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Are Nordic Saltmarshes Europe's Way to 'Live in Harmony with Nature'? Scientists Driven Future Scenarios via a Participatory Workshop

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Abstract: Saltmarshes have the ability to not only promote biodiversity, but to put nations on the path towards climate recovery and net-zero emissions through saltmarshes' capability to take up carbon. As the European Union's (EU) Green Deal sets out to reach net-zero emissions by 2050, innovative solutions will need to be identified, possibly even through better preserving century-old habitats such as saltmarshes. Based on the upcoming needs from the EU, in the Spring of 2021, a workshop was held with leading Nordic saltmarsh and blue carbon scientists using the transdisciplinary methods of Systems Thinking and Bayesian Belief Networks to identify solutions that can include saltmarshes in future policy. These joint methods elicited multiple future scenarios in which data were collected on perceived notions of the value of saltmarshes and how to better govern them to ensure their longevity. The models developed in this study include human perceptions and comprehensive quantitative scenarios through their ability to define paths forward in the form of comprehensive policy recommendations. We found through scenario analysis that a major belief among the stakeholders was numerous events of change such as 'outreach, getting salt marshes on the political agenda and forming new narratives would help to increase saltmarsh area via conservation and restoration prioritization' would have a positive impact of saltmarshes in Nordic countries.

Keywords: saltmarshes; nature-based solution; participatory workshops; Bayesian Belief Networks; biodiversity; Convention on Biological Diversity

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1. Introduction

Saltmarshes are typically coastal grass-dominated land masses that support some of the most productive ecosystems in the world [1]. They provide invaluable benefits (i.e., ecosystem services) such as retention and transforming nutrients and pollutants, controlling floods, and providing protection from storm surges and erosion [2–5]. The area of known data on saltmarshes' coverage in Nordic countries is estimated to be nearly 1440 km^2 [6], which has been on the decline since the end of the last ice age when the ecosystems were formed over 12,000 years ago. Moreover, reduction in the area has accelerated due to dredging and draining the marshes to build roads and houses or even using them as landfills [7] while recent studies show that home values increase when saltmarshes are preserved [8]. Human development and other land use along the coasts also threaten these habitats together as they cannot migrate inland as sea levels rise in many areas—a situation known as "coastal squeeze". The lack of societal knowledge and understanding about the value of marshes, including blue carbon and biodiversity-supporting potentials, are arguably among the reasons behind this habitat degradation and loss. Previous studies have already elucidated their blue carbon potential [9], as well as biodiversity optimization which can eventually lead to improving the recognition of the importance of saltmarshes, increasing priorities for their protection and even restoration [10]. Saltmarshes conservation

and restoration can be regarded as a nature-based solution (NBS) that can mitigate against and adapt to climate change impacts such as sea level rise, extreme weather events and increased CO_2 atmospheric concentration [3,11]. Saltmarshes can also help avoid emissions through protecting these specific ecosystems and thus reducing carbon's release [12].

We start our analysis by first providing background information about the role of Nordic saltmarshes in climate change adaptation, followed by an examination of the methodological setup and conceptual framework of the study. We then present the results of the participatory workshops and review policy action plans and challenges in managing saltmarshes in a region where outdoor activities and climate change mitigation are both under pressure. We conclude by discussing the importance of increasing our knowledge of these habitats in the Nordic region considering its role as natural protection against natural hazards and identify stakeholder-driven pathways to live in harmony with nature by 2050 via saltmarshes. This study examines saltmarsh habitats and combines the work of both natural and social scientists to identify saltmarsh's role in climate change mitigation and adaptation, while also assessing the decisions of landowners and government choices ruling over the management and areas of these habitats. Transdisciplinary research is vital as it can be incorporated into various natural and socio-economic frameworks such as the recent United Nations (UN) Biodiversity Conference where nations are informed by science to protect 30% of the Earth's land and 30% of the sea [13]. In this first-of-its-kind study, the aim is to disseminate results from the first stakeholder workshop which can be used by local and regional policymakers in their attempts to limit carbon emissions and warming temperatures across Europe. The workshop was held in March of 2021 and aimed to analyze and convey perceptions from scientists on what is needed to create concrete policy actions and future scenarios to ensure that Nordic saltmarshes are in as-good or better condition in the future compared to today. The findings may help define the best practices for policies and management to support saltmarshes and their role in climate change mitigation, adaptation and in stimulating biodiversity.

2. Background

Regardless of the powerful tools we have in internet search engines when googling the phrase 'saltmarsh' or 'Nordic saltmarsh' from popular science to news articles, the results about these habitats are scarce. Why is it that these remarkable habitats are rarely mentioned when it comes to solutions to ecosystem services and climate change adaptation? Moreover, these saltmarshes are vegetated marine habitats that store carbon in their plants and soils [14,15], also known as blue carbon [16]. They are found across coastal states and have been proven as a nature-based solution (NBS) for fighting coastal erosion, as well as increasing biodiversity [17–19] which will be vital in achieving the European Union's (EU) Green Deal goals of no net greenhouse gas (GHG) emissions by 2050 [20]. The Nordic Council of Ministers has created a strategy to invest more in climate adaptation and blue carbon for the Nordic region to be the 'most sustainable and integrated region in the world' [21,22]. In doing so, it is important to better understand these habitats and the stakeholders closely integrated with them to produce smarter policies as part of the science–policy interface.

To date, there have been few and far between systematic studies taking the work from natural scientists and combining it with the social sciences when it comes to Nordic saltmarshes. Utilizing stakeholder-driven data is critical for policymakers to better understand where potential conflicts in regulation might likely occur. Understanding stakeholder knowledge, such as how groups perceive potential changes in management and how it will affect them is vital to identifying and solving roadblocks before they begin [23]. This type of method is called scenario development, which was coined by Herman Kahn, and aids in realizing the interactions between social, economic and political factors [24] affecting research, which is often overlooked when undertaking traditional single-discipline studies.

Saltmarshes are found where the marine environment meets the terrestrial [1] and are often at the mercy of landowners and local regulations to ensure that their area does

not decrease. Given this, the need to rethink how Nordic saltmarshes are managed and subsequently how citizens perceive them will be important to answer the EU's Green Deal call—where citizens are empowered to aid in the transition towards a climate-neutral European future [25]. Considering this, our research brought the first round of stakeholders together via a participatory workshop with Nordic coastal marine and saltmarsh ecologists intending to understand how future scenarios affect Nordic saltmarsh extent and ecosystem services. The ultimate goal of these workshops is to aid in policy decision support management, which provides scenarios to policymakers in attempts to uncover how the system (Nordic saltmarsh) may be affected depending on which policy decisions are made. This is coupled with the aim of halting the degradation of current marshes, increasing the resilience of existing ones and providing incentives for saltmarsh restoration. Finally, we embrace the declaration from 2019 from the Nordic Council of Ministers and hereby strive to bridge the gap between policymakers and the management of land and coastal areas by communicating results that are easily accessible to citizens, stakeholders and policymakers.

3. Methodology and Scenario Development

Transdisciplinary studies are increasingly becoming the norm in research to aid in solving real-world problems [26]. Without an understanding of the entire system, studies are closed off to factors, both social and natural matters, that could be of influence. This is especially apparent when working with environmental research where 'science for society' must be evidence-based and include real-world impacts [27]. Therefore, this study's participatory workshop combines the semi-quantitative workshop outputs with qualitative research. The mixed-methods approach utilized in this study began by gathering the core project team of both natural and social scientists in a workshop to lay the foundation for transdisciplinary research into saltmarshes. These same methods can be used in broader sectoral workshops with various stakeholders; however, for the case of this study, these results are from academic coastal marine and saltmarsh ecology experts. We argue that because of this expertise, the results represent a starting point to further develop stakeholder perceptions for sectoral workshops in different case areas. From our workshop results, we wanted to explore and explain what this entails in terms of public awareness, political prioritization, regulation limitations and adaptation options and how these affect management and adaptive capacities at different governance levels of analysis.

The methods used were based on the need to quantify narrative-rich knowledge based on saltmarshes to make positive management decisions. This methodology helps to identify and understand how to optimize environmental decisions from a large list of priorities and values [28]. This is vital as management decisions should come from a wide range of stakeholders who have various ways of addressing and seeing a given problem. The process of conducting a mixed-methods study does not come without trade-offs. One "type" of method does not necessarily serve as a corroboration of another, nor does an addition of the second method ensure a complete reality. We understood from the previous literature [29,30] that there could be at least four outcomes of the results when combining these types of methods. The results from the different processes could *corroborate*, *elaborate*, *complement* or *contradict* each other. We addressed this by building in a step of user validation of the analysis.

The workshop was facilitated and run using the "*Systems Thinking*" method [31–33]. Systems Thinking uses a step-by-step problem-solving approach. This provides researchers the ability to understand problems from the underlying system feedback structure by eliciting information interactively from stakeholders—scientists in this case—who work in the given system of saltmarshes. Systems Thinking uses graphical tools in a workshop setting to explore real-world problems and discuss opportunities and pitfalls moving forward [34]. This process takes the form of the group identification of components and aims to develop a stakeholder-driven representation of a system. The models from this study are graphical visualizations of a basic construct of the system feedback structure and

rely on both qualitative and subjective interpretations of the results from the workshops [35]. The next section will explain more thoroughly the types of methods utilized in this study.

4. Conceptual Mapping with Vensim©

To set the scope for the workshop, we consulted with the team of five scientists regarding the selection of seven main themes or 'drivers' that would affect Nordic saltmarshes and their preservation, use and restoration of them. To do this, however, and to ensure cross-country comparison—and in future, cross-sectoral work—there is a need for methodological coherence. We, therefore, started with establishing initial drivers to be used in the mental modeling exercise by creating a conceptual map. This method of developing the drivers has been used in several studies previously [36–40]. We carried this out by first encouraging the core project group to come up with the main drivers individually; this was conducted by sending a link to a SurveyMonkey© questionnaire where they were allowed to suggest up to eight drivers which affect saltmarshes. The survey responses were sorted, and drivers were chosen if at least two researchers agreed upon them in the later validating session. In total, the scientists submitted 23 variables of similar context which were narrowed down to 6 overarching variables in total by the time of the workshop. The final list of drivers, decided upon by the core group of natural scientists, was (in no particular order): grazing, water level, climatic stressors, nutrient levels, human manipulation, and governance.

After agreeing on the variables as a group, the participants were informed that these drivers were for the purposes of discussion starters, and they could be changed to more relevant ones if needed. The conceptual map consisted of components or variables with key relationships between them. The purpose of a conceptual map is to use it either as a research tool for further exploration and quantitative modeling, or as a management tool for consensus-building amongst stakeholders and for exploring possible actions, whether at local, regional or global levels of governance [41,42]. A conceptual map was created as a way to allow stakeholders to be in the mindset for the next part of the workshop, which brought in scenario development known as Bayesian Belief Networks (BBN).

5. Bayesian Belief Networks

BBN was chosen to gain critical insight into future scenarios of policy options for understanding how to achieve Nordic saltmarshes that are in as-good or better condition as they are today. There are documented benefits to using BBNs such as high flexibility in causal relationships, the ability to integrate information from multiple sources, as well as answering several probabilistic queries about a specific topic needing input from expert sources [43]. This also allowed the stakeholders to think more critically and individually as compared to the group's conceptual Vensim map made in the first half of the workshop. Netica (www.norsys.com, accessed on 17 February 2022) was the software used for BBN modeling. The process of quantifying narrative-rich and inherently qualitative knowledge to make management decisions is difficult at best. On these grounds, BBN modeling was selected as the methodological framework for further exploration into future decision-making. BBN modeling utilizes the Bayes theorem, which facilitates diagnostic (bottom-up) and causal (top-down) inference of an acyclic graph [44]. In addition, it facilitates participatory modeling and is well-suited to represent causal relationships between variables in the context of variability, uncertainty and subjectivity [45]. This has been carried out before in biodiversity-related studies, demonstrating its ability to estimate trade-offs and synergies between ecosystem services [46].

The methodological process of developing BBNs through stakeholder engagement is outlined in detail elsewhere [38,40,47]. Briefly, however, the structure of a BBN is a system of nodes that are connected by arcs. Each node is treated as a variable, and therefore, must have more than one state, i.e., a negative and a positive state as defined by workshop participants (Figure 1). The underlying probabilistic framework (i.e., Bayes theory) provides a mechanism of directly integrating social, economic and environmental variables within

a single model [48]. The model represents a group-level belief about which variables are included and how the arcs connect them. Later, each stakeholder populated the Conditional Probability Table (CPT) with their probabilities providing individual-level parameterization. This was carried out directly after the group workshop, using SurveyMonkey©, where the probabilities they produced were laid out as several scenarios and the respondents were asked to rank these in terms of the probability of each becoming a reality. The individually parameterized CPTs were then combined into a single model as they share the same structure but have different values within the CPTs.

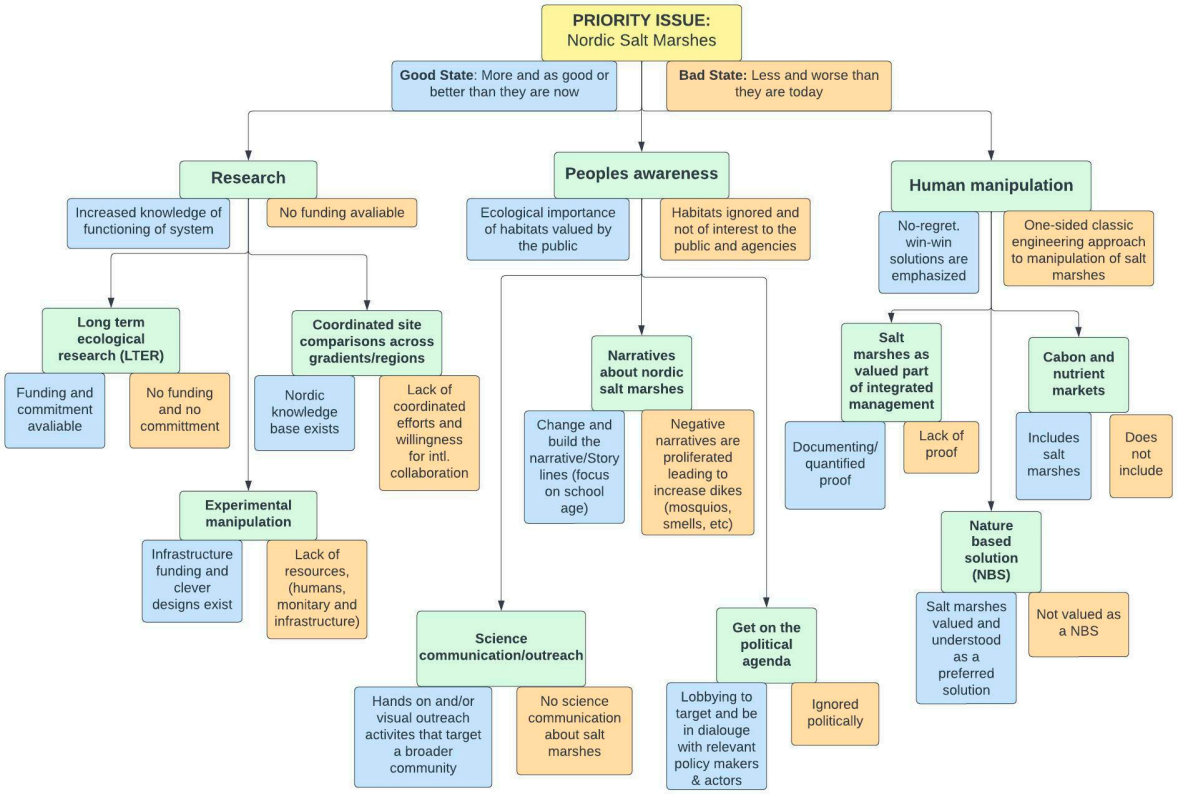

Figure 1. Priority issues mapped with online sticky notes during the workshop and later transferred to LucidChart for better readability. The green boxes represent the various 'stem variables' while the blue boxes are the 'good state' of said scenario and the orange represents the 'bad state' or worse case state of the stem variable, as decided upon by the workshop participants.

6. Results

The first workshop commenced when five scientists met together on the Microsoft™ Teams platform in March of 2021 with one senior researcher (workshop facilitator) and two research assistants. The first half of the workshop was dedicated to verifying the 'drivers' of the discussion (shown in blue boxes in Figure 2) and completing the mind map. The discussion started when the workshop facilitator asked participants to identify connections between the drivers, which started with 'grazing'. This was an important driver to the stakeholders as they believed that "*grazing affects/influences everything*" (Stakeholder 2). Nordic saltmarshes have been grazed for centuries and the scientists understood that this brings a higher diversity of plant species to the area rather than natural reed beds. However, one variable identified that will require more research is "which is better for carbon sequestration—grazed or ungrazed marshes?" The hypothesis by the stakeholders was that grazed saltmarshes would decrease carbon sequestration and biomass, but the current data on this are inconclusive.

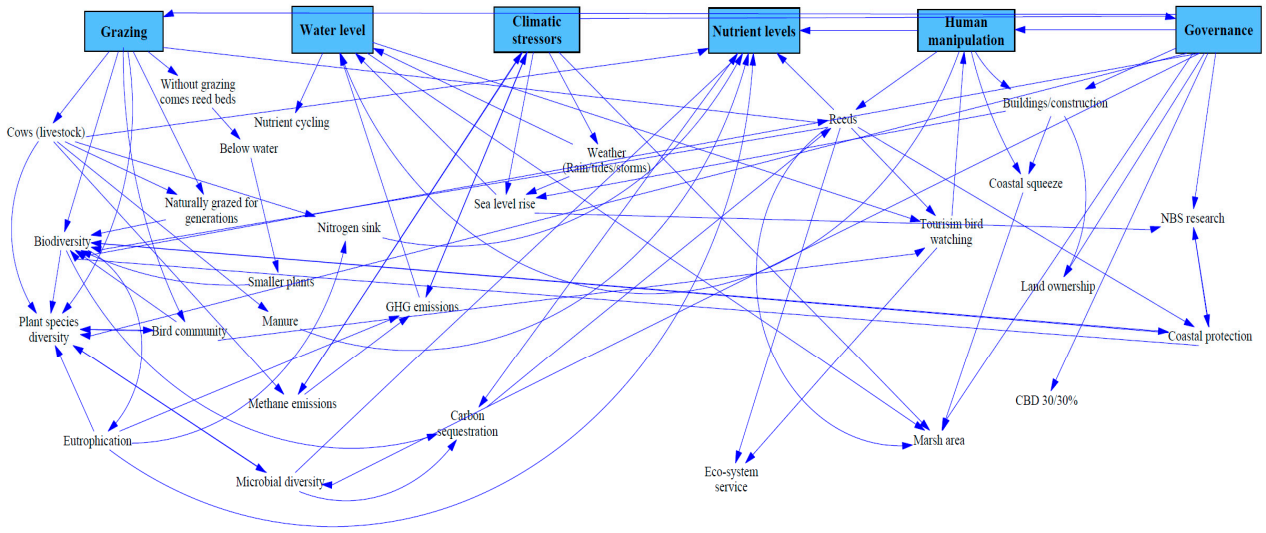

Figure 2. Vensim (vensim.com, accessed 3 March 2023) developed in the workshop. This is the representation of the systems-thinking part of the workshop, where the saltmarsh scientists discussed the effects of Nordic saltmarshes via the presented drivers (top blue boxes).

The results from Figure 2 and identifying interconnected processes within Nordic saltmarshes took nearly two hours and were later combined into a more minimalistic version, as seen in this paper by analyzing the transcription from the workshop and the first Vensim conceptual map after the workshop. The results represent a group model or collective view of causal pathways between variables as perceived by the scientists. One variable in particular, biodiversity, stood out during the workshop as a legitimate priority variable—meaning it is interconnected between multiple drivers and other variables, as demonstrated in Figure 2. This has identified an important discussion point to reach out to policymakers on saltmarshes' relation to biodiversity. The results of this are seen in the dendrogram in Figure 3. Biodiversity was a variable that the scientists anticipated would emerge as a priority variable to be further investigated. This assumption was well supported in the conceptual map and workshop discussions, as upon review of diagnostic plots in the Vensim program, we can see 'uses trees' that further reflect the interconnected nature of biodiversity on Nordic saltmarsh habitats. Transcribing the workshop helped to bring perceptions of the biodiversity connections:

"*Plant size is affected by grazing and the reeds are what you get without grazing. This is why grazing has been chosen as a biodiversity manipulation for a long time because you get smaller plants, so you get higher biodiversity*" (Stakeholder 1).

The workshop also brought out challenges within biodiversity and governance.

"*. . . biodiversity has traditionally been considered as plants and birds. However, governance affects whether a saltmarsh is grazed*". (Stakeholder 4) Leading to a higher or lower rate of biodiversity.

Bird species were also an important part of the biodiversity of a saltmarsh where *'A lower plan biodiversity affects bird species'* (Stakeholder 1). This process of conceptualizing conflicts and connections aided in the transition to the next stage of the workshop and the BBN exercise.

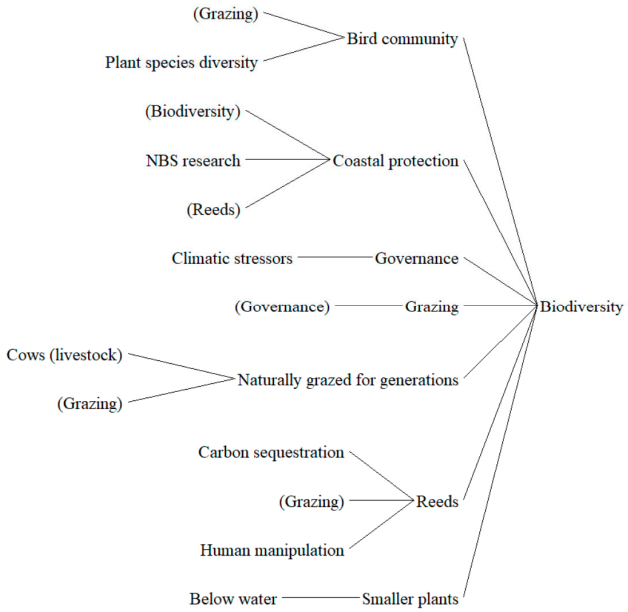

Figure 3. Vensim dendrogram highlighting the hierarchical network of stakeholder-identified elements connected to the biodiversity of saltmarshes.

7. BBN and Scenario Results

Given that the end of the participatory workshop is to create stakeholder-driven scenarios which can be manipulated by policymakers, the following section presents the outcomes of this process. This section compares priority issues, primary and secondary variables and preferred outcomes from the second half of the workshop. The priority issue for the scientist workshop was that Nordic saltmarshes should be good or better than they are today. Guidance was given on the selection of dichotomous states that each variable should provide a desirable and undesirable state, respectively (See Figure 1). For the next step of the BBN development process, the stakeholders were to identify three primary variables that they were told would directly influence their capacity to manage their priority issue at the most desirable state. After a round of discussion, the stakeholders agreed upon the following three primary variables (where dichotomous states were assigned to each):

- Successful research (states = 'increased knowledge', 'no funding available');
- People's awareness of Nordic saltmarshes (states = 'valued by the public', 'habitats ignored');
- Human manipulation of saltmarshes (states = 'win-win solution', 'one sided approach').

The stakeholders, together, were then asked to assign percentages to each of the three primary variables. This was to reflect the proportional influence that these had on the priority state of saltmarshes being good or better than they are today—the separate percentages summed up to 100%. The results are presented in Figure 4, which demonstrates that the stakeholders anticipated that if 'business as usual' were to remain, there was less than a 44% chance that saltmarshes are good or better than they are today.

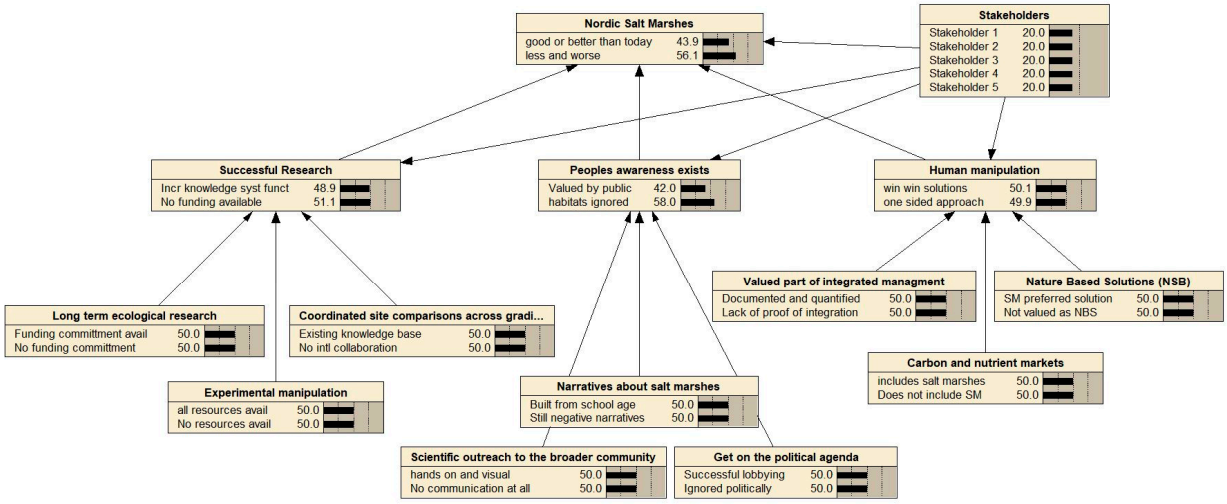

Figure 4. Modelled probability outputs of BBN in the state of 'business as usual'.

After the workshop, the BBN developed by the scientist's stakeholder group was subjected to a control test (Figure 5). This is a formal diagnostic process whereby the primary variables are manipulated to see which has the greatest impact on the priority issue when adjusted. This analysis highlighted that the influence of successful research and having saltmarshes valued by the public could increase Nordic saltmarshes to be over 70% good or better than they are today. The importance of this was also reflected in the narratives where scientists believed to date that there is far too little long-term research funding going into saltmarsh research as well as not being valued by the public.

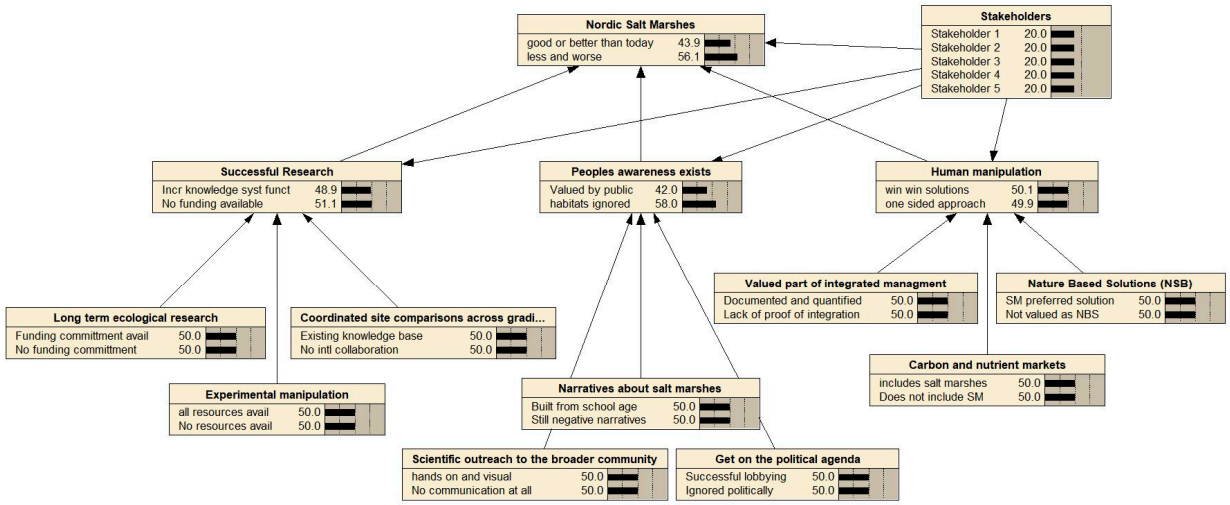

Figure 5. Manipulated probability outputs with specific stem variables being set to 100% (seen in grey).

Finally, when investigating the auxiliary node representing the individual stakeholder beliefs (top right node in Figure 5), it was observed to have not so strong of an influence on the priority node (top middle node in Figure 5). This demonstrates that there was little variability and/or divergence between the scientists' opinions, and for the most part, they shared very similar perceptions about the scenarios they were individually asked to weigh. This is comparable to the data gathered from the conceptual map, where stakeholders discussed the need for more public awareness around what saltmarshes are and the benefits they can provide to society. These probabilities of BBN scenarios can be used as a tool by policymakers to understand how their decisions on saltmarshes can affect the entire system. Policymakers can then manipulate scenarios under research, awareness-raising and human

manipulation to better understand the outcomes of how to better preserve saltmarshes in the Nordic region.

8. Discussion

The results demonstrate how utilizing scenario analysis via the BBN methodology in a workshop setting can aid in uncovering barriers and opportunities in policy for improving saltmarsh's habitats, thus increasing their ecosystem services and ability to take up carbon. In the first round of scenarios, the stakeholders from the natural sciences believed that three key elements are needed to ensure that saltmarshes have an as-good or better status in the future than now; these were: (1) to increase public awareness of their importance, (2) put saltmarshes on the political agenda and (3) provide funding for further research. This then indicated that more research on the ecological functions of saltmarshes under different management scenarios would support management decisions to increase saltmarsh land area and associated benefits for climate change mitigation, adaptation and biodiversity. The results of this study demonstrated how stakeholder-driven scenarios can be used to develop policy input and action. These results should be communicated to land managers and policymakers who are tasked with becoming climate neutral by 2050. It should be kept in mind that the perspectives represent the specific team of scientists involved in the study and could vary for other stakeholder groups. Hence, the recommendations should not stand alone any more than biological data should, but represent an important first step to integrating social and natural sciences in management recommendations. Finally, what we see in the BBN diagrams is that scientists consider that the most likely and high-impact scenarios or saltmarsh longevity involve the need for more research on saltmarsh ecological research in combination with increased public awareness on the importance of saltmarshes and putting them higher on the policy agenda as nature-based solutions addressing multiple societal challenges.

9. Conclusions

The main aim of this research was to provide the methodological backdrop in scientists' future scenarios for saltmarsh management. This will then be taken to local stakeholders in five Nordic case areas to further develop the results and validate based on more stakeholder groups. So, are Nordic saltmarshes northern Europe's way to live in harmony with nature? When examining this question at the *global level*, one can find that the recent adoption of the UN Global Biodiversity Framework will require numerous solutions towards fighting biodiversity loss and reducing emissions—NBSs such as preserving saltmarshes can indeed be one piece of the puzzle. The same can be found at the *regional level* within the EU's Green Deal, which made the promise to reach net-zero emissions by 2050. As any global regulation will need to be implemented at the *national level*, it is important to invest in research that is area-based. Investing in transdisciplinary research can also aid in translating results into policy action. The lessons learned from this process are that when we co-produce knowledge in collaboration with stakeholders, we can better assess opportunities and pathways forward for challenges to a given issue area which can then be translated into policy action. This is especially true with complex issues such as climate change. The stakeholders within this field are diverse and attempt to come up with joint solutions to this challenging issue. Further work includes bringing in other stakeholders from various Nordic *local level* sectors involved with Nordic saltmarshes (landowners, policymakers, public) into separate workshops and then finally holding a joint workshop where we can develop a joint policy action plan based on a selection of the "best" scenarios developed during these workshops. This analysis is thus a first step of a larger process involving multiple and diverse stakeholder groups in decisions regarding the fate and management of Nordic saltmarshes which contribute important but sometimes overlooked benefits to society.

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