A Work Project, presented as part of the requirements for the Award of a Master's degree in Impact Entrepreneurship & Innovation from the Nova School of Business and Economics.

SCALING STRATEGIES FOR NATURE-BASED SOLUTIONS - A CASE STUDY OF SEAFORESTER

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14-12-2024

Abstract

Marine reforestation has not yet received much attention, although it is a very effective way of mitigating climate change. This project aims to demonstrate how kelp reforestation projects can be implemented and scaled. Using qualitative data collection methods and an inductive approach to data analysis, the aim is to understand how the organisation SeaForester might scale its activities. The research has identified key enablers and barriers that influence SeaForester's scaling approach, while the results of this work project serve to improve their scaling strategy. Further, the findings might contribute to the implementation and scaling of Nature-based Solutions more broadly.

Keywords: scaling strategies, social innovation, nature-based solutions, sustainable development, marine reforestation techniques, blue economy.

Acknowledgements

I would like to dedicate this work project to the SeaForester team, whose commitment to driving transformative change exemplifies the power of collective action in addressing environmental challenges. Their perseverance in overcoming complex problems to achieve sustainable, long-term impact truly inspired me. I would like to thank Professor Anne-Laure Fayard for her guidance and support throughout the development of this work project.

Introduction

The threat of severe environmental damage due to climate change is constantly increasing (UNEP, 2021). Ecosystem degradation and biodiversity loss undermine the need to address this global crisis effectively (UN, 2022). Terrestrial forests are often cited as crucial for reducing carbon emissions and thus mitigating the effects of climate change (The Guardian, 2024). However, they are losing their ability to absorb carbon due to drought or forest fires, posing a threat to global emissions targets. As a result, other Nature-based Solutions (NbS), such as kelp reforestation, are becoming increasingly important (Duarte et al., 2017). Kelp forests are complex marine habitats consisting of large brown seaweeds that cover around a third of the world's coastline, supporting local biodiversity (Teagle et al., 2017; Jayathilake & Costello, 2021). Scientists have found that kelp forests account for about two percent of the total global carbon sink by sequestering carbon in deep ocean sediments (Filbee-Dexter & Wernberg, 2024). However, kelp forests are disappearing dramatically worldwide, with a loss of 40–60 percent in the last 50 years (Wernberg et al., 2023). Their disappearance is due to a number of stressors that are aggravated by climate change (Araf eh-Dalmau et al., 2020). These include biological, physical, and chemical threats, such as ocean warming (Smale, 2020), marine heatwaves, and the increasing grazing pressure from herbivores caused by the spread of species such as sea urchins (Vergés et al., 2014). Human-caused factors such as increasing sedimentation due to the industrialisation of coasts and water pollution have further damaged these ecosystems (Gorman & Connell, 2009; Coleman et al., 2008). If kelp forests are displaced by other species, they are unlikely to recover naturally within a reasonable timescale, even if the causes of the damage are removed (Chemello et al., 2023). This underlines the importance of restoration efforts even further. Targeted initiatives to restore

kelp forests are urgently needed, as these forests have been largely neglected in global policy, legislation and restoration targets (Feehan et al., 2021).

This work project, titled “Scaling Strategies for Nature-based Solutions: A Case Study of SeaForester“ focuses on exploring strategies, barriers, and enablers for scaling kelp reforestation. Based on a Directed Research Internship (DRI) with the organisation SeaForester, this work project explores the following research question: “What are the key strategies, barriers, and enablers for scaling Nature-based Solutions?“ It further contributes to the existing literature on scaling strategies for NbS, with a particular emphasis on kelp reforestation. It also provides input into the design of SeaForester's long-term scaling strategies and addresses their key barriers and enablers.

The work project is divided into five main sections. The first section provides a literature review covering the definition of NbS, key concepts related to scaling and innovation in the context of social organisations, and barriers and enablers to scaling NbS. Section two describes the research methodology, while section three presents the findings. These findings are then analysed and discussed in section four. Recommendations are also made in this section. Section five concludes the work project by summarising the main conclusions and addressing the limitations of the research.

1. Literature Review

1.1 The Concept of Nature-Based Solutions

NbS are increasingly recognised as important for mitigating climate change, disaster risk reduction, biodiversity loss, water purification, and various socio-ecological challenges (IUCN, 2020). Specifically, they are defined as initiatives that promote the protection and restoration of natural and modified ecosystems to address societal challenges while supporting

social and economic development (Cohen-Shacham et al., 2016). The term NbS was developed and promoted by the International Union for Conservation of Nature (IUCN) in the late 1990s and early 2000s and has been widely recognised as valuable across sectors (IUCN, 2020). Moreover, NbS are being promoted in global frameworks such as the Paris Agreement and the United Nations (UN) Sustainable Development Goals (SDG's) (Filbee-Dexter et al., 2024). These frameworks aim to address global issues such as poverty and climate change to achieve a sustainable future by 2030 (UN). Research shows that by 2030, NbS could provide around 30 percent of the cost-effective mitigation needed to keep global warming below two degrees centigrade, making integrating NbS into key economic sectors essential (IUCN, 2020).

Due to its high ecological and socio-economic value, kelp reforestation is one of the most efficient NbS on a global scale (Eger et al., 2023). The large brown seaweed provides a wide range of ecosystem goods and services. These can be direct or indirect. Direct benefits include commercial uses such as kelp harvesting. Kelp forests can further enhance the value of fisheries production by improving the nutrient cycle, with an annual economic value of USD 500 billion (Blamey & Bolton, 2018; Eger et al., 2023). Indirect benefits involve coastal protection, and carbon storage and sequestration. In addition, kelp has the significant advantage of being a fast-growing species that can regenerate forests in just two to three years, whereas terrestrial forests take decades to provide relevant benefits (Smithsonian, 2024).

1.2 Innovating and Scaling NbS - Theoretical Approaches: As the literature on NbS often refers to the need to scale these organisations - a need also expressed by SeaForester - this section explores the concept of scaling in more detail. While there is no specific literature on

scaling NbS, there is an extensive literature on scaling social organisations. Social organisations typically aim to address societal issues, often in contexts where traditional business models may not be applicable, and focus on creating value for communities or the environment rather than just maximising profits (Dees et al., 2004). This is closely related to the objectives of NbS, which seek to provide ecosystem services, promote biodiversity, and support sustainable development (Wiek et al., 2011). To achieve a higher level of social impact, two concepts were mentioned: organisational growth and ecosystem growth (Appendix I). The most direct and popular of these strategies is organisational growth, also defined as “scaling-out“ (Riddell & Moore, 2015). This involves increasing the reach of the organisation to target a larger number of beneficiaries or a wider geographical area with its products and services (Dees et al., 2004; Vickers et al., 2017). In contrast, the ecosystem growth strategy addresses social problems on a more systemic level, by creating an ecosystem around the organisation. In such cases, the scaling approach is indirect as it aims to maintain and develop an enabling environment for social enterprises by advocating for other social enterprises, creating knowledge, providing training, and supporting their legitimacy (Bloom & Dees, 2008; Thompson et al., 2018). This strategy aligns with the “scaling-up“ and “scaling-deep“ approach of Riddell and Moore (2015). Scaling-up is about expanding systemic influence through policy and structural reforms, removing systemic barriers, and incorporating NbS into laws and institutional frameworks. Scaling deep, on the other hand, aims to integrate solutions into cultural and social norms (Appendix II).

The success of scaling social organisations is closely linked to the organisation's impact creation logic. This logic refers to the established framework of strategies, resources, and processes that enables the organisation to leverage existing knowledge to achieve predictable and measurable results (Seelos & Mair, 2017). It consists of three interconnected elements:

the problem space, which defines how the organisation frames and understands the challenges it wants to address; the resources and capabilities, which include the available technical, financial, and human resources; and the mission and strategy, which determine the organisation's long-term goals and actions (Figure 1). Together, these components shape the organisation's approach to solving problems, using its resources effectively, and aligning activities with its overarching goals.

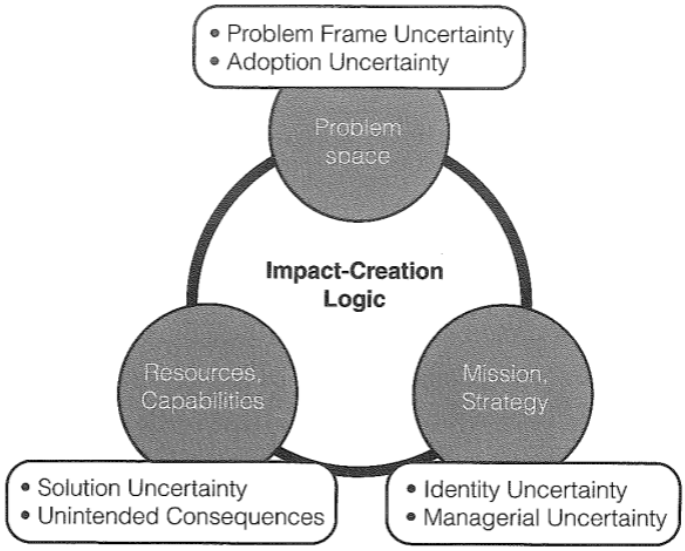

Figure 1 - Six types of uncertainty associated with innovation, defined as actions outside their established impact creation logic.
Source: Seelos & Mair 2017.

While scaling draws on this proven logic, it alone is not sufficient to address the dynamic and complex challenges that NbS often face, such as environmental variability and systemic threats. These challenges require innovation, such as the development of new approaches, technologies, and techniques to address problems in an adaptive way. However, innovation requires moving away from the organisation's conventional impact-creation logic, which entails six different types of uncertainty as illustrated in Figure 1. This in turn points to the danger of over reliance on innovation.

Walske and Tyson (2015) caution equally against relying too heavily on innovation without a tailored scaling strategy and emphasise the importance of incorporating immediate impact with controlled, high-risk innovation efforts. Combined, these frameworks highlight the need for a balanced scaling strategy for NbS - one that scales proven solutions to ensure operational efficiency, while encouraging innovation to address environmental challenges.

1.3 Decisive Factors to Scaling marine-related NbS: The successful implementation of these strategies in NbS projects depends on several critical factors (UNEP, 2022). While many factors affect NbS broadly, certain elements are especially relevant for marine and kelp reforestation. The literature identifies five key factors that are essential for scaling marine-related NbS: In addition to ecological considerations, funding, regulatory frameworks, technological advances and organisational capacity play a critical role in either facilitating or hindering their scaling efforts (Seddon et al., 2021).

Environmental factors are among the most decisive components, as marine-related NbS depend on the stability and resilience of natural underwater ecosystems (Eger et al., 2020). Climate-induced events, such as wildfires, hurricanes, or contamination, can significantly affect the success of marine-related NbS initiatives (Redmond et al., 2014). In addition, the variability of local environmental conditions poses a challenge for replicating NbS in different geographical locations (Lehmann et al., 2015).

To navigate these environmental challenges and implement adaptive and innovative practices, **financial capital** is a crucial component for scaling restoration activities. Uncertain funding has led to sporadic maintenance of restoration sites and ultimately to project abandonment (Eger et al., 2020). Simultaneously, restoring ecosystems is costly and labour-intensive, averaging tens of thousands of USD per hectare in marine ecosystems (Bayraktarov et al.,

2016). Financial sources for kelp restoration projects usually consist of a mix of for-profit and non-profit funds, which can be defined as “blended finance“ (Rode et al., 2019). Investments from non-profit (e.g. government) sources are typically motivated by the contribution of publicly available ecosystem services. However, governmental funding remains underfunded and insufficient to scale NbS, emphasising the need for increased private funding. In contrast, private funding usually requires financial returns. To attract these profit-driven funding sources, instruments such as payments for ecosystem services or blue bonds - a type of debt instrument to support marine and ocean-based projects - can be utilised (Thiele & Gerber, 2017). These bonds are then sold to investors and used to finance marine-related projects such as protecting marine ecosystems, improving biodiversity, and promoting a sustainable marine industry (Silver & Campbell, 2018). Alternatively, companies may invest in restoration projects that produce goods themselves, such as sea urchin roe or harvested kelp, while still contributing to the restoration of underwater ecosystems (Gentry et al., 2020). Whether public or private funding, both require that the benefits of the restoration work are known and can be measured (Eger et al., 2020). However, the benefits of kelp forest ecosystems are not yet well recognised, resulting in a lack of the necessary financial support (De Groot et al., 2013).

Governmental authorities play a crucial role in enabling NbS to achieve meaningful scale, as they provide the legitimacy for the implementation of projects (Van Tatenhove, 2011). Nevertheless, they may establish restrictive policies that prioritise economic development over environmental protection, which can limit the legal scope for NbS initiatives (Díaz et al., 2019). On the other hand, international agreements might also promote the scalability of NbS (Eger et al., 2020). For instance, the UN Decade on Ecosystem Restoration and the UN Decade of Ocean Science for Sustainable Development have set international objectives with binding targets for kelp restoration.

In addition to external conditions, internal **organisational factors** are relevant for the scaling success of NbS (Eger et al., 2020). This is due to their ability to implement effective strategies and consider areas such as project management, stakeholder coordination, and governance structures. Organisations might face constraints related to staffing capacity, continuity of funding, or technical expertise. Adaptive management therefore plays a decisive role in the long-term success of an organisation (Eger et al., 2020). It requires effective monitoring and the rapid mobilisation of resources to address identified problems and make improvements through feedback loops (Appendix III).

Stakeholder engagement and networking across sectors have been recognised as especially valuable for resource pooling (Reed et al., 2014; Riddell & Moore, 2015). Collaborations among different stakeholders from academia, government, and industry suggest that cooperation between these sectors can help to reduce individual costs per unit and accumulate varying levels of expertise (Gann et al., 2019).

Technological factors can both enable and inhibit NbS scaling. Advances in monitoring tools, such as remote sensing, satellite imagery, and drone technology, can significantly improve the ability to identify suitable geographic locations for restoration projects and monitor ecosystem changes over time, while optimising project management (Lehmann et al., 2015). This might help secure funding by enabling adequate reporting. Conversely, limited access to these resources, particularly in low-income regions, can be a barrier.

2. Methodology

2.1 Research Setting

The research was integrated into a Directed Research Internship at SeaForester. The environmental impact organisation, based in Portugal, focuses on innovative marine

reforestation techniques to restore kelp forests and underwater ecosystems (Appendix IV). SeaForester was founded by Pål Bakken in 2016 and currently consists of a small, dedicated team of professionals. This includes a Chief Executive Officer (CEO), a Chief Operating Officer (COO), a scientific and nursery department, and accounting staff. SeaForester was established as a for-profit company with the mission to restore kelp forest ecosystems along degraded coastlines worldwide. Their goal is to restore 100,000 hectares by 2040. The organisation aims to turn research and development (R&D) into innovative solutions for kelp restoration, including restoration techniques, nursery design and optimisation, seed production, and impact monitoring. SeaForester has developed two major technological innovations for kelp restoration: the green gravel technique and mobile nurseries. The green gravel technique involves seeding substrates (e.g. gravel) directly with kelp propagules in a nursery (Figure 2). After a period of cultivation, they can be easily deployed from a boat, overcoming the limitations of long dives (Appendix V). Using this technique, entire kelp forests can be restored.

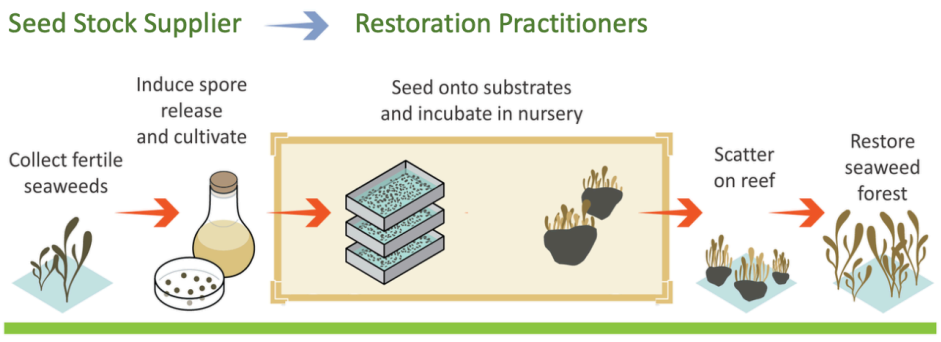

Figure 2 - Cross-sectoral approach to marine forest restoration - Cultivation of green gravel
Source: SeaForester 2024

Additionally, the organisation has developed mobile nurseries that serve as innovative systems for the cultivation of kelp on land. These are set up near the affected coasts and enable the large-scale cultivation of kelp under controlled conditions.

To successfully implement its innovative reforestation activities, SeaForester relies on partnerships and financial support. Their key stakeholders include local communities, businesses, investors, donors, and national governments. SeaForester's financial support is based on various sources, such as corporate partnerships, funds, and platforms. In addition, the local government institution, the Câmara Municipal in Cascais, is collaborating with SeaForester to meet environmental regulations and increase the value of marine ecosystems to local communities. As a result, SeaForester has already made considerable progress in achieving its goals. In addition to developing their innovative green gravel method and mobile nurseries, the company has expanded globally by opening a site in Germany. Last year, the organisation deployed 70,000 seeded stones and established key partnerships, including a major collaboration with Nestlé Purina Europe. Internationally recognised, they were finalists in the world-renowned Earthshot Prize.

Despite this significant progress in reforestation, SeaForester faces several challenges in expanding its activities, mainly because the organisation is still in a crucial testing and development phase. At this stage, techniques need to be refined to achieve higher success rates, including kelp survival and growth. Moreover, securing long-term capital financing presents just as much of a risk as external environmental influences.

2.2 Data Collection Methods

To investigate how SeaForester might scale its activities in the long term, qualitative research and action research were combined. Qualitative research, using primary and secondary sources, was employed to gain a comprehensive understanding of the issue, while action research allowed the data to be utilised for developing practical solutions tailored to the specific needs of the organisation (Dovetail, 2023). As an intern and member of the operations

team, over the course of six months, I participated in meetings and brainstorming sessions, developed proposals for partnerships, took on responsibility for various marketing efforts, and had several informal discussions with team members and external partners. For the data analysis, I combined participant observations with benchmarking, internal semi-structured interviews, and semi-structured interviews with external partners.

2.2.1 Benchmark

The benchmarking analysis compared SeaForester with three leading organisations in the field of marine-related NbS: Oyster Heaven, Coral Vita, and Kelp Blue. There are two main reasons why these companies were selected to explore different scaling strategies that could be applied to SeaForester. Firstly, they operate within the marine ecosystem, necessitating similar environmental challenges to be addressed through various innovative strategies. Secondly, these organisations face the challenge of operating in the unstable, unestablished blue economy market. A thorough examination of their business models and financing strategies is thus valuable for SeaForester. The benchmarking analysis focussed on four key areas: financing strategies, innovation and technology adoption, partnerships, and impact measurement. Data was collected from secondary sources such as annual reports and websites.

Oyster Heaven, registered as a private limited company in the United Kingdom, focuses on the restoration of oyster reefs utilising innovative mother reef technology. They operate primarily in Europe and the USA. Coral Vita is a for-profit social enterprise that restores coral reefs through land-based coral farming and innovative techniques such as micro-fragmentation. The company primarily operates in the Bahamas and collaborates with reef-dependent businesses, including tourism operators, dive shops, and resorts. Kelp Blue,

established as a private company, cultivates giant kelp to produce natural biostimulants while promoting the health of marine ecosystems and sequestering carbon in the ocean. The company operates in Namibia, New Zealand, and Alaska.

2.2.2 Semi-structured Interviews

Five semi-structured interviews were conducted internally with three SeaForester team members and two key partners. Participants were selected based on the relevance of their roles to SeaForester's scaling strategies, including the CEO, the COO, the scientific manager, and two funding partners of SeaForester: Mossy Earth and SeaTrees. Each interview lasted approximately half an hour, in addition to several informal conversations with the same three SeaForester team members. The aim was to explore the opportunities SeaForester faces in relation to its scaling activities and to identify the required skills and resources to maintain and scale its operations. The interview guide presented in Appendix VI served as a reference for the interviews. However, due to its semi-structured nature, the flow of the conversation was adapted to each interviewee. Additionally, archival data, including SeaForester's annual reports, company presentation decks, and internally produced research papers, were utilised.

2.2.3 Data Analysis

For the data analysis, an abductive approach was used, as defined by Timmermans and Tavory's (2012). The five key factors proposed by Seddon et al. (2021) that are essential for scaling marine-related NbS (environmental considerations, funding, legal framework, technological advancement and organisational capacity) shaped the data analysis (observation notes, interviews and benchmarking). The notes and transcripts of the interviews, as well as

company documents (presentations and reports), were used to identify which themes emerged. Additionally, written notes were discussed with my advisor in our bi-weekly meetings.

3. Findings

The findings are structured around three main areas: scaling barriers, scaling enablers, and SeaForester's scaling strategy.

3.1 Scaling Barriers

One of the key themes that emerged from the interviews was the multitude of barriers that SeaForester faces in scaling its restoration efforts. These barriers can be categorised into environmental, regulatory, financial, and technological constraints.

The analysis of the data reveals that **environmental threats** negatively impact the marine environment, which in turn hinders SeaForester's reforestation efforts. These threats — such as rising sea temperatures, marine heatwaves, ocean acidification, invasive species, increasing storms, and fluctuating nutrient levels — directly affect the survival and growth of kelp (Jan Verbeek, Scientific Manager at SeaForester). These factors destabilise the ecosystems necessary for kelp growth, lead to unpredictable success rates, and often require significant adjustments in restoration techniques. Therefore, costs increase, processes are delayed, and resources might be wasted. This year's autumn storm meant that the last deployment could not take place due to the turbulent waves (Ari Greenberg, COO at SeaForester). Additionally, interviews with external partners revealed that these ecological challenges also affect marine NbS projects on a global scale, complicating long-term planning of reforestation activities and the calculation of success rates. Leah Hays (Programme Director at SeaTrees) highlighted the impact of climate change-related events, such as coral bleaching in the Caribbean, making

coral restoration there particularly challenging. Moreover, severe hurricanes in Florida made it impossible to conduct a mangrove planting project.

Furthermore, **regulations** pose significant constraints on SeaForester's reforestation efforts. Several interviewees mentioned that governmental authorities still do not recognise the importance of kelp reforestation. Jan Verbeek emphasised that it was relatively easy to obtain research permits on a small scale, but the process became increasingly difficult as SeaForester attempted to scale to larger, commercially viable operations. He stated that the delays in obtaining the necessary permits - which sometimes took months or even years - affected SeaForester's ability to meet project schedules, as the projects rely on specific seasonal windows for kelp planting. This can also lead to a waste of resources and subsequently hinder the organisation's ability to scale.

Moreover, several interviewees frequently mentioned the unpredictability of corporate philanthropy and **market fluctuations**, which make financial planning difficult. The lack of a well-established market for marine ecosystem services, comparable to the carbon credit market for land-based projects, limits the financial sustainability of SeaForester's initiatives. Corporate investors typically finance terrestrial reforestation to enhance their reputation, save on taxes, or offset carbon emissions. However, such measurable benefits are not yet available for marine reforestation, making it challenging to attract new investors on a larger scale. In addition, SeaForester's sales are largely reactive, with potential investors approaching the organisation but often finding current offerings inadequate (Ari Greenberg). As a result, SeaForester currently relies on grants and donations, which are "very competitive and time-consuming" and often not a reliable source for long-term support, as Jan Verbeek stated.

Lastly, **technological solutions** can be useful, but they can also serve as a barrier, as monitoring restoration efforts on a large scale can be costly, as Jan Verbeek emphasised.

Moreover, there are no standardised solutions; therefore, customised deployment and monitoring systems are required, as the ecological conditions for kelp deployment vary from place to place. He further pointed out that the monitoring approaches needed for kelp reforestation are a relatively new discipline and therefore much more complex and costly to develop than monitoring on land.

3.2 Scaling Enablers

While SeaForester faces several challenges that make its reforestation efforts considerably difficult, there are also factors that favour their scaling development, including partnerships, governmental support, and innovative technology.

Several interviewees stressed the importance of **partnerships and stakeholder engagement**. Leah Hays stated: “The best approach is often to involve locals, knowledge, and people who have observed that particular area over years and years and who have developed, through trial and error, developed the best way to do something.“ Accordingly, SeaForester has developed strategies not only to work closely with local governments to navigate complex regulatory frameworks but also to include fishing communities that provide crucial support for restoration efforts. The fisher communities play a critical role and must be “actively involved so that they understand the benefits of kelp reforestation, as this directly impacts their livelihoods“ (Jan Verbeek). Fisher communities are essential stakeholders because kelp forests provide a habitat for fish and can contribute to an increase in fish populations, which in turn positively impacts the fisher communities. By involving these communities, SeaForester ensures that reforestation efforts align with local economic interests. In addition, the fishing communities provide valuable local knowledge about the marine environment, such as changes in the ecosystem. Moreover, SeaForester is working with local diving clubs to

execute and monitor their reforestation efforts. Divers play a critical role in implementing and monitoring of the reforestation activities and ensure that the deployment and control of kelp growth are carried out effectively.

Furthermore, SeaForester's collaboration with the Câmara Municipal in Cascais has an enabling function for its reforestation efforts, as this collaboration provides SeaForester with **regulatory and logistical support**. The involvement of the municipality facilitates the authorisations for the operations and ensures that the reforestation activities comply with local regulations. SeaForester's collaboration with the Câmara Municipal creates a mutually beneficial dynamic, as the municipality benefits from enhanced marine ecosystems that promote communal well-being. Simultaneously, SeaForester benefits from streamlined regulatory processes and local advocacy. In addition, to navigate regulatory challenges on a broader scale, SeaForester has brought in an environmental lawyer, a former marine minister, who provides a link to authorities to overcome governmental barriers.

Moreover, several interviewees highlighted that although environmental issues pose significant challenges, they force the development of **innovative technical solutions**. For instance, Leah Hays explained how one of their projects in Hawaii was affected by the forest fires on Maui. However, the project helped to stop those fires by creating an invasive vegetation and fire break that prevented the fire from devastating the land. Simultaneously, the data analysis reveals that environmental constraints forced SeaForester to develop adaptive solutions. In addition to exploring selective breeding techniques for kelp species, that are more tolerant of higher temperatures, SeaForester has implemented four technological interventions to increase the success of kelp survival. These include substrates, sea socks, tetrapods, and floating forests (Appendix VII).

3.3 SeaForester's Scaling Approach

Internal interviews revealed that SeaForester's scaling strategy prioritises **global expansion** in the coming years (Appendix VIII). The first target location is Norway, chosen for its already established partnerships and governmental support. Collaborations with organisations such as the Norwegian Institute for Water Research (NIVA) and Akvaplan-niva have supported innovative projects such as "Restoring Norway's Underwater Forests" and the "Blue-Foresting" initiative. Additionally, SeaForester is exploring potential sites in Central Europe, focusing on cold-water regions, and later aims to expand into warm-water areas, such as Eastern Australia. Certainly, SeaForester has yet to determine how to scale on an operational level: "Is it going to be a franchise that we set up in other countries? Or is it going to be another organisation that SeaForester supports and funds remotely?" (Jan Verbeek).

Ari Greenberg further confirmed that expanding production capacity is a key milestone for SeaForester (Appendix IX). Their focus is on shortening the production cycle from twelve to eight weeks, reducing the time between rearing in the laboratory and the deployment of the stones. Equally important is the reduction in costs per hectare, as he stated, which can be achieved through economies of scale. Economies of scale refer to the reduction of production costs on average and therefore lower the costs per unit through increased production (Silberston, 1972). Another targeted goal is the establishment of a third mobile nursery, which will double SeaForester's existing capacity. In addition, mobile nurseries are one of SeaForester's major advances, that facilitate the entry into new markets by securing permits early, which is essential to expand restoration to new locations without the need for permanent on-site facilities, as Jan Verbeek highlighted.

Moreover, the analysis of the data reveals that **technological innovations** are crucial for global expansion, as they have been defined as "significant enablers for cost reduction on a

larger scale“ (Jan Verbeek, Scientific Manager at SeaForester). The benchmark analysis further emphasises the role of technology, particularly in monitoring. Oceanographic sensors, satellite imagery, underwater surveys, ecological assessments, remote sensing technology, and genetic analysis are used to monitor the survival rates, growth metrics, and structural integrity of the various marine species. For instance, Kelp Blue has established a real-time monitoring system to calculate the amount of carbon stored. That data is being used to assess the environmental costs and benefits of their restoration efforts. Similarly, SeaForester has introduced innovative monitoring techniques, including satellite-based monitoring, to enhance its restoration efforts. These systems are utilised before, during, and after restoration to gather and process data, which is then reported back to partners and investors. The collected data includes baseline metrics such as biological and ecological parameters, seed stone development (kelp survival, growth, and anchoring), and kelp forest development (canopy cover and biomass). The monitoring process is divided into two phases. Phase one refers to the combination of open-source satellite data and the spatial and temporal harmonisation of the data. Ocean health indicators are also derived. Phase two consists of high-quality satellite imagery and other data sources. In addition, SeaForester has piloted two advanced monitoring systems: automated seafloor mapping and remote satellite assessment. These techniques help to determine suitable remediation sites, such as identifying subsoil substrates and locations for restoration sites.

While SeaForester seeks to increase its production capacity and thus reduce costs over time through the implementation of innovative techniques, such as monitoring, identifying appropriate sources of funding is inevitable. Simultaneously, the benchmark reveals, that all three organisations have developed diverse **funding strategies** to support their marine restoration initiatives. External investment from investors and the development of business

models were combined. Investors include impact investors who prioritise environmental and social returns alongside financial returns, as well as traditional private investors. Business models involve selling restoration services and licensing technologies to create a revenue stream to scale their operations. Kelp Blue, for instance, commercialises by-products of its restoration work. Their harvested kelp is used to produce natural bio-stimulants that are marketed to the agricultural sector to increase crop productivity. This product-based approach allows Kelp Blue to generate income while contributing to marine ecosystem benefits.

In contrast, SeaForester's **funding strategy** in its early years was based primarily on obtaining grants (Pål Bakken, CEO at SeaForester). However, the organisation has since diversified its funding portfolio. Current financial sources still include grants, but also corporate investors such as Purina and donor platforms like SeaTrees and Mossy Earth. According to the data analysis, potential funding partners can be defined as “ocean-related clients with a direct physical link to the sea, such as oil and gas companies, cruise lines and boat companies, and offshore wind farms needing to offset the environmental impact of large oceanic installations like wind turbines“ (Pål Bakken). Additionally, large corporations and big polluters driven by environmental, social, and governance (ESG) policies may invest for regulatory compliance.

To secure these funding sources on a larger scale, SeaForester has prioritised commercialisation and the definition of its business model. Since the start of this year, the organisation has adapted its internal structure, including hiring a COO, to support this commercial focus by establishing its operations department. Furthermore, SeaForester has recognised the value of targeted marketing strategies to raise general awareness of marine restoration efforts and attract potential investors and partners. The focus is on educating the private sector about the long-term economic value of marine ecosystem services and the viability of kelp reforestation as an alternative to tree planting (Ari Greenberg).

Moreover, SeaForester constantly tracks the development of the blue economy and emerging trends that might be relevant to examine. The data analysis further emphasises the importance of recognising new approaches such as biodiversity credits. These credits are intended to better qualify the actual improvement in biodiversity and the monitoring of project impacts compared to carbon credits, as Leah Hays explained. Biodiversity credits could be attractive to investors as the success of the restoration measures can be transparently demonstrated and certified.

4. Discussion and Recommendations

This section analyses SeaForester's scaling efforts and provides recommendations on how the barriers to these efforts could be addressed. The proposed incentives do not constitute a formal strategy; instead, they are initiatives that emerged from the findings as potentially relevant to the scaling success of SeaForester.

SeaForester's Scaling Approach: The data analysis suggests that SeaForester's scaling approach aligns with scaling-out (Riddell & Moore, 2015), as evidenced by their goal to restore 100,000 hectares by 2040 and their strong emphasis on geographic expansion. Scaling-out involves replicating proven solutions across diverse locations to broaden impact. Although SeaForester heavily focuses on scaling-out, its innovative green gravel technology is not yet ready for replication as it needs to be redefined and adapted to different geographical locations. Moreover, SeaForester incorporates scaling-up (influencing policy, legal frameworks, and institutional systems to create systemic change) and scaling-deep (creating cultural or behavioural shifts by embedding the innovation within communities) approaches. SeaForester's scaling-up efforts, such as the collaboration with governmental and academic institutions, help to build systemic support and credibility. These partnerships - such

as the one with the Câmara Municipal in Cascais - enable SeaForester to influence local governmental structures and overcome regulatory constraints. Simultaneously, the active involvement of fishery communities ensures that reforestation initiatives are embedded in the local context and have a cultural impact. Increasing the involvement of key stakeholders and regulatory authorities could support their efforts to scale-up and deep, while enhancing their scaling-out approach by securing permits for large-scale reforestation projects.

Challenges: Innovation vs. Scaling: Although SeaForester aims to scale-out, the organisation faces significant challenges, including environmental variability and internal organisational inefficiencies. Environmental variability refers to the differences in coastal conditions, marine heatwaves, and invasive species, highlighting the need for adaptive innovation, as emphasised by Walske & Tyson (2015). The authors advocate balancing proven scaling strategies with high-risk innovation efforts. For instance, the effectiveness of the green gravel method depends on local ecological factors, making it challenging to achieve consistent results across diverse sites. SeaForester's innovative approaches, such as substrates, sea socks, tetrapods, and floating forests, demonstrate a proactive effort to address the environmental challenges by improving kelp survival rates. Meanwhile, their innovative monitoring system provides significant opportunities to enhance site selection and demonstrate data-based impact. However, these innovative efforts require a critical evaluation to ensure that they align with the organisation's mission to optimise resources and capabilities, and resolve specific environmental challenges, referencing the impact-creation logic of Seelos & Mair (2017). For instance, if green gravel fails to deliver consistent results due to environmental variability, SeaForester risks allocating valuable resources to efforts with limited impact. To mitigate this, they could improve their innovations through adaptive

testing, using monitoring data to enhance their green gravel technique and ensure that every innovation contributes to their mission.

Moreover, to fully realise the potential of SeaForesters' scaling efforts, it is critical to make a clear, yet interconnected distinction between the production and operations departments. The reason for this is that both departments are central to SeaForester's scaling efforts: firstly, to secure funding, and secondly, to further refine their reforestation technology. However, organisational inefficiencies arise when the responsibilities of these departments overlap. This difficulty stems from the fact that SeaForester's team is still very small, is in a crucial testing and development phase, and consists mainly of scientific members. It is therefore recommended that SeaForester's operations team focusses on securing financial capital, developing a clear business plan, managing long-term planning, and building strategic partnerships. These tasks are fundamental to securing the resources and governmental support needed to scale in all dimensions - up, out, and deep (Ridell & More, 2015). In the meantime, SeaForester's production team should prioritise refining the green gravel technique to improve their proof of concept, which in turn can be used to secure more funding from the operational team. A proof of concept refers to the demonstration intended to verify that concepts, such as SeaForester's green gravel technique, are practical and feasible for real-world applications, used to reduce risks in development and to validate a technique's potential before significant resources are invested (Turner & Ledwith, 2018). Conversely, securing more funding will also lead to an increase in technological refinement. These reciprocal links should be communicated through a structured management system and constant dialogue between these two departments to ensure alignment and adaptability (Eger et al., 2020).

Funding Strategy: SeaForester's innovations require considerable financial capital, as emerged from the interviews. Currently, SeaForester's primary reliance on grants and

donations highlights a critical barrier to long-term scalability. While grants and donations have supported early-stage efforts, they lack the stability and scalability required for sustained growth. The literature emphasises the importance of diversified funding models, defined as blended finance (Rode et al., 2019). Clear evidence of the effectiveness and scalability of the green gravel method is therefore required. SeaForester should focus on refining their proof of concept, reducing uncertainties, and building credibility not only for investors but also for key stakeholders, which might be beneficial for scaling-deep. In addition, a clear business plan with a promising outlook is essential for securing further capital. Despite attracting outside capital, the commercialisation of kelp-based products such as bio-stimulants or licensing technologies, as highlighted in the benchmark, could create a dedicated revenue stream for SeaForester, indicating financial independence and leveraging their scaling-out approach.

Data Collection & Monitoring: SeaForester's data collection is critical to providing a proof of concept and a long-term strategy, as it delivers transparency and credibility to the process. Advanced data collection not only validates reforestation methods but also directly supports scaling-up by providing policymakers with evidence of its impact. Currently, monitoring measures provide the necessary transparency, such as kelp biomass, biodiversity, and environmental parameters, and show the progress of green gravel technology, as indicated by the interviewees. However, further development of these technological systems, such as remote sensing or artificial intelligence (AI) powered analyses, could enable accurate tracking of important parameters, including carbon sequestration. The resulting data-driven credibility and transparency could attract more external capital or facilitate the utilisation of biodiversity credits.

5. Conclusion and Limitations

The increasing challenges caused by climate change and biodiversity loss necessitate innovative and scalable solutions to restore ecosystems and mitigate environmental degradation. NbS such as marine reforestation have proven to be a promising approach to address these ecological needs. SeaForester is demonstrating this potential by developing innovative techniques such as the green gravel method to achieve its goal of reforesting 100,000 hectares of kelp forests globally by 2040. However, as highlighted in this work project, environmental, financial, regulatory, and technological constraints must be considered when scaling such initiatives. This work project utilised qualitative data to analyse SeaForester's scaling strategies and identify its key barriers and enablers. The findings highlight the importance of refining technical solutions to address environmental variability, diversifying funding sources, including a blended-finance approach, and strengthening organisational capacity by separating departments between operations and production. Recommendations include refining SeaForester's proof of concept to validate the success of green gravel, developing a clear business plan to secure additional funding, adopting advanced monitoring systems to enhance data transparency, and exploring market-based financing mechanisms that could encompass biodiversity credits.

Lastly, the research was limited by the subjectivity of the primary data, as the data reflects the contributors' interpretations and views of the organisation and industry, which can lead to bias. Further limitations include the small number of interviews due to the organisation's limited size.

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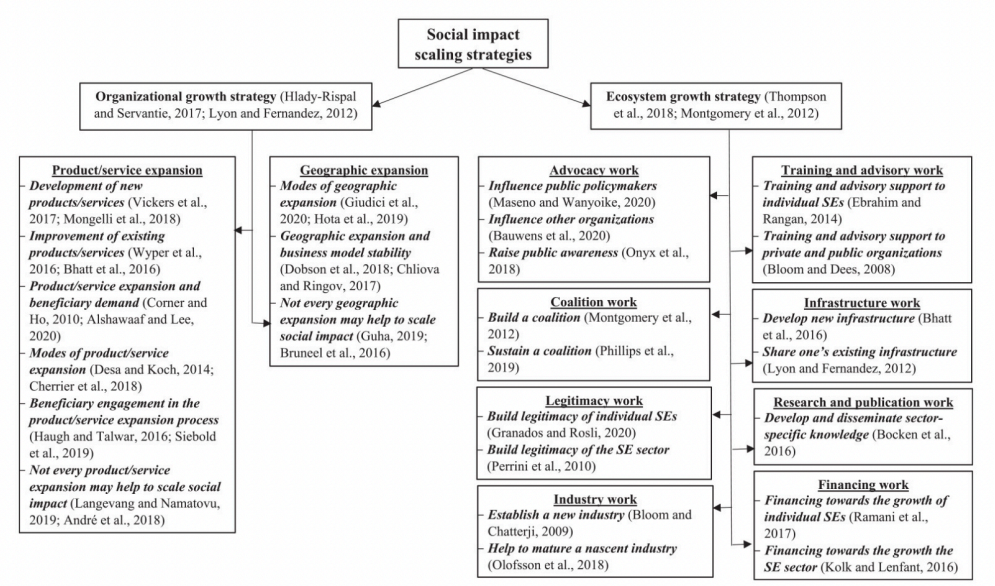
Appendices

Appendix I - A summary of key insights into social impact scaling strategies in social enterprises

Source: https://www.researchgate.net/publication/351824180_Social_impact_scaling_strategies_in_social_enterprises_A_systematic_review_and_research_agenda



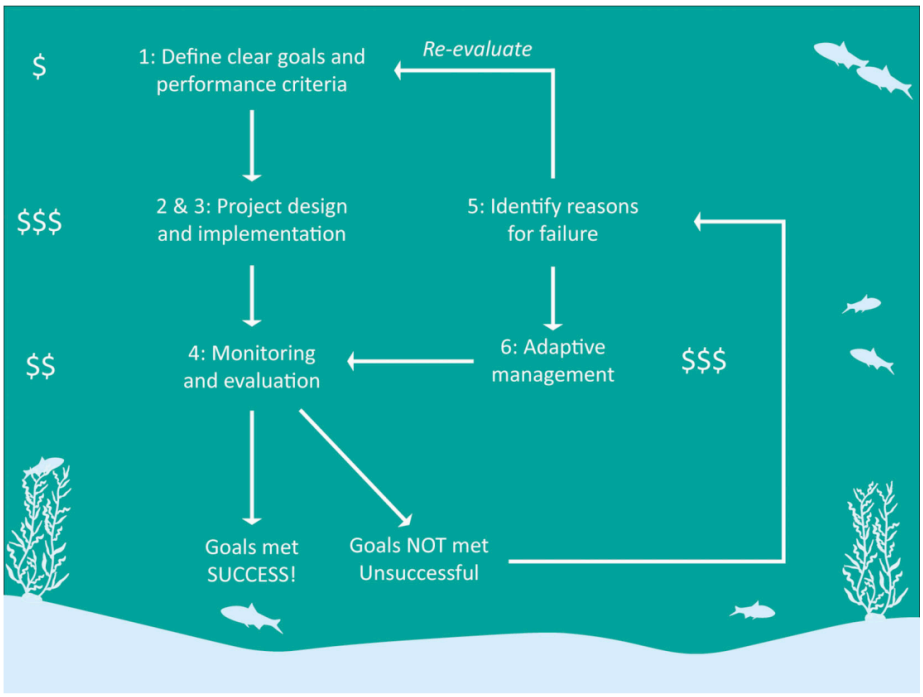
Appendix II - Three types 'of scaling' and their main strategies

Source: https://www.researchgate.net/publication/298971574_Scaling_Out_Scaling_Up_Scaling_Deep_Strategies_of_Non-profits_in_Advancing_Systemic_Social_Innovation

	Description	Main strategies
Scaling out:	**Impacting greater numbers**. Based on the recognition that many good ideas or initiatives never spread or achieve widespread impact	**Deliberate replication**. Replicating or spreading programmes geographically and to greater numbers while protecting the fidelity and integrity of the innovation **Spreading principles**. Disseminate principles, but with an adaptation to new contexts via co-generation of knowledge, leveraging social media and learning platforms: 'open scaling'
Scaling up:	**Impacting law and policy**. Based on the recognition that the roots of social problems transcend particular places, and innovative approaches must be codified in law, policy and institutions	**Policy or legal change efforts**. New policy development, partnering, advocacy
Scaling deep:	**Impacting cultural roots**. Based on the recognition that culture plays a powerful role in shifting problem-domains, and change must be deeply rooted in people, relationships, communities and cultures	**Spreading big cultural ideas** and reframing stories to change beliefs and norms. Intensively share knowledge and new practices via learning communities, distributed learning platforms and participatory approaches **Invest in transformative learning**, networks and communities of practice

Appendix III - Flow chart of best-practice steps involved in restoration projects. Dollar signs indicate the relative costs of each step.

Source: https://www.researchgate.net/publication/ 344484329_Financial_and_Institutional_Support_Are_Important_for_Large-Scale_Kelp_Forest_Restoration



Appendix IV - Successful planting trials of Kelp using the green gravel technique

Source: SeaForester Annual Impact Report 2023

Appendix V - SeaForester Deployment of 27,000 seeded stones in July 2024

Source: Designed by the author

Appendix VI - Interview Guide

Source: Designed by author

1. Internal Interviews

Duration: 30 minutes - 1 hour

A. Background and Role

1. Please describe your current role at SeaForester and how it contributes to the organisation's mission.

B. Barriers and Opportunities for Scaling

2. Along the value chain, what do you see as the key opportunities and barriers for scaling SeaForester's activities?
3. How do ecological, financial, regulatory, and technological factors impact your department's operations?

4. What are the biggest challenges SeaForester is currently facing in scaling its operations?

C. Solutions and Scaling Strategies

6. What strategies do you believe are most effective for scaling kelp reforestation efforts?
    - Is SeaForester leveraging these strategies effectively? Why or why not?

7. What role does innovation play in achieving scalable and sustainable marine restoration?
    - Are there risks in balancing proven methods and new innovations?

8. What solutions can you identify to overcome the barriers mentioned earlier?

D. Monitoring and Impact Demonstration

9. How important is monitoring and demonstrating impact for scaling SeaForester's activities?
10. What systems does SeaForester currently have in place to measure impact?
11. What innovations in monitoring could enhance the scalability of SeaForester's work?

E. Partnerships and Collaboration

12. What types of partnerships have been most beneficial for SeaForester so far?

F. Future Vision and Additional Insights

13. What is your vision for SeaForester's growth in the next 10 years?

G. Additional Insights

14. Is there anything else you would like to share that might be relevant for this project?

Thank you very much for your time and insights!

2. External Partner Interviews

Duration: 30 minutes - 1 hour

A. Background and Role

1. Can you provide an overview of your organisation and its involvement in marine restoration?
2. What role does your organisation play in supporting SeaForester's mission?

B. Barriers and Opportunities for Scaling

3. Along the value chain, what do you see as the key opportunities and barriers for scaling marine restoration projects like SeaForester's?
4. How do ecological, financial, regulatory, and technological factors influence scaling efforts in this field?
5. Are there specific challenges or opportunities your organisation has encountered when collaborating on marine restoration projects?

C. Solutions and Scaling Strategies

6. What strategies do you believe are most effective for scaling marine restoration efforts?
7. How can innovation drive scaling in marine restoration? Are there risks in implementing innovative approaches?
8. In your opinion, what are the most critical solutions for overcoming barriers?

D. Monitoring and Impact Demonstration

9. How important is demonstrating impact in marine restoration?
10. How does your organisation view the importance of measurable outcomes in collaborative projects?
11. Are there any monitoring tools or techniques your organisation has found particularly effective?

E. Partnerships and Collaboration

12. What makes a partnership with SeaForester or similar organisations successful?
13. Are there specific stakeholders or sectors that could play a more significant role in scaling marine restoration?

F. Future Vision

14. What is your vision for the future of marine restoration in the next 10 years? Can you refer to emerging trends?

G. Additional Insights

15. Is there anything else you would like to share that might be relevant for this project?

Thank you very much for your time and insights!

Appendix VII - Adaptive Interventions for the Survival of Kelp

Source: Designed by the author

Adaptive Technology Interventions

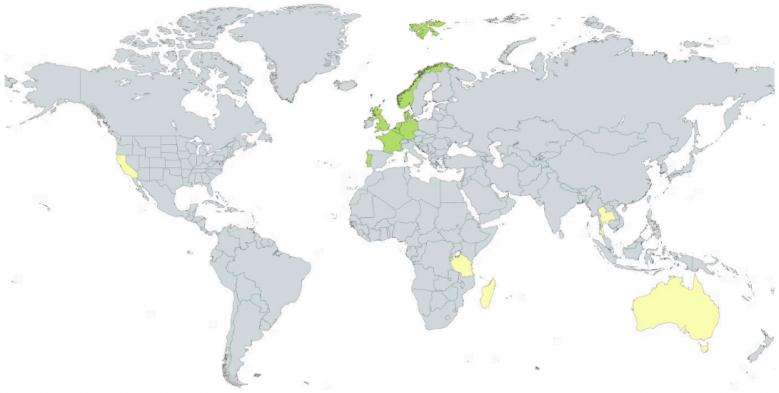
- ***Substrates*:** Optimized for enhanced kelp productivity, these substrates are critical for the success of deployments in varied marine environments.
- ***Sea Socks*:** Designed to increase the stability and success of kelp seedlings in their early stages.
- ***Tetrapods*:** Provide structural support and protection, ensuring sustainable growth and reducing the impact of environmental stressors.
- ***Floating Forest:*** Designed for areas that require an inverted kelp forest.

Sea Socks

Appendix VIII - SeaForester's Geographic Expansion

Source: Designed by the author

Geographic Expansion



Primary Sites: Portugal, Norway*, Central Europe, UK

Secondary Sites: California, Australia, Thailand, Madagascar, Tanzania

2025 Goal

- *2025 Activate largescale liscenses in Norway for restoration. Begin Trials for both Norway restoration and North Sea.

Appendix IX - Scaling Production Capacity over Time

Source: Designed by the author