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Governance for a Resilient Baltic Sea Ecosystem

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Abstract: The Baltic Sea has one of the most established governance regimes, evolving with the Helsinki Convention in 1972 to protect the ecosystem. This agreement has changed and now includes signatories of all the Baltic Sea Coastal States, eight of which are EU members and Russia, the only non-EU state. Despite this robust governance regime, the Baltic Sea is subject to numerous anthropogenic stressors, including nutrient enrichment from surrounding farms and from wastewater treatment plants. This has compromised the ecosystem integrity, resulting in a Baltic Sea plagued by eutrophication which threatens the provision of ecosystem services. This paper investigates how human actions can be governed to ensure a resilient Baltic Sea Ecosystem. It examines eutrophication governance of the Baltic Sea through the lens of resiliency. It looks at the seven pillars of building resiliency as found in the literature: maintaining diversity and redundancy, managing connectivity, managing slow variables and feedbacks, fostering complex adaptive systems thinking, encouraging learning, broadening participation and the promotion of polycentric governance systems. Ultimately, this paper aims to guide policymakers on actions to restore the Baltic Sea ecosystem resiliency to ensure continued provision of ecosystem services.

Keywords: Baltic Sea, environmental governance, resiliency, eutrophication, policy, nutrient enrichment

1. Introduction

The Baltic Sea is a large transboundary water system in northern Europe and is shared by nine coastal countries: Germany, Poland, Denmark, Sweden, Finland, Russia, Latvia, Lithuania and Estonia (Figure 1). Its catchment area also encompasses five more countries: Norway, Belarus, Ukraine, Slovak Republic and the Czech Republic. Its coast is home to 85 million inhabitants, who exert much anthropogenic stress on the ecosystem of the Baltic Sea. This coupled with the its shallow nature, large drainage basin and changing meteorological conditions, makes its ecosystem particularly vulnerable to pressures such a nutrient enrichment from agriculture and wastewater treatment plants, hydrologic modifications and aquatic invasive species. Moreover, nutrient enrichment leads to eutrophication which is regarded as the most serious threat to the resiliency of the Baltic Sea ecosystem.

However, the initial efforts at governing the Baltic Sea focused heavily on diplomacy rather than pollution control with the signing of the Convention on the Protection of the Marine Environment of the Baltic Sea Area (also known as the Helsinki Convention) in 1974, and establishing the Helsinki Commission (HELCOM) as the oversight body. This governance arrangement has evolved into a complex multilevel governance arrangement with many levels of actors including macroregional (European Union), national, regional, municipal, community and private. Despite this, environmental problems such as eutrophication abound and threaten the resiliency of the ecosystem. These changes will continue and will be exacerbated with the all encompassing stressor of climate change. How then can the capacity of the governance system be built to deal with unexpected change? This is a question of resiliency, moving beyond looking at the governing of the ecosystem

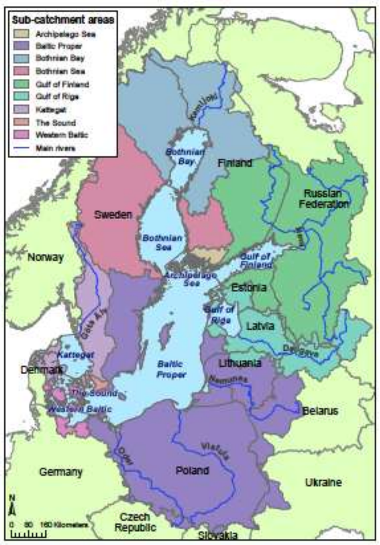


Figure 1. Figure showing the Baltic Sea catchment area and sub-basins [1]

to recognizing that it is the actions of actors that affect the ecosystem and the interaction of actors and nature that needs to be governed. As such, this paper aims to investigate how the interacting systems of actors and the Baltic Sea environment can be governed to ensure resiliency to eutrophication, so that there is continued provision of ecosystem services.

This paper examines eutrophication governance of the Baltic Sea through the lens of resiliency. It assesses the seven pillars of building resiliency as found in the literature [2]: maintaining diversity and redundancy, managing connectivity, managing slow variables and feedbacks, fostering complex adaptive systems thinking, encouraging learning, broadening participation and the promotion of polycentric governance systems. Ultimately, this paper aims to guide policymakers on actions to restore the Baltic Sea ecosystem resiliency.

2. Baltic Sea Eutrophication Governance

2.1 Eutrophication of the Baltic Sea

Eutrophication is one of the most serious environmental problems plaguing the Baltic Sea. The problem is not new as the Baltic Sea has been designated a eutrophic marine environment since the beginning of the 20^{th} century [3]. The entire Baltic Sea is considered affected by eutrophication, with the sole exception of the open Bothnian Bay [4]. This is driven by anthropogenic inputs of the nutrients nitrogen and phosphorus from the large catchment area of more than 1 700 000 square km[5]. The population density varies from less than 1 person per square km in the northern and northeastern parts to more than 100 persons per square km in the south and southwestern parts [5]. The land use structure follows the same pattern, a high proportion of farmlands in the eastern, western and southern parts and mainly forests, wetlands and barren mountains in the north [5]. Land based sources of excess nitrogen and phosphorus are the main causes of eutrophication of the Baltic Sea, with approximately 75% of the nitrogen load and at least 95% of phosphorus load enter the Baltic Sea via rivers or waterborne discharges [5]. The remaining 5% of nitrogen load originates from atmospheric depositions [5].

2.2 Eutrophication governance

Governance moves beyond government to include non-state actors and institutions (Hooghe and Marks, 2001) steering activities for eutrophication abatement efforts. Management operationalizes the vision and implements the decisions made by governance actors. Formal Baltic Sea governance efforts evolved into a multi-level governance arrangement with HELCOM. HELCOM moved beyond diplomacy to pollution abatement efforts in the 1990s when it shifted focus to more real-world measures. One example of this was the introduction of pollution 'hot spots' of inadequate wastewater treatment introduced in 1992, which were mostly delisted under HELCOM's Joint Comprehensive Environmental Action Programme [8]. Moving forward, in 2007 the contracting parties (the Coastal states and the EU) signed the Baltic Sea Action Plan (BSAP), which sets out a programme for the achievement of the good ecological status of the Baltic Sea by 2021. Eutrophication is one of the four focus areas, along with biodiversity, hazardous substances and maritime traffic. Under the BSAP, HELCOM set a goal of a Baltic Sea unaffected by eutrophication as evidenced by concentrations of nutrients close to natural levels, clean water, natural level of algal blooms, natural distribution and occurrence of plants and animals and natural oxygen levels [6]. In order to achieve this, the contracting parties agreed to country-wise nutrient reduction requirements set by HELCOM in order to diminish nutrient inputs in each sub-region of the Baltic Sea to the maximum allowable levels [6]. Implementation of these measures is left to each contracting party.

In addition to HELCOM, there are other actors in the Baltic Sea eutrophication governance, some introduced through EU measures. All of the coastal countries with the exception of Russia, are also signatories to several EU directives that have implications for nutrient inputs to the Baltic Sea. These include the Marine Strategy Directive (MSD), the Water Framework Directive (WFD), the Urban Waste Water Treatment Directive (UWWTD), the Nitrates Directive (ND) and the National Emissions Ceilings Directive (NECD). The MSFD aims to achieve good environmental status of the marine environment by 2020 through an integrated cross sectoral approach. These other directives stipulate standards for water quality of surface and ground water, for wastewater treatment, for agriculture and for airborne emissions of nitrogen oxides and ammonia. The EU has also unveiled a macro-regional strategy for the Baltic Sea, the European Union Strategy for the Baltic Sea Region (EUSBSR) in 2009 with three key objectives to save the sea, connect the region and increase prosperity [9]. For implementation, the Action plan contains thirteen policy areas (PA) and four horizontal actions (HA), under which a number of flagship projects have been funded.

Other actors in Baltic Sea governance include municipalities and non-governmental organizations. Organizations such as the Union of Baltic Cities (UBC) serves as a common forum for cities to address Baltic Sea matters, such as sharing of agricultural best practices to reduce nutrient input into the Baltic Sea. A lot of these organizations have applied for and achieved observer status to HELCOM, which gains them the right to attend HELCOM meetings but not to take part in the decision making process. A comprehensive list of these organizations can be found on HELCOM's website.

3. Methodology

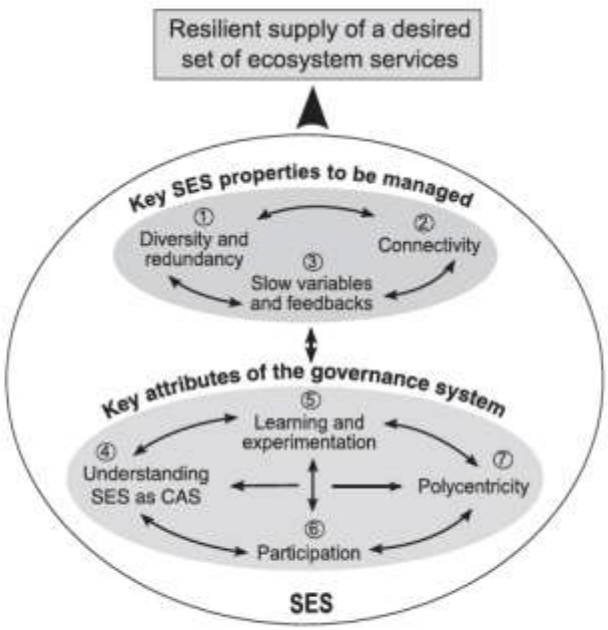
3.1 Theoretical Framework - Social Ecological Systems, Ecosystem Services and resiliency

Whist the literature speaks to water governance, it is really the governance of human actions that impact water resources. The concept of social-ecological system (SES) was introduced to capture the process linking humans, the environment, and the feedback system between them; SES places equal emphasis on the resource to be managed and the social institutions impacting and impacted by the resource [10]. SES are complex adaptive systems (CAS), or self organizing systems that can change and reorganize in response to a stressor, such as nutrient enrichment. Under the lens of eutrophication, as an example, agricultural practices result in nutrient leaching into the Baltic Sea impacting its ecosystem, resulting in the growth of algae and affecting the recreational value of the Sea and the ability of fish to survive in the Sea. The recreational value of the Sea and the ability of fish to survive and thus be available for fishing, are called ecosystem services (ES). ES are the benefits people derive from an ecosystem and they include provisioning services such as food and water, regulating services that affect climate such as floods, diseases, wastes and water quality and cultural services that provide recreational, aesthetic and spiritual benefits and supporting services such as soil formation, photosynthesis and nutrient cycling [11]. A resilient Baltic Sea ecosystem unaffected by eutrophication will be providing ecosystem services such as food (fish), recreation (boating, habit for cottages, swimming), aesthetics value and commercial value of shipping unaffected by eutrophication.

Whilst engineering has conceptualized resiliency as the reestablishment of a disturbed system back to a preferred and restored steady state, ecological resiliency refers to a concept of multiple steady states and a bouncing forward under disturbance to a new steady state. Under the latter lens, the resilience of a natural system such as the Baltic Sea is defined as "a measure of the ability of the system to absorb a change of state variables, driving variables and parameters and still persist" [12, p17]. Seen through this lens, resiliency embraces variability, redundancy, and learning and focuses on policy that allows the system to embrace change, rather than controlling it [13].

3.2 Principles for enhancing resiliency

This paper uses principles for enhancing resiliency developed by the Stockholm Environmental Institute (SEI), developed by a literature review and enhanced through key informant interviews with experts and by experts. These principles are as follows: (P1) maintain diversity and redundancy, (P2) manage connectivity, (P3) manage slow variables and feedbacks, (P4) foster an understanding of SES as complex adaptive systems (CAS), (P5) encourage learning and experimentation,(P6) broaden participation, and (P7) promote polycentric governance systems [2] (Figure 2).



(**a**)

Figure 2. This is a figure showing the seven principles for enhancing resiliency of a SES system, grouped into those that relate to generic social-ecological system (SES) properties to be managed and those that relate to key properties of the SES governance [2]

3.2.1 (P1) Maintain diversity and redundancy

In a Social-Ecological System (SES) such as the Baltic Sea ecosystem, elements of the system can exhibit diversity such as the population, cultural groups, livelihoods, landscape, and governance institutions. These elements provide different options for responding to changes such as nutrient enrichment and dealing with uncertainty and surprise. Whilst diversity includes variety (how many elements), it also encompasses balance (how many of each element), and disparity (how each element differs from the other)[14]. Ecosystem services such as recreational value and aesthetics are produced by many SES elements, each with different reaction to stressors due to physical characteristics, different timings, or different spatial scales; this variety allows some system elements to persist through disturbances, continuing to provide ecosystem services [2]. A related principle, redundancy refers to the replication of each of these elements or pathways in the system [15]. It allows some system elements to compensate for the loss of others [2].

3.2.2 (P2) Manage connectivity

Connectivity refers to the nature of connections between individual elements of the social-ecological system. It is defined by the way and degree with which resources, ecosystem elements and actors interact across patches, habitats or social domains the SES [2]. The structure (presence or absence of links between components) or strength (intensity) of connections between nodes (system elements such as landscapes, actors, patches) determines the effect of connectivity on resilience [2]. Structure in the eutrophication governance network can refer to the communication channels between HELCOM actors and EUSBSR actors whilst strength would refer to the frequency of interactions such as meetings and phone calls amongst these actors to discuss eutrophication of the Baltic Sea issues.

3.2.3 (P3) Manage slow variables and feedbacks

The presence of algae in the Baltic Sea is linked to slowly changing variables such as phosphorus content of the bottom sediments, which can be connected to the amount of phosphates applied to fields in the watershed. The underlying structure of the SES is determined by slow variables, but the functioning of the SES arises from connections and feedbacks between fast variables that respond to conditions created by slow variables [2]. Feedbacks are the two-way connections that loops variables that can either reinforce (positive feedback) or dampen (negative feedback) the effects of stressors on the system [2]. An example of positive feedback in eutrophication governance is the introduction of non-governmental actors into the decision making process, who then introduce their networks into the governance, leading to more communication and flexible decision making structures. An example of dampening feedback in eutrophication governance is monitoring information that reveals that too much phosphorus is entering the Sea, which leads to adjustment of fertilizer applied to the fields, which leads to reduced runoff into the fields.

3.2.4 (P4) Foster an understanding of SES as complex adaptive systems (CAS)

Eutrophication can be described as a wicked problem, where knowledge is incomplete and actor values can be conflicting. A complex adaptive systems (CAS) approach means that key actors such as scientists, mangers and decision makers understand that several connections can be occurring simultaneously and at different scales [2]. For eutrophication governance, in order to build resilience and continue providing ecosystem services, it means that the unpredictability and uncertainty of the SES is acknowledged and that a number of different viewpoints are considered in the governance process. This means building management systems that accommodate uncertainty through learning and experimentation, rather than trying to eliminate it. Resilience is enhanced through this principle through integrated approaches that acknowledge the importance of slow variables, lags and feedbacks in the SES system.

3.2.5 (P5) Encourage learning and experimentation

Learning refers to "the process of modifying existing or acquiring new knowledge, behaviors, skills, values or preferences" [2, p494]. For eutrophication of the Baltic Sea, knowledge is always incomplete or changing. The phosphorus loading of the Sea changes as does the amount of fertilizers that runoff from crops or the loading of phosphorus in wastewater from sewage treatment plants. Constantly monitoring and incorporating this new knowledge into simulation models means that there is a greater chance to represent reality, leading to solutions that can be implemented easily. When different types of knowledge are appreciated and incorporated into the decision making process, it leads to more buy in of the information, a greater system flexibility leading to more experimentation and risk taking. Learning can occur at multiple levels, leading to different ways of enhancing resilience. Single loop learning involves asking the question, are we doing the right things (changes can be made through changes in skills, practices) while double loop learning involves asking the question, are we doing the right things (e.g. considering the impact of nutrient enrichment measures) and finally, triple loop learning involves asking the question, how do we know the right thing to do is this (questions of values and norms are considered) [2].

3.2.6 P6) Broaden participation

Participation by different stakeholders can involve a range of actions from sharing information to being part of the decision making process. Participation refers to the active engagement of relevant actors in the governance process [16]. The participation of a diverse group of stakeholders in eutrophication governance can lead to more acceptance of new regulations, to more monitoring actions at different levels of stakeholders, aid in understanding of the feedback systems that lead to eutrophication. It can also improve the ability to detect and interpret instances of shocks to the system that are e.g. associated with heavy precipitation events. Participation leads to increased collaboration, accountability, and the improved ability to incorporate knowledge into the decision making process [2]. Knowledge of actors such as farmers can be helpful in defining loading limits and implementation measures for nutrient abatement that are realistic and hence, stand a greater chance of being effective.

3.2.7 (P7) Promote polycentric governance systems

Polycentric governance refers to a governing system that has multiple centers of power (polycentric) rather than one decision making authority (monocentric) and is better able to cope with change and uncertainty [17]. Under a polycentric governance system, issues at different geographic scopes can be managed at different scales, leading to greater overlap and redundancy that increases resilience of the system [17]. This is different from multi-level governance which involves different stakeholders at all levels whereas polycentric governance implies the presence of a network of different governance structures that facilitates choice alternatives. Polycentric governance is characterized by dialogue and steering by groups with differing sources of legitimacy, and may be practiced through different organizational types e.g. government department, river basin units, nongovernmental organization etc. [2]. In such systems, each governance unit has autonomy within a demarcated geographic location, and can link with others horizontally on common issues and be nested within broader governance units vertically [2]. Such broader levels of governance can step up when other levels fail.

3.3 Data Sources

This study relies on document analysis of key documents including reports of key Baltic Sea Organizations such HELCOM, the EU and academic literature.

4. Results and Discussion

This section analyzes the seven principles for building the resiliency of social-ecological systems by focusing in on the Baltic Sea eutrophication governance. Each of the seven principles will be discussed as follows: maintaining diversity and redundancy, managing connectivity, managing slow variables and feedbacks, fostering complex adaptive systems thinking, encouraging learning, broadening participation and the promotion of polycentric governance systems [2] (see figure 1).

4.1. Maintaining diversity and redundancy

Since the initial signing of the Convention for the Protection of the Baltic Sea Marine Environment in 1974 (Helsinki Convention), which included only coastal countries, the governance of the Baltic Sea eutrophication has extended to include non-governmental actors. HELCOM has a formal system of registering observers, organizations that can contribute to matters dealt with by HELCOM. However, not all interested parties can be granted observer status. In addition to contributing to HELCOM's mandate, the organization must have a formal structure and must have membership in a wide number of Baltic Coastal States or can be a country that is invited by HELCOM to be an observer [18]. Observers are grouped into two categories; governments and intergovernmental organizations and international non-governmental organizations.

The observers which fall under the governments and intergovernmental organizations are as follows[18]: Government of Belarus, Government of Ukraine, Intergovernmental Agreement on the Conservation of Small Cetaceans of the Baltic North Sea (ASCOBANS), Baltic 21-An agenda for the Baltic Sea Region, Baltic Pilotage Authorities Commission (BPAC), Baltic Sea Parliamentary Conference (BSPC), Baltic Sea Commission (BSC), Boon Agreement, The Great Lakes Commission, Intergovernmental Oceanographic Commission (IOC) of UNESCO, International Atomic Energy Agency (IAEA), International Council for the Exploration of the Sea (ICES), International Maritime Organization (IMO), Oslo and Paris Commissions (OSPAR), United Nations Environment Programme (UNEP), UNEP/African Eurasian

Waterbird Agreement (AEWA), United Nations Economic Commission for Europe (UNECE), Whole Health Organization Regional Office for Europe and the World Meteorological Organization. By including national governments that are not coastal countries, a diversity of views is being entertained by HELCOM and this can lead to different ways of looking at the same issue and innovative problem solving by tapping on different strengths. As noted here, diverse organizations even from outside the region such as the Great Lakes Commission signals the intention to learn from other regions of the world, which is good for building resiliency. However, there is a notable absence of the Food and Agricultural Association (FAO), a specialized agency of the United Nations that aims to achieve food security by supporting countries through capacity building, information sharing, policy transfer, strengthening political will and supporting the transition to sustainable agriculture. Since all the Baltic Sea countries are members of FAO, this organization should be an ally in nutrient reduction measures by agriculture.

The observers that fall under the category of international non-governmental organizations include[18]: Baltic Farmers' Forum on Environment (BFFE), Baltic Operational Oceanographic System – BOOS, Baltic Ports Organisation (BPO), Baltic Sea Advisory Council (BSAC),Baltic Sea Forum (BSF), Baltic Sea States Subregional Co-operation (BSSSC), BirdLife International, BONUS Baltic Organizations' Network for Funding Science (BONUS EEIG) , CEFIC, Coalition Clean Baltic (CCB), Conference of Peripheral Maritime Regions of Europe - Baltic Sea Commission (CPMR), European Anglers Alliance (EAA), European Boating Association (EBA), European Chlor-Alkali Industry (EURO CHLOR), European Community Shipowners' Association (ECSA), Cruise Lines International Association Europe (CLIA Europe, former European Cruise Council (ECC)), European Dredging Association (EuDA), European Network of Freshwater Research Organizations (EurAqua), Fertilizers Europe, European Sea Ports Organisation (ESPO), The Coastal and Marine Union (EUCC), EUREAU (European Federation of National Associations of Water and Wastewater Services), Federation of European Aquaculture Producers (FEAP), Federation of European Private Port Operators (Feport), Global Water Partnership Central and Eastern Europe, Interferry, INTERTANKO, International Association of Oil and Gas Producers (OGP), International Chamber of Shipping (ICS), International Dialogue on Underwater Munitions (IDUM), John Nurminen Foundation (JNF), Local Authorities International Environmental Organisation(KIMO International) , Low Impact Fishers of Europe (LIFE), Marine Stewardship Council (MSC), Nordic Hunters' Alliance (NHA), Oceana, PlasticsEurope, Sea Alarm Foundation, Union of the Baltic Cities (UBC), World Wide Fund for Nature (WWF). This list represents a variety of organizational forms such as NGOs, community groups, international organizations, representing a multitude of interests that directly and indirectly impact nutrient enrichment of the Baltic Sea. Representation includes membership of farmers, oceanographers, shipping, fishers, wastewater operators, all of whom have the potential to provide redundancy as they can overlap in function when it comes to protecting the Baltic Sea from nutrient enrichment, and provide a diversity of responses because of their different sizes, cultures, funding mechanisms and internal structures which can respond differently to social, economic and political challenges. However, it is noted that Russia is a missing actor in most of these organizations, limiting a key player in Baltic Sea nutrient enrichment. Inclusion of Russia in key organizations has the potential to make them more effective at representing the entire Baltic Sea Region, increasing diversity further.

4.2 Managing Connectivity

One of the first steps in managing connectivity is the mapping of the relevant parts and their interactions. This was done in a study evaluating 23 catchment factors that determine total phosphorus and total nitrogen loading to the Baltic Sea using standard correlation and clustering which found that the number of pigs and the human population per Wastewater Treatment Plant per square km were positively related to phosphorus and nitrogen loading [19]. The number of inhabitations connected to the wastewater treatment plant is better correlated to nutrient loads rather than general population density, indicating that correct operating of the plant is important for nutrient reductions [19]. This study also found that the area under cultivation and the number of cattle influences nitrogen rather than phosphorus load and that the area of forests positively impacts load reductions of both nutrients. Trees are important for nutrient immobilization and across Europe, recognizing the impact of forest fertilization on nutrient loading, this practice has been reduced considerably since the 1980s [19]. Measures such as a decline in forest drainage schemes and buffer strips along streams and lakes and modified clear cutting methods have been successful in reducing nutrient losses from commercial forests [20].

Connectivity of social actors in the Baltic Sea system can improve resilience through improved governance opportunities. All but one (Russia) of the Baltic Sea coastal countries are EU members, making them signatories to multiple legislations that have direct repercussions for Baltic Sea policy and management. The EU strategy for the Baltic Sea region (EUSBSR) is an attempt to integrate and enhance cooperation of EU member states in the Baltic Sea region (Germany, Denmark, Sweden, Finland, Estonia, Poland, Latvia, Lithuania) through collaboration on thirteen policy areas (PA) and four horizontal actions (HA). These are captured under three main headings of saving the sea, connecting the region and increasing prosperity. The process of developing the EUSBSR included consultations with the public, which increased information sharing and had the potential to build trust and legitimacy of the strategy. Contributions were received from one hundred sources including member states, regions, non-governmental and international organizations, the Stockholm conference and four round tables at Kaunas, Gdansk, Copenhagen and Helsinki, a Youth Conference in Hamburg and almost one hundred organizations and individuals who responded to an online consultation [20]. These consultations revealed key themes emerging from stakeholders including; recognition of the need for the strategy, recognition of the need for an integrated approach to overcome obstacles, the important role of the Commission in developing and oversight of the strategy, including coordination of the many partners, the need for actions to be followed by concrete impact on the ground, no new institutions and no declarations without assigned actions [20]. The policy area, PA Nutri aims at reducing nutrient inputs to the Baltic Sea to acceptable levels. One achievement of PA Nutri was the organization of a stakeholder seminar 'Reducing nutrient inputs to the Baltic Sea – how to strengthen project partnership in the region, on April 14 2016; this forum provided a good forum for cooperation and interviewed stakeholders confirmed that more cooperation has been developed on water projects [21].

Despite this progress, there has been a number of challenges related to the large number of institutions and organizations in the region. One of the key challenges relates to the functional division of labour amongst the numerous organizations (such as CBSS, UBC, BSSSC, the Nordic Council etc.), a function that the EU cannot accomplish although it is an observer to many of these organizations [22]. The EUSBSR benefits from the institutional density but it is also one of its major challenges. This problem can be traced to unclear agendas and directives of some of the collaborations, a natural consequence of the intergovernmental nature of the institutions where issues are added to be addressed, eroding the mandate of the organization [22]. In order to increase the efficiency of the strategy, there is a recommendation to narrow its scope to channel political energy on specific tasks [22]. Another notable challenge is the absence of Russia from the strategy, as it is the only littoral country that is not a member of the EU.

4.3 Managing Slow Variables and Feedback

There are many different ways in which the Baltic Sea ecosystem can be configured, many ways in which the variables can be connected and interact with one another to reduce nutrient enrichment and hence, enhance ecosystem services. One way of reducing anthropogenic nutrient enrichment from landscape involves the implementation of solutions based on Ecohydrology (scientific basis of hydrology/biota interactions in the catchment, using a systemic framework on how to use ecosystem processes in integrated water resources management), solutions such as closing the water and nutrient cycles and enhancing retention of nutrients on the land [23]. Under this approach, load reductions should be made in river catchments through the enhancement of mosaic catchments, especially where diffuse pollution load is highest. Phosphorus downstream in rivers is transported in particulate form, and the seasonality of phosphorus export increases down the river continuum [24]. Diversified plant community mosaics have the highest potential for nutrient assimilation and as such, the rehabilitation of forest and rush mosaics in river valleys based on native species should be implemented [25]. The annual phosphorus retention in meadows and rushes vegetation of the lowland river floodplain is over 10kg/ha/yr., a figure that has the potential to reduce the phosphorus load on the Baltic Sea by over 10% and can be improved by biomass sequential cropping [25].

The construction of reservoirs is another strategy that can reduce nutrient and micropollutant loads from river catchments for reservoirs act as sinks for contaminants due to the decreased flow (sedimentation further enhanced with flocculants) [26] [27]. A 45% of suspended particulate matter, 28% of total phosphorus and a 34% reduction of total nitrogen was achieved in water outflow from the Sulje W Reservoir in central Poland [26]. These results show that reservoirs are effective for the retention of nutrients and suspended particulate matter, with the processes in reservoirs having the potential to improve the river ecosystem below the reservoir and reduce the impact of nutrients on the coastal area [27]. There are potential downsides to reservoirs including hydrologic modifications and the eutrophication of reservoirs, which is a major ecological problem of surface waters [28]. There are always costs for large environmental improvements but there are low cost alternatives including wetland restoration, reductions in fertilizer use, improved manure management, improved wastewater treatment and phosphate reductions in detergents [29].

Another key area of importance in managing slow variables and feedbacks to improve resiliency of the Baltic Sea to nutrient enrichment is the internal nutrient of the Baltic Sea. HELCOM has reported decreased nutrient inputs to the Baltic Sea since the 1980s, but this has not resulted in corresponding decline in the eutrophied state of the Baltic Sea [4]. Since the 2003-2007 assessment periods, signs of declining nutrient levels were observed in the Kattegat, Bornholm Basin, Eastern Gotland Basin, Northern Baltic Properand the Gulf of Riga, but no signs of decline in chlorophyll trends [4]. There are increasing nutrient levels observed in Western Gotland Basin, Eastern Gotland Basin, and the Gulf of Finland and the Bothnian Sea [4]. The abatement of eutrophication of the Baltic Sea is slowed down by the long residence time in the Baltic Sea, as well as feedback mechanism that release phosphorus from oxygen depleted sediments and also due to the prevalence of blooms of nitrogen fixing cyanobacteria in the main sub basins of the Baltic Sea [4]. Characteristics of the Baltic Sea restrict the mixing of the water, making the problem worse.

4.4 Fostering Complex Adaptive Systems Thinking

The complex adaptive systems (CAS) thinking approach implies the acceptance of uncertainty and unpredictability and the acceptance of multiple perspectives, accepting several connections at the same time at different levels. By inviting observers to its meetings, HELCOM is inviting a diversity of perspectives to inform its mandate. However, the exclusion of Russia from many EU strategies and directives such as the EUSBSR introduces greater uncertainty and barriers to responding to changes in the environment promptly. HELCOM also conducts research for scientific legitimacy of its recommendations but there is no means of evaluating the implementation by its members, other than self-reporting. This limits the ability to evaluate and modify the programs for more efficiency and effectiveness. Also, by not incorporating a flexible loading reduction target in its Baltic Sea Action Plan (BSAP), HELCOM is not accepting uncertainty and change as a natural part of the wicked problem of eutrophication. HELCOM should utilize scenario planning with its members to explore and evaluate alternative development and nutrient reduction pathways and assess the consequences of each action. It should also examine critical thresholds of nutrient loadings that lead to eutrophication, considering system boundaries and thresholds for more effective nutrient reduction measures. Participatory science should be used to develop understanding of the interacting drivers of eutrophication.

4.5 Encouraging Learning

HELCOM is recognized by stakeholders in the region as the scientific leader on Baltic Sea matters. The BSAP is based on results from engineering models, based on scientific inputs. However, much is still to be done to improve knowledge of the system for improved nutrient management measures. There are still a lot of unknowns about internal loading of nutrients in the Baltic Sea, which contributes to the debate of whether nutrient reductions should be inland or in the sea, and this has received much attention in the media in Finland [30]. There is general agreement by HELCOM and most of the literature that both external nitrogen and phosphorus should be reduced to reduce algal blooms but some scientists have also suggested that nitrogen loads should not be limited in order to cut down summertime eutrophication [31]. These scientists believe that due to the uncertainties related to the nitrogen cycle and the cost effectiveness of nitrogen reduction efforts, nutrient reduction measures should focus on phosphorus [31]. They argue that the lower nitrogen concentrations may increase the risk of cyanobacterial blooms, that laboratory experiments do not provide adequate information to guide decision makers and in the long term, phosphorus is limiting primary production [31].

HELCOM has used the NEST model to develop loading targets for the BSAP. According to HELCOM, the total annual cost of implementation of the BSAP is EUR 3 billion [6]. However, it has been criticized for lack of incorporation of cost of implementation with the loading targets [32]. More research is needed to incorporate costing or economic measures into ecosystem models, whilst incorporating a long time perspective and uncertainty [32]. This would also help with implementation measures, as economically less well off countries would have better incentives for implementation measures, as the BSAP and Helsinki Convention are non-binding agreements. The large differences in loading reductions required by member countries leads to significant differences in nutrient reduction costs. Countries such as Russia and Poland with the largest nitrogen and phosphorus reduction targets respectively, face large costs and not corresponding benefits. Further research incorporating socio-economic analysis should also include research on nutrient trading schemes.

4.6 Broadening Participation

Participation through active engagement of eutrophication stakeholders helps to build trust and relationships needed to improve the legitimacy of knowledge and authority during decision making processes. Incorporating members of the public and public organizations into its meetings as formal observers is one step in the engagement of the public in Baltic Sea matters. However, the process of selecting these observers ensures that only organizations that "can contribute to matters dealt with by HELCOM, that it has a membership in a wide number of the Baltic Coastal States and an organised internal structure" can be granted observer status [18]. This process excludes key stakeholders who do not have presence in all the Baltic Sea states, such as local farmers associations. Whilst the Baltic Farmers Forum on the Environment is listed as an international non-governmental organization observer, clicking on the link to its website shows that it is a federation of Swedish farmers, and not representing farmers in the entire Baltic Sea region. Further, whilst members of the public can be invited as observers, they have no permanent seat at the table and hence, no direct voice in the decision making process. Involving groups such as farmers into the decision making process means adding perspectives from the field that can lead to greater understanding of the complex interactions in the ecosystem and also lead to greater acceptance of measures recommended by HELCOM.

4.7 The Promotion of Polycentric Governance Systems

Polycentric governance systems in eutrophication governance imply the presence of a network of different governance structures that facilitate choice alternatives for nutrient reduction measures. It can be argued that the EUSBSR Nutri group and the HELCOM Agri sub groups are steering groups with different levels of legitimacy and as such, represent elements of a polycentric governance system. The EUSBSR Nutri group's legitimacy is rooted in the EUSBSR, which is a macro-regional strategy of the EU and hence represent a binding commitment. On the other hand, the HELCOM Agri group, which is presented as a temporary group on HELCOM's organizational chart to deal with sustainable agricultural practices, is rooted in voluntary implementation of measures and trust. Another example of polycentric governance is the steering by the John Nurminen Foundation, a nongovernmental organization that together with the government of Finland funded and implemented a project in collaboration with St. Petersburg. This project upgraded key Wastewater treatment plants, resulting in the reduction of 1700 tonnes (70%) from 2004, signifying a reduction of almost 30% of phosphorus load into the Gulf of Finland [33]. This represents a polycentric governance system, as it harnessed existing governance structures to facilitate financing alternatives. It harnessed the relationship established by the Finnish Ministry of Environment with the St. Petersburg water utility since 1991, helping in the improvement of sewerage treatment and basic infrastructure of wastewater treatment. The John Nurminen Foundation signed an agreement for the improvement of phosphorus efficiency at the central, southwestern and northern water treatment plants of St. Petersburg. Utilizing its strength in coordination and planning the John Nurminen Foundation led the technical planning of the investment and the coordination of the Finnish and Russian planning work. The Finnish Ministry of the Environment, the Swedish International Development Co-operation Agency (SIDA) and the John Nurminen Foundation participated in the financing of the project, the latter to the tune of 2.5 millino euros [33].

The EUSBSR aims to mobilise all EU funding and policies and coordinate actions of the EU, EU countries, regions, pan-Baltic organizations, financing instructions and non-governmental bodies for a well connected, environmentally sustainable and a prosperous region. Its governance structure holds the promise of polycentric governance, as there are multiple centres of authority. However, in practice, it is a two tiered governance arrangement with the European Commission as the overall coordinator and the coordination of priority areas the remit of different member states. This governance system places the Commission in a vulnerable position and implies that some countries are more central to the implementation of the strategy than others. This results in a situation where countries that are most in need of successful implementation are the ones least involved in the steering of the strategy [22]. This problem could have been less important if there were an overall entity in charge of the strategy. The Commission is unable to offer solutions to align policies and funding at various levels of governance (EU, national, Sub-national), and promoting accountability in implementation [22]. In a commission whose priorities include security and migration policies, its role in governance of the strategy to monitor implementation and assure future direction is challenging [22]. This can also be solved through the appointment of an entity in charge of the overall strategy.

5. Conclusions

This paper examined the governance for a resilient Baltic Sea ecosystem to nutrient enrichment, so that ecosystem services such as recreation, aesthetics and fishing can be preserved. It investigated how the interacting systems of actors and the Baltic Sea environment is governed to ensure resiliency to eutrophication, so that there is continued provision of ecosystem services. It examined Baltic Sea eutrophication governance thorough the seven pillars of building resiliency as found in the literature: maintaining diversity and redundancy, managing connectivity, managing slow variables and feedbacks, fostering complex adaptive systems thinking, encouraging learning, broadening participation and the promotion of polycentric governance systems. Whilst diversity is encouraged through the invitation of observers to HELCOM's processes, there is not inclusion of key groups such as farmers to ensure that traditional sources of knowledge are incorporated into the governance process. Greater diversity of knowledge needs to be incorporated into the governance system by giving the public a permanent seat on the organizational chart of HELCOM. Whilst the EUSBSR aims to connect the region, this connectivity and promise of polycentric governance system needs to be implemented through stronger leadership, or the presence of an overall coordinator other than the European Commission. As such, the governance system of the Baltic Sea eutrophication governance needs to change from a multilevel governance system to a polycentric governance system to better cope with the uncertainty and hence, to build resiliency to nutrient enrichment.

6 References

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