Chapter 2
Eutrophication and the Ecosystem Approach to Management: A Case Study of Baltic Sea Environmental Governance

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Abstract This study investigates if and how present institutional structures and interactions between scientific assessment and environmental management are sufficient for implementing the ecosystem approach to management (EAM) in the case of Baltic Sea eutrophication. Concerning governance structures, a number of institutions and policies focus on issues relating to eutrophication. In many cases, the policies are mutually supportive rather than contradictory, as seen, for example, in the case of the mutually supportive BSAP and MSFD. The opposite is true, however, when it comes to the linkages with some other policy areas, in particular regarding agricultural policy, where the EU CAP subsidises intensive agriculture with at best minor consideration of environmental objectives, thereby undermining EAM. Enhanced policy coherence and stricter policies on concrete measures to combat eutrophication seem well needed in order to reach stated environmental objectives. When it comes to assessment-management interactions, the science-policy interface has worked well in periods, but the more specific that policies have become, for example, in the BSAP case, the more question marks have been raised about science by affected stakeholders. At present, outright controversies exist, and EAM is far from realised in eutrophication policy in the Baltic Sea region. Besides coping with remaining uncertainties by improving the knowledge on problems and solutions – not least in terms of the socio-economic impacts of eutrophication – it may therefore be valuable to develop venues for improved stakeholder participation.

Keywords Institutions • Science-policy studies • Marine strategy framework directive • Baltic Sea action plan • Common agricultural policy

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M. Gilek et al. (eds.), *Environmental Governance of the Baltic Sea*,
MARE Publication Series 10, DOI 10.1007/978-3-319-27006-7_2

2.1 Introduction

Anthropogenic nutrient over-enrichment is one of the oldest environmental problems. It has escalated during the last century with the exponential increase of human population and consumption, and today eutrophication is a global problem (Díaz and Rosenberg 2011; Rockström et al. 2009; Wassmann and Olli 2006). Eutrophication in marine systems is well described, both for the global and the regional level (Boesch 2002; Jørgensen and Richardson 1996; Wassmann and Olli 2006).

Eutrophication can be defined as an increased input of nutrients or organic matter into an ecosystem, resulting in an increase in primary production (Nixon 1995, 2009). Key indicators of aquatic eutrophication include increases in the total amount of phosphorus and nitrogen, chlorophyll and decreased water transparency. The primary effects are increased production of filamentous algae, changed species composition of microalgae and an increased probability for harmful, and potentially toxic, algal blooms. A complex array of secondary effects may also occur, for example, oxygen deficiency and poorer living conditions for perennial underwater vegetation, immobile zoobenthos living in bottom sediments and certain fish species (Fig. 2.1). These may in turn amplify ecological and associated socio-economic impacts, potentially impeding recovery processes (Lundberg 2005). Extended hypoxic (low oxygen saturation) or anoxic (complete oxygen deficiency) bottom areas (so-called dead zones) are key resultant stressors in marine ecosystems, and the Baltic Sea is the largest stressed ecosystem in the world in this respect (Carstensen et al. 2014; Díaz and Rosenberg 2008).

The first signs of eutrophication on a larger scale in the Baltic Sea became apparent in the 1960s, when oxygen deficiency in the central area was linked to human activities (Elmgren 2001; Fonselius 1969; Jansson 1997; Lundberg 2014). The main anthropogenic sources of eutrophication are agriculture (including crop cultivation and animal husbandry), industries, municipal sewage water and atmospheric deposition (Elmgren and Larsson 2001; HELCOM 2009a, 2013; Wassmann and Olli 2006). However, there was a time lag of two decades after the initial findings in the 1960s, before the issue generated broader public awareness. Today, though, the network of organisations working for the protection and restoration of the marine environment is well developed in the countries surrounding the Baltic Sea (Kern and Löffelsend 2004; Lundberg 2013).

2.1.1 Governance of Baltic Sea Eutrophication and the Aims of the Study

Eutrophication, along with overfishing and the presence of hazardous chemicals, constitutes the most serious environmental problems and risks in the Baltic Sea, posing severe threats to biodiversity as well as to other ecosystem services such as

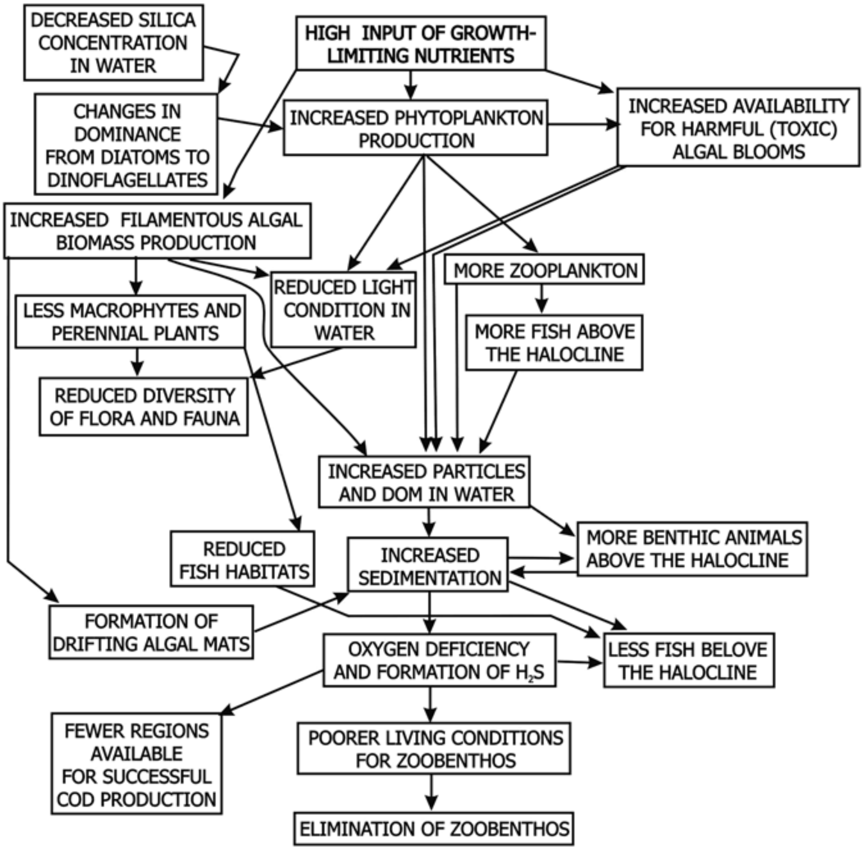

Fig. 2.1 A conceptual model describing the complex primary and secondary ecosystem effects of eutrophication in a marine area

commercial fish and nutrient cycling (HELCOM 2009a, 2010; Korpinen et al. 2012; UNEP 2005). The consequences of eutrophication in the Baltic Sea may ultimately be an ecological regime shift – i.e. a situation where the ecosystem shifts from one relatively stable state to another with unknown thresholds between the states – with associated risks of detrimental effects on ecosystem services and an unknown degree of resilience (Österblom et al. 2010; Österblom et al. 2007).

Traditionally, the governance approach toenvironmental problems and risks has presupposed that various phenomena in natural systems can rationally be dealt with by straightforward science-based management (Linke et al. 2016). The basis for this view has been a reductionist scientific approach, within an international framework of environmental governance, fragmented into sectors and countries and divided into national and international levels (Mee 2005). For example, fisheries and agricultural management have been based on sector-specific laws, policies and institutions (e.g. Sielke and Dreyer in 2015; Mee 2005; Mee et al. 2008), and their relationship to other sectors has seldom been considered.

However, eutrophication is a complex phenomenon. Apart from the intricate array of primary and secondary ecological impacts shown in Fig. 2.1, nutrient sources are diverse and stem from numerous natural and anthropogenic sources in several sectors, both in the drainage basin in question and on a wider international scale through atmospheric and riverine transport (Lundberg 2005, 2014). The relationships between these socio-economic pressures and the marine ecological state are usually non-linear (Mee 2005) and prone to quick and fundamental shifts when thresholds are passed (e.g. Österblom et al. 2010). Furthermore, it may take a long time before any reductions in nutrient input from land may allow for an improved situation (Elofsson 2010). The degradation of organic matter can, for example, be inhibited by negative effects of existing hypoxia on infauna (sediment living animals) (Conley et al. 2007) or by so-called internal loading if buried phosphorus leaks from anoxic sediments (Vahtera et al. 2007; Zillén et al. 2008). In addition, other major disturbances, such as overfishing, and introduction of invasive species may also influence the recovery of an ecosystem from eutrophication. Variability in climate-related factors, such as storms and water temperature and stratification, may additionally cause unexpected responses. The interwoven links between marine eutrophication and all these natural as well as human-induced, biotic as well as abiotic, processes, systems and feedback mechanisms (Caddy 1993; Cloern 2001; McQuatters-Gollop et al. 2009) make science-based reductionist governance models highly insufficient. As Elliot (2002) has pointed out, the management of marine ecosystems needs to consider this full complexity.

In response to these shortcomings, the ecosystem approach to management (EAM) has emerged during the last decades as a central component of environmental governance (Atkins et al. 2011; Curtin and Prellezo 2010; Trush and Dayton 2010). In the words of Browman and Stergiou (2004), EAM is based on the insight that the whole complex ecosystem (including its capacity to deliver important ecosystem services) is greater than the sum of its parts. Problems and risks need to be managed in a holistic manner, not independent of each other (Hammer 2015), and both ecological and social dimensions need to be considered. Moreover, EAM takes into account existing knowledge as well as uncertainties and other forms of complexity. Besides for being different because it is based on a multiple factor approach, EAM also differs from traditional management in its application to a specific geographic scale (Curtin and Prellezo 2010).

EAM is defined in the Convention for Biological Diversity (CBD 1998, 2004) as well as in conventions on regional seas, for example, those concerning the governance of the North Sea and the Baltic Sea (HELCOM and OSPAR 2003). It is also included in several policies and laws, for example, the EU Water Framework Directive (WFD) (EC 2000), the Marine Strategy Framework Directive (MSFD) (EC 2008) and the Helsinki Commission's (HELCOM) Baltic Sea Action Plan (BSAP) (HELCOM 2007a).

Implementation of EAM in the case of eutrophication requires comprehensive knowledge on how both ecosystems and sociopolitical systems function. It remains to be seen, however, whether or not the institutions, policies, action plans and measures in place today in the Baltic Sea region are sufficiently developed to do so in order to promote and reach agreed environmental targets. With that question in mind, this study describes and analyses (1) the formal institutional structures and (2) the interactions between scientific assessment and environmental management in the case of eutrophication in the Baltic Sea region. The aim is to investigate how and to what extent public governance structures and policies take on and implement EAM and what that might mean in relation to environmental policy objectives in place. Furthermore, the study focuses on the question of assessment-management interactions with respect to knowledge integration and the way uncertainty and disagreement is dealt with or not. For practical reasons all atmospheric sources of nitrogen deposition, such as road-based transportation, are not included. Primary focus is placed on the public governance system as it plays the most important role in Baltic Sea environmental governance (Kern 2011).

2.2 Material and Methods

The study is based on both an analysis of documents and a series of interviews. The empirical material presented and analysed consists of various scientific, legal and policy documents as well as of results from qualitative semi-structured interviews with 17 key stakeholders, of which four were active on an international basis and the rest in three countries. Several of those interviewed came from Finland and Sweden, thereby allowing us to assess the situation in two countries well known for comparatively ambitious environmental policies. The interviewees represented four groups: public decision-makers and authorities (six persons), scientists (five persons), NGOs (four persons) and national interest organisations (two persons) (Table 2.1). Public decision-making institutions and authorities were included by persons from the secretariat of the international HELCOM body, ministries of environment and rural affairs in Finland and Sweden and the Swedish Environmental Protection Agency (SEPA). SEPA is partly an independent authority, but it is acting on the basis of Swedish and EU law.

The Baltic Sea environmental scientists came from three universities in Sweden and two research institutes in Denmark and Finland. The non-governmental organisations were both international environmental NGOs and voluntary and politically independent organisations, like the Union of the Baltic Cities (UBC), a network of over 100 cities in the Baltic Sea region. The WWF Sweden, the Coalition Clean Baltic (CCB), the John Nurminen Foundation and the Baltic Sea Action Group (BSAG) were international or national environmental NGOs. The biggest national interest organisations of agriculture in Finland and Sweden, MTK (the Central Union of Agricultural Producers and Forest Owners) and LRF (the Federation of Swedish Farmers), respectively, represented the last stakeholder group.

Table 2.1 The groups of stakeholders interviewed and the organisations and institutions they came from

Group of stakeholder	Organisation	Country
Authorities	HELCOM	International
	Ministry of Environment	Finland
	Ministry of Environment	Sweden
	Ministry of Rural Affairs	Sweden
	Swedish Environmental Protection Agency, SEPA	Sweden
Scientists	Lund University	Sweden
	Stockholm University	Sweden
	Uppsala University	Sweden
	National Environment Research Institute, Aarhus University	Denmark
	Finnish Environment Institute	Finland
NGOs	WWF	International
	Coalition Clean Baltic, CCB	International
	John Nurminen Foundation	Finland
	Baltic Sea Action Group, BSAG	Finland
	Union of the Baltic Cities, UBC	International
National interest organisations	Central Union of Agricultural Producers and Forest Owners, MTK	Finland
	Federation of Swedish Farmers, LRF	Sweden

The empirical work presented in this chapter was performed in 2009–2014 as part of the research projects RISKGOV[1] and COOP.[2] The interviews followed a common guideline from the RISKGOV project (see Gilek et al. 2016) but were especially adapted to suit the key aspects and questions in relation to eutrophication in the Baltic Sea region. The interviews, which lasted approximately between 1 and 2 h, were taped and transcribed, while the interviewed persons were assured anonymity. The analysis of the material followed the empirical methods of qualitative content analysis (Kvale 1996; Silverman 1993).

2.3 Governance Structures Related to Eutrophication

The structure of governance bodies, policies and regulatory frameworks plays an important role in developing and implementing EAM. For example, the level of coordination between institutions and legislation, both vertically and horizontally, influences the effectiveness of risk mitigating measures. On the one hand there might be tensions between top-down management and local influence, and on the

[1] Environmental Risk Governance of the Baltic Sea Studies (2009–2015) www.sh.se/riskgov

[2] Cooperating for Sustainable Regional Marine Governance (2012–2015).

other hand, there might be goal conflicts or synergies at similar levels in the environmental governance landscape. In the following, we will first describe and then analyse the situation in the case of eutrophication in the Baltic Sea.

2.3.1 Key International and Regional Governance Structures

The European Union's importance in the Baltic Sea region has increased significantly over time, not least after the 2004 EU enlargement (Kern and Löffelsend 2008; Kern et al. 2008; Tynkkynen et al. 2014). The EU has a unique capacity to legislate and set supranational demands in the field of environmental protection that are often binding for EU member states. The EU legislation of most importance for mitigating eutrophication in the Baltic Sea consists of WFD and MSFD, as well as the Urban Waste Water Treatment Directive (UWWTD) (EEC 1991a) and the Nitrates Directive (ND) (EEC 1991b).

The 1991 UWWTD focuses on the collection, treatment and discharge of urban wastewater and on the treatment and discharge of wastewater from certain industrial sectors.[3] The ND from the same year instead aims to protect natural ground and surface water quality from nitrate pollution caused by agriculture and is thus one of the key instruments for mitigating eutrophication.

On a broader scale, WFD renewed the EU's water policy in the year 2000, and it covers the protection of inland surface waters, transitional waters, coastal waters and groundwater. The ultimate aim is to prevent further deterioration and to achieve a "good status", which includes eutrophication parameters of all European waters by 2015 by the help of River Basin Management Plans. The watercourses in the EU are divided into separate water units according to the natural geographical and hydrological conditions. MSFD covers the entire marine area, outside the coastal reach of the WFD. MSFD was adopted in 2008 for a more effective protection of the marine environment and as a central component of the then emerging integrated maritime policy of the EU. It thus complements WFD for offshore waters and sets out similar goals ("good environmental status"), albeit with a deadline 5 years later (2020). The implementation rests mainly with member states, which are supposed to collaborate in marine regions, one of them being the Baltic Sea. MSFD is explicitly stated to be based on the ecosystem approach to management.

Last but definitely not least in this context, the EU's Common Agricultural Policy (CAP) is central for the nutrient impact from crop to livestock production (see, e.g. Chen et al. 2014; Schumacher 2012). After a so-called health check in 2008, CAP became a target for contested reform between 2010 and 2013, with one among several aims being "greening the CAP", the latter based on studies showing obvious

[3] Related to wastewater treatment, both HELCOM and EU have taken decisions and measures against phosphates in, e.g. detergents, which have led to environmental improvements but also to criticism for filling an "alibi function" and consequently drawing attention away from other more complex issues (see further Schumacher 2012).

shortcomings in relation to environmental objectives (e.g. Baldock et al. 2002). The European Commission indeed presented proposals in that direction (European Commission 2011a), even though they were seen as relatively minor steps (SBA 2012; SRU 2013; Allen and Hart 2013). However, as the regulatory process went on, even these proposals were significantly watered down (European Commission 2012a; IEEP 2013), to the extent that the EU Environment Commissioner stated at the end of the process that he could "only regret that the numerous exemptions, loopholes and thresholds have made the greening so complicated and at the same time have greatly lowered the level of environmental ambition[4]".

In these regulatory contexts, the legislative process is dominated by co-decision, meaning involvement of three large institutions, the European Commission, with its monopoly to present legislative proposals, the Council and the European Parliament, being the key bodies negotiating and jointly adopting the final laws. Much of the implementation, however, rests with the member states, including the national application of the CAP.

Besides legislation, the EU Strategy for the Baltic Sea Region (European Commission 2009a, 2012a) aims at managing the Baltic Sea as a common resource from several perspectives, including environmental issues. The strategy involves all EU members bordering the Baltic Sea and also has the objective to govern EU external issues, such as the relations with the Russian Federation, which contributes significantly to emissions responsible for eutrophication. The original 2009 strategy underlined the need for concrete action instead of new institutions, and linked to the strategy, the European Commission presented an "indicative action plan", which expressed "reduce nutrient inputs" as one of four priorities in the save the sea section of the plan (European Commission 2009b). After evaluation (European Commission 2011b), the strategy was updated and renewed in 2012 (European Commission 2012b).

Turning to the regional Baltic level, the HELCOM operative body of the Helsinki Convention has aimed since the 1970s to promote cooperation between the Baltic Sea states and to monitor and assess the state of the marine environment. HELCOM consists of the parties to the Helsinki Convention of 1974 and is governed both by declarations adopted at infrequent ministerial meetings and by an operative body with an office in Helsinki, under which several staff and expert groups work on, e.g. monitoring and assessment, as well as with drafting proposals on measures and implementation.[5]

Concerning eutrophication, the 1974 Convention contained (Annex 3) specified goals, criteria and measures for preventing land-based pollution, such as emissions of nutrients from sewage water. A central target was then set in a 1988 Ministerial Declaration (HELCOM 1988), which called for a 50 % reduction of nutrient discharges to water and air between 1987 and 1995. In the 1992 renewed version of the Convention, pollution from agriculture was included (Annex 3) as were quite detailed provisions on, for instance, animal density, manure storage and fertilisers.

[4] See, e.g. Janez Potocnik at https://twitter.com/janezpotocnik22/status/350610909284143104

[5] See further at www.helcom.fi

To operationalise the Convention, HELCOM traditionally focuses on adopting more detailed recommendations to the parties of the Convention, specifying, e.g. proposed measures for reaching agreed objectives in the Convention and various declarations, for instance,[6] Recommendation n.b. 28E/4 on plant nutrients (HELCOM 2007b). The binding decisions following agreements within HELCOM are therefore foremost supposed to be taken on a national level, and to be carried out through national implementation programmes (NIPs) (Backer et al. 2010; Tynkkynen et al. 2014), or at the EU level. Since the most central HELCOM agreements are adopted at the ministerial level, i.e. with strong governmental support, a high level of implementation is generally expected, to judge from our interviewees, even though the legislative power as such is weaker than at the EU level. On the other hand, HELCOM, in contrast to the EU, involves all countries in the Baltic Sea region, where the Russian Federation is an important stakeholder from an environmental point of view (Tynkkynen et al. 2014).

The work of HELCOM has changed over time, following the fall of the Berlin Wall, the resultant 1992 amendment of the Helsinki Convention and the enlargement of the EU. More recently, HELCOM has opened more broadly for participation of non-governmental organisations, such as the Swedish and Finnish national agricultural organisations LRF and MTK, and the NGOs WWF and CCB, which all have observer status. Interviewees highlighted that this reflected an important attitude change since stakeholders such as farmers and NGOs generally are seen to play important roles when it comes to eutrophication management.

HELCOM's most central and precise tool at present for marine governance is the 2007 BSAP, which aims to achieve good ecological status in the Baltic Sea by 2021, much in line with WFD and MSFD (Backer and Leppänen 2008; Backer et al. 2010). The BSAP aims to take a broad and systematic approach and defines visions, goals, objectives, indicators, environmental targets and concrete management actions (Backer et al. 2010), which are stated explicitly to be based on EAM and aim to guide the implementation of environmental measures (Backer and Leppänen 2008; Backer et al. 2010; European Commission 2009a; HELCOM 2007a, 2010). In BSAP, national reduction targets for nitrogen and phosphorus are specified.

2.3.2 Analysis of Structural Challenges

As pointed out earlier, the number of governmental bodies and regulatory frameworks related to governance of eutrophication in the Baltic Sea region is high. Governance at the international level dominates and steers the direction of action, with EU legislation and HELCOM action plans and recommendations as the most

[6] HELCOM has adopted a number of Recommendations related to eutrophication, for instance, regarding: wastewater (nb. 6/7), phosphorus (13/10) and nutrients in general (7/2) in agriculture, nitrogen in sewage water (16/17) and agriculture (24/3); see http://helcom.fi/helcom-at-work/recommendations

prominent features. Global organisations such as IMO (the International Maritime Organization) and ICES (the International Council for the Exploration of the Sea), however, also play important roles. The prominent role of international bodies means that governance is significantly a top-down approach.

When it comes to EU legislation, ND and UWWTD both aim at controlling and reducing emissions in the aquatic environment from agriculture and municipalities, respectively. However, even if ND clearly has led to decreased nitrogen emissions from EU agriculture over time (Velthof et al. 2014), it has been considered far from sufficient, influencing, e.g. only a few percent of the nitrogen emissions from manure management (HELCOM 2006b). Similarly, UWWTD requirements are too weak in relation to agreed objectives for the Baltic Sea (Schumacher 2011). Evident shortcomings can be seen also in the case of WFD when it comes to obtaining the good status objective by 2015 (European Commission 2012c). Regarding the MSFD, the implementation is still at an initial stage, but, for example, the definitions of good ecological status for the so-called descriptor 5 for eutrophication ("human-induced eutrophication is minimised, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algae bloom and oxygen deficiency in bottom waters") have been shown to mostly not be adequate (European Commission 2014), including for the Baltic marine region (Milieu 2014).

Coordination of the many governmental bodies and regulatory frameworks at EU, Baltic Sea and national levels is a further key structural challenge. A majority of the interviewees saw significant problems with overlapping roles and ineffectiveness among the actors involved in eutrophication governance in the Baltic Sea region, for example, risks for duplicating similar measures (see also Tynkkynen et al. 2014). Cooperation of multiple actors is required for the implementation of policies to be successful at the regional level (Joas et al. 2007).

The EU Strategy for the Baltic Sea Region (EUSBSR) (European Commission 2009a) is intended to stimulate much needed coordination and cooperation, by integrating different policies and directives in different areas. An important mechanism of the strategy is the promotion of so-called flagship projects with potentially high macro-regional impact in terms of contributing to the fulfilment of agreed objectives. For example, linked to the priority areas of nutrients (PA Nutri), several flagship projects have been initiated, such as Baltic Deal, to promote practices to reduce nutrient losses from agriculture and a flagship project aiming to support the implementation of HELCOM Recommendation 28E/7 on phasing out phosphates in detergents.[7] However, also central to addressing eutrophication would be if the strategy would help to coordinate MSFD and other environmentally focused tools with policies that promote development of the agricultural sector, in particular the referred CAP (European Commission 2011a), but that is so far not done adequately. While the strategy's theoretical structure might seem carefully planned, some interviewees stated that the programme might be too general and vague and too top-down regulated inside the EU. Regarding agriculture, the Commission's action plan to the strategy identifies a need to mitigate nutrient losses, but the strategy and plan

[7] See more about PA Nutri on http://groupspaces.com/eusbsr-nutrient-inputs/

present no proposal on how to restructure CAP – for instance, the present focus on subsidising quite intensive conventional agriculture – in order to promote the marine environmental objectives at hand, not even after the recent CAP reform. There is an obvious lack of integration of the various policies (Baldock et al. 2002; Schumacher 2011; Tynkkynen et al. 2014). It is therefore not surprising that also the interviewees often considered CAP not to be in synergy with MSFD and neither with WFD. Furthermore, communication with Russia is also problematic. In the interviews, opinions were raised that the Russian stakeholders wanted to focus more on cooperation within HELCOM, instead of on EU-related instruments.

Turning to the national level, much of the EU legislation, such as MSFD as well as BSAP allow, presume and sometimes also demand that countries adapt implementation to national circumstances, giving nation states a central role. However, the 2011 National Implementation Plans (NIPs) linked to BSAP diverged quite substantially in terms of content, structure and detail, as well as with respect to implementation of EAM-related measures (Gilek et al. 2013). Only about half of NIPs (e.g. Russia, Estonia and Sweden) gave information on costs and financing (Gilek et al. 2013), and not all countries described planned projects and measures. Regarding EAM implementation, several countries including Denmark, Finland and Russia did not explicitly mention EAM in their NIPs, whereas others referred to EAM principles in a non-specific way. It was also striking that multi-sector cooperation, stakeholder participation and communication, as well as adaptive governance generally were given limited attention. These NIPs revealed that key aspects of EAM have hardly been implemented in national governance frameworks to tackle eutrophication. The dominance of end-of-pipe methods for reducing nutrients, such as wastewater treatment, is increasingly expensive and hard to expand further and therefore insufficient for achieving the significant reductions needed for fulfilling BSAP and MSFD goals.

2.4 Assessment and Management of Eutrophication

EAM evidently relates to both science and policy. For example, the organisation of risk assessment activities and integration of knowledge across different scientific disciplines, as well as addressing ways to cope with uncertainty and disagreement, are central for EAM implementation. On the one hand, formal assessments established by experts based on solid consensual knowledge play an indispensable role for being able to characterise problems and develop science-based advice on particular measures. On the other hand, scientific uncertainty and sociopolitical ambiguity challenge the conventional view on management and open for controversies that might necessitate not only precautionary approaches but also institutionalising deliberative forums. In the following, we will first describe and then analyse the situation in the case of eutrophication in the Baltic Sea.

2.4.1 Key Assessment-Management Interactions

Scientific knowledge and science-based advice have at least since the 1970s played a key role in eutrophication management of the Baltic Sea, for example, influencing decisions on which nutrients to prioritise in wastewater treatment (e.g. Elmgren 2001). Over the years, these interactions between science and policy have developed and changed under the influence of, for example, changes in the knowledge base vis-à-vis remaining uncertainties, stakeholder and public perceptions of eutrophication and associated societal consequences and trade-offs. Interactions have also changed due to transformations of national and international environmental governance arrangements (e.g. Linke et al. 2014). Originally, scientific assessments and science-based advice mainly influenced management measures at the national level. Examples of these are Swedish measures in the 1970–1980s to introduce and expand nitrogen treatment in coastal sewage treatment plants (Elmgren 2001). Successively, collaboration in science and management at the regional Baltic Sea and international (e.g. European) levels increased in importance in response to the large spatial scale of eutrophication impacts and potential solutions in the Baltic Sea. Today the role of science remains strong in the development of policy and management measures, and although the national level is still important for generating environmental assessments linked to various objectives, the regional (i.e. HELCOM) and European (i.e. EU institutions) levels have become the primary domains for science-based policy advice.

When it comes to the regional Baltic Sea level, HELCOM and not the EU is the overall coordinator of the commonly nationally based assessments of eutrophication impacts. In line with ambitions to coordinate national assessment activities and implement EAM, HELCOM has developed a new holistic environmental assessment strategy (HOLAS). This strategy involves recurring integrated thematic assessments of, for example, eutrophication and hazardous chemicals, as well as holistic assessments that aim at assessing ecosystem quality and integrating various societal pressures. An initial holistic assessment was published in 2010 (HELCOM 2010), based on the results from thematic assessments of various environmental issues and objectives linked to BSAP and EU Directives, such as WFD and MSFD (Gilek et al. 2015). To facilitate these thematic assessments and to improve methodological harmonisation and data integration possibilities in the region, HELCOM has also developed various tools for assessing, for example, eutrophication (HELCOM Eutrophication Assessment Tool, HEAT) (HELCOM 2006a, 2009a) and biodiversity (HELCOM Biodiversity Assessment Tool, BEAT) (HELCOM 2009b).

Regarding HELCOM's various proposals on management measures, the 2007 BSAP (with updates in 2013), with its acknowledgement of EAM and agreed national reduction targets for nutrients, is of central importance. According to several interviewees, BSAP evolved as a reaction to the perceived failure of the above-mentioned HELCOM target of 50 % nutrient reductions, which was not based on any scientific studies on what is needed to reach a desired state of the marine environment. In contrast, BSAP was in line with EAM and based on scientific assessments of ecological indicators that relate to specific policy objectives associated with “good ecological status” (Backer 2008; HELCOM 2007a, 2010). The actual forebearer to the agreed specific reduction targets and their division among the countries was the decision support system Baltic Nest[8] created within a Swedish research programme (MARE, 1999–2006) and run by the Baltic Nest Institute (BNI 2014). The Baltic Nest system integrates environmental data with economic parameters to build scenarios and generate advice to decision-makers in HELCOM. The reason for including the economic dimension is the understanding among HELCOM parties that a harmonised and collective approach to management is the best way to reach positive environmental outcomes. One motive for this is the desire to achieve as cost-effective nutrient reduction as possible (see, e.g. Elofsson 2002).

2.4.2 Analysis of Assessment-Management Challenges

The new holistic HELCOM assessment strategy (HOLAS) has in many respects implied an improved integration of (mainly natural) science knowledge. For example, the strategy involves an improved spatial *integration* of knowledge of the entire Baltic Sea area, and a wider span of measurements and data are now integrated (e.g. nutrient concentrations, biota, water, oxygen levels). However, although the holistic HELCOM strategy does include specific (albeit rather limited) sections discussing social and economic aspects (HELCOM 2010), the integration of social and economic aspects is still rather limited in HELCOM activities. This is discernible at both the assessment and management levels. However, there is a high awareness of this lack of integrated interdisciplinary assessments among decision-makers and scientists alike (as observed in our interviews), and recent efforts by the international research network BalticSTERN to develop, for example, cost-benefit analyses of eutrophication management in the Baltic Sea have started to improve the situation (BalticSTERN 2013). According to these estimates, the societal benefits for reaching BSAP targets would exceed costs (amounting to 2300–2800 million euro, depending on how cost-effective measures are) by 1000–1500 million euros annually. More recent studies have estimated that the costs could be higher (Wulff et al. 2014). Investigations like these are nevertheless important in order to provide ground for better integration of social and natural parameters.

In spite of this, our interviewees underlined several remaining challenges for achieving adequately integrated assessments of eutrophication. These challenges relate to, for example, a substantial shortage of data from some geographic areas and problems in reaching agreement among countries and stakeholders on target levels and thresholds to base thematic assessments on (e.g. Haahti et al. 2010; Lundberg 2013). Consequently, we conclude that, despite recent efforts by HELCOM and BalticSTERN to develop integrated assessments of eutrophication to support

[8] See Baltic Nest at http://www.balticnest.org

EAM, there is still quite a way to go before socio-economic consequences and concerns are sufficiently addressed in assessments and science-based advice.

In terms of *uncertainty challenges*, both BSAP and MSFD do, in line with EAM, refer to ecosystem complexity and the importance of applying a precautionary approach in marine environmental governance (cf. Udovyk and Gilek 2014). For example, HELCOM and OSPAR (2003) define EAM in the marine environment as:

> [….] the comprehensive integrated management of human activities based on the best available scientific knowledge about the ecosystem and its dynamics, in order to identify and take action on influences which are critical to the health of marine ecosystems, thereby achieving sustainable use of ecosystem goods and services and maintenance of ecosystem integrity. […] The application of the precautionary principle is equally a central part of the ecosystem approach.

However, studies of guideline, assessment and advice documents linked to MSFD (Udovyk and Gilek 2014) and the HELCOM BSAP (Udovyk and Gilek 2013) reveal a rather limited acknowledgement and management of uncertainty. In fact, irreducible uncertainties associated with ecosystem dynamics and interdependencies are rarely mentioned in assessments and science-based advice (Udovyk and Gilek 2013). Similarly, there are hardly any references to strategies or methods for coping with such uncertainty. Instead, in line with the notion of achieving "best available knowledge", assessment and advice documents mainly acknowledge uncertainty caused by low precision and accuracy in methods and a general lack of scientific data for certain geographical areas and ecological endpoints.

The general strategy applied for managing epistemic uncertainty is to obtain more data through an expanded monitoring network, with larger geographic and temporal coverage (HELCOM 2009a). Such a traditional empirical approach in science has in many ways been successful in and instrumental to reaching a consensual understanding of the sources and impacts of eutrophication and of the importance of various nutrients (e.g. Conley et al. 2009a; Elmgren 2001). However, for generating science-based advice on nutrient reduction requirements to reach environmental objectives, alternative modelling approaches would be needed to better control uncertainty associated with ecosystem dynamics (e.g. Udovyk and Gilek 2013). Interestingly, however, our interviews revealed a not so uncommon "downplaying" of model and scenario uncertainties in science-policy interactions linked to development of BSAP. Presumably, this can to some extent be explained by a common ambition among scientists (Baltic Nest) and decision-makers (HELCOM) involved to facilitate a regional agreement on nutrient reduction targets (cf. Linke et al 2014). A strong acknowledgement of uncertainty could in this respect have been a reason for disagreement rather than agreement.

An overview of scientific studies on Baltic Sea eutrophication exposes several scientific *disagreements* on the sources and impacts of eutrophication that in various ways have had significant repercussions on stakeholder conflicts and management decisions at national and regional levels (e.g. Elmgren 2001). At an early stage of Baltic-wide eutrophication assessment and management, there was in the 1960s a lively debate on whether or not anthropogenic eutrophication of the open Baltic Sea was possible at all. Once compelling evidence for such large-scale human-induced eutrophication was available, there was instead an infected debate whether nitrogen or phosphorus is the main causative nutrient in need of reduction measures (e.g. Elmgren 2001).

Today, these natural science-based disagreements on nutrients have, according to the interviewed scientists, been handled, and quite a consensual scientific view exists, that emissions and levels of both nitrogen and phosphorus need to decrease (Conley et al. 2009a). However, some scientific disagreements still exist, mainly with regard to methodological details, but still also according to our interviewees to which nutrient to preferentially reduce.

As mentioned above, the process to develop and agree on the 2007 BSAP was associated with a rather surprisingly low level of disagreement among stakeholders. This consensual assessment-management process has been attributed to the close cooperation between the Baltic Nest Institute and HELCOM while developing science-based advice (Linke et al. 2014). For example, it has been argued that the "HELCOM-Nest nexus" demonstrates how scientific assessments and science-based advice may underpin the legitimacy of political claims for regional environmental management (Linke et al. 2014). However, interviews with various actors revealed that the interplay between scientific data used in the Baltic Nest system and HELCOM's management responses is interpreted differently by stakeholders in the Baltic Sea region. Some see the Baltic Nest system as a concrete and illustrative tool for coming up with effective remedies, while others are more critical and argue that the model has received too much attention at the expense of other models (cf. Linke et al. 2014). Recently, strong criticism from, for example, farmers has also been voiced concerning the political conclusions on the sharing of responsibility for national reduction obligations (BFFE 2013; Linke et al. 2014; LRF 2013). The Baltic Nest model is, however, under continuous development and improvement (BNI 2014; Johansson et al. 2007), and the linkage between risk assessment and risk management remains central to the governance of eutrophication in the Baltic Sea.

What also came up in interviews is that there is an ongoing discussion, linked to implementation of eutrophication policy, in the scientific literature on the potential effectiveness and efficiency of various management measures. For example, there are disagreements concerning which specific reduction measures are most cost-effective when comparing costs for direct emission reduction measures with costs for land-use changes designed to increase nutrient retention (e.g. Elofsson 2010; Gren 2008; Huhtala et al. 2009; Lundberg 2013). Some studies and experiments have also suggested and tested alternative, technical solutions to reduce nutrient concentrations in the Baltic Sea such as artificial oxygenation, changes in saltwater inflow and chemical sequestration of phosphorus buried in the sediment (see, e.g. the review by Conley et al. 2009b). Still, although some "engineering"-type measures, such as phosphorus binding with aluminium, were argued to potentially be effective in specific coastal areas, their potential to address open sea eutrophication was generally seen as marginal by the scientists, NGOs and decision-makers we interviewed. The overall view is that external nutrient reduction – i.e. before nutrients enter the sea – is the only truly effective long-term strategy to combat eutrophication (as, e.g. also argued by Conley et al. 2009a).

2.5 Conclusions and Recommendations

This study has described and analysed if and how present institutional structures and interactions between scientific assessment and environmental management are sufficient for implementing EAM in the case of Baltic Sea eutrophication and what that might mean in relation to the policy objectives in place. We have also studied knowledge integration and the way uncertainty and disagreement is dealt with or not when it comes to assessment-management interactions.

Regarding *governance structures*, we have shown that there is a wide array of eutrophication-related policies and institutions in place at national, Baltic Sea and European levels. Obviously there is a risk that such complex structures may imply contradictory, overlapping or redundant institutional arrangements which might lead to institutional tensions and inefficiencies (cf. Tynkkynen et al. 2014). However, we have in this case study observed mostly synergistic institutional interactions to deal with Baltic Sea eutrophication, where policies focused on mitigating eutrophication seem to mutually enforce each other. A striking example here is MSFD and BSAP where nothing in BSAP prevents implementing MSFD and vice versa. On the contrary, the eutrophication segments of these policies seem to have developed in a rather co-evolutionary manner – both are, for example, explicitly based on EAM and a Baltic Sea-wide coordination of management measures. These synergies support the implementation of MSFD and BSAP and may even strengthen the regulatory weaker HELCOM's position and role in eutrophication governance, especially since Russia is a party to the Helsinki Convention (cf. Söderström et al. 2015).

However, there are also obvious conflicting institutional interactions linked to eutrophication, particularly between sectoral (e.g. agriculture) and environmental policies in the EU system (cf. Tynkkynen et al. 2014; De Santo 2015). Most important for this context, the CAP continues to subsidise intensive agriculture with at best only minor consideration of environmental objectives for the marine environment, allowing for high inputs of nutrients, of which much ends up in the Baltic Sea sooner or later. In spite of EAM being expressed in MSFD, and in spite of the aim of EUSBSR, no effective coordination mechanism in relation to agriculture is in place today.

In order to enhance possibilities to reach the eutrophication objective in place, a number of structural changes seem warranted:

First, multi-sector coordination of policies is needed within European, regional and national institutional structures. This is most obvious within the EU, where goals and means in the EU's CAP should be adequately adapted to EU's environmental objectives (as, e.g. manifested in the MSFD), in line with the environmental integration principle in the treaty (TFEU 2007, Article 11). Without EU regulatory harmony between the policy domains of agriculture and environment, EAM will hardly be applied in a relevant manner in reality. Second, further multilevel coordination of objectives and policies adopted by institutions at European, Baltic Sea and national levels is possible, for example, between the EU and HELCOM. HELCOM, and the EU, should strive to create and strengthen synergies with each other's policies based on EAM. We see, for example, no reason why the objectives, timetables and programmes should differ between, for example, MSFD and BSAP. Finally, effective concrete measures and financing for these are, at the end of the day, always indispensable, irrespective of the institution and regulatory level. Several ideas for potentially positive concrete measures also came up in this study, not least in the interviews, for example, regarding the short-term need for reducing the use and, thereby, the losses of fertilisers and nutrients, respectively, and the long-term need for more fundamental structural changes in agriculture, for instance, by changing the geographical balance between husbandry and crop production. The latter would most likely necessitate a major CAP reform, though, as well as comprehensive national strategies.

When looking at *assessment-management* (*science-policy*) *interactions* in the process leading up to BSAP, what is clear is that this was characterised by a rather straightforward translation of results from the Baltic Nest system to science-based advice and subsequent decisions. This process seems to have been facilitated by a tight coevolutionary interplay focussing on consensual knowledge between scientists linked to the Baltic Nest Institute and those involved in the management regime under HELCOM. During this initial stage of BSAP development, scientific uncertainty linked to eutrophication assessments and advice was not a primary issue of concern, and hardly any major disagreements among either countries or stakeholder groups could be observed. Today, however, during the ongoing national implementation of BSAP, engagement and critique, not least by some farmer's organisations, on eutrophication management strategies and measures, have grown and become far more detailed in terms of, for example, uncertainties and which measures to optimally take, in particular in relation to interpretations of cost-benefit analyses. Such increased stakeholder engagement and disagreement in response to implementation of proposed concrete nutrient reduction measures is probably what is to be expected given that different stakeholders' values and interests are related to different costs and benefits during implementation.

Our analyses of science-policy interactions also reveal that significant challenges still remain in terms of elaborating concrete strategies for implementing EAM, which we argue is needed to reach a good environmental status in terms of eutrophication in the Baltic Sea:

First, integration of various forms of knowledge relating to social, economic and environmental risks, costs and benefits of eutrophication is indispensible for implementing EAM. However, despite a general awareness of this need among decision-makers, scientists and other stakeholders, and despite recent substantial contributions by the BalticSTERN research network, socio-economic knowledge, assessments and advice on eutrophication are still in need of development. One set of issues far from resolved concerns how to optimally allocate responsibilities for reducing nutrient loads in line with BSAP and if optimal means cost-effective (by means of, e.g. cap and trade) or something else (e.g. BalticStern 2013; Ahtiainen et al. 2014; Tynkkynen et al. 2014; Wulff et al. 2014). Second, given the complex ecosystem dynamics associated with eutrophication, coping with fundamental uncertainties is a basic challenge when striving to implement EAM in the case of Baltic Sea eutrophication governance (cf. Österblom 2010). Finally, realising ambitions of developing integrated science-based advice on effective concrete measures will expose different norms, principles, methodologies, assumptions, etc. in different academic traditions and might potentially lead to increased levels of scientific – and in turn, broader – disagreement, at least in the short run.

In relation to these challenges and how they have been handled by the science system, it is interesting to note that, apart from the Baltic Nest Institute, the arenas for consensus building in the case of eutrophication have been rather diffuse, including a variety of HELCOM groups, projects and national review groups. Therefore, we consider (as also argued by some of our interviewed scientists) that improved regional integration and coordination of eutrophication-related science is needed, perhaps as a permanent independent Baltic Sea Science Panel that recurrently could review the state of science on environmental issues in the Baltic Sea and develop guidance on modelling and scenarios as well as on science-based approaches to better cope with knowledge integration and uncertainty. For example, linked to coping with fundamental uncertainties in science-based advice, precautionary strategies could be developed based on a combination of approaches and methodologies already published in the academic literature (Udovyk and Gilek 2013), for example, default factors and alternative principles for decision-making (cf. Karlsson 2005). In addition, some of our interviewees were of the opinion that it would be possible to learn from approaches for uncertainty appraisal developed by the Intergovernmental Panel on Climate Change (IPCC), to better cope with uncertainty in Baltic Sea eutrophication advice. It was also argued that one of the major advantages with IPCC's work with scenarios and related uncertainties is the number of independent institutions involved, which give the scenarios a certain legitimacy and credibility. Similarly, another potential learning point from the climate discourse would be to develop a nutrient cap and trade system for the Baltic Sea, which could be both goal and cost-effective.

Finally, in our summation of Baltic Sea eutrophication governance, we conclude that policy prescriptions in place are ambitious and promising and that the general knowledge base is quite well developed. Based on this, much has happened in order to mitigate eutrophication, but we can clearly see that several fundamental challenges remain in order to implement EAM and to ultimately reach the overall policy objectives in, for example, BSAP and MSFD. In terms of governance structure, there is primarily a need to improve coordination of agricultural and environmental policies and develop science-policy interactions in line with EAM, where it is vital that interdisciplinary integration and strategies for coping with uncertainty are improved.

Acknowledgments We thank the co-authors of the RISKGOV research report on eutrophication, which formed an important point of departure for this study: Britt-Marie Haahti, Eva Hedenström, Sebastian Linke, Gunilla Reisner and Markus Wanamo. All interviewees are thanked for their participation and valuable contributions. The work was funded by the Foundation for Baltic and East European Studies and the European Community's Seventh Framework Programme (2007–

2013) under the grant agreement no. 217246 made with the joint Baltic Sea research and development programme BONUS, as well as by the Swedish Environmental Protection Agency, the Swedish Research Council Formas and the Academy of Finland.

References

Ahtiainen H, Artell J, Elmgren R, Hasselström L, Håkansson C (2014) Baltic Sea nutrient reductions. What should we aim for? J Environ Manage 145:9–23
Allen B, Hart K (2013) Meeting the EU's environmental challenges through the CAP – how do the reforms measure up? Asp Appl Biol 118:9–22
Atkins JP, Burdon D, Elliott M, Gregory AJ (2011) Management of the marine environment: integrating ecosystem services and societal benefits with the DPSIR framework in a systems approach. Mar Pollut Bull 62:215–226
Backer H (2008) Indicators and scientific knowledge in regional Baltic Sea environmental policy. ICES J Mar Sci 65:1398–1401
Backer H, Leppänen JM (2008) The HELCOM system of a vision, strategic goals and ecological objectives: implementing an ecosystem approach to the management of human activities in the Baltic Sea. Aquat Conserv 18:321–334
Backer H, Leppänen JM, Brusendorff AC, Forsius K, Stankiewicz M, Mehtonen J, Pyhälä M, Laamanen M, Paulomäki H, Vlasov N, Haaranen T (2010) HELCOM Baltic Sea Action Plan – a regional programme of measures for the marine environment based on the ecosystem approach. Mar Pollut Bull 60:642–649
Baldock D, Dwyer J, Sumpsi-Vinas JM (2002) Environmental integration and the CAP. A report to the European Commission, DG Agriculture. IEEP, Brussels
BalticSTERN (2013) The Baltic Sea – our common treasure: economics of saving the sea. Report 2013:4. Swedish Agency for Marine and Water Management, Göteborg. Available from: http://stockholmresilience.org
BFFE (2013) Viewpoints from the farmer organisations around the Baltic Sea to the proposal for the ministerial declaration concerning revised HELCOM Baltic Sea Action Plan (BSAP). Available from: http://www.lrf.se
BNI (Baltic Nest Institute) (2014). Available from: http://www.balticnest.org/. Accessed 7 Nov 2014
Boesch DF (2002) Challenges and opportunities for science in reducing nutrient over-enrichment of coastal ecosystems. Estuaries 25(4B):886–900
Browman HI, Stergiou KI (2004) Perspectives on ecosystem-based approaches to the management of marine resources. Mar Ecol Prog Ser 274:269–303
Caddy JF (1993) Towards a comparative evaluation of human impacts on fishery ecosystems of enclosed and semi-enclosed seas. Rev Fish Sci 1:57–95
Carstensen J, Conley DJ, Bonsdorff E, Gustafsson BG, Hietanen S, Janas U, Jilbert T, Maximov A, Norkko A, Norkko J, Reed DC, Slomp CP, Timmermann K, Voss M (2014) Hypoxia in the Baltic Sea: biogeochemical cycles, benthic fauna, and management. AMBIO 43:26–36

CBD (Convention on Biodiversity) (1998) Report of the workshop on the ecosystem approach. Lilongwe, Malawi, 26–28 Jan 1998. UNEP/COP/4/Inf.9
CBD (Convention on Biodiversity) (2004) The ecosystem approach. Secretariat of the Convention on Biodiversity (CBD), CBD, Montreal
Chen Q, Kozar O, Li F, Pekonen A, Saarman P (2014) Eutrophication in the Baltic Sea – characteristics and challenges. Paper presented at HENVI Science Days, University of Helsinki, 13–14 May 2014
Cloern JE (2001) Our evolving conceptual model of the coastal eutrophication problem. Mar Ecol Prog Ser 210:223–253
Conley DJ, Carstensen J, Ærtebjerg G, Christensen PB, Dalsgaard T, Hansen JLS, Josefson AB (2007) Long-term changes and impacts of hypoxia in Danish coastal waters. Ecol Appl 17(5 Supp):165–184
Conley DJ, Paerl HW, Howarth RW, Boesch DF, Seitzinger SP, Havens KE, Lancelot C, Likens GE (2009a) Controlling eutrophication: nitrogen and phosphorus. Science 323(5917):1014–1015
Conley DJ, Bonsdorff E, Carstensen J, Destouni G, Gustafsson BG, Hansson LA, Rabalais NN, Voss M, Zillén L (2009b) Tackling hypoxia in the Baltic Sea: is engineering a solution? Environ Sci Technol 43:3407–3411
Curtin R, Prellezo R (2010) Understanding marine ecosystem based management: a literature review. Mar Policy 34:821–830
De Santo E (2015) The Marine Strategy Framework Directive as a catalyst for maritime spatial planning: internal dimensions and institutional tensions. In: Gilek M, Kern K (eds) Governing Europe's marine environment. Europeanization of regional seas or regionalization of EU policies? Ashgate Publishing, Farnham
Díaz RJ, Rosenberg R (2008) Spreading dead zones and consequences for marine ecosystems. Science 321(5891):926–929
Díaz RJ, Rosenberg R (2011) Introduction to environmental and economic consequences of hypoxia. Int J Water Resour Dev 27:71–82
EC (2000) Water Framework Directive, 2000/60/EC. OJ L 327, pp 1–72
EC (2008) Marine Strategy Framework Directive, 2008/56/EC. OJ L 164, pp 19–40
EEC (1991a) Urban Wastewater Treatment Directive, 91/271/EEC. OJ L 135, pp 40–52
EEC (1991b) Nitrates Directive, 91/676/EEC. OJ L 375, pp 1–8
Elliott M (2002) The role of the DPSIR approach and conceptual models in marine environmental management: an example for offshore wind power. Mar Pollut Bull 44(6):iii–vii
Elmgren R (2001) Understanding human impact on the Baltic ecosystem: changing views in recent decades. AMBIO 30:222–231
Elmgren R, Larsson U (2001) Eutrophication in the Baltic Sea area: integrated coastal management issues. In: von Bodungen B, Turner RK (eds) Science and integrated coastal management. Dahlem University Press, Berlin, pp 15–35
Elofsson K (2002) Economics of marine pollution. Dissertation, Swedish University of Agricultural Sciences
Elofsson K (2010) The costs of meeting the environmental objectives for the Baltic Sea: a review of the literature. AMBIO 39:49–58
European Commission (2009a) European Union Strategy for the Baltic Sea Region. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. COM(2009) 248 FINAL
European Commission (2009b) Commission staff working document accompanying the Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions concerning the European Union Strategy for the Baltic Sea Region. SEC(2009) 712/2
European Commission (2011a) CAP reform – an explanation of the main elements. MEMO/11/695
European Commission (2011b) Report from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on the implementation of the EU Strategy for the Baltic Sea Region (EUSBSR). COM(2011) 382 FINAL
European Commission (2012a) Concept paper – May 2012, Agricultural Council – greening

European Commission (2012b) Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions concerning the European Union Strategy for the Baltic Sea Region. COM(2012) 128 FINAL
European Commission (2012c) Report from the Commission to the European Parliament and the Council on the implementation of the Water Framework Directive (2000/60/EC). River basin management plans. COM(2012) 670 final
European Commission (2014) Commission staff working document. Annex accompanying the document Commission Report to the Council and the European Parliament the first phase of implementation of the Marine Strategy Framework Directive (2008/56/EC). The European Commission's assessment and guidance. COM(2014) 97 Final
Fonselius SH (1969) Hydrography of the Baltic deep basins. III. Fishery Board of Sweden. Ser Hydrogr 23:1–97
Gilek M, Hassler B, Engkvist F, Kern K (2013) The HELCOM Baltic Sea Action Plan: challenges of implementing an innovative ecosystem approach. In: Henningsen B, Etzold T, Pohl AL (eds) Political state of the region report 2013 – trends and directions in the Baltic Sea region. Baltic Development Forum, Copenhagen, Available from: http://www.bsr2013.eu
Gilek M, Karlsson M, Udovyk O, Linke S (2015) Science and policy in the governance of Europe's marine environment – the impact of Europeanization, regionalization and the ecosystem approach to management. In: Gilek M, Kern K (eds) Governing Europe's marine environment. Europeanization of regional seas or regionalization of EU policies? Ashgate Publishing, Farnham
Gilek M, Karlsson M, Linke S, Smolarz K (2016) Environmental governance of the Baltic Sea – identifying key challenges, research topics and analytical approaches. In: Gilek M et al (eds) Environmental governance of the Baltic Sea. Springer, Dordrecht
Gren IM (2008) Cost effectiveness and fairness of the HELCOM Baltic Sea action plan against eutrophication. Vatten 64:273–281
Haahti BM, Hedenström E, Linke S, Lundberg C, Reisner G, Wanamo M (2010) Case-study report eutrophication. Deliverable 2, RISKGOV project, http://www.sh.se/riskgov
Hammer M (2015) The ecosystem management approach. Implications for marine governance. In: Gilek M, Kern K (eds) Governing Europe's marine environment. Europeanization of regional seas or regionalization of EU policies? Ashgate Publishing, Farnham
HELCOM (1988) Declaration on the protection of the marine environment of the Baltic Sea, adapted on 15 February 1988 in Helsinki by the Ministers responsible for the environmental protection in the Baltic Sea states
HELCOM and OSPAR (2003) Statement on the ecosystem approach to the management of human activities. First joint ministerial meeting of the Helsinki and OSPAR Commissions, Bremen, 25–26 June 2003
HELCOM (2006a) Development of tools for assessment of eutrophication in the Baltic Sea. Baltic Sea Environmental Proceedings No. 104. Available from: http://helcom.fi
HELCOM (2006b) Eutrophication in the Baltic Sea; Draft HELCOM thematic assessment in 2006. Baltic Marine Environment Protection Commission, 27th Meeting, Helsinki, Finland, 8–9 March 2006
HELCOM (2007a) HELCOM Baltic Sea Action Plan. Available from: http://helcom.fi
HELCOM (2007b) HELCOM Recommendation 28E/4. Amendments to annex IIII "Criteria and measures concerning the prevention of pollution from land-based sources" of the 1992 Helsinki Convention
HELCOM (2009a) Eutrophication in the Baltic Sea – an integrated thematic assessment of the effects of nutrient enrichment in the Baltic Sea region. Baltic Sea Environmental Proceedings No. 115B
HELCOM (2009b) Biodiversity in the Baltic Sea – an integrated thematic assessment on biodiversity and nature conservation in the Baltic Sea. Baltic Sea Environmental Proceedings No. 116B
HELCOM (2010) Ecosystem health of the Baltic Sea 2003–2007: HELCOM initial holistic assessment. Baltic Sea Environmental Proceedings No. 122
HELCOM (2013) Approaches and methods for eutrophication target setting in the Baltic Sea region. Baltic Sea Environmental Proceedings No. 133

Huhtala A, Ahtiainen H, Ekholm P, Fleming-Lehtinen V, Heikkilä J, Heiskanen, AS, Helin J, Helle I, Hyytiäinen K, Hällfors H, Iho A, Koikkalainen K, Kuikka S, Lehtiniemi M, Mannio J, Mehtonen J, Miettinen A, Mäntyniemi S, Peltonen H, Pouta E, Pylkkö M, Salmiovirta M, Verta M, Vesterinen J, Viitasalo M, Viitasalo-Frösen S, Väisänen S (2009) The economics of the state of the Baltic Sea. Pre-study assessing the feasibility of a cost-benefit analysis of protecting the Baltic Sea ecosystem. Report 2-2009. In: The Advisory Board for Sectoral Research 2:2009. Available from: http://www.minedu.fi

IEEP (Institute for European Environmental Policy) (2013) Environment undermined in CAP deal, Brussels, 26.06.2013

Jansson BO (1997) The Baltic Sea: current and future status and impact of agriculture. AMBIO 26:424–431

Joas M, Kern K, Sandberg S (2007) Actors and arenas in hybrid networks: implications for environmental policymaking in the Baltic Sea region. AMBIO 36:237–242

Johansson S, Bonsdorff E, Wulff F (2007) The MARE research program 1999–2006 – reflections on program management. AMBIO 36:119–122

Jørgensen BB, Richardson K (eds) (1996) Eutrophication in coastal marine ecosystems, vol 52, Coastal and Estuarine Studies. American Geophysical Union, Washington, DC

Karlsson M (2005) Managing complex environmental problems for sustainable development. Academic thesis, Karlstad University Press, Karlstad

Kern K (2011) Governance for sustainable development in the Baltic Sea region. J Balt Stud 42:67–81

Kern K, Löffelsend T (2004) Governance beyond the nation state in the Baltic Sea region. Local Environ 9:451–467

Kern K, Löffelsend T (2008) Governance beyond the nation state: transnationalization and Europeanization of the Baltic Sea region. In: Joas M, Jahn D, Kern K (eds) Environmental policies in the Baltic Sea region. Governing a common sea. Earthscan, London

Kern K, Joas M, Jahn D (2008) Governing a common sea: comparative patterns for sustainable development. In: Joas M, Jahn D, Kern K (eds) Governing a common sea. Environmental policies in the Baltic Sea region. Earthscan, London

Korpinen S, Meski L, Andersen JH, Laamanen M (2012) Human pressures and their potential impact on the Baltic Sea ecosystem. Ecol Indic 15:105–114

Kvale S (1996) Interviews: an introduction to qualitative research interviewing. Sage Publications, London

Linke S, Gilek M, Karlsson M, Udovyk O (2014) Unravelling science-policy interactions in environmental risk governance of the Baltic Sea: comparing fisheries and eutrophication. J Risk Res 17:505–523

Linke S, Gilek M, Karlsson M (2016) Science-policy interfaces in Baltic Sea environmental governance: towards regional cooperation and management of uncertainty? In: Gilek M et al (eds) Environmental governance of the Baltic Sea. Springer, Dordrecht

LRF (2013) Hur återställer vi Östersjön? Effektivare strategier mot ett mindre övergött hav (in Swedish). In: Lantbrukarnas Riksförbund, Stockholm. Available from: http://www.lrf.se

Lundberg C (2005) Conceptualizing the Baltic Sea ecosystem. An interdisciplinary tool for environmental decision-making. AMBIO 34:433–439

Lundberg C (2013) Eutrophication, risk management and sustainability. The perceptions of different stakeholders in the northern Baltic Sea. Mar Pollut Bull 66:143–150

Lundberg C (2014) Water quality of the Baltic Sea. In: Ahuja S (ed) Comprehensive water quality and purification. Elsevier, Waltham, pp 251–269

McQuatters-Gollop A, Gilbert AJ, Mee LD, Vermaat JE, Artioli Y, Humborg C, Wulff F (2009) How well do ecosystem indicators communicate the effects of anthropogenic eutrophication? Estuar Coast Shelf Sci 82:583–596

Mee L (2005) Assessment and monitoring requirements for the adaptive management of Europe's regional seas. In: Vermaat J, Bouwer L, Turner RK, Salomons W (eds) Managing European coasts: past, present and future. Springer, Berlin

Mee LD, Jefferson RL, Laffoley D, Elliott M (2008) How good is good? Human values and Europe's proposed marine strategy directive. Mar Pollut Bull 56(2):187–204

Milieu (2014) Article 12 technical assessment of the MSFD 2012 obligations. Baltic Sea. Final version of report to the European Commission, 7 February 2014

Nixon SW (1995) Coastal marine eutrophication: a definition, social causes, and future concerns. Ophelia 41:199–219

Nixon SW (2009) Eutrophication and the macroscope. Hydrobiologia 629:5–19

Österblom H, Hansson S, Larsson U, Hjerne O, Wulff F, Elmgren R, Folke C (2007) Human-induced trophic cascades and ecological regime shifts in the Baltic Sea. Ecosystems 10:877–889

Österblom H, Gårdmark A, Bergström L, Müller-Karulis B, Folke C, Lindegren M, Casin M, Olsson P, Diekmann R, Blenckner T, Humborg C, Möllmann C (2010) Making the ecosystem approach operational – can regime shifts in ecological- and governance systems facilitate the transition? Mar Policy 34:1290–1299

Rockström J, Steffen W, Noone K, Persson Å, Chapin FS III, Lambin EF, Lenton TM, Scheffer M, Folke C, Schellnhuber HJ, Nykvist B, de Wit CA, Hughes T, van der Leeuw S, Rodhe H, Sörlin S, Snyder PK, Costanza R, Svedin U, Falkenmark M, Karlberg L, Corell RW, Fabry VJ, Hansen J, Walker B, Liverman D, Richardson K, Crutzen P, Foley JA (2009) A safe operating space for humanity. Nature 461:472–475

SBA (Swedish Board of Agriculture) (2012) A greener CAP? An analysis of the Commission's greening proposal for the Common Agricultural Policy. Report 2012:13, Jönköping

Schumacher T (2011) The capacity of the EU to address marine eutrophication. In: Pihlajamäki M, Tynkkynen N (eds) Governing the blue-green Baltic Sea. Societal challenges of marine eutrophication prevention, vol 31, FIIA Report. Finnish Institute of International Affairs (FIIA), Helsinki

Schumacher T (2012) Evaluation of the European Union's policies and legislation related to Baltic Sea eutrophication. PROBALT project. Research Group on International Political Sociology, Institute of Social Sciences, Kiel University, Kiel

Sellke P, Dreyer M, Linke S (2015) Fisheries: a case study of Baltic Sea environmental governance. In: Gilek M et al (eds) Environmental governance of the Baltic Sea. Springer, Dordrecht

Silverman D (1993) Interpreting qualitative data. Methods for analysing talk, text and interaction. Sage Publications, London

Söderström S, Kern K, Hassler B (2015) Marine governance in the Baltic Sea: current trends of Europeanization and regionalization. In: Gilek M, Kern K (eds) Governing Europe's marine environment. Europeanization of regional seas or regionalization of EU policies? Ashgate Publishing, Farnham

SRU (German Advisory Council on the Environment) (2013) Reform of the Common Agricultural Policy: opportunities for reorientation. Comment on environmental policy no 11. Berlin, January 2013

TFEU (2007) Consolidated versions of the treaty on European Union and the treaty on the functioning of the European Union. Off J Eur Union C 326:1–390

Trush SF, Dayton PK (2010) What can ecology contribute to ecosystem-based management? Ann Rev Mar Sci 2:419–441

Tynkkynen N, Schönach P, Pihlajamäki M, Nechiporuk D (2014) The Governance of the mitigation of the Baltic Sea eutrophication: exploring the challenges of the formal governing system. AMBIO 43:105–114

Udovyk O, Gilek M (2013) Coping with uncertainties in science-based advice informing environmental management of the Baltic Sea. Environ Sci Policy 29:12–23

Udovyk O, Gilek M (2014) Participation and post-normal science in practice? Reality check for hazardous chemicals management in the European marine environment. Futures 63:15–25

UNEP (2005) Lääne A, Kraav E, Titova G (eds) Baltic Sea, GIWA, Regional Assessment 17. University of Kalmar, Kalmar

Vahtera E, Conley DJ, Gustafsson BG, Kuosa H, Pitkänen H, Savchuk OP, Tamminen T, Viitasalo M, Voss M, Wasmund N, Wulff F (2007) Internal ecosystem feedbacks enhance nitrogen-fixing cyanobacteria blooms and complicate management in the Baltic Sea. AMBIO 36:186–194

Velthof GL, Lesschen JP, Webb J, Pietrzak S, Miatkowski Z, Pinto M, Kros J, Oenema O (2014) The impact of the Nitrates Directive on nitrogen emissions from agriculture in the EU-27 during 2000–2008. Sci Total Environ 468–469:1225–1233

Wassmann P, Olli K (eds) (2006) Drainage basin nutrient inputs and eutrophication: an integrated approach. University of Tromsø. Available from http://kodu.ut.ee/~olli/eutr

Wulff F, Humborg C, Andersen HE, Blicher-Mathiesen G, Czajkowski M, Elofsson K, Fonnesbech-Wulff A, Hasler B, Hong B, Jansons V, Mörth CM, Smart JC, Smedberg E, Stålnacke P, Swaney DP, Thodsen H, Was A, Zylicz T (2014) Reduction of Baltic Sea nutrient inputs and allocation of abatement costs within the Baltic Sea catchment. AMBIO 43:11–25

Zillén L, Conley DJ, Andrén T, Andrén E, Björck S (2008) Past occurrences of hypoxia in the Baltic Sea and the role of climate variability, environmental change and human impact. Earth-Sci Rev 91:77–92