject the unjustified argumentation against the Sustainable Use Regulation and the Nature Restoration Law. Open letter (Full Version, 9.7.2023). DOI: 10.5281/ZENODO.8033784.

Peristera Dimopoulou. (2024, June 17). *Nature restoration law: Council gives final green light*. Council of the EU. https://www.consilium.europa.eu/en/press/press-releases/2024/06/17/nature-restoration-law-council-gives-final-green-light/#:~:text=Today%20the%20Council%20formally%20adopted,need%20of%20restoration%20by%202050.

Perrow, M. R., & Davy, A. J. (2002). Handbook of ecological restoration. *Restoration in practice, 2*. Cambridge University Press.

Phillips, R. C., Grant, W. S., McRoy, C. P. (1983). Reproductive Strategies of Eelgrass (Zostera marina L.). *Aquatic Botany, 16*, 1–20. DOI: 10.1016/0304-3770(83)90047-5.

Pinnegar, J. K., & Engelhard, G. H. (2007). The ‘shifting baseline’ phenomenon: a global perspective. *Reviews in Fish Biology and Fisheries, 18*(1), 1‑16. DOI: 10.1007/s11160-007-9058-6.

Plummer, M. L., Harvey, C. J., Anderson, L. E., Guerry, A. D., & Ruckelshaus, M. H. (2013). The Role of Eelgrass in Marine Community Interactions and Ecosystem Services: Results from Ecosystem-Scale Food Web Models. *Ecosystems, 16*(2), 237–251. DOI: 10.1007/s10021-012-9609-0.

Pretty, J. (2003). Social capital and the collective management of resources. *Science, 302*(5652), 1912–1914. DOI: 10.1126/science.1090847.

REA. (2024, July 10). *REA projects helping restore Europe's forests, freshwater sources, coasts and wetlands.* https://rea.ec.europa.eu/news/rea-projects-helping-restore-europes-forests-freshwater-sources-coasts-and-wetlands-2024-07-10_en

Reusch, T. B. H. (2003). Floral neighbourhoods in the sea: how floral density, opportunity for outcrossing and population fragmentation affect seed set in Zostera marina. *Journal of Ecology, 91*, 610-615. DOI: 10.1046/j.1365-2745.2003.00787.x.

Reusch, T. B. H., Boström, C., Stam, W. T., Olsen, J. L. (1999). An ancient eelgrass clone in the Baltic. *Marine Ecology Progress Series, 183*, 301‐304. DOI: 10.3354/meps183301.

Reusch, T. B. H., Ehlers, A., Hämmerli, A., Worm, B. (2005). Ecosystem recovery after climatic extremes enhanced by genotypic diversity. PNAS, 102(8), 2826-2831. DOI: 10.1073/pnas.0500008102.

Rezek, R. J., Furman, B. T., Jung, R. P., Hall, M. O., Bell, S. S. (2019). Long-term performance of seagrass restoration projects in Florida, USA. *Scientific Reports, 9*(1), 15514. DOI: 10.1038/s41598-019-51856-9.

Richardson, B. J., and Lefroy, T. (2016). Restoration dialogues: improving the governance of ecological restoration. *Restoration Ecology, 24*, 668-673. DOI: 10.1111/rec.12391.

Richir, J., Luy, N., Lepoint, G., Rozet, E., Alvera Azcarate, A., & Gobert, S. (2013). Experimental in situ exposure of the seagrass Posidonia oceanica (L.) Delile to 15 trace elements. *Aquatic toxicology (Amsterdam, Netherlands), 140-141*, 157–173. DOI: 10.1016/j.aquatox.2013.05.018.

Rife, A. N., Erisman, B., Sanchez, A., and Aburto‐Oropeza, O. (2013). When good intentions are not enough … Insights on networks of "paper park" marine protected areas. *Conservation Letters, 6*, 200‐212. DOI: 10.1111/j.1755-263X.2012.00303.x.

Röhr, M. E., Holmer, M., Baum, J. K., Björk, M., Boyer, K., Chin, D. (2018). Blue Carbon Storage Capacity of Temperate Eelgrass (Zostera marina) Meadows. *Global Biogeochemical Cycles, 32*(10), 1457–1475. DOI: 10.1029/2018GB005941.

Rohwer, Y., & Marris, E. (2016). Renaming restoration: conceptualizing and justifying the activity as a restoration of lost moral value rather than a return to a previous state. *Restoration Ecology, 24(*5), 674–679. DOI: 10.1111/rec.12398.

Roth, M. (2023). Ausverkauf von Klima- und Naturschutz ‐ Das Papier des Koalitionsausschusses kritisch betrachtet, JuWissBlog Nr. 11/2023 v. 31.03.2023, https://www.juwiss.de/11-2023/.

Sala, E., & Giakoumi, S. (2018). No-take marine reserves are the most effective protected areas in the ocean. *ICES Journal of Marine Science, 75*(3), 1166–1168. DOI: 10.1093/icesjms/fsx059.

Sandifer, P. A., & Sutton-Grier, A. E. (2014). Connecting stressors, ocean ecosystem services, and human health. *Natural Resources Forum, 38*(3), 157‐167. DOI: 10.1111/1477-8947.12047.

Saraiva, S., Markus Meier, H. E., Andersson, H., Höglund, A., Dieterich, C., Gröger, M., et al. (2019). Baltic Sea ecosystem response to various nutrient load scenarios in present and future climates. *Climate Dynamics, 52*(5-6), 3369–3387. DOI: 10.1007/s00382-018-4330-0.

Saunders, M. I., Doropoulos, C., Bayraktarov, E., Babcock, R. C., Gorman, D., Eger, A. M. et al. (2020). Bright Spots in Coastal Marine Ecosystem Restoration. *Current Biology, 30* (24), 1500-1510. DOI: 10.1016/j.cub.2020.10.056.

Savchuk, O. P. (2018). Large-Scale Nutrient Dynamics in the Baltic Sea, 1970–2016. *Frontiers in Marine Science, 5*, 450. DOI: 10.3389/fmars.2018.00095.

Scanes, C. (2018). Animals and Human Society. Chapter 19: Human Activity and Habitat Loss: Destruction, Fragmentation, and Degradation. London United Kingdom: Elsevier/Academic Press, 451-482. DOI: 10.1016/B978-0-12-805247-1.00026-5.

Schleswig-Holstein. (2024a). Aktionsplan Ostseeschutz 2030. https://www.schleswig-holstein.de/DE/landesregierung/themen/kueste-wasser-meer/konsultationsprozess-ostsee/downloads/aktionsplan_ostseeschutz.pdf?__blob=publicationFile&v=1

Schleswig-Holstein. (2024b). Auswertung der schriftlichen Hinweise, Anmerkungen und Stellungnahmen im Rahmen des Konsultationsprozesses über einen möglichen Nationalpark in der schleswig-holsteinischen Ostsee. https://www.schleswig-holstein.de/DE/landesregierung/themen/kueste-wasser-meer/konsultationsprozess-ostsee/downloads/downloadsKonsultationsprozess/Kommunikationsauswertung_Konsultationsprozess.pdf?__blob=publicationFile&v=3

Schubert, P. R., Hukriede W., Karez, R., Reusch, T. B. H. (2015). Mapping and modeling eelgrass Zostera marina distribution in the western Baltic Sea. *Marine Ecology Progress Series 522*, 79-95. DOI: 10.3354/meps11133.

Schuhbauer, A., Chuenpagdee, R., Cheung, W. W. L., Greer, K., Sumaila, U. R. (2017). How subsidies affect the economic viability of small-scale fisheries. *Marine Policy, 82*, 114-121. DOI: 10.1016/j.marpol.2017.05.013.

Schumacher, J. (2022). *Ein Nationalpark in der Ostsee - ja oder nein?* NDR. https://www.ndr.de/nachrichten/schleswig-holstein/Ein-Nationalpark-in-der-Ostsee-ja-oder-nein,nationalparkostsee100.html

Sea rangers. (n.d.). *Drone inspections*. https://searangers.org/case-studies/drone-inspections/.

Seagrass-Watch. (n.d.). *Our team*. https://www.seagrasswatch.org/team/

SERE2024. (n.d.*). 14th European Conference on Ecological Restoration*. Bridging Science, Practice, and Policy of Nature Restoration. https://sere2024.org/

Short, F. T., & Wyllie-Echeverria, S. (1996). Natural and human-induced disturbance of seagrasses. Environmental Conservation, 23(1), 17‐27.

Short, F. T., Davis, R. C., Kopp, B. S., Short, C. A., Burdick, D. M. (2002). Site-selection model for optimal transplantation of eelgrass Zostera marina in the northeastern US. *Marine Ecology Progress Series, 227*, 253‐267. DOI: 10.3354/meps227253.

Short, F., Carruthers, T., Dennison, W., & Waycott, M. (2007). Global seagrass distribution and diversity: A bioregional model. *Journal of Experimental Marine Biology and Ecology, 350*(1-2), 3–20. DOI: 10.1016/j.jembe.2007.06.012.

Society for Ecological Restoration International Science & Policy Working Group. (2004). *The SER International Primer on Ecological Restoration*. https://cdn.ymaws.com/www.ser.org/resource/resmgr/custompages/publications/SER_Primer/ser_primer.pdf

State of Queensland (1994). Fisheries Act 1994.

Steinfurth, R. C., Lange, T., Oncken, N. S., Kristensen, E., Quintana, C. O., & Flindt (2022). Improved benthic fauna community parameters after large-scale eelgrass (Zostera marina) restoration in Horsens Fjord, Denmark. *Marine Ecology Progress Series, 687*, 65‐77. DOI: 10.3354/meps14007.

Steinfurth, R. C., Nielsen, B., Elsberg, L. F., Lange, T., Oncken, N. S., Quintana, C. O., et al. (2024). Macrofaunal colonization after large-scale sand-cap and Zostera marina restoration of organic enriched sediments in a Danish fjord*. Marine Ecology Progress Series, 729*, 63–79. DOI: 10.3354/meps14511.

Stevenson, A., Ó Corcora, T. C., Hukriede, W., Schubert, P. R., Reusch, T. B. H. (2023). Substantial seagrass blue carbon pools in the southwestern Baltic Sea include relics of terrestrial peatlands. *Front. Mar. Sci., 10*, 527. DOI: 10.3389/fmars.2023.1266663.

Stolte, A., Dederer, G., Lamp, J., Fenn, C., Lee, M., Frank, W., et al. (2022). The quest for ghost gear in the German Baltic Sea: A team effort between WWF, divers, fisherfolk, and public authorities. *Frontiers in Marine Science, 9*, 535. DOI: 10.3389/fmars.2022.981840.

SUPERB. (2024, March 13). *Forest Restoration Talks*. Webinar 15: Ecosystem Restoration on a landscape level: how can it work in practice? https://forest-restoration.eu/resources/#tab-multimedia.

Tan, Y. M., Dalby, O., Kendrick, G. A., Statton, J., Sinclair, E. A., Fraser, M. W., et al. (2020). Seagrass Restoration Is Possible: Insights and Lessons From Australia and New Zealand. *Frontiers in Marine Science, 7*, 367. DOI: 10.3389/fmars.2020.00617.

Uhl, F., Martius, J., Oppelt, N. (2024). Erstellung von GIS-Karten zur Kohlenstoffspeicherung an der deutschen Nordseeküste. Methodische Projektdokumentation. https://www.nabu.de/imperia/md/content/nabude/meeresschutz/240126_nabu_nordsee-kohlenstoff_projektdokumentation.pdf

Umwelt Bundesamt. (2024, March 22). *Gewässertyp des Jahres 2024 ‐ Flaches Küstengewässer der Ostsee*. https://www.umweltbundesamt.de/themen/wasser/gewaessertyp-des-jahres/gewaessertyp-des-jahres-2024-flaches#kurzbeschreibung-des-gewassertyps

UN environment programme. (2022). Decisions adopted by the Conference of the Parties to the Convention on Biological Diversity, 15. Kunming-Montreal Global Biodiversity Framework (cbd.int).

United Nations. (n.d.). International Decades. https://www.un.org/en/observances/international-decades

Unsworth, R. K. F. & Cullen, L. C. (2010). Recognising the necessity for Indo-Pacific seagrass conservation*. Conservation Letters, 3*, 63–73. DOI: 10.1111/j.1755-263X.2010.00101.x.

Unsworth, R. K. F., de León, P. S., Garrard, S. L., Jompa, J., Smith, D. J., & Bell, J. J. (2008). High connectivity of Indo-Pacific seagrass fish assemblages with mangrove and coral reef habitats. *Marine Ecology Progress Series, 353*, 213–224. DOI: 10.3354/meps07199.

Unsworth, R. K. F., Nordlund, L. M., & Cullen-Unsworth, L. C. (2019). Seagrass meadows support global fisheries production. *Conservation Letters, 12*(1), 11. DOI: 10.1111/conl.12566.

van der Heide, T., van Nes, E. H., Geerling, G. W., Smolders, A. J. P., Bouma, T. J., & van Katwijk, M. M. (2007). Positive Feedbacks in Seagrass Ecosystems: Implications for Success in Conservation and Restoration. *Ecosystems, 10*(8), 1311–1322. DOI: 10.1007/s10021-007-9099-7.

van Katwijk, M. M., Bos, A. R., Jonge, V. N. de, Hanssen, L. S. A. M., Hermus, D. C. R., & Jong, D. J. de (2009). Guidelines for seagrass restoration: importance of habitat selection and donor population, spreading of risks, and ecosystem engineering effects. *Marine pollution bulletin, 58*(2), 179‐188. DOI: 10.1016/j.marpolbul.2008.09.028

van Katwijk, M. M., Thorhaug, A., Marbà, N., Orth, R. J., Duarte, C. M., Kendrick, G. A., et al. (2016). Global analysis of seagrass restoration: the importance of large-scale planting. *Journal of Applied Ecology, 53*(2), 567–578. DOI: 10.1111/1365-2664.12562.

van Tussenbroek, B. I., Soissons, L. M., Bouma, T. J., Asmus, R., Auby, I., Brun, F. G. (2016). Pollen limitation may be a common Allee effect in marine hydrophilous plants: implications for decline and recovery in seagrasses. *Oecologia, 182* (2), 595–609. DOI: 10.1007/s00442-016-3665-7.

Walters, C. J. (2007). Is Adaptive Management Helping to Solve Fisheries Problems? AMBIO: A Journal of the Human Environment, 36(4), 304‐307. DOI: 10.1579/0044-7447(2007)36[304:IAMHTS]2.0.CO;2.

Wang, Y.-R., Hessen, D. O., Samset, B. H., & Stordal, F. (2022). Evaluating global and regional land warming trends in the past decades with both MODIS and ERA5-Land land surface temperature data. *Remote Sensing of Environment, 280*(3), 113181. DOI: 10.1016/j.rse.2022.113181.

Waycott, M., Duarte, C. M., Carruthers, T. J. B., Orth, R. J., Dennison, W. C., et al. (2009). Accelerating loss of seagrasses across the globe threatens coastal ecosystems. *Proceedings of the National Academy of Sciences of the United States of America, 106*(30), 12377–12381. DOI: 10.1073/pnas.0905620106.

Williams, S. L. (2001). Reduced genetic Diversity in Eelgrass Transplantations affects both Population Growth and individual Fitness. *Ecological Applications, 11*(5), 1472‐1488. DOI: 10.2307/3060933.

Wood, G., Marzinelli, E. M., Coleman, M. A., Campbell, A. H., Santini, N. S., Kajlich, L., et al. (2019). Restoring subtidal marine macrophytes in the Anthropocene: trajectories and future-proofing. *Marine and Freshwater Research, 70*(7), 936. DOI: 10.1071/MF18226.

Worm, B., Barbier, E. B., Beaumont, N., Duffy, J. E., Folke, C., Halpern, B. S. (2006). Impacts of biodiversity loss on ocean ecosystem services. *Science, 314*, 787–790. DOI: 10.1126/science.1132294.

Worm, B., Reusch, T. B. H. (2000). Do nutrient availability and plant density limit seagrass colonization in the Baltic Sea? *Marine Ecology Progress Series, 200*, 159–166.

WWF Germany (2023). Conserving Nature & Shaping Transformation: WWF Germany I Strategic Direction towards 2030 (Internal document).

WWF. (n.d.). *Über Uns*. Über uns (wwf.de)

Yu, L., Renton, J., Burian, A., Khachaturyan, M., Bayer, T., Kotta, J. et al. (2024). A somatic genetic clock for clonal species. *Nature Ecology & Evolution*. DOI: 10.1038/s41559-024-02439-z.

Zimmermann, C., Kraus, G., and Kraft, N. (2024, 06. March*). Hat Deutschland am 29. Februar seine Fischreserven verbraucht*? Thünen-Institut. https://www.thuenen.de/de/newsroom/mediathek/faktencheck/hat-deutschland-am-29-februar-wirklich-seine-fischreserven-verbraucht

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Appendices

Appendix 1: Restoration Projects of Marine Habitats

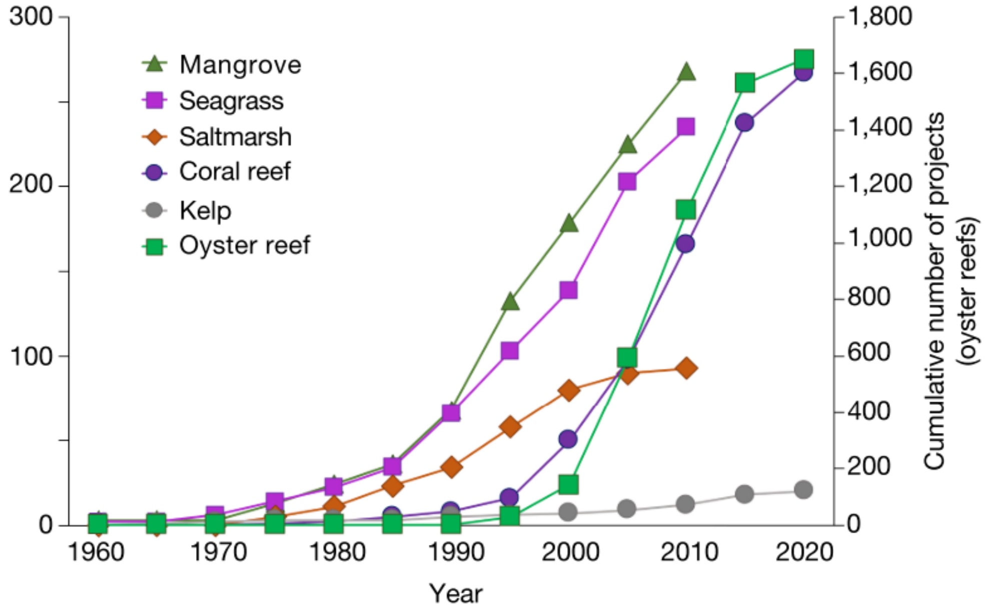

Figure 14: Restoration projects of marine habitats worldwide over the last decades. The number of seagrass and mangrove restoration projects rapidly increased from the 1980s on. Oyster and coral reef restoration projects increased later, approximately at the beginning of the 2000s. Significantly fewer restoration projects are those that focus on saltmarshes and Kelp forests (adapted from Duarte et al., 2020).

Appendix 2: The Importance of Scale in Seagrass Restoration Projects

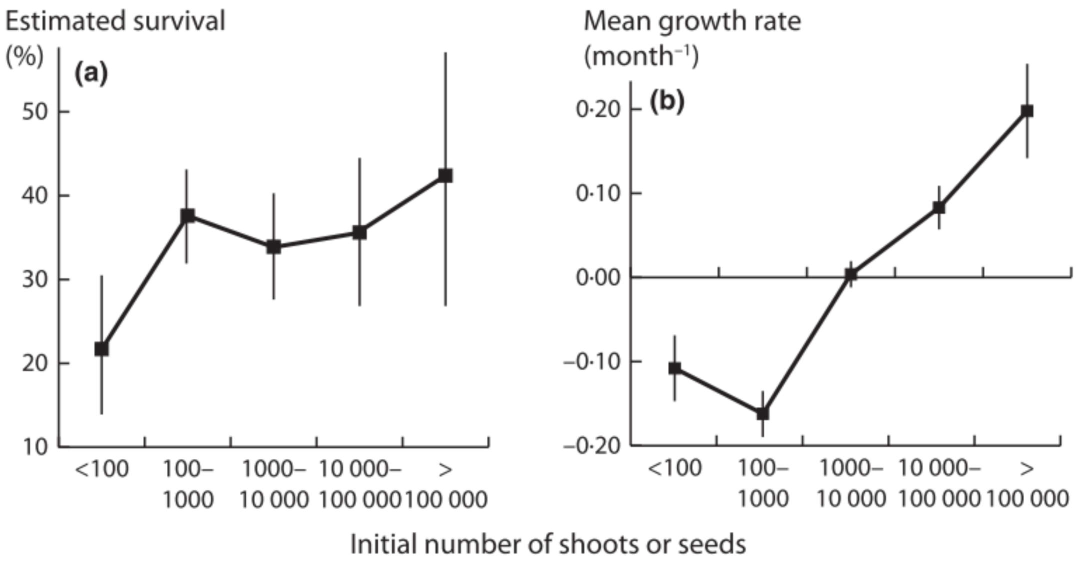

Figure 15: Seagrass survival (a) and growth (b) regarding the scaling effort of seagrass restoration. Due to positive feedback mechanisms, seagrass restoration is more successful the higher the initial planted shoot number (adapted from van Katwijk et al., 2016).

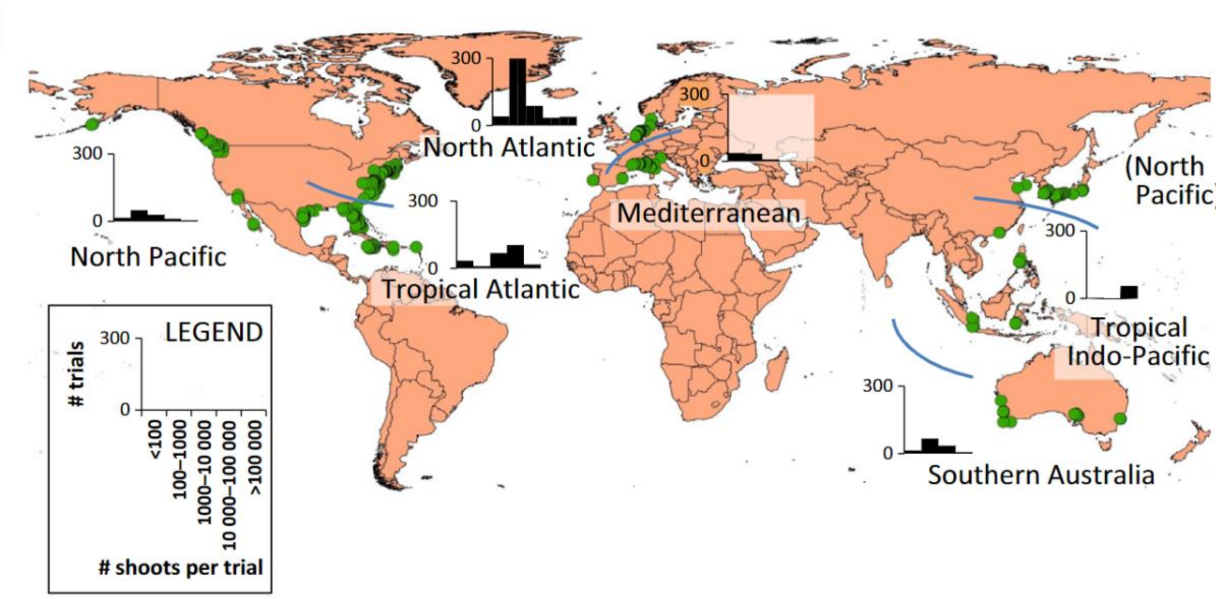

Figure 16: Seagrass restoration projects worldwide split into the size of the scale (adapted from van Katwijk et al., 2016).

Appendix 3: Ecosystem Services & Functions of Seagrass

Table 3: Ecosystem Services and functions of seagrass. The categories are based on Nordlund et al. (2016) and Fitzimons et al. (2019).

Ecosystem service/function	Beneficiaries	Mechanism
Fish nursery	Commercial and recreational fishers	Eggs can be attached to plants, and juvenile fish find shelter and protection from predators
Fish habitat	Commercial and recreational fishers	Through food availability and shelter function, it is a habitat for many (commercial) fishes such as Hering, Sprout. and cod
Biodiversity enhancement and ecosystem stability	Associated species	Attracting many species and creating a complex food web by providing refuge and feeding ground
Habitat for Invertebrates, and vertebrates	Associated species, commercial fishers	Providing shelter and food for associated fauna between leaves and in benthos, protection from predators, and provision of food
Food for animals	Sea cows and sea turtles	Some species are specialized in feeding on seagrass as their primary food source
Nutrient cycling	Many species (in the tropics: mangroves and coral reefs)	Uptake of nutrients and storage and recycling in water and sediment
Uptake of toxins and pathogens	Local community, tourists, many species (e.g., corals)	Increasing the water quality and enhancing the environment for humans and many species
Water purification	Local community, recreational visitors, commercial fishers, governments	Trapping of particles with the leaves and absorbing excess nutrients and toxins
Carbon burial	Government, and global population	Through photosynthesis and long-time storage of carbon in rhizomes and sediment
Sediment accretion	Local community, and government	By trapping particles with the leaves, sediment gets accumulated
Coastal protection, wave dampening	Landowners, local community, and government	Slowing down of wave and current energy with seagrass canopy
Erosion prevention, Sediment stabilization	Local community, Seagrass itself	Especially in dense populations by physically dampening wave energy with seagrass canopy and stabilizing sediment with underground structures
Recreation	Tourism sector, tourists, local community	The higher presence of many species and purification of water attracts visitors to diving and snorkeling
Bioindicator	Scientists, government	Indicating the health of the water and ecosystem since seagrasses are sensitive to environmental changes
Education	Scientists, local community, global population	Increasing awareness of marine ecosystems and the associated species
Bequest value	Upcoming generations of the global population	The value of the ecosystem that needs to be sustained for further generations

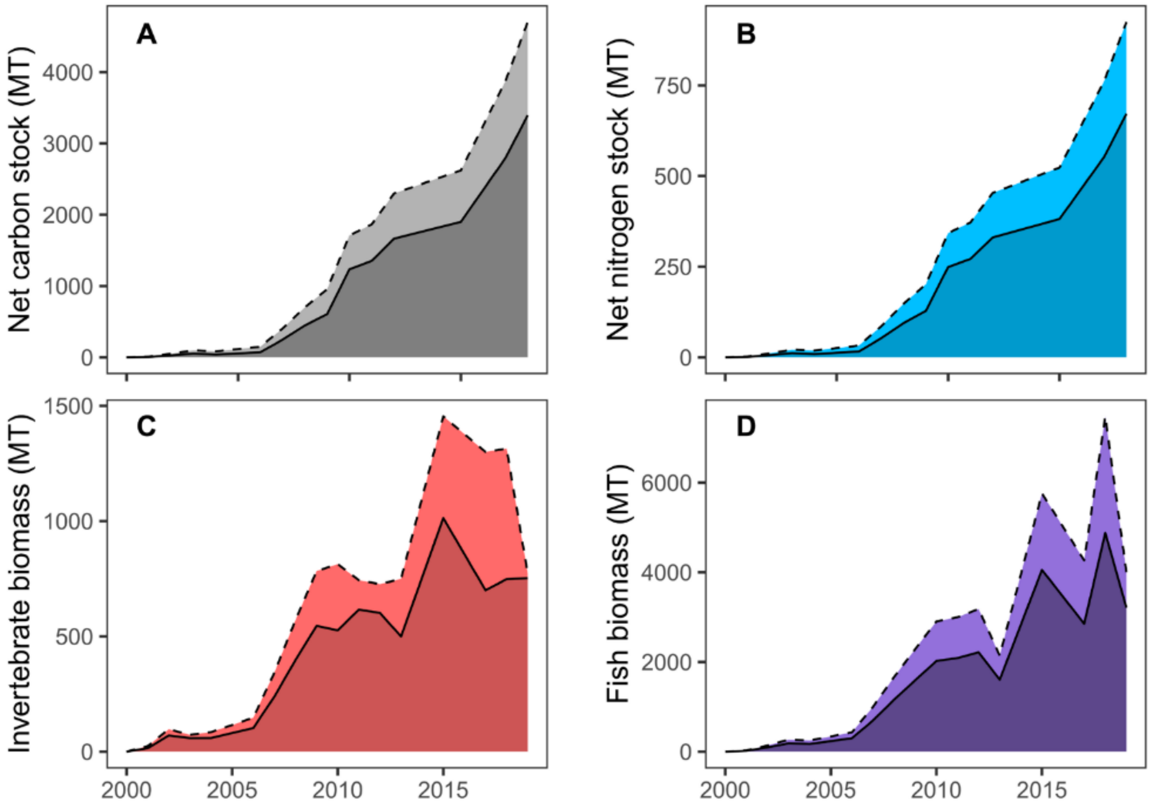

Figure 17: Ecosystem services associated with the restoration of eelgrass over time in the eastern shore of Virgina (adapted from Orth et al., 2020).

Appendix 4: Restoration of Seagrasses

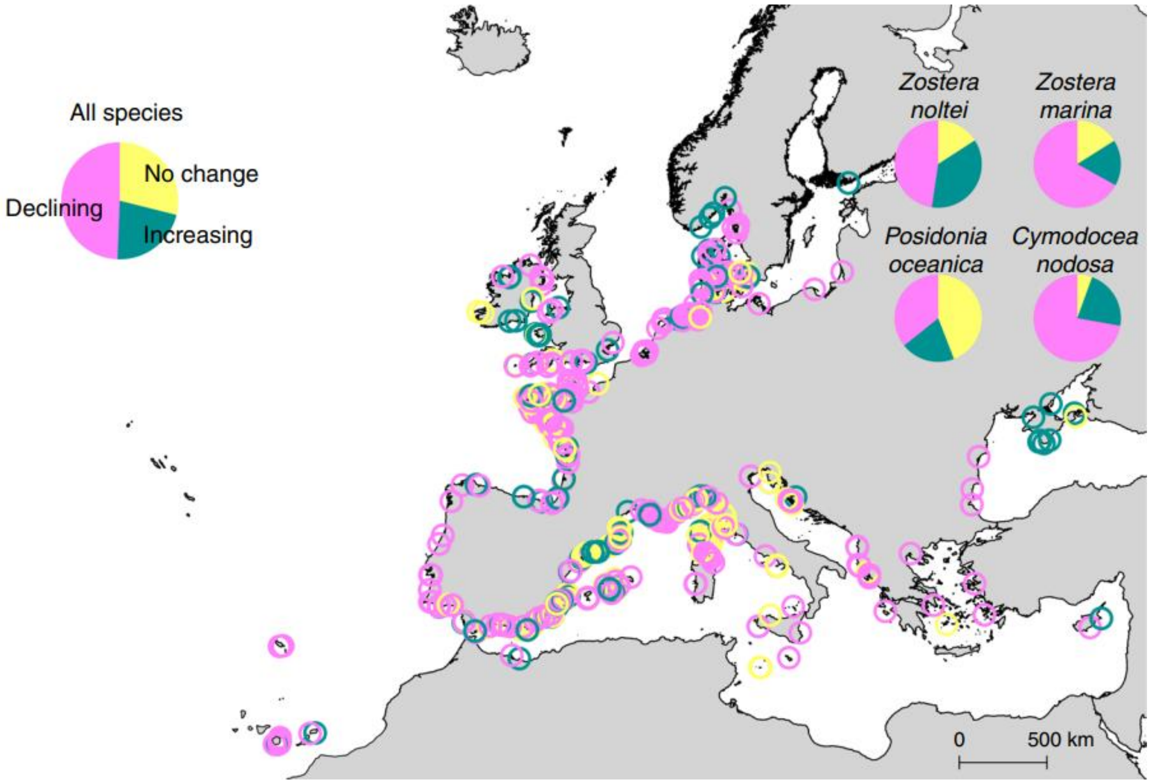

Figure 18: Status of seagrass meadows in Europe between 1869 and 2016. Most of the decline had its peak in the 1970s (adapted from de los Santos et al., 2019).

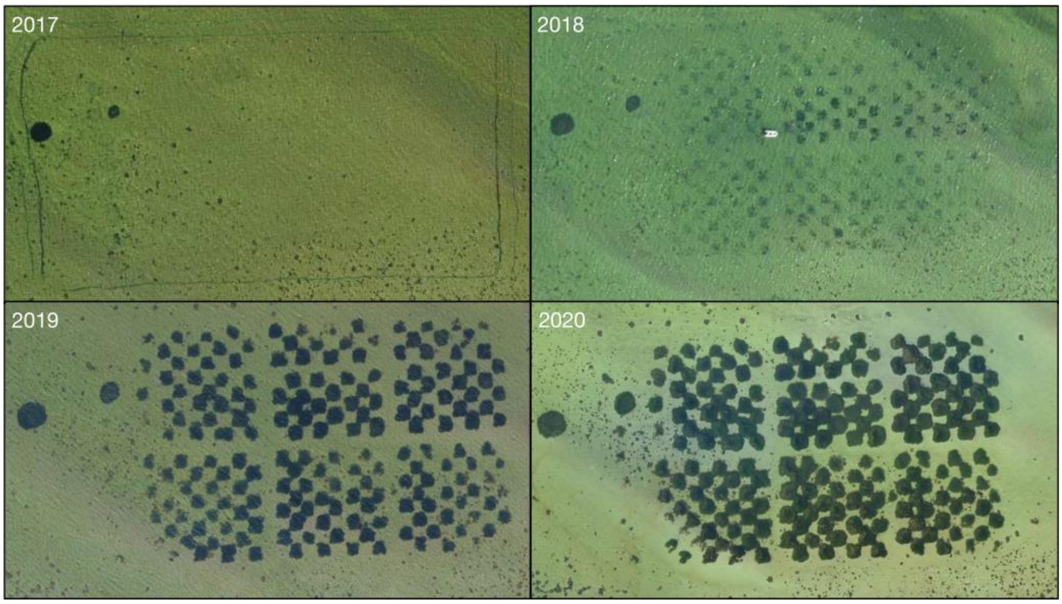

Figure 19: Development of Seagrass restoration in the Horsens Fjord, Denmark. Shoots were transplanted in a chess pattern for optimal expansion through vegetative reproduction (adapted from Steinfurth et al., 2022).

Appendix 5: Interview BfN

Linda Westphal & Kevin Dietz, BfN

30.05.2024

Clara Taetz: What role does BfN play in coordinating between different stakeholders, such as government agencies, NGOs, and scientific institutes, to plan and implement restoration measures for (marine) habitats?

Kevin Dietz: BfN has a coordinating role, so we take on topics for the BMUV and then coordinate where we still need information, where something needs to be mapped or monitored, where we have areas to implement restoration measures, and how these should be structured. We are in close contact with other authorities, be it government agencies such as the BSH which is responsible for spatial planning and the allocation of areas for the North Sea and Baltic Sea, or NGOs or institutes for projects for which we create research projects that we then award to them. There are a wide variety of projects. In this case, we also have research projects that deal specifically with restoration measures. In other words, what something like this could look like, or to fill gaps in our knowledge. Be it the reintroduction of oysters, or the placement of stones for geogenic reefs, or that we want to have key habitats investigated, which are particularly important and what restoration measures could look like for them. However, we are also responsible for coordination by participating in various committees, be it in exchange with the BMUV or the coastal federal states.

Linda Westphal: Perhaps as a small addition here. The BfN accompanies the entire process, i.e., from the idea or needs assessment, which habitats of which species are in a critical state, which methods are available to restore or support these biotypes or habitat types or species. And then the accompanying monitoring, or the implementation of compensation measures, which are then carried out by others. But from this development of needs, through research, to the implementation of the measures, the BfN accompanies this completely, but exclusively in the EEZ. However, this does not mean that the research projects cannot take place on the coast. Although the aim is for the measures to take place specifically in the EEZ, research is still carried out on the coast or on land.

Clara Taetz: What could something like this look like, for example?

Linda Westphal: The sturgeon, for example, is a migratory fish species that has almost been wiped out. We have been working with the IGB (Leibniz Institute of Freshwater Ecology and Inland Fisheries) in Berlin for many years, for example. Projects are underway to set up sturgeon breeding facilities, rear the young and then release them. However, they are then released into limnic systems, i.e., rivers, where they will then return in the long term as adult migratory fish to spawn. But the aim is, of course, for them to return to the Baltic Sea and build up a stable population there. In other words, the goal is in the Baltic Sea, but the BfN must nevertheless also be active on land, in the river.

Clara Taetz: To what extent are restoration measures also being considered in the EEZ? Are there favored habitats?

Kevin Dietz: In a way, the ANK is a funding pot from which money comes. Unfortunately, projects in our field are not part of the ANK. However, there is not only the ANK, but also the 'Meeresnaturschutzkomponente', the 'EEZ title' and the 'AHP' (species assistance program). Depending on how the research project is structured and organized, this can be done via the various funding titles. A lot of funding is allocated via the ANK, as the Restoration Ordinance covers not only the marine but also the terrestrial area. We are not responsible for the entire restoration regulation in the marine sector, but in the terrestrial sector. This means that the majority of the projects based at the ANK are not in the marine sector. A parallel team that works a lot with natural carbon reservoirs has many of its projects at the ANK.

Clara Taetz: To what extent are restoration measures also being considered in the EEZ? Are there favored habitats there? How can it be determined whether such measures actually contribute to the functionality of the ecosystem there in the long term (as they were often not historically located there)?

Linda Westphal: Nature conservation is then about actual restoration, which means we want to know exactly which habitats originally occurred in a place and which have (probably) been lost due to anthropogenic influences. In the German North Sea, for example, the European oyster was present over a very large area, i.e., large parts that were a continuous oyster reef and that has been completely lost due to overfishing and bottom trawling. Another aspect is that the geogenic reefs, i.e., the natural stone deposits. These were mainly erratic blocks of glacial origin. They were brought here by moraines during the ice age and then removed from the seas in the course of stone fishing. These are two typical habitat types that have been lost over large areas and that we either want to improve in their structure or restore completely. It is important to know what the species inventory was like historically, and we will now be launching projects on this too. For example, the project "The Baltic Sea and North Sea a hundred years ago". We want to investigate the past and see what we are missing today compared to one hundred years ago or even earlier. So that we can close the gaps there and restore the ecosystem in a more targeted way.

Clara Taetz: Is the BfN planning to carry out restoration directly in the offshore wind farms, i.e., not with historical reference, but on artificial structures?

Kevin Dietz: There are no considerations in that sense. That would all fall under the heading of multi-use, i.e., how the wind farms could be used in further ways. This is difficult to handle for nature conservation because multi-use is based on the assumption of a benefit, and it is always better for nature conservation if there is less benefit. And if you say you are going to introduce restoration measures within wind farms, the question would be whether the various users are prepared for anything to happen at all. In addition, if we say that we will also use the areas for restoration measures, the pressure on other areas outside the wind farms could then quickly increase, i.e., people will say that you have your areas there, which means that we will then use the areas outside the wind farms for other forms of use. That is why it is somewhat critical to say that we are targeting our measures at wind farms. We always must weigh up which animals will settle there within the wind farm; after all, these are artificial structures that are brought in where there may not have been any reefs at all before and a transformation is brought about. We want to restore old systems. There are currently no active projects.

Clara Taetz: There are currently no designated areas for restoration, is this mostly done in the MPAs of the Natura 2000 network?

Linda Westphal: At the moment, our restoration measures are completely limited to the nature conservation areas in the EEZ, and we are currently unable to plan measures outside of these protected areas. It would be great if this were possible at some point, in areas where use is not ruled out, such as under shipping routes.

Clara Taetz: What's the biggest challenge in marine habitat restoration in the EEZ? Is there a lack of people or groups that take responsibility or carry out projects?

Kevin Dietz: The way it works for us is that we set up research projects ourselves and then award them to institutes or NGOs that apply for them. At the same time, they can approach us with project ideas so that we can then give them a grant. In other words, it works without any problems, that's not the difficulty. The difficulty lies in finding areas where we can implement measures, as we are restricted by fishing and other reference conflicts to the protected areas where there is no ground-touching fishing. This is also since the North Sea no longer has any free areas available, but everything there is used in one way or another. That's why the biggest problem is finding areas where something like this can be introduced and then have a long-term effect. There is no point in establishing something somewhere if it is immediately destroyed again by fishing.

Clara Taetz: Does the BfN have any influence on the BSH and on what is included in the maritime spatial plan?

Kevin Dietz: We have an influence on this to a certain extent. The land development plan and marine spatial development plan are submitted to us by the BSH, and we can then comment on them. We can then bring in the nature conservation aspects, which would then speak in favor of an area or not. Ultimately, however, the BSH has the greater decision-making power. They also have to comply with the implementation requirements set by politicians. This is also one of the biggest problems for marine nature conservation, namely that climate protection is not equated with marine nature conservation, but marine nature conservation includes climate protection. It is difficult for nature conservation to manage the balancing act because, of course, conservationists also want to promote climate protection. The question is at what price?

Clara Taetz: From your experience, what are (and have been) the best arguments to convince policymakers of the need for restoration measures (biodiversity, natural climate sink, food [here mostly fish], coastal protection, culture [aesthetics], monetary value)?

Kevin Dietz: All representatives are aware that climate protection must be pursued. But every user naturally has their own interests. The biggest argument is climate protection, that something has to happen, but also the extinction of species. The directives and regulations are also based on this. I would say that is what we can achieve the most with. If we demonstrate that this is a goal that must be achieved, and that Germany has committed itself to achieving it. A solution must then also be found. That is why the Nature Restoration Law (NRL) would have been so good. Unfortunately, we can only refer to the existing directives and explain once again how seagrass meadows, for example, contribute to CO2 storage. But here, too, there are different approaches. For example, it [seagrass] is compared with CCR or

CCS, i.e. the technical injection of CO2 into the sea, because it is perhaps more efficient, i.e. it can store more CO2. In other words, it's always a matter of weighing up, or perhaps talking up, which is better.

Clara Taetz: Besides the coastal area, is seagrass restoration also a possibility, or even planned, in the offshore area with wind turbines?

Kevin Dietz: As far as the restoration of seagrass meadows is concerned, in Germany it actually takes place in the coastal seas, which means it doesn't affect us. There are no ideas within the BfN regarding the reintroduction of seagrass in the EEZ.

Linda Westphal: In the Baltic Sea, geogenic reefs are also being restored in shallow water areas in the EEZ, with the aim of allowing macrophytes to recolonize naturally. This is primarily Fucus spp. (seaweed).

Clara Taetz: To what extent does the fishery play a role in the implementation of restoration plans?

Linda Westphal: Fisheries have the same problems as we do. With every wind farm, they also lose areas that were previously used for fishing. The wind farms are fishing exclusion zones and, as a result, fishing is becoming increasingly concentrated outside the wind farms. If you look at the area development plan, you can see that a large and significant part of the EEZ is planned for offshore wind. Then there is the infrastructure, i.e., all the power lines, converter platforms, submarine cables and shipping routes. We have a lot of interest groups and user groups in the EEZ, and space is limited.

Kevin Dietz: Bottom-contact fishing was only recently excluded from the [MPA] Borkum Riffgrund. This was previously still possible and therefore no possibility for us to carry out restoration measures there. You have fewer users within the marine protected areas. We now also hope that the 30/10 target - i.e., 30 % of the seas under protection and 10 % under strict protection - will continue to be enforced and that this will make even more area available where there is no form of use at all.

Clara Taetz: In various conversations, webinars, and literature, it was possible to crystallize that knowledge gaps are often the biggest challenge only in rare cases, but often a lack of coordination to bring all the pieces of the puzzle together. Can you imagine the BfN taking on the role of a major coordinator in Germany to bring all the players together and drive the projects forward? How closely is the BfN linked to the BMUV in that regard?

Kevin Dietz: We report to the BMUV, i.e., we manage projects for the BMUV or take on certain topics. It depends on how the capacities and personnel are distributed and whether the topic is closer to the BfN or the BMUV. There is a great need for coordination. In the case of the NRL, this would also have come our way. In the case of the NRL, for example, the various ministries would have to sit at the same table, the BMWK, the BMUV, but also the ministry for transport, also the individual state authorities, those of the coastal federal states, but also institutes and NGOs. However, there are also various committees, be it the BLANO (Federal/State Working Group for the North and Baltic Seas), the OSPSAR or the HELCOM agreement, in which we are also involved and where such discussions and coordination take place.

Linda Westphal: There are also standardized procedures. So, if an impact is approved, for example the construction of a wind farm, then the project developers must compensate for this impact. This procedure is coordinated. In so-called planning approval procedures, the amount of compensation that the operator or company has to provide is determined. And then, on the one hand, there is real compensation, which is also carried out by the BfN, which is then coordinated, in which areas and to what extent this takes place, and how the measure is developed. We have written clear instructions in this regard, so-called measure identification sheets. And if we are unable to offer real compensation, for example, because we don't have any areas, then a compensation payment is also possible. This means that they [the operators/companies] then pay compensation money and the BfN, for example, can then implement a measure independently. This is specifically about restoration. That is why we are already starting with the first oyster reefs being built by wind power companies. The park itself is already considered compensated because they have excluded the fishery there, but the entire infrastructure, the submarine cables that are still being built, still have to be compensated for. For example, through restoration measures.

Clara Taetz: What is the legal, political basis for restoration (without the NRL)?

Kevin Dietz: The NRL would have had the advantage of being binding and mandatory for the member states. We are now guided by various directives, such as FFH and the MSFD, in which specifications are made as to what should be achieved. Germany is trying to take a pioneering position and achieve these goals. The problem is that it is not always mandatory and therefore very flexible as to how something is achieved. But these are nonetheless the legal tools that we use to justify why we are pursuing recovery measures.

(The interview was originally held in German and translated with deepl.com)

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Appendix 6: Table of possible Stakeholders for Seagrass Restoration

Table 4: Possible Stakeholders for seagrass restoration in Mecklenburg-Vorpommern.

Category of Stakeholder	Organization	Contact	Contact Details
(possible) Volunteers	e.g., from Diving schools in MV	Landestauchsportverband Mecklenburg-Vorpommern e.V.	vorstand@ltv-mvrt Tel.: 0381 2013642
Company active in seagrass restoration	ZosteraTec	Mathias Paschen, Project Leader of ‚Aqua-Zostera-MV' (and manager of mariKom)	Tel.: 0151 52418318
Company processing washed-up seagrass	Build Blue	Vincent Xaver Clemens Marnitz, Manager	marnitz@summit-invest.de
Fisheries	Landesamt für Landwirtschaft, Lebensmittelsicherheit und Fischerei Mecklenburg-Vorpommern: Fischerei und Fischwirtschaft	Thomas Richter, Department head	Thomas.richter@lallf.mvnet.de Tel.: 0385 58861870
Governmental Agency	Bundesamt für Seeschifffahrt und Hydrographie (BSH)	e.g., Lea Haefke, Marine Spatial Development Plan	Lea.Haefke@bsh.de Tel.: 040 31903528
Governmental Agency	Bundesamt für Naturschutz (BfN)	Kevin Dietz and Linda Westphal, tackling marine restoration in the German EEZ	kevin.dietz@BfN.de Linda.Westphal@BfN.de
Local communities	Municipalities next to coast: Nordwestmecklenburg, Landkreis Rostock, Rostock, Vorpommern-Rügen and Vorpommern-Greifswald	NA	NA
Foundation	Stiftung Umwelt und Naturschutz MV	Paul Lesky, Regional development, and nature conservation Project developer	p.lesky@stun-mv.de Tel.: 0385 76074543
Organization for coastal management	SeaRanger MV e.V.	Oliver Greve, Manager of the fishing cooperative FG Wismarbucht eG	info@fg-wismarbucht.de Tel.: 03841 282565
Politics	Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz (BMUV)	Heike Imhoff, Head of Division 'Protection of the Marine Environment'	Heike.Imhoff@bmuv.bund.de
Tourism	Tourismusverband Mecklenburg-Vorpommern e.V.	Klara Pauline Seitz, Climate Protection	k.seotz@auf-nach-mv.de Tel.: 0381 4030673
Universities & Research Institutes	Geomar Helmholtz-Zentrum für Ozeanforschung Kiel	Prof. Dr. Thorsten Reusch, Project Leader of SeaStore	treusch@geomar.de Tel.: 0431 6004500

Appendix 7: The Five Principles of Ecosystem Restoration

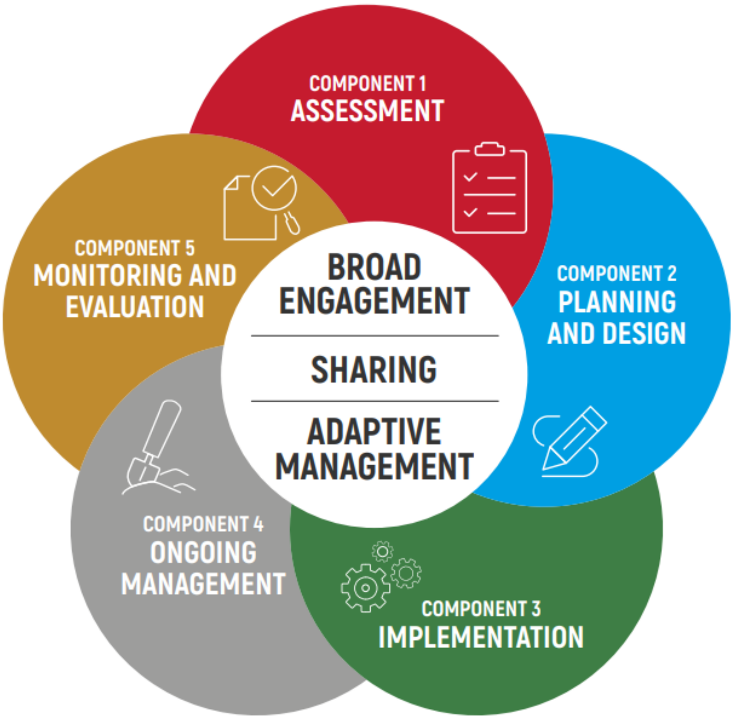

Figure 20: The five principles of ecosystem restoration (adapted from Standards of Practice to guide ecosystem restoration, 2024).

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