sustainability

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Stakeholder Perspectives on Blue Mussel Farming to Mitigate Baltic Sea Eutrophication

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Abstract: Here, we present an application of systems thinking to controlling Baltic Sea eutrophication—a wicked environmental problem characterized by multiple stakeholder perspectives and no single, agreed upon solution. The Baltic Sea is one of the most polluted waterbodies in the world. More than 40 years of land-based (linear) measures have failed to adequately control eutrophication, yet internal (circular) measures are rarely used. Farming native blue mussels for nutrient capture has been proposed as one measure for eutrophication control, but the relevant stakeholders disagree as to its environmental, social and economic benefits. Here, we present the views of four Swedish stakeholder groups—academics, entrepreneurs, municipal government employees and representatives of non-governmental organizations (NGOs)—on the sustainability of native blue mussel farming, a circular measure for eutrophication control. Using semi-structured interviews, we elicited stakeholder perspectives on the environmental, economic and social dimensions of blue mussel farming. The interviewees generally agreed that blue mussel farming is not currently economically sustainable, but that it can contribute to the social sustainability of coastal regions. Academics were skeptical of the environmental benefits, claiming that farms could reinforce eutrophication, whereas the remaining stakeholder groups argued for its potential to mitigate eutrophication. In a roundtable discussion conducted one year after the original interviews, all stakeholder groups agreed that blue mussel farming alone will not fix Baltic Sea eutrophication, but can be part of the solution together with land-based measures. All groups also agreed on the need for cautious upscaling, continuous environmental monitoring and constant improvement if blue mussel farms are to be part of a "toolkit" for eutrophication control. Our results highlight the fact that wicked environmental problems can be addressed when multiple stakeholder groups with differing perspectives have the opportunity to achieve consensus through dialog.

Keywords: Baltic Sea; blue mussel farming; circular economy; eutrophication; nature-based solutions; stakeholder collaboration; systems thinking

Citation: Žilinskaitė, E.; Blicharska, M.; Futter, M. Stakeholder Perspectives on Blue Mussel Farming to Mitigate Baltic Sea Eutrophication. *Sustainability* **2021**, *13*, 9180. https://doi.org/10.3390/su13169180

Academic Editor: Takeshi Miura

Received: 23 July 2021
Accepted: 11 August 2021
Published: 16 August 2021

1. Introduction

Marine eutrophication is a wicked problem embedded in complex and contested socio-ecological systems [1]. Eutrophication results from imbalances in biogeochemical cycles whereby excessive amounts of nitrogen (N) and phosphorus (P) from terrestrial inputs, e.g., agricultural runoff, wastewater and industrial emissions, cause the undesirable growth of aquatic plants, reduced oxygen concentrations, and subsequent habitat loss [2,3]. Typically, eutrophication is managed using a linear paradigm whereby the external inputs of nutrients from the catchment are reduced. New approaches based on internal (in-situ) measures and circular thinking (e.g., [4–7]) are needed. At present, internal measures to capture and/or remove nutrients directly from the waterbody are rarely employed, but they are desirable as they offer greater possibilities for circularity and nutrient reuse.

The Baltic is one of the most polluted seas in the world. Since the early 20th century, industrialization, agricultural intensification and population pressure have greatly increased pollutant loads in this land-locked basin [8]. Excessive N and P inputs have resulted in extensive toxic algal blooms and widespread bottom water "dead zones", which destabilize the normal functioning of a range of ecosystem services essential for biodiversity and the overall well-being of the Baltic and its surrounding catchment.

Until now, most legislative instruments to control Baltic Sea eutrophication, including the Baltic Sea Action Plan (BSAP), the Water Framework Directive (WFD, [9]) and the Marine Strategy Framework Directive (MSFD, [10]), have emphasized linear solutions that prioritize external measures in the catchment to reduce nutrient loads to the sea. These measures have had some degree of success as nutrient inputs from the land have decreased (through, e.g., improvements in wastewater and storm water systems, better agricultural nutrient management and in-catchment retention measures). However, internal loading, i.e., the release of legacy P that has accumulated in marine sediments, is still a significant factor impeding a timely recovery [11]. Internal measures that capture, remove and recycle excessive nutrients from the sea back to the land may have the potential to contribute to faster recovery and enhance circularity in the Baltic Sea region. Most efforts to date towards a goal of circular nutrient management in the Baltic Sea region have focused on nutrient reuse in the catchment [5,6]. Today, there is increasing awareness that marine biomass may also have a role to play in the circular nutrient economy [7].

One potential use of marine biomass to promote nutrient circularity involves farming and harvesting native blue mussels (*Mytilus edulis*) [12,13]. Unlike fish aquaculture, mussel farms require no external inputs of nutrients, and their harvest has a net positive effect on ecosystem nutrient balances. Blue mussels are a common filter-feeding Baltic bivalve that consume phytoplankton and detritus in the water column. Farmed filter feeders can provide several environmental services, e.g., increased water transparency and light penetration, higher oxygen levels, reduced nutrient concentrations and biodiversity restoration [14,15]. However, farmed bivalves may negatively affect environmental quality [14,16], and farming may not be economically viable.

Differing perspectives on measures to limit Baltic Sea eutrophication may be connected to the unequal prioritization of the environmental, social and economic dimensions of sustainable development (SD). From an environmental perspective, blue mussel farming can improve water quality and contribute to nutrient circularity. Mussel farming can increase economic activity if the harvested mussels can be used as food, feed or fertilizer in a circular system, whereby nutrients accumulated by mussels in the sea are used on land. Farms can also provide rural communities with employment opportunities and strengthens local businesses [17]. While blue mussel farming has been suggested as a means to strengthen all aspects of SD, it currently faces institutional obstacles in the Baltic Sea region [13].

It has been suggested that to promote the circular economy, there is a need not only for innovative concepts and new business models [5], but also for innovative actors that are supportive of new approaches [4]. However, to date, little is known about circular economy approaches in relation to the wicked problem of eutrophication, and particularly about the views of different stakeholders regarding their practical application. As different stakeholders may perceive and prioritize potential solutions differently [18], there is a need to recognize their various perspectives, which can be influenced by, e.g., culture, values, social norms, background knowledge, experiences and education [19]. For example, academics claim to produce valid knowledge and solutions to "hard-to-solve" problems, which they believe will allow non-academics to act accordingly [20].

However, other non-state actors, including civil society and the private sector (businesses and entrepreneurs), are likely to be equally, if not more, important in producing knowledge and solutions [21]. Environmental non-governmental organizations (NGOs) can create local solutions to global problems using bottom-up approaches [21]. Academics and NGOs can perceive businesses and entrepreneurs as either adversaries or collaborators, depending on the wicked problem [22]. Government actors can contribute to solutions in a top-down manner through regulatory enforcement, support of other stakeholder groups and forward-thinking legislation. These different perspectives and modes of action can result in stakeholder conflict and a failure to lay the groundwork for addressing wicked problems [23].

Even through all stakeholder groups agree on the need to control Baltic Sea eutrophication, the issue still has not been solved. Here, the differences between stakeholders' perspectives and their complex interactions can be seen as a set of interconnected parts of a system, which calls for a structured analysis with the appropriate set of tools and guidelines that can accurately describe a system and support the construction of reliable and flexible frameworks to address wicked problems. Systems thinking, or the organized study of systems, their feedbacks, and their behavior as a whole, is one tool for framing and analyzing wicked problems. Systems thinking uses a set of synergistic skills, tools and guidelines "to improve the capability of identifying and understanding systems, predicting their behavior, and devising modifications to them in order to produce the desired effects" [24], p.675. In other words, systems thinking opens up ways to reflect on complex and interconnected issues in a critical and holistic way, potentially offering solutions that consider the perspectives and problems of all stakeholders across multiple levels.

Here, we focus on the wicked problem of mitigating Baltic Sea eutrophication and the potential for systems thinking to frame Swedish stakeholder perspectives on the sustainability of blue mussel farming for eutrophication control. We investigate the range of Swedish stakeholder perspectives on environmental, economic and social dimensions of blue mussel farming as a circular alternative to address Baltic Sea eutrophication, and highlight the potential for collaboration between groups.

2. Materials and Methods

We interviewed key Swedish actors professionally involved in blue mussel farming or Baltic Sea environmental issues. As our goal was to identify and present the range of stakeholder perspectives, we aimed at interviewing representatives of all relevant stakeholder groups. As such, we did not aim at generalizing the findings, but only at providing insights into the complexity of blue mussel farming. Possible interviewees were identified through discussions with academics involved in mussel farming and a media analysis. Of the 23 individuals approached, 12 agreed to be interviewed, 4 declined and 7 did not respond to either the initial or follow up emails. As a result, 12 individuals representing eight organizations and four stakeholder groups (4 academics, 2 entrepreneurs, 4 NGO representatives and 2 municipal government employees) were interviewed. The latter group were included as municipalities in Sweden are responsible for social and environmental protection, water management, wastewater treatment, and other activities including approving mussel farms [25].

All interviews were conducted in English, took place between February and March 2019, and lasted from 45 minutes to 1.5 hours. Seven individuals were interviewed face-to-face and five by SKYPE. Interviews consisted of 33 predetermined open-ended questions focusing on stakeholders' perspectives on the environmental, social and economic dimensions of blue mussel farming (see Appendix A, Table A1). Interviewees were also asked to share their views on the potential of blue mussel farming to contribute to the circular economy. Altogether, 11 hours of interviews were audio-recorded and transcribed for a subsequent in-depth analysis based on the Grounded Theory framework for qualitative data analysis research designs [26,27]. A virtual roundtable discussion was organized and took place online on the 26th of November 2020. The same stakeholders (8) as interviewed for the survey were invited to share their perspectives on the strengths and limitations of blue mussel farming in the Baltic Sea. The other 4 original interviewees declined to participate in the round table.

Grounded Theory is a qualitative data analysis research approach [27], wherein data collection (interviews) is combined with data analysis (qualitative content analysis) to generate conclusions based on the empirical material [28]. It is a prominent strategy to efficiently position, collect, analyze and code interview data [26,27]. Grounded Theory uses the following four steps: (i) theoretical sampling, (ii) open coding, (iii) axial coding and (iv) selective coding.

Theoretical sampling includes the selection of participants and documenting their answers to the interview questions. The information collected is subsequently used to saturate categories (or collect enough information) to elaborate a theory and suggestions. In this context, a category represents a unit of information composed of various instances, happenings and events. The theoretical sampling data are grouped into major categories defined in the open coding step, which yields the concepts that are later to be grounded [26], p. 569. These concepts are elaborated in the axial coding step, wherein one open coding category to be focused on is identified (the "core phenomenon") and, going back to the collected data, specific categories are created around the core phenomenon. These categories are based on casual conditions (factors causing the core phenomenon), strategies (actions taken that address the core phenomenon), contextual and intervening conditions (situational factors, broad and specific, that influence the strategies) and consequences (outcomes of strategy implementation). In this specific study, four main categories around the core phenomenon were selected (general, environment, social and economy). Finally, during selective coding, the data are structured according to the interrelationship between categories and subcategories, relevant quotes are identified and tables are created for the presentation and organization of results (Figure 1). During the different stages of the coding process, memos were used as "reminders" or "crystalized ideas" to help us stay on track while determining categories and subcategories [26], p. 573.

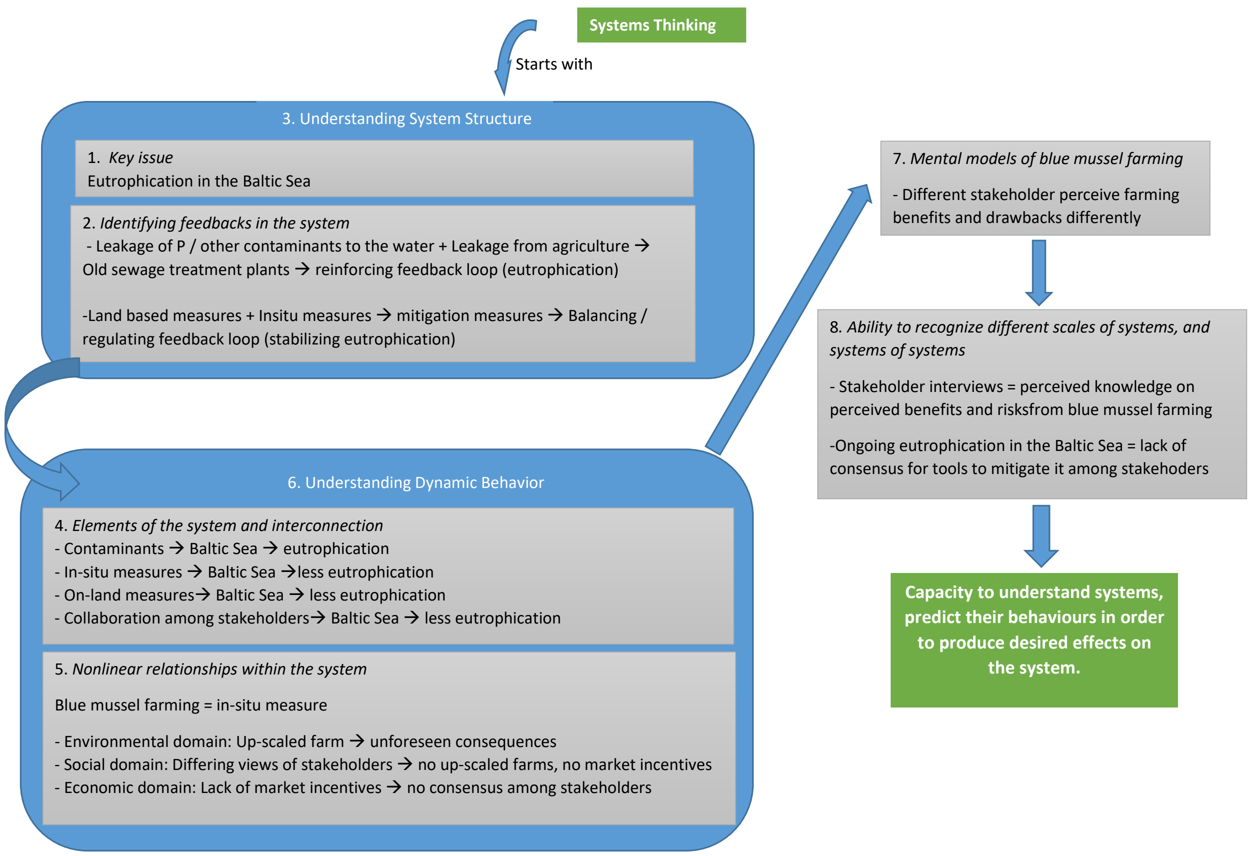

Figure 1. Graphical presentation (systemigram) of steps in framing stakeholder perceptions of the role of blue mussel farming in reducing Baltic Sea eutrophication.

3. Results

3.1. Survey Results—Environmental Aspects

3.1.1. Baltic Sea Internal Load and Natural Recovery

The majority of interviewed stakeholders agreed that water quality in the Baltic is adversely affected by the legacy of past nutrient inputs from land and that this hinders timely recovery from eutrophication (Table 1). Two NGO representatives argued that even though the nutrient load reaching the Baltic remains at levels last seen in the 1950s, there are studies showing increasing amounts of phosphorus (P) being released. The same individuals also claimed that land-based measures for nutrient load reduction during the last 40 years have not been that successful, and there is a need for more action, since the eutrophication issue has not yet been resolved. Another NGO representative claimed that the internal P load, which they stated to be more than 500,000 tons in total, still needs to be addressed. One entrepreneur stated that actions to promote recovery are needed because eutrophication is an "*ongoing problem*" (All interview quotes are reported in italics). One municipal employee and an entrepreneur agreed that the sea is not capable of recovery by itself. Another entrepreneur explained that even if nutrient leakage from the land could be totally stopped, natural recovery from eutrophication would take a very long time. According to one municipal employee, there is a need to "*deal with the old sins*" of eutrophication.

Table 1. Summary of stakeholder perspectives of Baltic Sea internal load and natural recovery, and environmental consequences of blue mussel farming in the Baltic Sea.

Satements	Academia	Entrepreneurs	Municipality	NGOs
Baltic Sea internal load and natural recovery				
External measures are enough to address Baltic Sea eutrophication	++			+
Phosphorus (P) concentrations are increasing in the Baltic Sea			+	+++
Natural recovery of the Baltic Sea is possible	+++	--	-	+
Internal P load is a problem	-	+	+	+-
Environmental aspects: positive				
Mussel farming is one of the solutions to Baltic Sea eutrophication	+	++	++	++++
Mussel farming contributes to the circular economy/closes nutrient loop	+++	+	++	+++
Mussels are a good source of protein	+	+		++
Mussel farms increase water clarity	+	+	++	++
Environmental benefits of mussel farms are greater than harms		+	+	++
Small scale farms do not cause unacceptable harm to the environment	++		+	++
Knowledge about Blue mussel farms efficiency to mitigate eutrophication comes from scaling up activities	++±	++	++	+++

Table 1. *Cont.*

Satements	Academia	Entrepreneurs	Municipality	NGOs
Environmental aspects: negative				
Baltic Sea environmental conditions are not favorable for Blue mussels	++++	+	-	++
Harm environment beneath farms	++++	- -	- -	- -
Complex, lacks holistic approach	+++			
Uncertain environmental impacts of mussel farming—an obstacle to implementation	+++±			-
Scaled up farms will cause unacceptable harm to the environment	++	± -	- -	+±

Note: The number of plus signs (+) indicates how many stakeholders agreed with the statements; minus signs (-) indicate disagreement, stacked plus/minus (±) means a stakeholder both agreed and disagreed, while an empty space ( ) means that the statement was not addressed.

Despite agreement amongst all stakeholders about the degraded state of the Baltic, there were different perspectives on the importance of internal loads (legacy nutrients released from the sediment) as a contributor to eutrophication and the potential for recovery in the Baltic ecosystem. One academic claimed that the Baltic has the capacity to recover on its own as long as *"nutrients transported into the sea are on a sustainable level"*; another argued that *"the environment is improving and getting better by itself, because we are reducing inputs to the Baltic Sea"*. They asserted that there is no need to be *"desperate"*, because the *"eutrophication is not getting worse"*, and the Baltic Sea currently has the same nutrient load as in 1940. They further emphasized that *"improvement in the environment"* is happening naturally and there is *"no need to speed this up"*. Another academic claimed that the sea has a *"self-cleaning capacity"*, and land-based actions are enough to reduce nutrient concentrations. They claimed that the Baltic is *"losing nutrients faster than it is gaining"*, and the best solutions is to *"let the time do the work"*, as *"the eutrophication issue will resolve itself in its own in some time"*. An NGO representative added that internal loads are not an obstacle if all on-land measures are implemented, stating that *"the environment has the capacity to recover itself, as long as we stop nutrients from land"*. However, both entrepreneurs and one municipal representative disagreed with this optimism and claimed that natural recovery in the Baltic is almost impossible, and additional actions are needed to mitigate eutrophication. They admitted that natural recovery is a possible scenario, but it would take too long and unexpected disturbances might contribute to further eutrophication.

3.1.2. Positive Aspects of Blue Mussel Farming

All interviewees perceived some environmental benefits to blue mussel farming, and nine of them, representing all sectors, agreed that it is one of the *"tools"* from the *"tool box"* to mitigate eutrophication, as framed by one municipal employee:

> *"For those of us who work with this more or less on a daily basis, we see the problem, eutrophication, and we have the tool box of all things you can do. We are doing all of these things and still the toolbox is not big enough. We are trying to find those tools, and I think it is easy to say, that it [blue mussel farming] is not efficient enough. But none of the tools are, so, we need to find even more tools. Maybe we need twice as many, and mussel farming would be only one of them"*.

Most interviewees agreed that improvements in land-based measures to control eutrophication are not enough (Table 1). They argued that internal measures such as blue mussel farming, algae and weed harvesting, and multi-trophic aquaculture must be added to the *"tool box"*. One NGO representative stated that blue mussel farming provides a partial solution to the problem of excessive nutrient loading to the sea. Four interviewees highlighted that blue mussels are rich in protein and can be used for animal feed or human food production, thus contributing to circularity. Finally, six stakeholders representing all sectors argued that blue mussel farms enhance water quality via increased water clarity and light penetration.

Four interviewees argued that the benefits of nutrient uptake overshadow possible environmental harms. Four other interviewees believed that the environment has the capacity to restore itself within two or three years following any damage from farming. One NGO representative also added that farms are easily monitored and can be moved in the event of negative effects, such as oxygen depletion causing anoxic and hypoxic bottom water. Furthermore, one entrepreneur argued that legislation is already very strict, and mussel farmers are encouraged to consider environmental risks. Finally, five stakeholders argued that small-scale farms do not harm the environment, but can be beneficial instead. Specifically, one municipal employee and one NGO representative mentioned pilot-scale farms with healthy below-farm environments.

Most stakeholders agreed that farm up-scaling is needed in order to assess eutrophication mitigation potential *"for real"*, as there is not enough information regarding potential environmental harm. Similarly, one academic reflected that there is a need for *"real data"* in order to prove or disprove scientific concerns, and that *"it is up to [practitioners] to prove"* that mussel farms are good for the environment. Another academic admitted that up-scaling, tracking and recording the environmental impact of big farms is *"the only way to go"* to determine whether blue mussel farms really are an environmentally friendly means of eutrophication mitigation.

3.1.3. Negative Aspects of Blue Mussel Farming

All interviewees reported some negative environmental aspects of blue mussel farming. Academics in particular claimed that environmental conditions in the Baltic are not conducive to blue mussel farming. They doubted that farming can contribute to solving coastal eutrophication, and suggested that control measures should be further developed on-land.

All academics argued that there are risks to the environment, e.g., when organic matter produced by mussels sinks to the sediment. As one academic said, mussel farming is a *"complicated"*, *"chaotic"* and *"problematic"* method, and its application requires a broad range of knowledge regarding the specific site, its biophysical conditions, and possible scale-dependent effects of farm size. The other three academics stated that only 25% of the nutrients consumed by blue mussels are removed during harvest, between 30 and 50% of ingested nutrients are deposited below the farm, and 25–45% stays in the water column. This results in higher nutrient loads that would occur naturally.

One academic also expressed concern about the consequences of *"local enrichment of nutrients"* from farms:

> *"(...) if the mussel farms situated in places where the water current is too low, the amount of feces and pseudo-feces underneath the farms will lead to hypoxia and release of ammonia and phosphate. So, the amount of nutrients in the water will stay rather constant or even increase which could lead to further eutrophication".*

Another academic mentioned that problems might not occur immediately, so mussel farmers could repeat their actions in multiple places without understanding their impacts.

Other academics worried that discussions around blue mussel farming practices are oversimplified and lack a holistic view on possible negative impacts in the near-farm environment. Furthermore, these academics were concerned that model predictions about how farms will affect the environment are highly uncertain. The need to investigate further and *"record what happens to the system"* was suggested by one NGO representative and another academic, as the behavior of complex systems cannot be calculated beforehand. In relation to existing uncertainties, one NGO representative recommended using the precautionary principle.

In contrast, both entrepreneurs argued that the negative effects of farms would only occur if they were located in sensitive environments. They argued that even if after investigations and monitoring the near-farm environment is adversely affected, it is easy to move farms from affected sites and place them elsewhere.

Two academics and one NGO representative were against up-scaling, arguing that it will cause more damage than benefit to the environment. However, entrepreneurs, municipal employees and two NGO representatives argued that if farms are placed in the appropriate areas and are well monitored, there would be no harm to the environment.

3.2. Survey Results—Social Aspects

3.2.1. Societal Perspectives on Blue Mussel Farming

Eight interviewees agreed that the general public can have positive attitudes towards blue mussel farming if they are informed about its purpose (Table 2). Municipal employees reflected that positive societal attitudes towards farming come from local experience and knowledge of farm activities. Municipal employees, one entrepreneur and one NGO representative argued that integration of the local community and local knowledge is essential to the placement of farms in locations that will not interfere with local activities or jeopardize sensitive environments. (Table 2). Some interviewees suggested more intense information dissemination about the potential of mussel farming for eutrophication mitigation, so that the local communities are informed about the concept and can be part of the activity.

Table 2. Stakeholder perspectives on the Swedish government and public views of blue mussel farming in the Baltic Sea.

Statements	**Academia**	**Entrepreneurs**	**Municipality**	**NGOs**
Public's opinion				
Positive if informed about farms purpose	++±	++	++	++±
Lack of knowledge regarding eutrophication mitigation	++		−	++++
Positive if public are integrated into process		+	++	+
Mussel farms are perceived negatively when they interfere with local activities/alter natural environment	+		++	
Swedish government perspective				
Positive towards Blue mussel farming due to benefits for economy and society	+++	++	++	+++
Critics towards the Government				
Baltic Sea issues - low on the agenda			+	
Lack of holistic approach on eutrophication mitigation measures	+			+
Simplest measure to mitigate eutrophication	+++			+

Note: The number of plus signs (+) indicates how many stakeholders agreed with the statements; minus signs (-) indicate disagreement; stacked plus/minus (±) means a stakeholder both agreed and disagreed, while an empty space ( ) means that the statement was not addressed.

One municipal employee believed that members of the public *"either have no opinion or like it"* if farms are implemented at a small scale, but as soon as farms are upscaled and alter the environment, people can change their attitudes. One academic suggested that floating buoys used in farms can irritate people due to aesthetics, destroyed natural environments, and disturbed water activities.

3.2.2. Swedish Government Perspectives on Blue Mussel Farming

Most interviewees believed that the Swedish government has a positive view on farming due to several *"attractive selling points"*, such as animal feed made from harvested mussels or human food production. It also contributes to rural employment, and demands low investment compared to other land-based eutrophication mitigation measures. These factors were perceived as a *"win–win scenario"* for both society and the government, with positive effects for the environment, society and economy.

In contrast, one municipal employee argued that Baltic Sea issues have never been *"high on the [Swedish government] agenda"*, which results in the Baltic being *"one of the dirtiest seas in the world"*. Additionally, one academic reflected that Swedish government representatives are not aware of the complexity and possibility of the environmental harm caused by mussel farms. Moreover, some stakeholders complained that the government chooses mussel farms as simple *"short-cut"* solutions to mitigate marine eutrophication (Table 3). According to one NGO representative:

Table 3. Stakeholder perspectives on issues related to the economic viability of blue mussel farming, as well as perceived reasons for why business incentives are currently lacking.

Statements	Academia	Entrepreneur	Municipality	NGOs
Economic viability				
Mussel farming is not economically viable	++++	++	++	++++
Need of payment for environmental services/governmental subsidies	++	++	++	++
Mussel farming is costly now, but will be more cost-effective in the future	++	+	++	++

Note: The number of plus signs (+) indicates how many stakeholders agreed with the statements.

> *"Instead of going into painful actions addressing agriculture, they [Swedish government] will go to sea-based actions—mussel farms. It is difficult to push the Swedish Board of Agriculture to [enforce] strict measures to regulate farmers, but that become popular to invest in innovative methods [as blue mussel farming], that haven't yet proven to work but at the limited scale show some benefits"*.

3.3. Survey Results—Economic Aspects

3.3.1. Economic Viability of Blue Mussel Farming

All interviewees agreed that blue mussel farming in the Baltic is not economically viable at present (Table 3). According to one academic, blue mussels in the Baltic grow too slowly because of low salinity levels. Many interviewees emphasized that farming solely for eutrophication mitigation is expensive, and to make the activity economically viable, policy makers need to adjust regulations in order to introduce payments to farmers for environmental benefits, rather than creating a commercial market for farmed mussels. The interviewees also argued that although farming is costly now, it has the potential to become more cost-effective in the future due to its potential for circularity (Tables 1 and 3). For example, a municipal employee noted that harvested mussels can be used on land for, e.g., animal feed, human food, fertilizers, and biogas production, which provides other income streams. One academic and two NGO representatives suggested that, compared to soya- and fishmeal, mussels are a sustainable method of feed production. Although current small-scale farms do not produce enough mussels to make commercial animal feed production competitive in a global market, two academics, both entrepreneurs and two NGO representatives agreed that up-scaling mussel production could benefit the economy and society (Table 3).

3.3.2. Reasons Behind Lack of Business Incentives

All stakeholders acknowledged that mussel farming is not currently economically viable. For economic viability, there has to be a demand and a market for harvested mussels, but this is not yet the case. One municipal employee stated that since farming is a costly activity, there are not many potential farmers *"knocking at the door to start the business"*. According to both municipal employees, one of the reasons that farming is not commercially viable is that the Swedish National Food Agency has not developed the necessary procedures for approving mussels produced in the Baltic for human consumption. One municipal employee emphasized the need for a *"program adapted to the [Baltic] specific conditions"*, so that blue mussels from the Baltic could be sold for human consumption, as is the case for mussels from the Swedish west coast. One NGO representative claimed that the problem from the beginning was that *"no one looked at cost efficiency"* of blue mussel farming, arguing that there was always *"more focus on environmental aspects and less on actual business potential"*. According to the NGO representative and one entrepreneur, it is important to investigate from the beginning if farms have the potential to be a cost-effective measure for eutrophication mitigation. If there is no economic potential, then it is more efficient to focus on other measures. According to the NGO representative:

> *"You can spend years on guessing (. . .) [environmental harms], but it is not relevant unless it does have a business side (. . .). You need to bring that in speed before you spend years on research about it"*.

They concluded that the biggest problem related to the economic viability of farming is that while both scientists and municipalities are involved in the process, the business perspective is lacking. Similarly, one entrepreneur added that there is a need to compete for *"the lowest cost and highest efficiency"* to get businesses interested. The same entrepreneur felt that the precautionary principle is too extreme, and it holds back any innovative solutions regarding eutrophication. According to them:

> *"We are way too protective; we cannot solve the Baltic Sea environmental problem, because of the environmentalist / marine biologists saying that we are not allowed to try new methods. (...) They (would) rather have a well-known but dead Baltic Sea, they prefer that to the unknown remediation technology"*.

Furthermore, the entrepreneur criticized the *"internal research battle"* amongst academics over the possible environmental harms of farming, instead identifying possible actions and exploring business potential. Similarly, one academic agreed that *"once there is a market for the product, then it will be more entrepreneurs getting in with innovations"*. Additionally, two academics argued that since the current farms are small and insecure, it is hard to attract business and investors. One NGO representative called farming a *"risky business"* from a long-term perspective.

3.4. Synthesis of Sectoral Perspectives on Sustainability

No individual stakeholder group took a systems perspective on the sustainability of blue mussel farming in the Baltic Sea. Each group prioritized different aspects of the issue based on their values, norms, background knowledge, experiences and education. The academics prioritized environmental dimensions and down-valued social and economic aspects. While they claimed to see circularity as important, they do not believe it can occur with Baltic mussels due to unsustainable economic and environmental conditions. Municipal employees put greater weight on the social and economic dimensions. They highlighted the importance of circularity, but also recognized the potential environmental harm highlighted by academics. Entrepreneurs prioritized economic and societal dimensions, and were relatively less concerned about environmental aspects. Lastly, NGOs were the only stakeholder group that attempted to balance the three dimensions.

Academics were the main voice highlighting potential environmental harm. They argued that complexity is underappreciated and that the Baltic conditions are not conductive to mussel farming as an efficient means of improving water quality. They also believe that the Baltic is able to recover from eutrophication with sufficient land-based measures. They noted that both civil society and the Swedish government perceive blue mussel farming positively. However, academics highlighted potential risks, and underlined that farming should not be seen as a simple and easy method for combatting Baltic Sea eutrophication. They also emphasized that farming is not cost-efficient and lacks market incentives, although it has potential for circularity.

Entrepreneurs saw the potential of blue mussel farming to mitigate Baltic Sea eutrophication. They argued that the Baltic is not able to recover on its own and there is a need for in-situ measures. They claimed that farms are not harmful to the environment and can be relocated if any harm occurs. Entrepreneurs also stated that civil society and the Swedish government perceive farming positively. Municipal employees saw farming as a part of the toolbox of measures to counteract eutrophication. They believed that the Baltic cannot recover by itself, even if there is a cessation in nutrient leakage from the land. They emphasized that in-situ measures support circularity and nutrient recycling.

Municipal employees stated that there is no environmental harm caused by small-scale pilot projects, but noted that constant oversight is important. They also claimed that the Swedish government favors farming due to employment prospects and economic benefits related to circularity. However, they also agreed that at present, farming is prohibitively expensive, and that payments for environmental services or subsidies from the national government are needed.

Representatives from NGOs have differing perspectives on farming and Baltic Sea eutrophication. Three of them stated that the Baltic cannot recover without external intervention and that internal loads are a threat, whereas the fourth stated that the sea is recovering, internal loads are not an obstacle, and on-land measures are enough to combat eutrophication. Three NGO representatives promoted the idea that in-situ measures will combat eutrophication, whereas a fourth claimed that it is only applicable in specific semi-closed areas. Three argued that farming has the potential to be upscaled and investigated further, whereas a fourth asserted that since the impact of large-scale farms is unknown, the activity should be prevented based on the precautionary principle. All NGO representatives affirmed that both society and the Swedish government can have a positive view of mussel farms if sufficiently informed about their purpose. However, one NGO representative criticized the Swedish government for choosing the simplest way to tackle the eutrophication issue instead of making costly changes in the agricultural sector, which they claimed is the biggest source of nutrient leakage. All four NGO representatives highlighted the need for market incentives and suggested payments for environmental services. They further emphasized that farming can contribute to circularity.

Some interviewees shared their thoughts about why different stakeholder groups have different perspectives on Baltic Sea blue mussel farming. Their explanations ranged from a lack of understanding of complex processes operating in the farm environment, to conforming to one's own *"identity"* and *"choosing to focus on [particular] aspects"* in relation to that. The latter point highlights the challenges to openness and understanding of other's perspectives and priorities. One interviewee stated it is necessary *"to see the whole picture"* in order to acknowledge different viewpoints. Three academics and two NGO representatives believed that it is important to collaborate with others. As described by one of the academics, it is always good to *"communicate on what [is] agree[d] and disagree[d]"*. One NGO representative said: *"it is important to listen to opposite [viewpoints] and understand what is relevant there"*. Furthermore, one academic emphasized that though collaboration, *"we might [...] come up with some solutions of how to do this better"*. Interviewees from all sectors emphasized the need for a dialogue wherein stakeholders would be able to interact and reach a consensus.

3.5. Round Table

All roundtable participants agreed on the need to continue working for a cleaner Baltic Sea. The biggest challenge identified during the roundtable was the need to improve the regulatory/policy environment, and to make blue mussel farming economically viable. Further discussions are needed as to whether mussel farms should be funded by the public or private sector, and whether the activity should be subsidized. All participants agreed that blue mussel farming alone will not solve the problem of Baltic Sea eutrophication, but that mussel farming can be part of the solution with other land measures.

4. Discussion

There are multiple stakeholder perspectives on potential actions for mitigating Baltic Sea eutrophication. The systemigram (Figure 1, concept adapted from [24]) illustrates the ongoing discussion about the possible role of blue mussel farming as one of the tools. The systemigram helps to create an overview on the issue from the systems thinking perspective: identifying the issue, looking for existing feedbacks in the system, describing different elements of the systems and their interconnections, determining nonlinear relations within the system, looking for mental models of blue mussel farming, and recognizing different scales of the systems. Following the suggested steps helps us to understand the situation of Baltic Sea eutrophication, as well as the strengths and limitations of blue mussel farming as one of the possible tools to combat the issue.

Baltic Sea eutrophication is a wicked problem, and every stakeholder group brings valid perspectives on blue mussel farming's potential benefits and risks. Despite having access to the same information, the interviewed stakeholders' groups have different perspectives on the potential utility of blue mussel farming as an internal measure to combat eutrophication. This is consistent with the social identity theory, which states that everyone acquires a sense of belonging to a specific group according to their own background [29]. Individuals must work to fit into a complex network of groupings that structure networks of relationships in which they find, create and define their place [29]. Once networks are defined and self-definition is clear, individuals tend to hold on to it and follow prescribed norms.

Given the complexity of the problem, there is a risk that stakeholders might fail to maintain an adequate systems perspective, leading every group to fail in considering at least one important dimension of the problem. Stakeholders tend to prioritize one or two of the sustainability dimensions, leaving aside the third. The sustainability dimensions prioritized or downplayed differ among stakeholder groups. In the case of farming in the Baltic, all interviewees agreed that the economic dimension seemed to be a limiting factor in the potential application of mussel farming, which could be a good starting point in exploring a common focus in the dialogue.

This failure to consider all three dimensions of sustainability can be considered an inappropriate use of systems thinking (trap), wherein just some parts of the systems are taken into account. The challenge here is to raise awareness of systemic perspectives on the issue and find a way to share and integrate the different perspectives [18]. This tendency to not consider all three dimensions of sustainability was most apparent in the original interviews. During the roundtable event, the different stakeholder groups gave greater consideration to all three dimensions.

In relation to complex and wicked problems, some researchers (e.g., [30,31]) suggest the integration of transdisciplinary knowledge, which is highly recognized in environmental science [31]. The varieties of knowledge and the incorporation of different stakeholder perspectives facilitate innovations in structure, mind-sets and practices, which may lead to the co-design and co-implementation of solutions [32,33]. Through transdisciplinary interactions, stakeholders might find an opportunity to reflect on their perspectives and be more open to accepting and understanding the foundations of other perspectives. This helps actors to perceive a holistic and systemic picture of different worldviews, which leads to a common ground and creates a pragmatic commitment to problem solving, rather than being academically correct [18].

Our study is the first to shed light on stakeholder perspectives about the potential use of blue mussel farming to address the eutrophication of the Baltic Sea. Such information is needed to better understand both the different natural science perspectives on the issue (e.g., [13,14,16]) as well as possible reasons for the failure to consider in-situ measures, such as mussel farming, in proposals for circular economy approaches to nutrient management in the Baltic Sea region [5,6].

While we acknowledge that only 12 stakeholders were interviewed, and thus one cannot generalize the findings, we also believe that our study presents a range of important considerations expressed by different stakeholders which can be a starting point for planning future circular economy approaches for the Baltic Sea. Based on our findings, future research could consider how different stakeholder groups perceive broader issues of nutrient circularity in the Baltic Sea region. Specifically, research is needed on: (i) systems thinking approaches that combine all three pillars of sustainability; (ii) stakeholder attitudes towards combining land-based and in-situ measures for Baltic Sea eutrophication control; and (iii) policy instruments that can facilitate a sustainable circular economy for nutrients.

5. Conclusions

One important challenge to resolving wicked environmental problems such as Baltic Sea eutrophication is the different perspectives and prioritizations amongst stakeholder groups. The successful resolution of such challenges requires a consideration of all dimensions of sustainable development, in alignment with a holistic view of the problem. With this in mind, the adoption of a systemic way of thinking and depicting systems elements, interconnections and purposes helps to identify issues and the potential of applied and promising solutions. Additionally, as different stakeholder groups prioritize these differently, it is difficult to achieve consensus. Thus, there is a need for transdisciplinary dialogue, which will allow for mutual understanding, trust building, and the finding of solutions to the increasingly urgent environmental problems we face today.

Author Contributions: Conceptualization, E.Ž. and M.F.; methodology, E.Ž., M.B and M.F.; formal analysis, E.Ž.; investigation, E.Ž.; writing—original draft preparation, E.Ž.; writing—review and editing, E.Ž., M.B. and M.F.; supervision, M.F. All authors have read and agreed to the published version of the manuscript.

Funding: Parts of this research were supported by the INTERREG Baltic Blue Growth project.

Institutional Review Board Statement: Informed consent was obtained from all subjects involved in the study.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy concerns raised by some interviewees.

Acknowledgments: We appreciate the participation of all interviewees and thank the Royal Swedish Academy of Agriculture and Forestry (KSLA) for hosting the round table event. We appreciate the comments of two anonymous reviewers which have allowed us to improve the manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Below is the list of questions that each stakeholder was asked during the interviews (Table A1).

Table A1. The list of questions that each stakeholder was asked during the interviews.

Sector	Subsector	Questions
General		- What are your views on blue mussel farming method as a mitigation tool for coastal eutrophication? Why do you think so? - What kind of successes do you see with blue mussel farming? - What kind of failures do you see with blue mussel farming?
Environment	Biophysical aspects	- How does blue mussel cultivation affect the environment beneath the farm? - Do you think blue mussel farming is an environmentally friendly method to mitigate coastal eutrophication? - How do you think blue mussel farming can become an environmentally friendly method? - Do you think it is worth taking risks and implementing blue mussel farms without having a comprehensive research on environmental harms? - Do you know if there is any kind of EIA of farms in the Baltic Sea region? - Do you think there is lack of research on environmental harms? Why?
	Measurements	- How do you think blue mussel measurement is implemented? - Do you think the measurements are reliable? Why? - Why do you think the measurements are reliable/not reliable? - What do you think makes them reliable/not reliable?
Social	Institutional aspects	- What kind of institutional challenges do you have to deal with during different stages of blue mussel farming implementation? - Why do you think the difficulties occur? - Who do you have challenges with?
	License	- Do you think it is hard to get a license for blue mussel farms? - What do you think are the reasons behind this?
	Public/Swedish Government opinion	- What do you think is the opinion of public on blue mussel farming? - What do you think is the opinion of governments on blue mussel farming? - Do you think there are any obstacles when searching for farming locations and farmers? - What do you think makes people become interested in blue mussel farming for coastal eutrophication mitigation processes?
Economy	Economy/Technology	- Do you think blue mussel farming in the Baltic Sea region can become economically sustainable? - How can it happen? - Do you think there is a need for better technology for blue mussel production in the Baltic Sea region?
	Circularity	- Could blue mussels be used for animal feed? Why? - Do you think it has a successful future? Why? - What are the obstacles with blue mussel feed for animals? - What are the strengths with blue mussel feed for animals? - Why do you think obstacles occur? - Do you think there is enough research done on toxins in blue mussels? - Do you think humans could safely consume poultry/chicken fed on blue mussels? Why? - What do you think about blue mussels as fertilisers? - What are the strengths and limitations?
Other	Climate	- Do you think climate change will affect blue mussel farming in the future? How?
	Replacement	- What would serve as a replacement for blue mussel farming?
	Collaboration	- Do you think countries can learn from each other using blue mussel farming method?
		- Do you think different opinion holding stakeholders should exchange their knowledge more? * - If so, do you think there is a need for an internal event? *

Note: The two last questions in the section Other (marked with a star (*)) were developed late in the interview processes and subsequently some stakeholders that were not asked the question during the interview were asked to respond to them by email.

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