Successful Knowledge Governance for Ecosystem-based Management

DIANA GIEBELS

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Succesvolle kenniscreatie en -benutting in de praktijk

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Diana Giebels
born in Xanten (Germany)

Erasmus University Rotterdam

Doctoral Committee:

Promotors: Prof.dr. M.W. van Buuren
Prof.dr. J. Edelenbos

Other members: Prof.dr. P.P.J. Driessen
Prof.dr. E.H. Klijn
Prof.dr. E. Turnhout

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"Choose well. Your choice is brief, and yet endless."
Johann Wolfgang von Goethe

Chapter 1

Introduction

1.1. WHAT IS ECOSYSTEM-BASED MANAGEMENT?

Ecosystem-based management[1] (EBM) is a special type of natural resource management that is unfamiliar to many people. However, most people have heard about the Great Barrier Reef. Located along the coastline of Queensland, Australia, the Great Barrier Reef constitutes the world's largest coral reef, in addition to being the largest living structure on our planet. Its impressive biodiversity includes 1,625 species of fish, more than 600 types of hard and soft corals, 215 different species of birds, 30 species of whales and dolphins, as along with six of the world's seven species of marine turtles. Its contribution to the Australian economy amounts to 6.4 billion Australian dollars and supports about 64,000 employed positions. Along with the Grand Canyon, the Northern Lights and Mount Everest, the Great Barrier Reef has been proclaimed one of the seven natural wonders of the world (GBRF, 2019).

More important to this thesis, the Great Barrier Reef also constitutes the world's most sophisticated case of ecosystem-based management (Olson et al., 2008; Ruckelshaus et al., 2008). This management philosophy is based on taking the ecosystem as the guiding entity for organization of managerial tasks. It envisions sustainable and place-based management of natural resources. By developing a holistic understanding of ecological systems and their interrelatedness with human use, EBM seeks to ensure the health of ecosystems and the durability of ecosystem services (McLeod et al., 2005).

As a management philosophy, EBM emerged from a paradigm shift in the field of environmental and natural resource management throughout the 1930s and 1940s, during which severe shortcomings of traditional approaches became evident (Grumbine, 1994). Traditional approaches tended to be characterized by reductionism and fragmentation, failing to take into account the benefits and services provided by an ecosystem as a whole (Tallis et al., 2010). They were driven by the short-term, sector-specific objectives of individual resource agencies that did not engage with external stakeholders or consult scientific sources for sound environmental assessments (Curtin and Prellezo, 2010). As an alternative to reductionism, EBM envisioned integrated, large-area management based on the principles of adaptive management, with the goal of balancing the use of ecosystems with their conservation and protection (Olsen and Nickerson, 2003; see also Table 1.1 for an overview).

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[1] In the literature ecosystem-based management is also referred to under the labels 'the ecosystem approach' and 'ecosystem management'. Throughout this thesis these labels are considered to be interchangeable. However, for communicative clarity, the term ecosystem-based management or its abbreviation EBM will be used consistently.

Table 1.1
The philosophical principles of EBM
(Source: Olsen and Nickerson, 2003)

The Philosophical Principles of EBM
Managing on the scale of the ecosystem(s)
Covering large spatial areas through inclusion of multiple scales
Planning characterized by long-term perspectives
Taking humans as integral parts of ecosystem(s)
Organizing decision-making based on research evidence, continuously monitoring and adapting to system changes
Assuring sustained production potential for ecosystem goods and services

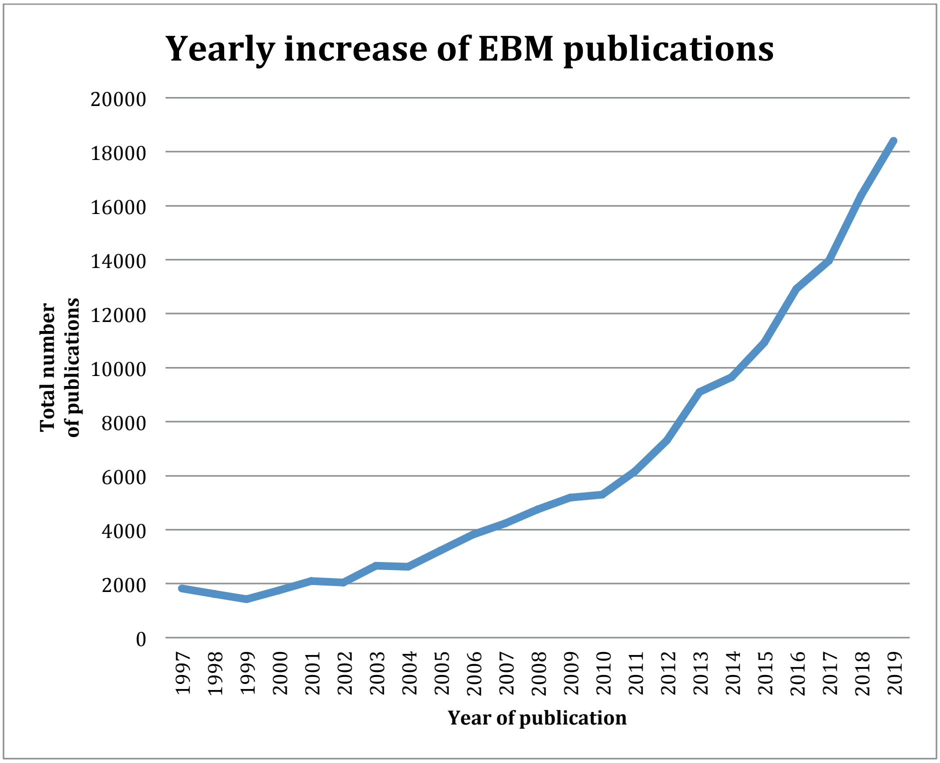
The conceptual development of EBM did not take hold until the 1980s, when it finally became a settled theme within the scientific and policy community (Grumbine, 1994). Since that time, the popularity of EBM has consistently increased (Curtin and Prellezo, 2010). A remarkable increase has also been observed in the number of publications relating to EBM, particularly since the beginning of this century. While only 1,819 EBM-related publications emerged in 1997, the body of literature on EBM had increased impressively to a total of 18,410 publications in 2019 (see Figure 1.1 for an overview of total publications per year, as derived from Sciencedirect.com).

In addition to its application in land management, EBM has been attracting growing interest and application within the context of marine systems in recent years (Arkema et al., 2006; Yaffee, 2012; Leslie et al., 2015). Approaches based on EBM are currently in use around the globe, including applications in the United States of America, Canada, the European Union, Australia and, most recently, in many developing countries (Leslie et al., 2015; see Picture 1.1 for an overview of worldwide EBM applications).

1.2. THE RESEARCH PROBLEM: KNOWLEDGE AS BOTH KEY AND PROBLEM IN EBM DECISION-MAKING

Despite the growing popularity and implementation of the ecosystem approach, and despite the rich body of scientific publications, the concept of EBM has yet to achieve maturity. Although the paradigm has clearly been settled, it continues to be dominated by a persistent scientific debate on the clarification of its philosophical principles, the practical implications of these principles and how they can be fulfilled and implemented (Haeuber and Franklin, 1996; Katsanevakis et al., 2011; Long et al., 2015).

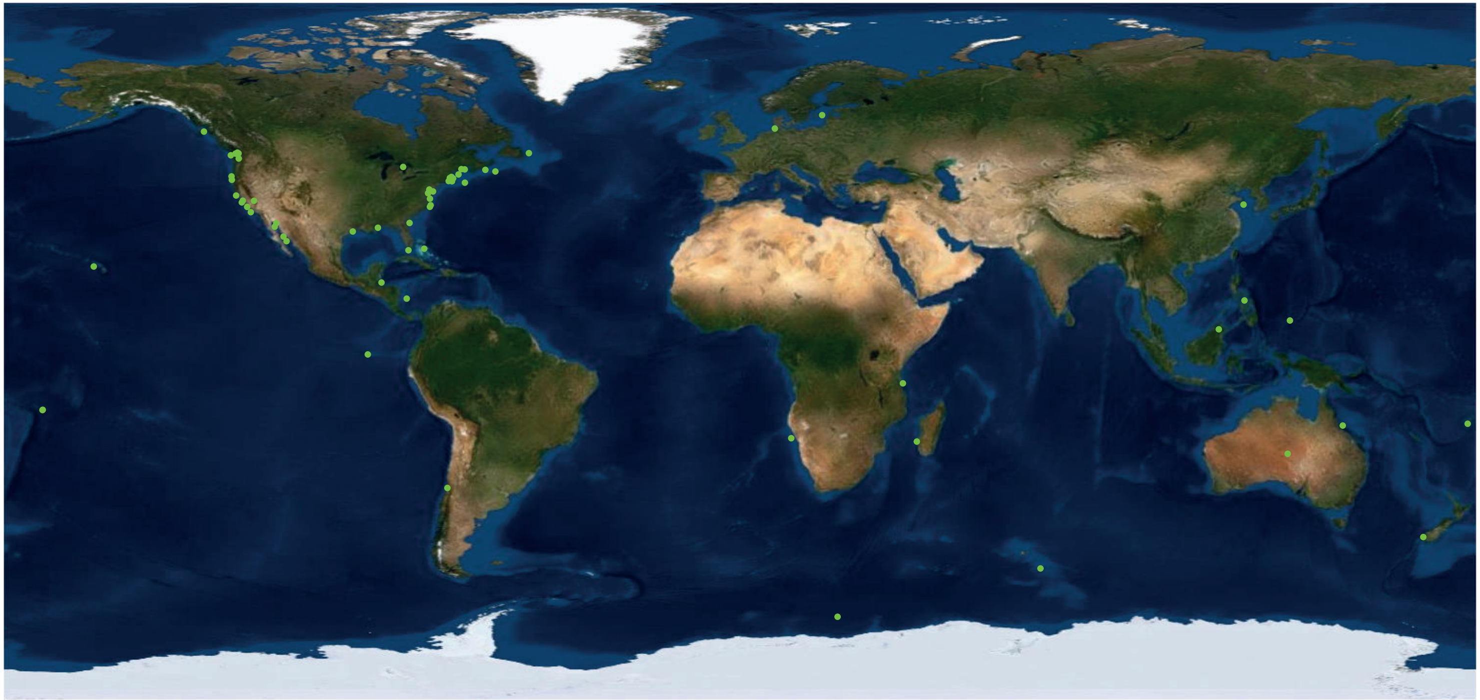
Figure 1.1
Yearly increase of EBM publications
(Source: Sciencedirect.com, accessed on 20.07.2020)



The implementation of EBM requires the integral consideration and management of all human activities that impact and exert pressure on an ecosystem. In marine systems like the Great Barrier Reef, pressure from shipping, tourism and coastal development, exert a cumulative impact on the ecosystem, as well as on its structure and functioning. Such pressure can cause aggregate-level changes within an ecosystem, as manifested in various processes, including eutrophication, toxic pollution and climate change (Halpern et al., 2008). Such changes give rise to new system states, which exhibit dynamic, evolutionary and often complex behaviour. Ecosystem-based management thus encompasses the management of continuously changing and partly unknown decision-making targets. Uncertainty constitutes a daily challenge for EBM decision-makers.

The implementation of EBM has thus come to be guided by the continuous generation and utilization of knowledge. Often referred to as 'adaptive management', the application of EBM involves basing decisions on knowledge that is continuously updated, thereby enabling learning about the dynamics, changes and development of ecosystems (Grumbine, 1997).

Picture 1.1
EBM implementation on the global scale
(Source: adapted from Ecosystem Management Initiative (2019), University of Michigan)



Comprehensive, science-led research and monitoring have typically been the primary means of organizing and structuring this part of the decision-making process (Long et al., 2015). In their turn, decision-makers are expected to use scientifically generated knowledge for the reconsideration and revision of their policies.

Given the importance attached to decision-making based on knowledge that reflects the complexity of socio-ecological systems, the EBM approach is both ambitious and demanding. Its use implies a heavy workload, due to the need to create holistic understanding of locally defined geographical systems, which are continuously influenced and changed by external developments (Koehn et al., 2013). Even when applied within highly favourable contexts (e.g. the Great Barrier Reef), it has become clear that a strong science-for-management programme can take decades to identify ecosystem pressures. Diffuse pressures including terrestrial pollution and fishing contribute to the ongoing degradation of ecosystem health (Brodie and Waterhouse, 2012).

Not surprisingly, the willingness and ability of environmental managers to apply EBM has been negatively affected by the high demands associated with EBM philosophy in terms of the generation and utilization of knowledge. High costs and time-consuming requirements of data collection, monitoring and analysis constitute severe challenges (Tallis et al., 2010; Koehn et al., 2013). The extensive use of knowledge for decision-making, which was acclaimed being the innovative and added value of the ecosystem-based management philosophy, thus turns out to hinder uptake of its implementation in practice. Instead of increasing the quality of decisions taken, the knowledge preambles of EBM philosophy seem to constitute a restricting bottleneck.

In this light, it is surprising to note the lack of attention that researchers within the discipline have devoted to the actual 'knowledge work' executed by decision-makers who have been successful in their attempts to organize EBM. "Despite general consensus within the scientific community that we have the scientific information needed to improve existing management practices, an explicit assessment of the state of knowledge and advice on how to apply this information to policy and practice has been lacking" (Lester et al., 2010). In particular, knowledge on "contexts in which learning and adaptation can occur" continues to be limited, thus constituting a key research need with regard to EBM (Leslie and McLeod, 2007).

To date, studies on EBM with an explicit focus on decision-making knowledge have tended to address their objects of study through the development of decision-support tools, recommendations for best practices or other types of blueprints. Examples include studies that develop structured decision-making frameworks (e.g. Espinosa-Romero et al., 2011) or advice on the management of uncertainty (e.g. Piet et al., 2017). Even what might be the largest and most long-term-oriented EBM study on decision-making, which was initiated by Steve Yaffee in 1995, adopts a merely descriptive focus by taking stock of established management structures (EMI, 2004).

Although the advances achieved through the aforementioned scientific efforts have proven their relevance and invaluable importance to fostering and facilitating decision-makers who are willing to implement EBM, very little attention has been devoted to developing a profound understanding of the way in which the knowledge demands of EBM are met and put into practice. As early as 1994, Grumbine linked this lack of conceptual maturation to the dominance of biological science within the discipline. Social scientific perspectives, including themes relating to the organizational change needed to foster the maturation of EBM theory and practice, had not gained much attention up to that point.

Acknowledging the persistence of this problem, Christie (2011) argues that environmental scientists continue to dominate the formulation of both research agendas and policy problems. According to a dominant belief within this tradition, the failure of decision-makers to implement ecologically adequate measures is due to the lack of sufficient knowledge at their disposal. Crucial social scientific research that could enhance understanding concerning the philosophy and its implementation – including research on the human dimension of EBM, as well as the comprehensive evaluation of the phenomenon and associated programmes – is still lacking (Christie et al., 2009, Christie, 2011).

In a review of 49 EBM plans, Arkema et al. (2006) provides additional evidence to support this claim. Despite an increase in the commitment of managers to the principles of EBM, the concrete translation of the philosophy seems to get lost upon entering the implementation stage. Of all managerial objectives and interventions reviewed for detailed EBM cases, fewer than 10% actually reflected EBM principles. Specific difficulties experienced by EBM managers include the need to incorporate and approach complexity, to organize science-based decision-making, adaptive management, monitoring, the definition and evaluation of interventions, stakeholder involvement and the organization of long-term management (Arkema et al., 2006).

1.3. THE RESEARCH AIM: EXPLORING, DESCRIBING AND EVALUATING HOW DECISION-MAKERS HAVE SUCCESSFULLY ACCOMPLISHED THE TASK OF KNOWLEDGE GOVERNANCE

For decades, EBM scholars have envisioned science as an important tool with which to inform decision-making practice, but have neglected the urgency of understanding the ways in which EBM theory should be informed by decision-making practice. In particular, the role of the decision-makers responsible for the actual implementation of EBM through the organization of salient, credible and legitimate knowledge has been largely ignored. Such understanding is crucial for EBM, as it can provide insight into its successful organization within a variety of socio-ecological settings (Olson et al., 2008; Christie et al., 2009). Instead of conceptualizing EBM decision-making as consisting solely of the generation and utilization of the best knowledge available, it is necessary to identify and understand the information strategies that effectuate EBM (Olson et al., 2008). This is particularly true in light of the most recent developments within the field.

Given the current increase in the number of EBM applications throughout the world, the decision-making contexts within which ecosystem managers operate are also becoming increasingly diverse. Traditional contexts, as represented by the iconic case of the Great Barrier Reef, reflect a high level of recognition of the ecological values that a region can represent. The philosophical principles of EBM thus almost naturally enjoy a high level of legitimacy. In the case of the Great Barrier Reef, this legitimacy is represented by and institutionalized through an administrative entity that holds juridical authority over the entire area. Established in 1975 and represented by the Great Barrier Reef Marine Park Authority (GBRMPA), this legal authority executes all tasks relating to EBM, including the conservation and sustainable use of ecosystems, in addition to community involvement, monitoring and performance evaluation (Australian Government, 2018; Curtin and Prellezo, 2010; GBRF, 2019). The management tasks of the GBRMPA were further intensified in 2004, with the adoption of a comprehensive spatial zoning plan and the largest public-participation effort in the history of Australia (Ruckelshaus, 2008). As a result, decision-making is characterized by an integrated, science-led research facilitation and represents the classical preambles of EBM philosophy.

In many other regions of the world, the conditions under which EBM approaches must be implemented are less favourable. The day-to-day challenges encountered within EBM contexts are defined by such characteristics as fragmented jurisdictions, a lack of legitimacy and non-comprehensive or timely restricted monitoring programmes (Yaffee and Wondolleck, 2003; De Jonge et al., 2006; De Jonge, 2007). An official mandate to implement EBM thus provides no guarantee of a successful decision-making process. Decision-makers must organize a complex process that spans a variety of decision-making levels, sectors and, ultimately, societal actors. They are expected to assure the accumulation, utilization and integration of available knowledge - which often stems from a variety of institutional backgrounds - in addition to initiating the creation of new knowledge that possesses cross-institutional legitimacy. Instead of focussing on the development of new operational tools to support decision-making, this thesis focuses on the actual decision-makers, with the primary objective of gathering insight into the ways in which decision-makers are able to organize knowledge for EBM decision-making.

Studying decision-makers and their approaches to knowledge governance

Adopting a decision-maker perspective on EBM requires acknowledging that system boundaries and their related knowledge needs are not necessarily defined by geographical data. It further requires understanding the ways in which decision-makers use information, knowing which sources they trust and grasping the ways in which they organize the necessary feedback loops between the various decision-making actors within the broader policy system (Head, 2016). Such a perspective must also acknowledge that decision-making actors are self-organizing entities that are in continuous interaction with their operational context, thereby giving rise to an emergent, often non-linear evolution to their own decision-making processes (Teisman and Klijn, 2008; Klijn, 2008). Typical practical problems arise from such issues as the identification of which data are generated within which administrative boundaries and the relative legitimacy of locally generated data and knowledge within and across other governmental bodies (Van Buuren, 2009; Edelenbos et al., 2011). One important research objective involves unravelling the varying degrees of knowledge gaps and the variety of needs for social learning and deliberation amongst participating actors (Bodin, 2017).

Empirical case studies - particularly comparative ones - focusing on the use of information (e.g. scientific studies) by public agencies are rare in the respective literatures of EBM and public administration (Olson et al., 2008; Head, 2016). For this reason, the research focus of this thesis has been narrowed to the investigation of how decision-makers are able to organize successful *knowledge governance*[2] for EBM and how the success of their endeavours is affected by the various decision-making contexts within which they operate.

Main aim of this thesis is to explore, describe and evaluate empirical approaches to knowledge governance as developed and applied successfully by EBM decision-makers within the professional field. Throughout the thesis, the concept of knowledge governance is used to refer to all tasks that are developed, employed or executed by mandated EBM decision-makers

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[2] Please note that the terms ‘knowledge governance’ and ‘knowledge management’ are used as synonyms throughout this thesis.

in order to organize the salient, credible and legitimate knowledge needed to realize EBM (a detailed definition of knowledge governance is also provided in Chapter 3). Knowledge governance thus entails more than simply generating and using the best available knowledge for decision-making. It also involves organizing an administrative-political process that can assure the availability and legitimacy of knowledge across administrative-political boundaries.

Inspired by Olson et al. (2008), who suggest that the generation of more empirical studies, and particularly case-study analyses and comparative studies, are needed to fill the social-scientific knowledge gap relating to EBM, the foundation for this thesis consists of case-study research. Relevant case studies have been selected from within a specific context: the Wadden Sea research area. This area is well known for its long-standing history of EBM, and it has received international recognition for its large-scale EBM approach (further details are provided in Section 1.5).

Decision-makers in the Wadden Sea area were approached through participation in publicly organized meetings and conferences, as well as through direct contact by telephone or email. They were asked directly and informally to share successful cases of EBM, while reflecting on the role of knowledge therein. Within this context, successful EBM projects were defined as those that had achieved their EBM goals, while simultaneously indicating that knowledge plays a crucial role throughout the decision-making process. In one case, success consisted of the restoration of the habitat of a nearly extinct species. In another, it consisted of extending a harbour area while addressing concerns of ecosystem health. This allowed the identification of a variety of EBM approaches, all of which have been successful, while reflecting a variety of approaches to knowledge governance, as applied throughout complex decision-making processes.

1.4. THE RESEARCH QUESTIONS

To capture the research focus on EBM decision-makers and whether and how they are successful in their attempts to organize knowledge governance for EBM, the main research question of this thesis was formulated as follows:

> How can EBM knowledge governance be organized successfully?

The primary research question was operationalized into four sub-questions, which have been developed and answered throughout the course of this thesis project. The first sub-question is aimed at unravelling exactly which knowledge requirements EBM philosophy imposes on decision-makers. This question was advanced in order to identify which knowledge is needed for EBM *in theory* and how decision-makers are expected to generate this knowledge for EBM. Sub-question 1 is thus:

1. Which knowledge requirements does EBM philosophy impose on decision-makers?

Directly following from the first sub-question, the second step requires understanding how EBM decision-makers put the knowledge-government demands that have been defined in theory *into practice*. In this regard, it was important to explore and describe the actual organisational patterns that decision-makers have been developing and following, in addition to evaluating whether and to what extent their approaches have been successful. Sub-question 2 is thus:

2. How do EBM decision-makers respond to knowledge requirements in practice, and how do they create common knowledge grounds in order to manage ecosystem-based adaptation?

The third sub-question is intended to link the evaluation of success to the particularities of context. It was advanced in order to investigate the existence and nature of relationships between the actual administrative-political context within which a decision-maker operates and the most preferable knowledge-governance approach that should be applied. Sub-question 3 is thus:

3. Can the success of EBM knowledge governance be explained by the administrative-political contexts in which decision-makers operate and, if so, how?

The case study evaluations also revealed that although all of the empirically applied approaches to knowledge governance were associated with successful decision-making processes and the achievement of EBM goals, none succeeded in realizing the full potential of the EBM paradigm. In particular, the lack of knowledge integration amongst the highly diverse knowledge sources involved led to a lack of quality. The final research question therefore examines how knowledge integration can be achieved through the application of a transdisciplinary approach to knowledge governance. Sub-question 4 is thus:

4. How can transdisciplinary knowledge management assist decision-makers in their attempts to organize holistic EBM knowledge governance successfully?

Table 1.2
Thesis outline based on research questions

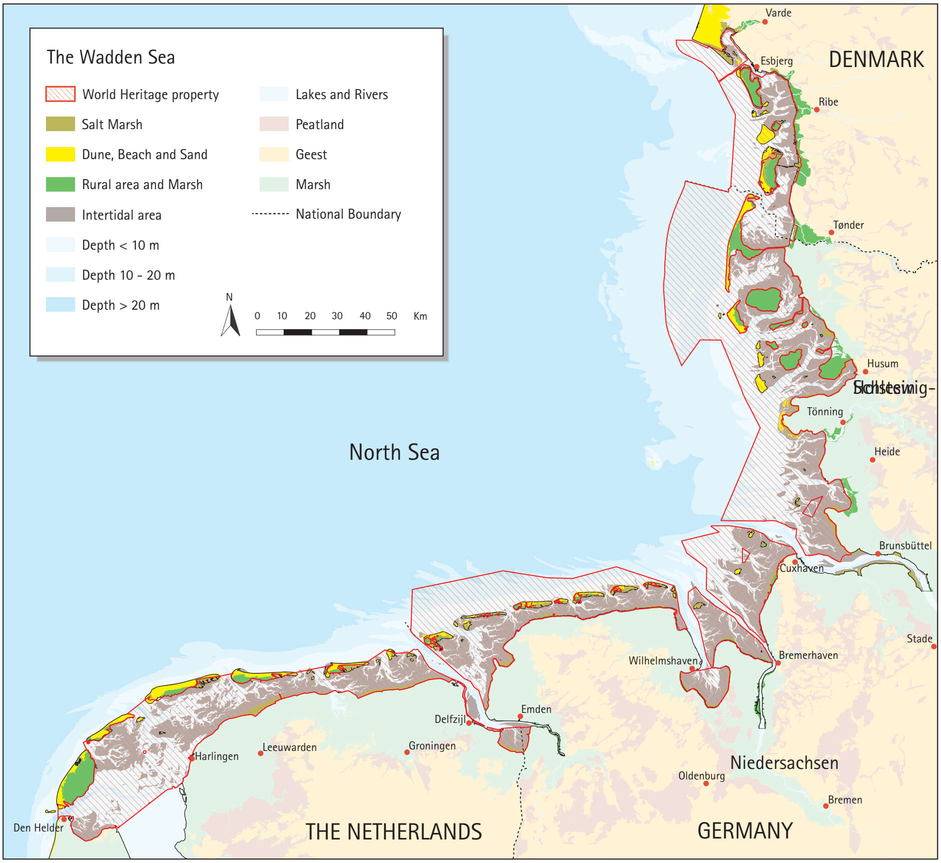
Chapter	Research question	Method	Published as
1 Introduction	Main research question		
2 Ecosystem-based management in the Wadden Sea: Principles for the governance of knowledge	RQ1 Which knowledge requirements does EBM philosophy impose on decision-makers?	Literature review and qualitative comparative case study analysis based on document analysis	Giebels, D., Buuren, M.W. van & Edelenbos, J. (2013). Ecosystem-based management in the Wadden Sea: Principles for the governance of knowledge. *Journal of Sea Research*, 82(3), 176-187
3 Using knowledge in a complex decision-making process - evidence and principles from the Danish Houting Project's ecosystem-based management approach	RQ2 How do EBM decision-makers respond to knowledge requirements in practice, and how do they create common knowledge grounds in order to manage ecosystem-based adaptation?	Single case study based on interviews and document analysis	Giebels, D., Buuren, M.W. van & Edelenbos, J. (2015). Using knowledge in a complex decision-making process - evidence and principles from the Danish Houting Project's ecosystem-based management approach. *Environmental Science and Policy*, 47, 53-67
4 Towards ecosystem-based management for Mainports: A historical analysis of the role of knowledge in the development of the Rotterdam Harbor from 1827-2008	RQ2 How do EBM decision-makers respond to knowledge requirements in practice, and how do they create common knowledge grounds in order to manage ecosystem-based adaptation?	Single case study based on secondary literature review, interviews and document analysis	Giebels, D. & Teisman, G.R. (2014). Towards ecosystem-based management for Mainports: A historical analysis of the role of knowledge in the development of the Rotterdam Harbor from 1827-2008, *Ocean and Coastal Management*, 108, 39-51
5 Knowledge governance for ecosystem-based management: understanding its context dependency	RQ3 Can the success of EBM knowledge governance be explained by the administrative-political contexts in which decision-makers operate and, if so, how?	Qualitative comparative case analysis	Giebels, D., Buuren, M.W. van & Edelenbos, J. (2016). Knowledge governance for ecosystem-based management: understanding its context dependency, *Environmental Science and Policy*, 55(3), 424-435
6 Transdisciplinary Knowledge Management: a key but underdeveloped skill in EBM decision-making	RQ4 How can transdisciplinary knowledge management assist decision-makers in their attempts to organize holistic EBM knowledge governance successfully?	Literature review and participative case study including action research	Giebels, D., Carus, J., Paul, M., Kleyer, M., Siebenhüner, B., Arns, A., Bartholomä, A., Carlow, V., Jensen, J., Tietjen, B., Wehrmann, A., Schröder, B. (2020) Transdisciplinary Knowledge Management: a key but underdeveloped skill in EBM decision-making, *Marine Policy*, 119
7 Conclusion and Discussion	Main research question		

The answers to the main research question and the four sub-questions are presented in subsequent chapters of this thesis. Answers to the sub-research questions have also been published in scientific journals. Table 1.2 provides an overview of the chapters in which the various questions are answered and the scientific journals in which the results have been published.

1.5. THE RESEARCH AREA: THE NORTH EUROPEAN WADDEN SEA

The empirical material for this thesis is based on the geographical area of the North European Wadden Sea (see Pictures 1.2 and 1.3). The Wadden Sea constitutes the largest tidal flat system in the world. With its highly dynamic landscape and rich biodiversity, the area forms a unique landscape that attained UNESCO World Heritage status in 2009 (CWSS, 2019).

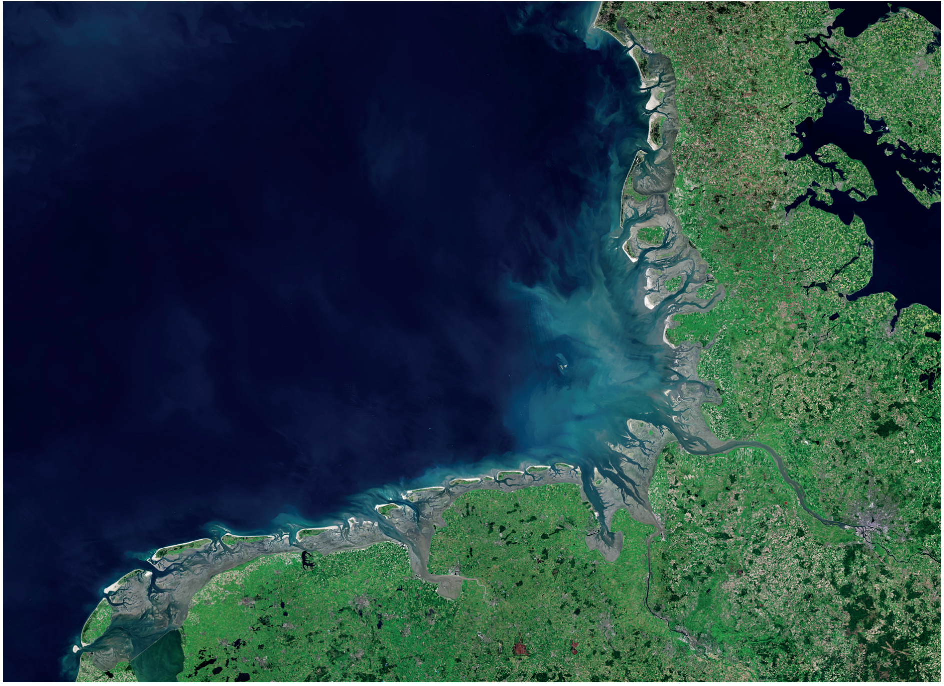
Picture 1.2
Map of the Wadden Sea and its major habitats
Source: © Common Wadden Sea Secretariat



Its governance authority is vested in a trilateral agreement involving all adjacent countries, including the Netherlands, Germany and Denmark. Important knowledge-governance strategies for the region include monitoring and assessment, adaptive management, collaborative planning and cross-jurisdictional coordination (EMI, 2019).

The development of environmental governance in the Wadden Sea area began in the 1960s, when "prominent scientists and NGOs in the region pressed for an international commitment to protect the Wadden Sea" (Olsen and Nickerson, 2003). At that time, scientists and non-governmental organizations were operating as advocates for the conservation and protection of the entire Wadden Sea ecosystem (Olsen and Nickerson, 2003; Enemark, 2005). The first agreement, which was reached in 1978, established the trilateral policy "to protect, conserve and manage the Wadden Sea ecosystem and its facets in an integrated and comprehensive way which would allow for sustainable use" (Enemark, 2005). The Common Wadden Sea Secretariat was established in 1987 as an institutional backbone that would be

Picture 1.3
Satellite image of the Wadden Sea with its three sub-regions
(Source: Satellitenbildwerkstatt e.K. (image processing), Brockmann Consult GmbH (scientific consulting), raw data: U.S. Geological Survey.)
https://www.waddensea-worldheritage.org/taking-shape



responsible for facilitating and supporting EBM across the adjacent countries, (Enemark, 2005).

At the individual national level, EBM was particularly fostered through supranational legislation stemming from the European Union (EU). Based on the Habitats Directive (1992), the Birds Directive (2009), the Water Framework Directive (2000) and the Strategic Environmental Assessment Directive (2001), EU legislation provides a general framework for environmental protection and the promotion of sustainable development (Katsanevakis et al., 2011). Furthermore, the EU Water Framework Directive explicitly reflects Europe's ambition to initiate the conservation of marine systems at the ecosystem level (De Jonge et al., 2006; De Jonge, 2007). Collectively, the Habitats Directive, the Water Framework Directive, the Integrated Coastal Zone Management Recommendation, the European Commission Marine Strategy and the Proposed Marine Framework Directive thus reflect a clear shift towards EBM in the standards of the EU (Apitz et al., 2006).

In the Wadden Sea area, knowledge plays a central role in informing the decision-making process. A general commitment to using the best available information, called the 'principle of careful decision-making' has been announced. Another guideline that has been inaugurated specifies that certain activities should not be conducted if sufficient scientific evidence is lacking. This knowledge-based approach to decision-making is unique in Europe. The Wadden Sea area is one of the few areas, if any other in Europe, where such a management approach is applied and politically accepted. In 2000 it was concluded that the targets comply with the requirements of scientific credibility, management usefulness and suitability for communication with stakeholders (De Jong, 2000).

In light of the context described above, the Wadden Sea research area is ideally suited for empirical work on the delicate art of knowledge governance in EBM. Decision-makers operating within the political-administrative context of the Wadden Sea are officially charged with the task of generating and utilizing knowledge in their daily work. The decision-making landscape is complex, however, given the diverse supranational, national, regional and local rules, regulations and initiatives that support EBM. The empirical material gathered from this area allows for the in-depth study of the ways in which decision-makers navigate within this landscape, the knowledge sources that they use and the relative legitimacy of these sources across different decision-making actors.

1.6. OUTLINE OF THE THESIS

Chapter 2 is dedicated to answering the first sub-question by summarizing the results of a literature review. It provides a detailed elaboration of the system complexity that decision-makers face when implementing EBM. Diverse literature relating to the role of knowledge in public decision-making and EBM is reviewed and combined to compile a catalogue of principles. This catalogue is subsequently used to define the theoretical requirements that EBM knowledge governance (EKG) imposes on decision-makers. It simultaneously functions as an analytical framework for the empirical reflection on decision-making practice. A test of the utility of the analytical framework is conducted, along with an initial empirical reflection on the ways in which decision-makers respond to knowledge-governance requirements in the administrative-political system of the Wadden Sea.

In Chapter 3, the analytical framework is further refined and explicated. It is supplemented by existing theory on potential decision-making behaviour and summarized in a visual representation. The developed framework is used for in-depth analysis of two selected case studies presented in chapter 3 and 4. Chapter 3 focuses on knowledge governance for EBM as it was developed for Denmark's second-largest river-restoration project, the Houting project. Chapter 4 presents the results of a similar analysis developed and applied to the latest phase of development for one of the largest harbours in Europe, Mainport Rotterdam. The two chapters provide in-depth empirical background on the way in which knowledge governance for EBM was organized successfully and how this successful organization related to the theoretically defined principles of EBM philosophy.

In light of the empirical case evidence, which reflects notable differences in the ways in which decision-makers take up and interpret their tasks of organizing knowledge governance successfully, Chapter 5 is intended to explain these differences. To this end, it combines political-administrative theory with the method of qualitative comparative analysis. The qualitative comparison was used to generate a deeper understanding about the relationship between success and the operational context of decision-makers. It suggests that the level of conflict in relation to the actual availability of knowledge as experienced by decision-makers, are important variables that define the successfulness of the approaches applied.

As further revealed in Chapter 5, the most demanding context for decision-makers to implement knowledge governance is defined by a high level of conflict and a low level of knowledge availability. This type of political-administrative context calls for a holistic approach to EKG. Given that holistic approaches to EKG are apparently rarely applied in EBM practice, a deeper investigation of available theory is needed in order to develop a profound understanding of what is involved in holistic EBM, how it works and how it can be brought into practice. In response to this research need, Chapter 6 presents a systematic review of the literature on transdisciplinary knowledge management (TKM). This body of literature proved the most helpful for developing a roadmap for decision-makers with regard to the integration of scientific and other sources of knowledge. It constitutes an important addition to the theoretical foundation of this thesis, given that the previously reviewed public-administration literature does not address this issue in detail.

Chapter 6 continues by providing unique, detailed case evidence of a project involving the organization of transdisciplinary knowledge management. Through participative case study research, the author of this thesis conducted a close examination of an EBM knowledge-governance process, while simultaneously designing and evaluating it. This governance process was conducted in the German, Lower Saxony part of the Wadden Sea area and organized under the umbrella of the RELEEZE project. The RELEEZE project aimed to develop an EBM perspective on coastal protection policy in the light of climate change.

The thesis concludes by summarizing the research progress achieved throughout this project (Chapter 7), including an overview of all major findings of the preceding chapters and a summary of the main research results. These findings provide answers to the research question and sub-questions, which together result in an administrative-political perspective on the successful organization of knowledge governance for EBM. The resulting perspective highlights the need to understand EBM knowledge governance as an outcome of a social process. It reveals that decision-makers utilize a variety of approaches to organize knowledge governance, all of which could potentially generate successful results. As also indicated by the findings, however, the success of each approach to knowledge governance depends on the operational context of the decision-maker. Neither the individual decision-maker nor the quality of the body of evidence produced can guarantee the success of the knowledge governance process in isolation. The interaction of a public decision-maker with all other relevant actors within the broader operational context is just as important. Hands-on advice concerning the possibility of managing knowledge governance within such complex decision-making contexts is provided. Chapter 7 ends by reflecting on the limitations of this thesis and outlining an agenda for future research.

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Chapter 2

Ecosystem-based management in the Wadden Sea: Principles for the governance of knowledge

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ABSTRACT

The governance of the Wadden Sea has to contend with a complex interplay of social and ecological systems. Social systems tend to be characterized by pluralism of – often conflicting – norms and values, and ecological systems are characterized by high complexity and natural and human-induced variability, leading to unpredictable and nonlinear behavior. This highly volatile situation challenges traditional forms of management as well as traditional ways of organizing knowledge for decision-making processes. Ecosystem-based management approaches have been developed to find more effective, holistic, and evidence-based strategies to deal with the challenges of complex socio-ecological systems. They also require another way of dealing with (scientific) knowledge, the way it is produced and applied. In this paper, from the perspective of ecosystem-based management, we define the specific principles that apply to the way knowledge is mobilized and applied within decision-making processes. We illuminate these principles by examining three empirical cases of ecosystem-based management within, or related to, the Wadden Sea area. Finally, we reflect upon our findings and elaborate on the extent to which our theoretical framework is capable of describing and assessing the interaction between knowledge and decision-making within ecosystem-based management approaches.

2.1. INTRODUCTION

The North European Wadden Sea is a marine wetland of outstanding international importance (Wadden Sea World Heritage, 2011). “Nowhere else in the world is there an area on a similar scale and multifaceted which contains such a complex of tidal flats, gullies, salt marshes, dunes and islands” (Enemark, 2005: 996). The preservation of that unique ecosystem encounters a variety of challenges. Environmental governance in the Wadden Sea is characterized by the involvement of many diverse institutions, overlapping jurisdictions, and different actors stemming from different backgrounds, bringing with them different vocabularies, knowledge, and ways of operating in the governance arena. As the ecological system of the Wadden Sea belongs to three adjacent countries, institutional complexity can for example be seen on the national level in the manifestation of local, regional, national authoritative layers, but also on the supranational level in the form of European Union (EU) Directives, such as the Water Framework and Habitat Directive. Additionally (though holding less binding authority), different international governance arrangements apply to the Wadden Sea ecosystem, as for example the Stade Declaration of the Trilateral Cooperation or the RAMSAR convention.

On the national level in the Netherlands, for example, five ministries, three provinces, and eighteen municipalities (Toonen, 2009) have political authority over different parts of the Wadden Sea. Furthermore, a variety of NGOs and commissions have a say in the decision-making process. No single authority has been established as sole responsible agency in the Dutch government system, but tasks and responsibilities are spread among different actors and organizations, such as the Interdepartmental Wadden Sea Commission, the Wadden Provinces Steering Group, the Wadden Sea Islands Consultation Group, the Association of Wadden Sea Municipalities, the Wadden Sea Area Coordination Body, and the Wadden Sea Advisory Council (Verbeeten, 1999). “Each of the authorities exercises its competencies within the existing legal framework and there is hence no specific authority with sole responsibility for the area” (Enemark, 2005: 1003).

Therefore, we can argue that decision-making about the Wadden Sea is a matter of *polycentric governance* (Bache and Flinders, 2004). Besides this social complexity, the actors in this polycentric governance system face the challenge of ecological complexity and its interconnectedness with social complexity (Folke et al., 2005; Gerrits, 2008). Because of these characteristics, the Wadden Sea represents a highly complex socio-ecological system. To handle this complexity, a governance system has been developing over a timescale of more than fifty years now, resulting in a management approach that has turned from partial nature conservation towards an acclaimed form of large-scale ecosystem-based management (Enemark, 2005; Olsen and Nickerson, 2003; Rösner, 2010; Weston, 2003: 5).

Ecosystem-based management approaches set the borders of policy problems around a commonly defined ecosystem-based area, trying to find and implement knowledge-based solutions. Knowledge for ecosystem-based management is thus by definition knowledge drawn from multiple sources and established in an attempt to serve the commonly defined ecosystem-based problems. Such knowledge tries to establish links between different scales and different levels (multi-scaling, multi-levelness) of the social as well as the ecological system and consequently can in turn serve as a basis for adaptive management (Medema et al., 2008; Pahl-Wostl, 2007).

More recently, the notion of adaptiveness has entered the literature on ecosystem-based management (Dekker et al., 2007). Adaptive management emphasizes the importance of experimentation, strengthening flexibility, long-term monitoring, continuous improvement, learning capacity, and stakeholder inclusiveness within policy processes around complex issues (Brunner et al., 2005; Folke et al., 2005; Folke et al., 2010). Adaptive approaches – theoretically – are able to adjust policies and management actions to new insights, changing circumstances, and evolving preferences (Termeer et al., 2010). Adaptive management can therefore be seen as an attempt to increase the resilience of governance systems to be able to adapt to continuous change, based upon the recognition that equilibrium situations both in social and ecological systems are only temporary and fragile.

The dynamic, multi-actor, multi-scale, and multi-level nature of adaptive management simultaneously implies specific characteristics and requirements in relation to the way knowledge is formed, produced, and used throughout decision-making. This topic is relatively unaddressed in environmental science. Therefore we pose the following main research question in this article: What principles does adaptive ecosystem-based management imply for the way knowledge is mobilized and applied within decision-making processes about the Wadden Sea? We answer this question in two ways: (1) by a theoretical study of adaptive and ecosystem-based management and (2) by an empirical investigation of three Wadden Sea cases. These cases are studied in an explorative way and are used to give substance and deeper meaning to the requirements distilled from theory. In this way, the theoretical investigation is further empirically explored and refined.

This article is structured as follows. In section 2.2, we elaborate on the theoretical characteristics of adaptive ecosystem-based management and discuss more specifically the implications of governance for ecosystem-based management. In section 2.3, we investigate the kinds of knowledge needed, from an ecosystem-based management perspective, within adaptive decision-making. In section 2.4, we provide empirical insights on how adaptive ecosystem-based management is applied in three selected empirical cases in the Wadden Sea. Using our theoretically derived framework, we reveal and discuss the differences and similarities of those empirical cases. We conclude in section 2.5 with an overall reflection on our empirical findings and their implications for our theoretical framework and for future research.

2.2. WHAT IS ECOSYSTEM-BASED MANAGEMENT AND WHERE SHOULD IT LEAD?

This section elaborates the basic principles of adaptive ecosystem-based management and defines more specifically what this perspective implies for the production and use of knowledge for this type of management. More specifically, we answer the question of what actually characterizes the (processes of producing) knowledge needed for adaptive management, given the complexity of the ecosystem-based governance context in which it is applied. The latter issue, in particular, is only marginally dealt with in the literature. Exceptions include Brunner et al., (2005: 33-34), who, using explorative empirical research, more systematically identify 15 characteristics of adaptive governance in terms of science, policy, and decision-making, and Medema et al., (2008). We go one step further by systematically dissecting the various implications with regard to the science–policy relation implicitly or explicitly formulated in ecosystem-based management approaches.

2.2.1. What is ecosystem-based management?

Ecosystem-based management appeared in the 1990s in the United States as a paradigm shift in the domain of natural resource management (Dekker et al., 2007). "As past efforts using top-down, government-mandated, expert-driven approaches to managing natural resources failed or met with public resistance and resentment new ideas came into play that took a different approach" (Meffe et al., 2002: 3-4).

Within the scientific literature, many definitions of ecosystem-based management can be found. From an extensive literature review, Meffe and Carrol (1997 in Meffe et al., 2002) have formulated an overarching definition. They describe ecosystem management as "an approach to maintaining or restoring the composition, structure, and function of natural and modified ecosystems for the goal of long-term sustainability. It is based on a collaboratively developed vision of desired future conditions that integrates ecological, socioeconomic, and institutional perspectives, applied within a geographic framework defined primarily by natural ecological boundaries" (Meffe and Carrol, 1997 in Meffe et al., 2002: 70).

Olsen and Nickerson (2003) identify six basic principles that characterize ecosystem-based management approaches. Following their argument, an ecosystem-based management approach aims on the protection of entire ecosystems rather than individual species. As a consequence, attention is now being focused on the multiple scales on which dynamics in an ecosystem may be classified and understood. It is important to fully understand the interrelated dependencies of an ecosystem by recognizing these multiple scales, and defining and explaining their dynamics within the ecosystem. This approach has been dominant in the scientific literature for some time now (Marceau, 1999, Termeer et al., 2010).

Instead of management decisions based on short-term perspectives, there is growing emphasis on long-term perspectives and systematic data (Day, 2008; Katsanevakis et al., 2011; Stelzenmüller et al., 2012). Ideally, in ecosystem complexity management, the continuous and accumulating process of knowledge generation goes hand in hand with an institutionalized flow of expertise to assist in decision-making (Folke et al., 2005; Pahl-Wostl, 2007; Rogers et al., 2000).

Managing the complexity of underlying ecological reality furthermore implies the necessity to acknowledge as well as to be able to handle uncertainty, to be aware of divergent perspectives, continuously shifting dynamics, and mosaics, and to be resilient (Gunderson, 1999). For managers themselves, this perspective implies acting as designers, teachers, and stewards rather than employing traditional command-and-control styles (Rogers et al., 2000).

Finally, in ecosystem-based management approaches, humans are considered as being integral parts of ecosystems (Olsen and Nickerson, 2003). In complex ecosystems there are many competing interests, and so it may be necessary to reconcile economic and ecological interests. In the Netherlands (as in most Western countries) where steering processes are generally characterized by polycentric steering forces, typically emerging from a highly dispersed and fragmented institutional landscape, ecosystem-based management is then a matter of establishing legitimate and inclusive governance processes. Establishing the legitimacy of the management regime can be achieved by taking into account the various (ecological, social, or economic) interests of the many users of ecosystems, for example through consensus building, multiple issues, and partnerships (Meffe et al., 2002).

In sum, earlier attempts to define the concept of ecosystem-based management in terms of *principles* have been made for example by Rogers et al. (2000: 510) and Meffe et al. (2002: 59). These authors basically address the same basic principles as Olsen and Nickerson (2003), although they apply a different focus of description. Rogers et al. (2000) focus on adaptive organizations as defined by the variables *leadership style*, *structure*, and *culture*, whereas Meffe et al. (2002) look at management itself without defining further variables. We are of the view, however, that all these authors are describing the same phenomenon, ecosystem-based management, and consequently their descriptions are complementary. In Table 2.1, we integrate all three views.

Table 2.1
Ecosystem-based management as a paradigm shift
Adapted from Meffe et al., 2002: 59; Olsen and Nickerson, 2003: 4; Rogers et al., 2000: 510.

From	To	Source
Individual species	Ecosystems	Olsen and Nickerson, 2003: 4
Small spatial scale - Management perspective based on equilibrium perspective, stability, climax communities - Reductionism; site specificity - Predictability and control	Multiple scales - Management perspective based on non-equilibrium; dynamics and resiliency; shifting mosaics - Holism; contextual view - Uncertainty and flexibility	Olsen and Nickerson, 2003: 4 Meffe et al., 2002: 59
Short-term perspective	Long-term perspective	Olsen and Nickerson, 2003: 4
Humans independent of ecosystems - Solutions developed by resource management agencies - Confrontation, single-issue polarization; public adversary	Humans as integral parts of ecosystems - Solutions developed through discussions among all stakeholders - Consensus building; multiple issues, partnerships	Olsen and Nickerson, 2003: 4 Meffe et al., 2002: 59
Management divorced from research - Primarily command-and-control - Functional hierarchies - Vertical communication - View uncertainty, complexity, and change as threats	Adaptive management - Primarily to coordinate and facilitate - Generative managers acting as designer, teacher, steward - Dynamic teams with blurred boundaries - Develop common purpose through collaborative goal setting - Generate, codify, and transfer knowledge - Driven by vision and values - Integrated operations across stakeholder–service provider boundaries - Enthusiastic sharing of knowledge (trust and openness) - Learn and adapt through hypothesis testing and critical reflection - Recognize when new knowledge allows you to make the next better decision - Treat uncertainty, complexity, and change as opportunities for learning and improvement	Olsen and Nickerson, 2003: 4 Rogers et al., 2000: 510
Managing commodities - Management organizing resource extraction	Sustained production potential for ecosystem goods and services - Management balancing between commodities, amenities, and ecological integrity	Olsen and Nickerson, 2003: 4 Meffe et al., 2002: 59

2.3. WHAT KIND OF KNOWLEDGE IS NEEDED FOR ECOSYSTEM-BASED MANAGEMENT?

On the basis of our elaborations in section 2.2, we can derive a few characteristics of the kind of knowledge needed for decision-making from the perspective of ecosystem-based management.

2.3.1. Knowledge taking account of ecological complexity

First, as ecosystem dynamics are complex (especially such open systems as the Wadden Sea), meaningful knowledge needs to be derived from inter- and multidisciplinary sources (Petts and Brooks, 2006). As ecosystems are by definition constituted by accumulated as well as interrelated forces, it is necessary to combine the knowledge of different scientific disciplines in order to fully catch their coherence, inter-connectivity, and dynamics. Multidisciplinary settings require researchers to take a broad and holistic view on research objects (Shove and Simmons, 1997).

Establishing understanding about the different scales of an ecosystem as well as the use of new information technologies, such as for example remote sensing and geographic information systems (GIS) and connecting databases, are important facilitators and catalysts to make differences and interconnections between ecological systems more visible (Marceau, 1999). Similarly, conducting experiments in a trial-and-error fashion and the use of general explanatory models on ecosystem dynamics (fundamental knowledge) and applying them to local circumstances (applied knowledge) may provide valuable sources of case-specific knowledge about an ecosystem.

As “the science applied in adaptive governance is contextual, necessitating interpretations and judgments that integrate what is known about the particular context” (Brunner et al., 2005: 24), the explicit inclusion of a broad range of knowledge sources, also known as transdisciplinary research (Scholz et al., 2006), is another characterizing feature of ecosystem-based knowledge. The participation of citizens, industry, and interests groups is essential to achieve effective ecosystem-based management (Meffe et al., 2002).

Furthermore, adaptive management approaches emphasize the necessity of long-term perspectives and systematic data gathering (Olsen and Nickerson, 2003). They are typically characterized by a high degree of institutionalized flexibility, enabling them to deal with disruptive events external to the ecosystem, uncertainty, and surprise as well as creating multi-level governance networks crossing authoritative boundaries (Folke et al., 2005). In essence, the shift towards an adaptive management approach therefore could be defined as a shift from “prediction and control to a management as learning approach” (Pahl-Wostl, 2007: 49).

To enable learning, knowledge generated thus always needs to be fed back into such private or public organizations as have the authority to take decisions about an ecosystem. In the scientific literature, the incorporation of frequent feed-back loops within decision-making processes has been recognized and addressed within a shift towards adaptive management approaches (Brunner et al., 2002, 2005; Folke et al., 2005; Pahl-Wostl, 2007).

On the other hand, the volatile character of ecosystems also establishes the need to monitor and evaluate the state of the ecosystem (Stelzenmüller et al., 2012). Especially within management regimes aiming at sustainable ecosystem management, the need for long-term monitoring and assessment of ecosystem development has been underlined (Day, 2008; Katsanevakis et al., 2011). Similarly, writers on adaptive management emphasize that decision makers need continuous information on the development of the ecosystem that they are trying to govern in a sustainable way (see for example Pahl-Wostl, 2007).

2.3.2. Knowledge taking account of social complexity

Establishing adaptive ecosystem-based management approaches in a context of governance can be a challenging objective. Here, the theory of “[g]overnance [refers to the] widespread belief that the state increasingly depends on other organizations to secure its intentions, deliver its policies, and establish a pattern of rule. By analogy, governance also can be used to describe any pattern of rule that arises either when the state is dependent upon others or when the state plays little or no role” (Bevir, 2007: 364).

By aiming to manage ecosystems in a holistic way, ecosystem-based management approaches therefore face one major governance challenge: to gain the commitment and support of relevant stakeholders who have an impact on the ecosystem. In other words, effective resource management requires the integration of different interests.

Effective ecosystem-based management furthermore implies taking seriously the complexity of governance networks. Such complex governance networks can be characterized by three aspects recurring in the literature: the involvement of many interdependent actors with different perspectives, who together have to solve ‘wicked’ problems, where solutions proposed for problems and challenges are contested because the different actors have divergent perceptions of the problem (and solution) (Klijn et al., 2010).

Establishing a meaningful relationship between knowledge and decision-making within such a complex governance network can be a very challenging task. As for example the literature on science–policy interfaces reveals, the use of knowledge in decision-making processes is accompanied by many problems. Knowledge about the object of a decision-making process may be incomplete and therefore difficult to use as a basis for decision-making when the aim is to reach a sound decision (Turnhout et al., 2007).

Besides incompleteness, uncertainty in scientific knowledge (Bradshaw and Borchers, 2000; Raadgever et al., 2010; Wardekker et al., 2008) may also lead to difficulties in its use and acceptance. Furthermore, in complex governance settings, knowledge may easily be used as a power tool, whenever opinions about the issue at stake are conflicting (van Buuren and Edelenbos, 2004) instead of being a common point of reference. Such problems are triggered as well as reinforced by cultural differences and institutional fragmentation between the two worlds of science and policy (Jones et al., 1999; Pohl, 2008). To counter these difficulties, modern (adaptive) governance settings stress the necessity to reconsider the clear-cut boundaries between policy, industry, society, and science and to search for new ways of making and interpreting science and its role in the policy process.

Literature concerned with the use of knowledge for decision-making in complex settings stresses the need to produce as well as use knowledge in a more dynamic way. The need for a more dynamic view has, for example, accompanied the call for environmental change (Guston, 2001; Petts and Brooks, 2006; Shove and Simmons, 1997), sustainable development (Bäckstrand, 2003; Irwin, 1995; Scholz et al., 2006), and modern complexity caused by climate change and globalization (Funtowicz and Ravetz, 1993; Gallopín et al., 2001).

The nonlinear and dynamic view of knowledge mobilization and production means that ecosystem-based management must take account of the complex relationships between science, society, and government in which knowledge is developed and used (Edelenbos et al., 2011; Funtowicz and Ravetz, 1993; Jasanoff, 2007; McNie, 2007; Nowotny et al., 2001; Sarewitz and Pielke, 2007; van den Hove, 2007). Knowledge then is a result of a *complex and dynamic interaction process* between scientists, societal groups and actors, and governmental actors (bureaucrats, policymakers, and politicians) (Edelenbos et al., 2011).

2.3.3. Knowledge is mobilized in an adaptive way throughout decision-making

From sections 2.3.1 and 2.3.2, we can deduce that the complex and dynamic nature of decision-making processes entails a variety of implications for interfaces between science, policy, and society through which knowledge is developed and used for adaptive ecosystem-based management. It is considered important to organize inclusive governance processes that try to connect different public knowledge streams among governmental representatives, public administrators, and citizens (Edelenbos, 2010; Edelenbos et al., 2011). To achieve effective collaboration among such differing stakeholders, it is important to take into account the variety of different values, interests, and ways of knowing (Meffe et al., 2002; Turnhout et al., 2008; van Buuren, 2009).

A high frequency and quality of communication among the different administrative levels as well as decision-making actors (who may stem from policy as well as from science or society) are therefore important instruments for knowledge managers and knowledge management systems (Cash et al., 2003). “Effective knowledge management is seen as a critical success factor in turning command-and-control management into learn-by-doing management” (Rogers et al., 2000: 505).

The development and integration of civic science (Lee, 1993) to professionalize such attempts and encourage the generation of contextual knowledge not generated within the formal scientific institutions (Irwin, 1995) might be a useful contribution to adaptive management. Civic science enables the use of local knowledge, which is often more experience-based and more aware of local contingencies (Weber et al., 2010). Reforms towards citizen representation and democratization of scientific institutions have been cited as conditions facilitating such processes (Bäckstrand, 2003). However, detailed insight into the specific characteristics and dynamics of such public regimes enabling the emergence of adaptive management is still rare (Shindler and Cheek, 1999).

On the other hand, it is also important to reconsider the role of involved scientific experts themselves (Funtowicz and Ravetz, 1993; Gallopín et al., 2001; Pielke, 2007; Swart and van Andel, 2008; van den Hove, 2007). Building strategic blocks in the form of social contracts between scientists may help to better address the high uncertainty and the public controversy surrounding complex policy problems (Gallopín et al., 2001). From a similar perspective, Pielke (2007) argues that, within decision-making processes, there is need for more openness about the role played by scientists, in order to openly address whether an expert is really providing different options on a policy choice (the honest broker) or trying to defend a favored position (the issue advocate). Swart and van Andel (2008) develop arguments in favor of an extended accountability for scientists. Each strategy may enhance the capability of science to handle uncertainty, which has been identified as one of the major challenges entailed in complex problems (Funtowicz and Ravetz, 1993).

Secondly, as ecosystem dynamics may be unclear as well as volatile, it consequently is important to enable an ongoing iterative process between knowledge production and use. Experimental designs, enabling learning by trial and error (Walters, 1986; Walters and Holling, 1990), as well as close and equal interaction between policymakers and knowledge producers, may enable such processes of joint fact-finding (Ehrmann and Stinson, 1999; Pahl-Wostl, 2007).

Thirdly, it is important to realize that, when it comes to the use of scientifically generated knowledge, decision makers often simply do not have the information they need. This lack of information, however, tends not to be caused by a shortage of scientifically produced knowledge, but rather stems from a mismatch between the kind of knowledge produced (supply) and the kind of knowledge actually needed (demand) (McNie, 2007). A better reconciliation of both the supply and the demand side of science and policy could for example be established by a three-step analysis including a demand side assessment, a supply side assessment, and the comparative overlay, resulting in a concrete opportunity matrix (Sarewitz and Pielke, 2007).

As mentioned in section 2.2.1, ecosystem-based management also implies the need for a body of knowledge that is perceived as legitimate for all actors participating in a decision-making process (Raadgever et al., 2010). Again, close interaction between all actors involved has often been cited as a prerequisite to establish legitimacy (Gerrits and Edelenbos, 2004; Huberman, 1994; Shove and Simmons, 1997). Such interpersonal contact can facilitate a mutual dynamic among researchers and users in each stage of the research (whether start-up, development, or completion). Ehrmann and Stinson (1999) define consensus-establishing processes as an additional necessity. This means that "stakeholders with differing viewpoints and interests work together to develop data and information, analyze facts and forecasts, develop common assumptions and informed opinion and, finally, use the information they have developed to reach decisions together" (Ehrmann and Stinson, 1999: 3). Sarewitz (2004) concludes that, for the effective organization of such inclusive processes, the value bases of disputes underlying environmental controversies must be fully articulated and adjudicated through political means before science can play an effective role in resolving environmental problems.

As a final topic, the ecosystem-based management perspective implies the notion that knowledge needs to be available at any time throughout an entire decision-making process. Knowledge then is not produced as a unique product delivered to policymakers, providing them with a final basis for decision-making. The production and use of knowledge becomes more an ongoing process of knowledge gathering, elaboration, discussion, negotiation, application, and adjustment. This also implies the necessity for researchers to consider the actual use of their knowledge when designing a research process (Shove and Simmons, 1997). Effective information management is needed to guarantee that clear information flows between the fragmented levels and scales involved in adaptive projects (Raadgever et al., 2010).

Science–policy–society interfaces installed to facilitate such adaptive information streams have to adjust to those implications. Here, the concept of science–policy–society interfaces refers to all those arrangements made to organize the exchange of knowledge between science, society, and policy (Edelenbos et al., 2011). Adaptive science–policy interfaces may be installed by legal obligations (e.g. assessment of the Natura 2000 sites as established by the EU); the establishment of new institutions (e.g. the Common Wadden Sea Secretariat); the reformation of existing ones (see for a broad overview on institutional reformation in the Wadden Sea: Toonen and Staatsen, 2004; Toonen, 2009; van Nieuwaal, 2011); or they may be less formalized through the emergence of complex networks (Klijn, 2008; Klijn et al., 2010).

In this section, we have discussed a number of criteria for knowledge that characterize adaptive ecosystem-based management. Table 2.2 provides a summary.

2.4. ECOSYSTEM-BASED DECISION-MAKING IN THE WADDEN SEA: SOME EMPIRICAL INSIGHTS

In this section, we use the constructed framework and criteria for knowledge in adaptive ecosystem-based management to analyze practices in the Wadden Sea. We do this in order to be able to test whether our framework is capable of explorative and explanatory research into adaptive ecosystem-based management in the Wadden Sea, and to see whether our framework needs further refinement and elaboration. For our empirical investigation and exploration, we focus on three cases: the extension of the Mainport Rotterdam, the Trilateral Cooperation, and Waddensleutels.

These cases have been selected on the following criteria. First they are based in, or are connected to, the Wadden Sea area. Secondly, they employ (to a greater or lesser extent) an acclaimed (adaptive) ecosystem-based approach. Cases that fulfill this criterion place the problem or goal at hand in the wider socio-ecological system of the Wadden Sea. Within these cases, we analyze whether and how knowledge production and application: a) takes account of ecological complexity; b) takes account of social complexity; and c) is organized in an adaptive way throughout decision-making. Tables 2.2 - 2.5 provide a summary of our findings. All the characteristics of ecosystem-based management that we discovered throughout our empirical analysis are highlighted in these tables.

For the empirical part of the research, our investigation is based on document analysis on the use of knowledge in Wadden Sea decision-making processes. The documents examined include scientific peer-reviewed articles and official announcements of institutions and stakeholders active in the Wadden Sea. The latter are taken from project and partner websites within the selected cases. Transcriptions from stakeholder interviews are used to supplement

Table 2.2
Summary of criteria for knowledge in adaptive ecosystem-based management

Implications from theory	Characteristics of knowledge production and application	Sources
Knowledge takes account of ecological complexity	Knowledge tries to catch the complex and volatile character of socio-ecological systems by:	
	a) promoting accumulation of data (open access)	a) Shove and Simmons, 1997; Petts and Brooks, 2006
	b) using real-life experiments and reflexive trial-and-error	b) Walters, 1986; Walters and Holling, 1990
	c) inter- or multidisciplinary cooperation	c) Shove and Simmons, 1997; Petts and Brooks, 2006
	d) long-term monitoring and assessment	d) Olsen and Nickerson, 2003; Day, 2008; Katsanevakis et al., 2011; Stelzenmüller et al., 2012
	e) giving attention to scale differences	e) Marceau, 1999; Termeer et al,. 2010
Knowledge takes account of social complexity	Knowledge reflects the various values, interests, and ways of knowing of the various actors involved (citizens, stakeholders, experts, bureaucrats):	
	a) knowledge is co-produced by experts, citizens/stakeholders, and policymakers, and their different knowledge sources are taken into account	a) Lee, 1993; Irwin, 1995; Meffe et al., 2002; Brunner et al., 2005; Scholz et al., 2006; Edelenbos, 2010; Weber et al., 2010; Edelenbos et al., 2011
	b) values and interests are taken into account in the knowledge process	b) Meffe et al., 2002; Sarewitz, 2004; Turnhout et al., 2008; van Buuren, 2009
	c) knowledge is used to facilitate a process of frame reflection and joint learning between actors	c) Ehrmann and Stinson, 1999; Gerrits and Edelenbos, 2004; Pahl-Wostl, 2007; Funtowicz and Ravetz, 1993; Gallopín et al., 2001; Pielke, 2007; Sarewitz and Pielke, 2007; van den Hove, 2007; McNie, 2007; Swart and van Andel, 2008
Knowledge is mobilized in an adaptive way throughout decision-making	Knowledge production is organized alongside processes of decision-making and implementation:	
	a) long-term interaction between scientists, stakeholders, and policymakers is facilitated	a) Cash et al., 2003; Rogers et al., 2000; Shove and Simmons, 1997; Raadgever et al., 2010
	b) adaptive science–society–policy interfaces are installed to enable flexible and tailor-made science–policy interactions	b) Bäckstrand, 2003; Toonen and Staatsen, 2004; Folke et al., 2005; Toonen 2009; van Nieuwaal, 2011
	c) knowledge enables learning on ecosystem dynamics and facilitates feed-back loops to decision-making	c) Folke et al., 2005; Brunner et al., 2002; Brunner et al., 2005; Pahl-Wostl, 2007

these findings. For each case, we have screened the collected information for the presence of ecosystem-based characteristics as described in section 2.3.

Here, it is important to re-emphasize that our investigation has an explorative character and meaning. The empirical investigation is based mainly on, and therefore limited to, secondary data available on the various decision-making processes. Consequently, our analysis does not provide detailed insights into the appropriateness, effectiveness, legitimacy, or efficiency of the ecosystem-based management approaches applied.

Another limitation of our dataset is constituted by the different timeframes in which the cases have been and still are evolving. This means that, for some cases, more information on the knowledge characteristics can be found than for others. The Waddensleutels decision-making process, for example, has only started to evolve. As a consequence, only a limited dataset is available. Only future research will be able to provide an in-depth analysis of the specific dynamics that will develop in this case.

2.4.1. Case 1: Extension of Mainport Rotterdam

The Extension of Mainport Rotterdam case describes the decision-making process initiated by the Dutch government in the 1990s around the objective of increasing the size of Rotterdam harbor. In the EU, such projects are regulated by EU environmental policy and should only be approved *after* their impact on the environment has been evaluated in order to assure the sustainability of the environment. An important tool of this EU policy is the so-called environmental assessment procedures.

In general terms, *environmental assessment procedures* are used in many countries around the world as a formal tool for decision-making, ensuring that the effects of projects, e.g. dams or railways, on the environment are integrally taken into account. Sadler (2003), for example, defines environmental assessment as “a systematic process of evaluating and documenting information on the potentials, capacities, and functions of natural systems and resources in order to facilitate sustainable development planning and decision-making in general, and to anticipate and manage the adverse effects and consequences of proposed undertakings in particular.” Since 1969, environmental impact assessments are common in the US. In the EU, they were adopted in 1985 (Vogel, 2005).

In the specific context of the Mainport project, the environmental assessment was carried out under the Environmental Impact Assessment (EIA) Directive (Directive 85/337/EEC) (EC, 2012). This procedure tries to catch the complexity of environmental relations by taking different policy sectors as well as their interrelatedness into account (Knill and Liefferink, 2007). Within the decision-making process, these assessments are obligatory *before* the approval of a project (*ex ante*) (Knill and Liefferink, 2007). Within the range of EU policy instruments, they belong to the *procedural* policy instruments: "They stipulate certain administrative and legal courses of action, without prescribing the actual result of such courses of action" (Knill and Liefferink, 2007: 43). The actual decision-making power thus remains independent from the results of the assessment. The procedure also entails a passive information right for citizens (Knill and Liefferink, 2007).

In the Mainport case, however, the Council of the State decided on 26 January 2005 that the EIA conducted was insufficient due to its failure to incorporate knowledge about the ecology of the Wadden Sea (Council of the State, 2005). This decision was triggered by intervention from the Dutch Fish Product Board. The board was concerned that the harbor extension would have a negative impact on the fish population in the Wadden Sea because of its potential harm to fish larvae transport. According to the Fish Product Board, the impact of mud and larvae transport was not investigated as it should have been in terms of the Habitat Directive, article 6, clause 3. On the basis of this regulation, it is necessary to investigate projects that are not directly related to a habitat area, but that nonetheless may have a significant effect on it (Council of the State, 2005).

As a consequence, further research was deemed necessary. This research came under the EU's Appropriate Assessment Procedure (AAP) (Hommes et al., 2009). The AAP is similar to the EIA policy instrument to the extent that it tries to approach the environment in a complex and integral manner. However, it differs from the EIA on two points. First, the AAP focuses "on species and habitats that are listed as sites' target features and impacts on overall site integrity." Secondly, the advice produced under the AAP procedure is binding (Natura, 2000).

From the perspective of ecosystem-based management, the Mainport project as such has an acclaimed ecosystem basis because of its attempts to balance economic (harbor extension), sociological (quality of living environment, recreation), and natural interests (quality of living environment, wildlife). Furthermore, the knowledge produced for decision-making was derived in an intra-, multi-, and transdisciplinary way, resulting in modeling about ecosystem dynamics, including water motion, mud and fish larvae transport, nutrients, and primary production (Hommes et al., 2009). On the basis of the EU's AAP, it was possible to take further concerns about interrelated ecological systems into account.

The building and understanding of resource and ecosystem dynamics were generated within expert groups. Calculated effects of expert modeling were assessed at stakeholder meetings. According to Hommes et al. (2009), "This resulted in a valid, context-specific knowledge base. However, the diverging stakeholders' perceptions (multi-actor complexity) were not addressed in the investigations.” Consequently, stakeholder discussions were not used to adapt the knowledge base.

Some participants in the decision-making process perceived this lack of interaction between knowledge generation, modeling, and discussion as a shortcoming, and also as decreasing the legitimacy of the body of knowledge produced (Hommes et al., 2009). Additionally, this decision-making process may be characterized as less adaptive because no opportunities for experimentation and inclusion of lay knowledge were integrated either.

Furthermore, the limited timeframe of seven months (budget costs amounted to 2.5 million dollars) set by government for the production of the AAP knowledge (Hommes et al., 2009) may also have had a detrimental effect on the adaptiveness of knowledge production. Additionally, decision-making was designed in a linear way, and this restricted the possibilities for using adaptive knowledge throughout the entire decision-making process. No agreements were made on long-term assessment and monitoring. Solely the results of expert modeling were used to facilitate decision-making at specific points in time, and this stopped after the crucial decision was taken.

Inclusion of lay knowledge was, however, facilitated within this decision-making process. As already mentioned, the Dutch Fish Product Board’s concern about the potentially negative effects of harbor extension on fish larvae transport to the Wadden Sea triggered the AAP. Establishing and incorporating this local expertise into decision-making meant that the knowledge generated about the relevant ecosystem became more context specific.

2.4.2. Case 2: QSRs of the Trilateral Cooperation

The Trilateral Cooperation between the Netherlands, Germany, and Denmark has emerged as a transnational policy network in the Wadden Sea (CWSS, 2011). “Since 1978, the responsible ministries of the Netherlands, Denmark and Germany have been working together on the protection and conservation of the Wadden Sea covering management, monitoring and research, as well as political matters” (CWSS, 2011). In this capacity, the Trilateral Cooperation acts as a kind of an overarching governance regime for the development of ecosystem-based management in the Wadden Sea (Olsen and Nickerson, 2003).

One specific feature of this transnational cooperation is the monitoring and assessment tool, the so-called Trilateral Monitoring and Assessment Program (TMAP). TMAP is a long-term collection and assessment program of the ecological status of the Wadden Sea, resulting in concrete quality status reports (QSRs). According to Enemark (2005), these knowledge products form a common database for the Wadden Sea, facilitating scientific as well as informative activities.

Table 2.3
Characterizing features of knowledge governance for adaptive ecosystem-based management in the Mainport Rotterdam case

Implications from theory	Characteristics of knowledge production and application	Empirical reflection on characteristics in the Mainport Rotterdam case
Knowledge takes account of ecological complexity	Knowledge tries to catch the complex and volatile character of socio-ecological systems by:	Knowledge mobilization regulated through EU environmental policy
	a) promoting accumulation of data (open access)	a) promotes accumulation of data and provides those to decision makers in the form of assessment reports simultaneously accessible to all interested parties
	b) using real-life experiments and reflexive trial-and-error	b) not provided within EIA procedure
	c) inter- or multidisciplinary cooperation	c) procedure facilitates integration of diverse scientific disciplines
	d) long-term monitoring and assessment	d) monitoring and assessment restricted to the specific project under evaluation
	e) giving attention to scale differences	e) scale differences can easily be taken into account as the procedure is set up to evaluate single projects
Knowledge takes account of social complexity	Knowledge reflects the various values, interests, and ways of knowing of the various actors involved (citizens, stakeholders, experts, bureaucrats):	
	f) knowledge is co-produced by experts, citizens/stakeholders, and policymakers, and their different knowledge sources are taken into account	f) knowledge is produced within expert groups; EIA procedure obliges only passive public involvement
	g) values and interests are taken into account in the knowledge process	g) EIA facilitates interest of project initiators; experts/citizens or stakeholders are not taken actively into account; nonetheless, interest representation of Dutch Fish Product Group enforced through legal means resulted in additional knowledge gathering (regulated through AAP)
	h) knowledge is used to facilitate a process of frame reflection and joint learning between actors	h) the EU procedure entails a passive information right for citizens/stakeholders; some participants problematized the lack of interaction

Table 2.3 (continued)
Characterizing features of knowledge governance for adaptive ecosystem-based management in the Mainport Rotterdam case

Implications from theory	**Characteristics of knowledge production and application**	**Empirical reflection on characteristics in the Mainport Rotterdam case**
Knowledge is mobilized in an adaptive way throughout decision-making	Knowledge production is organized alongside processes of decision-making and implementation:	
	i) long-term interaction between scientists, stakeholders, and policymakers is facilitated;	i) fixed points in time for interaction; time frame bounded by duration of project assessment
	j) adaptive science–society–policy interfaces are installed to enable flexible and tailor-made science–policy interactions	j) adaptive science–policy interfaces; procedural regulation; because of single project design tailor-made science–policy interaction is guaranteed
	k) knowledge enables learning on ecosystem dynamics and facilitates feed-back loops to decision-making	k) unclear to what extent learning on ecosystem dynamics could be facilitated within expert groups; no monitoring and assessment after project evaluation

QSRs for example support the decision-making process by identifying areas in need of further improvement (Enemark, 2005). To establish an effective link with the policy level, the QSRs are prepared as a basis for decision-making *before* the regular Trilateral Conferences. At these conferences, the ministers in charge of the different national governments negotiate on shared principles about future developments in the Wadden Sea. To make effective negotiations possible, the parameters used for the monitoring and assessment program have already been agreed upon in these three member states. Furthermore, "The TMAP data are stored in regional databases according to a common format so that they can be exchanged between the regions and used for the elaboration of regular QSRs"[3] (Enemark, 2005: 1003–1004).

The knowledge generated has a strong multi- and interdisciplinary character. QSR (1999), for example, includes data on protection and management, human activities, climate, marine chemistry, and biology. Therefore, the bodies of knowledge created also fulfill the requirement to be context specific. As the status report also includes an evaluation of activities that have an impact on the ecology of the Wadden Sea, a strong commitment towards learning about ecosystem dynamics is evident. To facilitate such learning, the effect of interventions is assessed and monitored. The body of knowledge thus established is intended to enable policymakers to adapt their policies when necessary.

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[3] For example, in the 1999 QSR, the following parameters were monitored and assessed: water, sediment and biota, the tidal area, salt marshes, birds, marine mammals, and estuaries (Enemark, 2005).

Furthermore, the institutional design of task and working groups, supported and coordinated by the common secretariat (CWSS), stimulates culture-sensitive learning in cross-national contexts (interview 26 August 2011). As the example of the working group on salt meadows revealed, it proved impossible to agree on similar parameters for the monitoring of meadows. Different cultural customs on the management of these Wadden Sea sub-ecosystems formed a social barrier to any attempt at harmonization. However, as an adaptive result, the cooperation managed to achieve an 'agree to disagree' consensus (interview 26 August 2011).

Within the Trilateral Cooperation, knowledge is derived not only from scientific institutes, but also from a variety of monitoring sources. For the fish monitoring, for example, data were derived from "log book data of fishing areas of the German fleet" and privately operating consulting companies (BioConsult) (Jager et al., 2009: 34–35).

The QSR 2009 furthermore reveals a functioning link between knowledge producers and knowledge users. As the following citation reveals, recommendations on data tend to have an impact on decision-making: "The previous Quality Status report [...] underlined the need for a regular assessment of the fish fauna and formulated recommendations on management, monitoring and research. [...] it was advised to include fish monitoring in the ongoing Trilateral Monitoring and Assessment Program [...] revision process." (Jager et al., 2009: 4).

Recommendations thus are both derived and incorporated throughout adaptive decision-making on a long-term basis. This citation may also indicate that the body of knowledge is perceived as being legitimate for participants of the decision-making process, although unfortunately no systematic data on legitimacy are available yet. However, the decisions taken by the Trilateral Cooperation have the status of voluntary agreements. Therefore, they are not legally binding. As a consequence, decisions taken on the knowledge generated about the ecosystem do not automatically imply the implementation of ecosystem-based management decisions (Weston, 2003).

Nevertheless, in principle, the reports provided through TMAP are suitable for the adaptive use of knowledge (as fitting to our formulated requirements) throughout an entire process of decision-making, as knowledge about the Wadden Sea ecosystem is continuously available, consistent, and legitimate.

2.4.3. Case 3: Waddensleutels

The aim of the Waddensleutels project is to gain more insight into the dynamics of mussel bed restoration. The scientific knowledge available about this issue is fragmented. No single theory has yet gained legitimate, explanatory status among scientists. As a consequence, nature restoration organizations with responsibility to restore mussel beds in the Wadden

Table 2.4

Characterizing features of knowledge governance for adaptive ecosystem-based management in the Trilateral Cooperation case

Implications from theory	Characteristics of knowledge production and application	Empirical reflection on characteristics in the Trilateral Cooperation case
Knowledge takes account of ecological complexity	Knowledge tries to catch the complex and volatile character of socio-ecological systems by:	
	a) promoting accumulation of data (open access)	a) knowledge derived in an intra- and multidisciplinary way
	b) using real-life experiments and reflexive trial-and-error	b) not applicable in our case analysis
	c) inter- or multidisciplinary cooperation	c) orientation of knowledge mobilization in the Trilateral Monitoring and Assessment Program (TMAP) augmented by transdisciplinary data supplements stemming from professionalized institutions
	d) long-term monitoring and assessment	d) TMAP facilitates long-term monitoring and assessment
	e) giving attention to scale differences	e) modeling of Wadden Sea ecosystem includes a diverse range of ecosystem scales
Knowledge takes account of social complexity	Knowledge reflects the various values, interests, and ways of knowing of the various actors involved (citizens, stakeholders, experts, bureaucrats):	
	f) knowledge is co-produced by experts, citizens/stakeholders, and policymakers, and their different knowledge sources are taken into account	f) no direct co-production between experts, citizens/stakeholders, and policymakers
	g) values and interests are taken into account in the knowledge process	g) cooperation produces knowledge regularly presented to decision makers on a voluntary basis (not binding on decision makers)
	h) knowledge is used to facilitate a process of frame reflection and joint learning between actors	h) frame reflection and joint learning could be traced within the unsuccessful attempt to develop common parameters to monitor salt meadows
Knowledge is mobilized in an adaptive way throughout decision-making	Knowledge production is organized alongside processes of decision-making and implementation:	
	i) long-term interaction between scientists, stakeholders, and policymakers is facilitated	i) cooperation operating since 1978
	j) adaptive science–society–policy interfaces are installed to enable flexible and tailor-made science–policy interactions	j) regularly feed-back loops to decision-making organized through Trilateral Conferences
	k) knowledge enables learning on ecosystem dynamics and facilitates feed-back loops to decision-making	k) unclear to what extent learning on ecosystem dynamics could be facilitated through trilateral conferences; trilateral conferences, however, facilitate feed-back loop to decision-making on a four-year basis

Sea do not know what to do (*Nieuwsbrief Waddensleutels*, February 2011). By conducting an experiment on mussel restoration, the project aims to explore the micro-dynamics of the Wadden Sea ecology in order to learn more about the dynamics on a higher (macro) scale. From an ecological point of view, mussels, like oysters and seaweed, are part of the fundamental building blocks of the Wadden Sea ecosystem (Waddenvereniging, 2012).

The specific aim is to explore the factors that restrict and the factors that restore the settlement and sustainability of the mussel beds that dry at low water. Thirty-six artificial mussel beds will be installed and monitored in the Wadden Sea to enable scientists to monitor long term the naturally restoring effects as well as the restricting effects (Waddensleutels, 2011). Through various experimental projects around mussel beds, scientific experts hope to gain more insight into the dynamics evolved (Waddenvereniging, 2012).

Because of its experimental design, the project will potentially provide a fertile context for social learning based on trial and error. However, the project coordinator of the related Wadden Sea policy program warns against coming to conclusions too quickly: "Coming to premature and overly broad conclusions on the experiment's outcomes and making them public may run the risk of polarization" (*Nieuwsbrief Waddensleutels*, February 2011).[4]

The results of these experiments will be used to produce an "opportunity map", on which areas providing the most fertile breeding grounds for mussel restoration will be indicated. This map is intended to form the basis for future decision-making within the nature restoration institutions in the policy field of mussel bed restoration. Through close cooperation and interaction between scientists and policymaking institutions throughout the entire project, the project organization hopes to ensure the legitimacy, at all relevant authoritative levels, of the knowledge produced. However, further systematic evaluative research will be needed in order to provide evidence to this assumption.

Inclusion of lay knowledge is not directly facilitated within the project. Cooperating organizations are exclusively professional institutions: Natuurmonumenten, Staatsbosbeheer, Rijksuniversiteit Groningen, Nederlands Instituut voor Ecologie (NIOO-KNAW), and Koninklijk Nederlands Instituut voor Zeeonderzoek (NIOZ). However, commitment to raising awareness among citizens and other societal actors has been announced (*natte Wad*) (Waddensleutels, 2012a).

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[4] Free English translation of the following Dutch qoute: "*Raak niet verblind door de hypotheses. Dit is geen verwijt richting Waddensleutels, maar iets waar een project als dit voor moet waken. Zoekt Waddensleutels te snel met vergaande conclusies de publiciteit, dan kan dat leiden tot verharde stellingnames en tegenstellingen.*"

Table 2.5

Characterizing features of knowledge governance for adaptive ecosystem-based management in the Waddensleutels case

Implications from theory	Characteristics of knowledge production and application	Empirical reflection on characteristics in the Waddensleutels case
Knowledge takes account of ecological complexity	Knowledge tries to catch the complex and volatile character of socio-ecological systems by:	
	a) promoting accumulation of data (open access)	a) accumulation of data proved difficult due to fragmented knowledge and institutions
	b) using real-life experiments and reflexive trial-and-error	b) strong emphasis on design of a real-life experiment; discussion and lack of clarity about how to organize reflexive trial-and-error
	c) inter- or multidisciplinary cooperation	c) as scientific knowledge is fragmented on mussel restoration, a strong orientation towards inter- and multidisciplinary cooperation is necessary
	d) long-term monitoring and assessment	d) bounded by experimental funding
	e) giving attention to scale differences	e) by exploring the micro-scale through experimental design, project intends to enable learning on Wadden Sea ecosystem development on the macro-scale
Knowledge takes account of social complexity	Knowledge reflects the various values, interests, and ways of knowing of the various actors involved (citizens, stakeholders, experts, bureaucrats):	
	f) knowledge is co-produced by experts, citizens/stakeholders, and policymakers, and their different knowledge sources are taken into account	f) no direct co-production of knowledge between experts, citizens/stakeholders, and policymakers; however, a concrete end-product (in the form of an opportunity map) has been agreed on; commitment towards future citizen involvement
	g) values and interests are taken into account in the knowledge process	g) a consensus among fragmented values and interests has been established on the basis of a voluntary commitment called Convenant transitie mosselsector en natuurherstel Waddenzee
	h) knowledge is used to facilitate a process of frame reflection and joint learning between actors	h) strong commitment towards learning by doing; facilitation of frame reflection and joint learning by symposium as well as commitment to continuous interaction between government, interest groups, and science
Knowledge is mobilized in an adaptive way throughout decision-making	Knowledge production is organized alongside processes of decision-making and implementation:	
	i) long-term interaction between scientists, stakeholders, and policymakers is facilitated	i) interaction bounded by experimental timeframe
	j) adaptive science–society–policy interfaces are installed to enable flexible and tailor-made science–policy interactions	j) direct link between a multidisciplinary research team and two nongovernmental environmental organizations has resulted in the agreement about a clear end-product, but ongoing discussion on the specific point(s) in time when research results between decision makers and knowledge products should be exchanged over the course of the project
	k) knowledge enables learning on ecosystem dynamics and facilitates feed-back loops to decision-making	k) experimental design enables learning by doing

From an ecosystem-based management perspective, it furthermore is important to note that a direct link has been established between a multidisciplinary research team and two nongovernmental environmental organizations (Staatsbosbeheer and Natuurmonumenten) (Waddensleutels, 2011). This direct link has been established on a voluntary base by the *Convenant transitie mosselsector en natuurherstel Waddenzee*, originally signed by diverse Dutch governmental bodies and societal organizations. According to Waddensleutels, the covenant functions as a source of support and consensus within what was formerly a fragmented landscape in terms of institutions and knowledge (Waddensleutels, 2012b).

2.5. CONCLUSION AND DISCUSSION

In this article, our aim was to develop and test a framework to analyze the way, and the extent to which, certain knowledge characteristics and requirements (derived from the literature on adaptive ecosystem-based management) were taken into account in implementing adaptive ecosystem-based management approaches to manage the Wadden Sea. In this final section, we first reflect on the empirical insights from the case studies; and secondly we reflect on the applicability of our framework and discuss the ways it can be further developed.

On the basis of a theoretical investigation of state-of-art literature within the domains of ecosystem-based management, governance, and science–policy interfaces, we were able to deduce three main implications for knowledge. First, knowledge needs to take account of ecological complexity, trying to handle the complex and volatile character of ecosystems by enhancing multi-, trans-, and interdisciplinary research and applying long-term views on monitoring and assessment. Secondly, knowledge needs to take account of social complexity by incorporating the variety of interests, values, and ways of knowing of private as well as public professionals. Following from the theoretical notion that ecosystem-based management approaches imply the acknowledgement of ecological *and* social complexity, we recognize thirdly that knowledge needs to be mobilized in an adaptive way by factoring in the long-term facilitation of decision-making, enabling learning on ecosystem dynamics, and incorporating adaptive science–society–policy interfaces.

Our empirical investigation reveals that, in all three selected cases, the production of knowledge in an attempt to cope with ecological complexity is indeed evident. Knowledge for decision-making based on inter- and multidisciplinary research can be observed. It is striking that, in their efforts to deal with the complex, dynamic, and volatile character of the Wadden Sea, none of our selected cases experienced a lack of coordination of scientific knowledge through multi- and interdisciplinary approaches as a serious problem. This multi- and interdisciplinary work took different shapes and forms, such as scientific modeling (Mainport

Rotterdam), the creation of long-term scientific databases (Trilateral Cooperation), and experimental design (Waddensleutels).

Also striking is the absence of direct citizen involvement in the production of knowledge in adaptive ecosystem-based management approaches in the Wadden Sea. In all three observed cases, no direct and continuous co-production of knowledge between experts, citizens/stakeholders, and policymakers took place. It would be interesting to devote more explicit attention in the framework to explaining this observation. To do so, we need a dynamic measure of actor involvement in which we pay attention to *the extent to which*, and *points in time* when, coordination and co-production take place between various knowledge sources and the decision-making process itself. This seems to be a necessary refinement of our framework. On the other hand, the application of civic science by the use of context-specific knowledge generated at institutions other than universities seems to be quite common. In the Trilateral Cooperation, the fish monitoring for example was supported by data from the German fleet and a consultancy company called BioConsult.

From our empirical investigation we can also conclude that ecosystem-based management approaches tend to deal with social complexity in quite different ways. Although in the Mainport Rotterdam case stakeholders were actively involved within an ongoing decision-making process, they were not connected to this process in terms of influencing knowledge production itself. This finding indicates the necessity to incorporate a more refined parameter of legitimacy in our research framework, which would allow a better understanding of a) whether the lack of involvement is linked to a lack of legitimacy and b) more and better understanding of how citizens give legitimacy to knowledge produced in complex ecosystem-based management approaches in general.

Arguing from our theoretical findings in section 2, it can furthermore be questioned whether and to what extent opportunities for learning have been or could be realized in any of the selected cases. A lack of close interaction and frequent feed-back loops between knowledge producers and knowledge users may have restricted the emergence of learning and in turn restricted ecosystem-based adaptiveness. However, our framework does not allow for a systematic assessment of this dynamic. We need to develop further when and how learning takes place in adaptive ecosystem-based management. More longitudinal case study research is needed to really establish this. Further in-depth and long-term analysis on stakeholder positions would be needed in order to trace possible learning dynamics.

On the basis of our framework, we can furthermore observe that the form in which science–policy interfaces have emerged to facilitate the adaptive use of knowledge for decision-making varies greatly from case to case. In the Trilateral Cooperation and Waddensleutels cases, adaptive science–policy interfaces were facilitated through voluntary agreements between knowledge users and knowledge producers, whereas the Mainport Rotterdam is *a priori* regulated by EU environmental policy procedures. Within the Trilateral Cooperation and Waddensleutels cases, a more inclusive structure tends to be applied to the science–policy interface through regular conferences and symposia; whereas on the other hand the EU procedure implies a fixed and mandatory structure to courses of interaction. These structural differences also have implications for the actual political impact of the knowledge produced. The end product of the AAP procedure (Mainport Rotterdam) has a binding character, whereas the EIA, TMAP, and opportunity map function as (more or less) free-to-choose knowledge bases. This difference raises the question of whether knowledge results are really followed up in national decision-making processes.

Overall, we thus can observe that the mobilization of knowledge bases into decision-making processes differs significantly from case to case. We have found out that adaptive knowledge mobilization is traceable in the form of varying links between decision makers and knowledge sources (forms) as well as points in time where exchange between decision makers and knowledge sources (frequencies) is happening. In our framework, we therefore need to pay more explicit attention to the extent and the organizational forms of linkages between knowledge (co-)production and decision-making arenas at different governmental levels. More attention needs to be paid to the way knowledge is connected and scaled-up and really consolidated in political decision-making.

All these insights and refinements of our framework bring us to our final reflection that it is important to pay more attention to the fact that ecosystem-based management approaches tend to emerge in a variety of circumstances and contexts. In our cases, the nature and effectiveness of science–policy interactions in adaptive ecosystem-based management depends strongly on the specific setting in which the Wadden Sea projects or programs are situated. The further development of an assessment framework to tackle questions like, for example, the extent to which empirical ecosystem-based management approaches are able to develop effective knowledge mobilization therefore needs to be addressed in a more context-specific way. Context then needs further refinement around a) the specific parameters of knowledge, policy, and mobilization characteristics of a specific ecosystem-based decision-making process and b) the ongoing interaction between those parameters. Additionally, this finding supports the argument that no panaceas exist, and consequently any evaluation and assessment attempt should be based on the level of one specific decision-making process.

For such an attempt, the parameter of social complexity, for example, could be broadened by acknowledging the specific arena wherein the complexity becomes visible. For example in the Waddensleutel case, social complexity arose among scientists because of scientific fragmentation, whereas in the Mainport case social complexity was more a matter of societal interests (the Dutch Fish Product Group versus the extension of the Mainport Rotterdam). It would be valuable to gain more insights into the dynamics and similarities, as well as differences, in each arena and to explore in more depth the relation between complexity and the actual mobilization of knowledge throughout decision-making.

In sum, our theoretically derived framework is capable of facilitating explorative and descriptive research into the use of knowledge for decision-making in adaptive ecosystem-based management. The framework needs further enhancement and refinement of its parameters to make them more sensitive to the context specificity and the dynamic evolution of empirical reality of ecosystem-based management approaches in the Wadden Sea, as well as in other regions of the world.

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Chapter 3

Using knowledge in a complex decision-making process – evidence and principles from the Danish Houting Project's ecosystem-based management approach

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ABSTRACT

In ecosystem-based management (EBM), the use of knowledge is considered an important means to reach sound decisions. However, EBM approaches typically entail complex decision-making processes, involving multiple actors and policy levels. Hence, it is questionable whether and how knowledge can be used as a means to reach sound decisions. This paper explores and evaluates the knowledge governance employed by decision-makers to successfully implement EBM in a complex setting. Conclusions are drawn from a case study based on 30 qualitative interviews, document analysis, and observational participation in Denmark's second largest river restoration project, the Houting Project. Our findings suggest that disjointed knowledge governance, knowledge bases acknowledging different values and interests, and the use of experiments were crucial to the success, but at the same time partly restricted the quality, of decision-making in the project. Several suggestions are made on how to compensate for the shortcomings identified.

3.1. INTRODUCTION

Ecosystem-based management (EBM) has been defined as "an approach to maintaining or restoring the composition, structure, and function of natural and modified ecosystems for the goal of long-term sustainability. It is based on a collaboratively developed vision of desired future conditions that integrates ecological, socioeconomic, and institutional perspectives, applied within a geographic framework defined primarily by natural ecological boundaries" (Meffe and Carrol, 1997 in Meffe et al., 2002: 70).

Another distinguishing feature of EBM is that it presupposes an explicit way of dealing with knowledge. Traditionally, the use of science has been identified as crucial to facilitate and enable sound decision-making for EBM (Leslie and McLeod, 2007; Olsen and Nickerson, 2003). However, the integration of other types of knowledge sources, like experts and citizens, has also been elaborated (Meffe et al., 2002). Brunner et al. (2005) furthermore have emphasized continuing as well as integrating knowledge production and application as a requirement to establish long-term dialogue between all actors involved, enabling each of them to take adaptive, ecosystem-based decisions.

Thus, the EBM paradigm can be considered part of the 'family' of adaptive approaches. As a decision-making principle, the concept of adaptability has been defined as taking decisions on the basis of the best available knowledge about the ecosystem in question (Olsen and Nickerson, 2003). As a management style, the adaptive notion emphasizes the need and importance of experimentation, flexibility, long-term monitoring, continuous improvement, and learning capacity (Folke et al., 2005). As a governance style, it has been defined as collaboration between science, society, and policy (Brunner et al., 2005; Nelson et al., 2008).

From a public management perspective, the paradigm shift towards EBM introduces the shift from 'simply' managing ecosystems to more complex approaches. The typical multi-actor, multi-level, and multi-sector compositions of these public management processes provide a complex context in which public decision-makers are operating (Bruijn and Heuvelhof, 1999). This context will typically include diverse international policy levels, a broad range of stakeholders, and complex perceptions of the relevant policy problem (Meadowcroft, 2002).

The production and application of knowledge within such complexity-acknowledging approaches is typically far from being straightforward. Knowledge generated about the complexity of an ecosystem may be characterized by incompleteness, ambiguity, and uncertainty and may therefore be disputable by the different actors involved (Nowotny et al., 2001; Turnhout et al., 2007, 2008; van der Sluijs, 2005). As soon as interest conflicts are added, knowledge easily becomes a source of power (Ozawa, 1996; van Buuren and Edelenbos,

2004) and a tool to acknowledge rather than dissolve existing boundaries (Gieryn, 1983; Swart and van Andel, 2008). Knowledge remaining stuck in one institution instead of being used for sound decision-making has been identified as a major barrier to adaptive approaches (Pinkerton, 1999).

Furthermore, Holmes and Clark's (2008) study reveals that, also on those occasions where government actively initiates programs to enhance the use of science in environmental decision-making, clear communication between science and policy is not easily achieved. Mechanisms like agenda-setting and subjective interpretation still work as intervening and disturbing variables. Using a survey, Petts and Brooks (2006) for example found that the incorporation of lay knowledge was characterized by a fundamental cleavage between expert and lay conceptualization of the relevant environmental problem, thereby personally challenging the professional functioning of the expert. Since Kingdon (1984) modeled policy processes as confluent streams, it furthermore has more and more been emphasized that the dynamic of policy problem solutions is often a matter of coupling a solution to a problem rather than organizing a conscious attempt at common knowledge production.

The EBM paradigm, however, implies the need for integral, system-wide knowledge that adequately reflects the state of the ecosystem and simultaneously is seen as legitimate by all actors involved (Brunner et al., 2005). Other authors have suggested that a knowledge management strategy (van Buuren, 2009) or joint knowledge production (Edelenbos et al., 2011; Hegger et al., 2012) might be needed to achieve successful knowledge utilization – a feature that has especially been related to decision-making processes requiring multi-actor collaboration (Innes and Booher, 1999).

Another problem, connected to the former, arises because "EBM [is] an iterative process that requires flexibility and adaptation, since both knowledge and systems change over time" (Leslie and McLeod, 2007: 544). The effective implementation of ecosystem-based approaches requires adaptive management regimes to be applied, using policy as a means to test and experiment in order to learn about the complex interrelatedness between social and ecological systems (Brunner et al., 2005; Folke et al., 2005; Walters, 1997).

In light of the above-stated, empirically defined, and partly ambiguous challenges, it becomes clear that knowledge utilization for EBM may be less straightforward than the theoretical principles of EBM suggest, especially for EBM approaches in a complex setting, which by definition include a wide range of public and private actors. It is therefore important to increase our in-depth knowledge of the practical implementation of EBM knowledge governance. To date, the EBM literature lacks a detailed understanding of strategies empirically developed and applied by decision-makers in their quest for sound EBM.

In this paper, we therefore try to answer the central research questions of whether and how successful EBM approaches are empirically able to create common knowledge grounds and use them as a means to manage a process of ecosystem-based adaptation. To answer these questions, we conducted an in-depth case study of a complex, but successful, case of EBM. More specifically, we explored a) why exactly decision-makers needed knowledge in their quest for ecosystem-based adaptation, b) the knowledge sources they used to fulfill these needs, and c) how they organized the process of knowledge production and application. In addition, we evaluated whether the knowledge governance approach chosen was indeed adequate to reach EBM. To facilitate and structure the explorative part of our case study research, we developed a theoretical framework operationalizing the role of knowledge in EBM by merging EBM theory with complex decision-making literature. For the evaluative part of our study, we modified the EBM knowledge governance principles as defined by Giebels et al. (2013) by adding a qualitative evaluation scheme.

We elaborate the explorative framework in section 3.2. Section 3.3 describes the research methodology, and sections 3.4 and 3.5 present the results of our empirical analysis. In section 3.5, we conclude and reflect on our empirical findings in relation to the EBM literature.

3.2. UNDERSTANDING THE ROLE OF KNOWLEDGE IN DECISION-MAKING FROM AN EBM PERSPECTIVE

Before empirically analyzing the role of knowledge in EBM, we need to know which elements are at play whenever knowledge utilization occurs. As the EBM literature currently lacks detailed information on that issue, we make use of scientific publications from the field of evidence-based decision-making, informed decision-making, science–policy interfaces, and knowledge management. We augment this literature with conceptualizations taken from the literature on complex decision-making. We have identified the following, recurring elements.

3.2.1. Why is knowledge needed?

From the EBM perspective, the main need for knowledge derives from management's need to know about the ecosystem at stake (Brunner et al., 2005; Folke et al., 2005; Meffe et al., 2002; Olsen and Nickerson, 2003). This would for example imply generating knowledge about the current, historical, or expected future states of an ecosystem. This basic knowledge is needed to develop, assess, and adapt decisions and decision-making options and, where applicable, to find innovative solutions to decision-making problems. Typically, knowledge for decision-making is generated in the form of scenarios, planning studies, or financial feasibility calculations (Simonen et al., 2009). In public decision-making processes, knowledge is also used to communicate or create consensus among a broader public or specific stakeholders (Mayer et al., 2004). Furthermore, to enable learning about and among actors, knowledge dissemination, e.g. in the form of knowledge-sharing platforms or gatherings, is essential (Folke et al., 2005; Scholz et al., 2006; Walters and Holling, 1990).

3.2.2. Which knowledge sources can be mobilized?

Knowledge drawn from scientific sources traditionally plays a crucial function in environmental decision-making. "As the main instrument through which humans view, understand, and modify nature, the sciences have always held a privileged position in environmental debates." (Chilvers and Evans, 2009: 355). With the growing debate on modern complexity however, authors have argued that other sources of knowledge and expertise – external to traditional governmental expertise – have also become important (Bäckstrand, 2003; Irwin, 1995; Pierre and Peters, 2000; Weber et al., 2010). From the EBM perspective, such sources are rather diverse and may range from scientific knowledge and experts to lay knowledge (Brunner et al., 2005; Meffe et al., 2002).

3.2.3. Through which links is knowledge connected to decision-making?

Various literatures concerned with the role of knowledge in decision-making indicate, furthermore, that it is important to distinguish between different knowledge links. Knowledge links describe the interaction patterns between knowledge sources and knowledge users. Two major types of interaction logics can be distinguished: a product logic and a process logic. The main distinction between these two types relates to whether or not a direct interaction between two or more human beings is involved. Product logic applies to all uses of knowledge throughout decision-making where a specific knowledge product (e.g. a report, a scientific publication) is used at a certain point in the decision-making process but the actual knowledge source has not been interacting with the knowledge user at any other stage of the process.

In process logic, knowledge utilization is perceived as an outcome of an interactive process of humans holding, perceiving, and arguing from diverse or common knowledge sources. This type of knowledge utilization has for example been described using the concept of joint fact-finding (Ehrmann and Stinson, 1999) and joint knowledge production (Edelenbos et al., 2011; Hegger et al., 2012). In a process of joint fact-finding, "stakeholders with differing viewpoints and interests work together to develop data and information, analyze facts and forecasts, develop common assumptions and informed opinion and, finally, use the information they have developed to reach decisions together" (Ehrmann and Stinson, 1999: 3).

It is also important to consider in which forms/through which channels knowledge sources are linked to the decision-making process (Mitroff, 2008). Examples of different forms directly connected to decision-making include the appointment of judging committees, scientific modeling, or – in its most comprehensive form – systems thinking (Davidson and Rowe, 2009; Mitroff, 2008). Hoppe (2005) enhances the above descriptions by implicitly acknowledging that knowledge utilization is also influenced by the different motives that actors may employ throughout their engagement. Basically, he distinguishes between knowledge utilized as a result of coincidence, production on demand, pushed by stakes, or facilitated learning. Similar, Pielke (2007) developed the concept of "issue advocates" and ascribed it to those knowledge pushes triggered by scientists themselves. In our conceptual model, we therefore acknowledge that linkages can be triggered by, and emerge through, different forms of interaction (see also Table 3.1).

On the basis of the above-cited literature, we distinguish three different interaction types: static, interactive, and adaptive. Applied in a static link, knowledge is typically used as a final package, either from knowledge source to decision-maker or from decision-maker to knowledge source. However, there is no direct influence or agreement between them either beforehand or throughout the process. In line with Hoppe's (2005) ideas of enlightenment or technocratic interaction, the static perspective presupposes that the knowledge and policy systems in essence co-exist, but are independent of each other, each evolving by its own dynamics. Links between knowledge and decisions typically emerge spontaneously and are coincidental. No negotiation or deliberation takes place between actors.

An interactive link between knowledge and decision-making, on the other hand, suggests a more continuous interaction between both. Typically, the interactive mode of linking is characterized by some point of coordination between knowledge source and decision-maker or decision-maker and knowledge source. Different sources of knowledge (expert, lay, and administrative) are aligned and connected to become meaningful for decision-making (Edelenbos et al., 2011). Interactive knowledge production can be arranged by boundary managers (Pohl, 2008), e.g. policy entrepreneurs (Guston, 2001), or be a result of adversarial and dispositional interaction. It is important to notice that "[b]oundary work adjusts the boundary between academic and the governmental policy culture, but it does not question the boundary as such." (Pohl, 2008: 49).

The last feature in particular could be seen as a main distinguishing element between interactive and adaptive approaches. The interactive perspective does not emphasize the need for knowledge sources and decision-makers to work together in a fully integrated and long-term process. The adaptive mode of linking explicitly presupposes the need for shared process in which common knowledge grounds are generated. Pohl (2008) labels this type of linking as co-production. "Co-production means that the interaction between several policy cultures becomes a core element of the research process." (Pohl, 2008: 49).

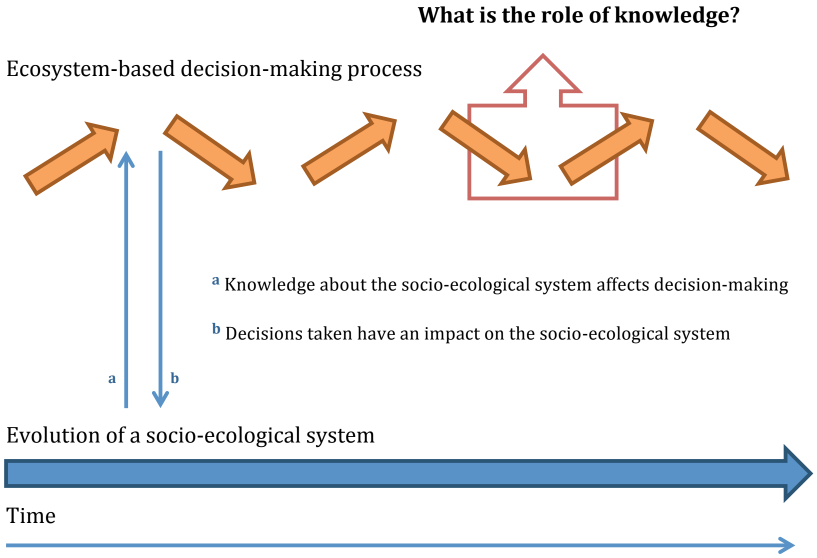
The adaptive linkage thus is mainly distinguished from the static and interactive modes by long-term interaction between knowledge sources and decision-makers, characterized by a search for a reflexive ecosystem-based body of knowledge. In principle, for that type of knowledge, it is essential for all actors involved to have reached agreement about what the state of the ecosystem is and should be, what the individual elements are that constitute the ecosystem, and how those should be measured and evaluated (Leslie and McLeod, 2007; Nelson et al., 2008).

In the EBM literature, adaptive linkages have been defined as a necessity through which the need for regionally defined, contextual knowledge can be satisfied (Brunner et al., 2005; Newson, 2009). These presuppose close cooperation and mutual adjustment between decision-makers and knowledge sources. Confirming that theoretical assumption, other studies indicate that common agreement on the use of knowledge sources is important to achieve successful multi-actor collaboration (Hegger et al., 2012; Innes and Booher, 1999) and to enhance the use of science in environmental policymaking (Holmes and Clark, 2008).

3.2.4. Analyzing the role of knowledge in EBM approaches based on an empirically informed decision-making model

In light of the empirically informed decision-making literature, it is important to perceive EBM as an evolutionary decision-making process, consisting of several decision-making rounds (Teisman, 2000). Each round includes different actors and rules that together aggregate into a decision. These actors may emanate from different administrative layers and different policy domains, both public and private (Edelenbos et al., 2011; Edelenbos and Teisman, 2013). Continuous knowledge generation and utilization among these actors has been identified as an essential activity to generate a process of adaptive decision-making (Brunner et al., 2005; Folke et al., 2005; Giebels et al., 2013; Olsen and Nickerson, 2003; Pahl-Wostl, 2007). Combining that need for adaptation with the empirically informed model of decision-making processes, we arrive at the graphical schema, visualized in Figure 3.1a. The figure visualizes EBM as a continuously evolving decision-making process, by theorizing the process consisting of in essence different decision-making rounds, each indicated by a separate orange arrow. On the basis of the literature discussed above, we expect each round – consisting of different knowledge actors interacting with decision-makers – finally to aggregate into a decision. The thick blue line indicates the – in essence independent – development of the socio-ecological system that the EBM approach intends to govern. Independence means that the system will evolve regardless of whether a governance approach is employed or not. The little blue arrows – connecting the socio-ecological system with the decision-making process – indicate, however, that governance is fed by knowledge generated about the system, and in turn that decisions taken can affect its future development. The thin blue line at the bottom of the figure indicates that we can measure and perceive the evolution of that system in terms of time.

Figure 3.1a
Graphical schema of analytical framework (macro level)


What is the role of knowledge?
Ecosystem-based decision-making process
a Knowledge about the socio-ecological system affects decision-making
b Decisions taken have an impact on the socio-ecological system
a
b
Evolution of a socio-ecological system
Time

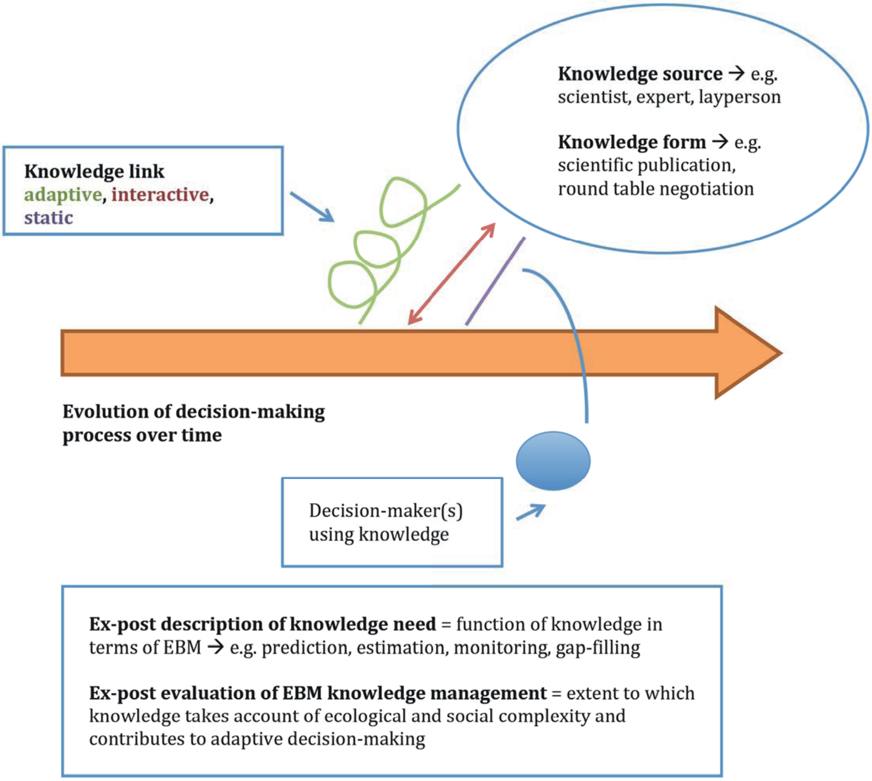
See Figure 3.1b

Developing further on this theoretical positioning, we have operationalized the role of knowledge on the micro level as visualized in Figure 3.1b. Figure 3.1b theorizes one decision-making round (=one orange arrow) consisting of the decision-maker(s) using knowledge in a quest for ecosystem-based adaptation. It furthermore reveals that potentially different knowledge sources can be connected to the decision-making process in different forms and through different links. Table 3.1 summarizes in more detail how we have operationalized each of the variables included in Figure 3.1b. This operationalization constituted the base for our empirical exploration and evaluation, including the design of our interview questionnaire.

3.3. RESEARCH METHODOLOGY

For our empirical analysis, we deliberately selected the Danish Houting Project. The Houting case describes the decision-making process in Denmark's second-largest river restoration project. The project was initiated to restructure several Danish river systems in such a way that an almost extinct fish species, the North Sea Houting, would gain back its habitat. We selected this case as a typical, yet extreme, case of EBM as this case study type has the potential to reveal more information than a representative one (Stake, 1995; Yin, 1984). Our case analysis describes the main developments in the decision-making process that

Figure 3.1b
Graphical schema of analytical framework (micro level)


Knowledge source → e.g.
scientist, expert, layperson
Knowledge form → e.g.
scientific publication,
round table negotiation
Knowledge link
adaptive, interactive,
static
Evolution of decision-making
process over time
Decision-maker(s)
using knowledge
Ex-post description of knowledge need = function of knowledge in terms of EBM → e.g. prediction, estimation, monitoring, gap-filling
Ex-post evaluation of EBM knowledge management = extent to which knowledge takes account of ecological and social complexity and contributes to adaptive decision-making

evolved under the coordination of Danish regional and national authorities. Our analysis of the process starts in 1988, when the Counties of Ribe and Sønderjulland published an important monitoring report (*SNÆBLEN – en truet fiskeart*) on remaining Houting populations. It ends in 2012 with the completion of major parts of the actual river restoration.

The Houting Project exemplifies a typical EBM approach because it is a river restoration project with the proclaimed aim of managing the Houting species, focusing on habitat restoration (dealing with a single species in the context of the ecosystem it needs to survive) instead of managing the protection of a single species (stocking program). Human impact on the Houting habitat was taken into account and modified where necessary. Sustainability – a distinct aim of the project – was meant to be achieved through the full restoration of the Houting habitat, enabling the species to reproduce again in an autonomous manner, in turn making the publicly organized and financed stocking program redundant. Integration and operation across a diversity of policy sectors, policy levels, and public and private actors were needed; and, in the search for solutions, the management regime intensively relied on knowledge.

To reconstruct the use of knowledge throughout the Houting Project, we conducted 30 interviews with 28 participants from the project. The main selection of participants was based on the project managers' identification of key knowledge sources that were involved throughout the decision-making process. In an attempt to gain as much in-depth information as possible, respondents were additionally asked during their interview to name other persons whom they personally would identify as key participants from their own perspective. Furthermore, we studied project documents, consulted websites, and participated in project meetings.

Interviews were conducted on the basis of a semi-structured open-ended questionnaire based on the operationalized core concepts (see Table 3.1). That design was chosen to give participants the opportunity to recount their own personal involvement in, and perception of, the

Table 3.1
Operationalizing the role of knowledge

Name of variable	Definition	Categories
Knowledge need	The need for knowledge arising from the quest for ecosystem-based adaptation	Decision-makers dealing with knowledge quests in their search for ecosystem-based adaptation - to know the underlying ecosystem - to know the underlying social system - to develop decision options - to assess decision options - to adapt decision options - to inform broader public and stakeholders about project plans - to mediate with, and gain commitment of, broader public and stakeholders - to develop innovative solutions - to share generated knowledge and experiences
Knowledge sources	Sources decision-makers use throughout their quest of ecosystem-based adaptation	A high diversity of knowledge sources will be consulted, typically these will emanate from either - Public authorities (bureaucratic knowledge) - Universities (academic knowledge) - Experts (expert knowledge) - Laypersons (lay knowledge)
Knowledge links	*Form*: the knowledge products 'produced'	*Formal (tangible products)*, e.g. scientific publication,report, model, press release *Informal (intangible products)* e.g. meetings, field visits, expert meetings, negotiations
	Interaction pattern: the way knowledge sources are linked to decision-making	Static Interactive Adaptive

Houting Project and the role of knowledge therein. Key participants typically came from very different disciplines and organizations and were involved in different subparts and at different junctures in the decision-making process. Respondents for example varied between civil servants, scientists, experts, and volunteers, with biological, hydrological, engineering, or experience-based backgrounds, and working at national ministries, municipalities, institutes, universities, engineering agencies, or private interest groups. Consequently, each respondent reconstructed a different piece of the bigger process. During the interviews, the questionnaire was used as a checklist to ensure that all deductively derived issues were indeed tackled.

Respondents were asked to recount a) their personal background and involvement in the Houting Project, b) the kind of knowledge they brought into the decision-making process, c) the way their knowledge was linked to the decision-making process, d) whether they experienced problems and would like to make suggestions for improvements, and e) other persons they deemed crucial for the project. On average, each interview session lasted two hours. For the data analysis, we used our a-priori defined theoretical framework and core concepts (Table 3.1) as a template. We disentangled all the different types of knowledge sources that we came across in the key participants' narratives. For each knowledge source, we described how and in what form it was linked to the decision-making process.

3.4. EMPIRICAL ANALYSIS: THE ROLE OF KNOWLEDGE IN THE HOUTING CASE

To structure the presentation of our empirical results, we describe the diversity of knowledge needs, sources, and links in subsections for each knowledge source separately. Where participants raised objections to the chosen knowledge governance approach or made suggestions for improvement, we also mention these in the text.

3.4.1. Knowledge from public authorities

3.4.1.1. Fish monitoring reports

At the beginning of the process, decision-makers needed to know the actual population sizes and habitat locations of the Houting species in their river systems. Systematic fish monitoring was conducted in order to fulfill that knowledge need. This entailed the counting and monitoring of actual fish populations. The monitoring was organized and facilitated at regional level by the county authorities and resulted in formal fish monitoring reports. An experienced expert was charged with that task. Throughout the monitoring program, the expert was appointed as a civil servant at one of the participating regional authorities. In that way, a long-term and mutually adjusting relationship between authorities and knowledge sources could be guaranteed. From the EBM perspective, we characterize that link as being only partly adaptive, as the monitoring was not prolonged into a constant monitoring program after completion of the actual river restoration projects. Several participants mentioned that continuation of the monitoring program would have been crucial to assess the impact of the restoration activities on the Houting population and to learn about its further development in the restored river systems and the effectiveness of the individual restoration projects.

3.4.1.2. Round tables

Whereas other fish species, like salmon, have been extensively researched in Denmark, knowledge about the lifecycle, swimming and migration behavior, breeding grounds, and habitat preferences of the Houting species was lacking. Decision-makers invited diverse experts with experience of river restoration in general and the Houting species in particular to compensate for that lack of knowledge. These experts came from government, university institutes, and interest groups. Together they negotiated on common threshold values to guide and facilitate sound decision-making during a round table meeting. An example of such a threshold value was an agreement that a specific maximum river-bed rise should not be exceeded. Round tables were thus used as an informal and interactive knowledge platform. As an interactive follow-up, participating parties were asked to indicate further research needs in relation to the Houting and could issue research proposals to decision-makers. Decision-makers then decided which proposals would be accepted.

3.4.1.3. Public hearings

A quite different function of knowledge could be ascribed to those times of knowledge dissemination initiated to inform local residents. Public hearings were organized to inform citizens about the project and its effects in their specific local area, while simultaneously enabling the procedural lodging of objections and project adjustments. Through public hearing procedures, municipalities standardly handled all claims/objections and decided on whether to adjust public project plans or not. Citizen knowledge thus was used in a formal and interactive fashion throughout the decision-making process. Public hearings were, however, conducted in a full procedural fashion, meaning that citizens' input took the form of written letters, leaving full power to the decision-makers to decide whether or not to accept the suggestions and claims/objections.

3.4.1.4. International conference

Also, an international conference was organized to which decision-makers invited all project participants as well as anybody with an interest in river restoration in general and the Houting species in particular. The conference was not directly linked to decision-making as such, but, from the EBM perspective, this conference established important platforms for knowledge sharing, exchange, and learning. The conference format was organized in a static manner in the sense that participation was in principle open to anyone with an interest and typically evolved in a coincidental manner. Several participants criticized that no specific aims concerning the Houting decision-making process were incorporated.

3.4.1.5. Site visits

Site visits were used as a means to present knowledge about the project itself (e.g. completed river restoration projects) to members, experts, friends, and other people with an interest. Such visits were typically facilitated by members of the project organization as well as Houting experts not directly related to the project organization but part of the Houting knowledge network. These site visits were not connected to actual decision-making, but, from the EBM perspective, they were an important way to communicate about the project.

3.4.2. Knowledge from universities

Scientific knowledge has been linked to the decision-making process at various junctures and has played a diversity of roles. Interestingly, all scientific publications were connected in a static manner. The first scientific paper came by coincidence and as a surprise to the Houting Project members when in 2005 a scientific study was published claiming that the Houting species was actually extinct (Freyhof and Schöter, 2005). The scientists behind this publication were not directly affiliated to the Houting Project. However, as the scientific contestation of the actual existence of the Houting population did not go unnoticed by the Danish media, societal debate was triggered around the legitimacy of the Houting Project. It was questioned how public money could be used for the protection of a fish that actually did not exist anymore.

In reaction to this debate, Danish authorities initiated an investigation into Houting DNA. The DNA analysis was deemed necessary, as the main argument made by Freyhof and Schöter (2005) was based on morphological traits, which they found different between the Houting species deemed extinct (*Coregonus oxyrinchus*) and those populations still existent. The DNA research was able to prove a close genetic linkage between the surviving populations and the extinct Houting species, as well as the genetic distinctiveness from European lake whitefish (which would not have been worth protecting under the Houting Project). A scientific paper resulting from the DNA investigation was published by Hansen et al. in 2008. Utilization of that knowledge was derived in a static manner. Although the study was funded by the Houting Project and the Danish Forest and Nature Agency, we evaluate this link between knowledge and decision-making as a static link because the funding bodies did not interfere with "the study design, collection, analysis, and interpretation of data, writing of the manuscript and the decision to submit the manuscript for publication" (Hansen et al., 2008: Acknowledgements).

A similar function can be ascribed to the use of the scientific gap-filling efforts of Poulsen et al. (2010a, 2010b, 2012). In the scientific community, gaps on the Houting (e.g. on lifecycle, migration, and swimming behavior) were still apparent. Poulsen et al.'s scientific studies can thus be seen as an attempt to fill those gaps. It is, however, important to note that, at the time of publication of these studies, almost all the restoration projects were already in the implementation or completion phase. As a consequence, the newly generated scientific studies could not be used for decision-making in relation to the projects as such. Still, as scientific gap-filling efforts, they deliver important insights for further river restoration projects in general and for the Houting species in particular. Similar to the other scientific papers discussed above, these studies emerged in a static fashion.

3.4.2.1. Knowledge from specific academic institutes

As a subcategory of knowledge from universities, the Danish National Institute of Aquatic Resources (DTU) was linked as a scientific institute to the Houting Project. Representatives of the institute were invited by the public authorities to the round table negotiations initiated at the start of the project. From the EBM perspective, their main task could be described as the concrete application of fundamental, scientific knowledge to the specific regional situation. Their advice in general is not binding for public authorities. Traditionally however, Danish authorities consult DTU for advice on all river- and fish-related questions. In the Houting case, the management regime organized the feedback loop to DTU in the form of research proposals that were intended to reflect the knowledge gaps that needed to be filled before the Houting Project should start. In a formal and interactive fashion, a few research proposals were accepted by the project organization. One of the conducted studies, for example, successfully filled knowledge gaps about the genetic fitness of the different Houting populations. DTU Aqua, however, was critical about the low percentage of accepted research proposals. In their view, a river restoration project should be conducted only after all knowledge gaps arising from ecological complexity had been filled.

3.4.3. Knowledge from experts

Experts were involved at different junctures throughout the decision-making process. Engineers, for example, were needed to plan and implement the river restoration work (e.g. Rambøll) and to model river currents (e.g. the Danish Hydraulic Institute (DHI)). Experts were typically linked to decision-making in an interactive way through contracts and worked on their own plans and solutions in the framework of the decision-makers' designed plans. Typically, experts' work ended with a concrete implementation plan or, when it was deemed necessary by the decision-makers, experts provided a diversity of plans (scenarios) as optional choices. For some restoration projects, experts were asked to develop different decision options and to present these at meetings with citizens and decision-makers. Afterwards, the most favorable options were chosen by authorities and citizens in an interactive way. Experts were linked in a formal way throughout decision-making, while however the implementation phase of the restoration work was characterized by a mixture of formal and informal knowledge transfer.

Expert knowledge also functioned as an innovative source to solve project-specific problems at other junctures. To give a few examples: the invention of new fishing techniques feasible for catching Houting in different phases of lifecycle, use of citizen-friendly techniques by building companies to decrease the disruptive impacts of construction work for citizens, and the development of an enhanced model for the calculation of Houting swimming behavior were achieved. This expert knowledge was connected to decision-making in a formal and interactive link similar to those described above. In addition, knowledge was linked to the project in the form of informal and interactive expert advice. Bent Lauge Madsen, a retired, though well-known, expert in the field of river restoration is one such example.

3.4.4. Lay knowledge

3.4.4.1. Knowledge from interest groups

Also interest group knowledge was incorporated, with the inclusion of the Danish Angling Society as a prominent example. As the biggest interest group represented throughout the decision-making, the Angling Society participated through informal, interactive meetings and gave advice on concrete projects. However, their input became formal after dissatisfaction of actual impact on decision-making arose and interest groups started to use juridical channels to criticize some of the river restoration project plans.

3.4.4.2. Citizen knowledge

At specific sites on the river system, historical pictures of the original river bed and narratives from citizens were used to reconstruct and plan the re-meandering of river beds. From the EBM perspective, such knowledge can be crucial to decide which particular actions need to be taken on the very specific scale of selected locations. These knowledge sources were linked in a static manner to decision-making, as they were not structurally embedded in the decision-making process but linked by coincidence and as a result of informal meetings. No specific procedure was developed to utilize this type of citizen knowledge. Inclusion remained at the discretion of the decision-making actors. However, a more procedural utilization of citizen knowledge was generated through the public hearings (see section 3.4.1.3).

Local knowledge was also taken into account during informal negotiations with local property owners. These negotiations were in the first instance organized to gain the official commitment of landowners (e.g. farmers, mill owners) to the project. That commitment was crucial to the success of the project, as parts of the Houting habitat were located on privately owned land. Only through private actors' commitment and public purchase of private property could the river restoration be constructed. Negotiations were set up in an adaptive way. Decision-makers visited each stakeholder personally to explain, discuss, negotiate, and eventually adapt. These visits were organized in informal types of face-to-face gatherings (also named coffee-table negotiations). If the stakeholder decided to join the project, negotiations ended with a formal commitment letter and contract. From the EBM perspective, these adaptive knowledge links also helped to adjust the national project plans to local site conditions.

3.4.4.3. Knowledge from museums

To inform broader society about the project, knowledge was displayed in museums and experience centers. For the Houting case, this was for example done at the AQUA in Silkeborg. This is an experience and education center focusing on species living in oceans and on land as well as other water-related issues. Furthermore, the Fisheries and Maritime Museum in Esbjerg provided documentation and an exhibition of the Houting species and Danish fish and fishery history in general.

3.5. EVALUATING THE KNOWLEDGE GOVERNANCE EMPLOYED IN THE HOUTING PROJECT

Having introduced the various knowledge sources utilized during the Houting Project, we now evaluate whether and to what extent the chosen knowledge governance approach contributed to the achievement of EBM. To do so, we make use of, and further operationalize, the knowledge governance principles as defined by Giebels et al. (2013). Based on a literature review, these principles briefly theorize EBM knowledge governance as characterized by a) knowledge that takes account of ecological complexity, b) knowledge that takes account of social complexity, and c) knowledge that is mobilized in an adaptive way throughout decision-making. These categories have been further operationalized by more detailed principles.

To be able to use these principles ex-post to evaluate the empirical case under investigation, we further operationalized them by adding a qualitative measurement. The measurement consists of two different categories. The first category indicates whether and to what extent our collected data reflect an application of each principle. The letter A indicates that our data reveal an application of the principle. The letter N indicates that the principle has not been applied. The second category of our measurement reflects the subjective perception of the interviewed actors regarding the overall knowledge quality reached through the knowledge governance applied. A double plus (++) means that the application is perceived as resulting

Table 3.2
Overview of knowledge sources linked to the decision-making process

Knowledge source	**Knowledge link**			**Knowledge need**
	Form	**Formal or informal**	**Interaction pattern**	
Public authorities	Fish monitoring reports	Formal	Partly adaptive (monitoring program not prolonged until the end or after the restoration project)	To know the underlying ecosystem To assess decision-making options
	Round table meeting	Informal	Interactive	To know the underlying ecosystem To develop decision-making options
		Formal	Interactive	To know the underlying ecosystem To develop decision-making options
	Public hearings	Formal	Interactive	To know the underlying social system To inform broader public To assess decision-making options To adapt decision-making options
	International conference	Informal	Static	To inform broader public To share experiences and knowledge
	Site visits	Informal	Static	To inform broader public
University	Scientific peer-reviewed publications	Formal	Static	To know the underlying ecosystem To assess decision-making options To mediate with and gain commitment of broader public and stakeholders
	Institutes at university	Formal	Interactive	To know the underlying ecosystem To assess decision-making options
Experts	Development of construction plans with engineers	Formal and Informal	Interactive	To develop decision-making options To assess decision-making options To adapt decision-making options
	Involvement of experience and knowledge of popular experts, such as for example a retired river restoration expert	Informal	Interactive	To develop decision-making options To assess decision-making options
	Experts developing innovative solutions to decision-making problems	Formal	Interactive	To develop innovative solutions
Lay knowledge	Participation of Angling Society	Formal and Informal	Interactive	To know the underlying ecosystem To develop decision-making options To assess decision-making options

Overview of knowledge sources linked to the decision-making process (continued)

Knowledge source	Knowledge link			Knowledge need
	Form	**Formal or informal**	**Interaction pattern**	
	Coffee-table negotiations	Formal and Informal	Interactive	To inform stakeholders To develop decision-making options To assess decision-making options To adapt decision-making option
	Pictures of historical river bed	Formal	Static	To develop decision-making option
	Experience and education center displaying Houting and the Houting project	Formal	Static	To inform broader public
	Documentation and exhibition of Houting in a museum	Formal	Static	To inform broader public

in knowledge useful for the ecosystem-based adaptation process, while simultaneously no suggestions for improvement have been made by participants. A single plus (+) indicates that the application has contributed to EBM knowledge, but that suggestions for improvement have been made. A minus (–) indicates that the application is perceived as undermining the EBM approach.

In our analysis, we have also related the ++, +, and – scores to the non-application of a principle. We decided to do so, as the principles defined by Giebels et al. (2013) were established on the basis of theoretical literature, mainly lacking large N empirical falsification. Hence, we cannot judge beforehand a) whether all principles really need to be applied to reach ecosystem-based knowledge governance and b) whether the non-application of a principle might even have been essential to reach successful EBM knowledge governance. Table 3.3 provides an index of the qualitative evaluation scores applied. An overview of the EBM knowledge governance principles and their empirical manifestation can be found in Table 3.4. In sections 3.5.1 - 3.5.3, we briefly discuss each principle's empirical manifestation and the assigned evaluation score in more detail.

3.5.1. Knowledge taking account of ecological complexity

Knowledge that tries to catch the complex and volatile character of socio-ecological systems is typically characterized by accumulated data sets providing open access, experiments, interdisciplinary and multidisciplinary cooperation, long-term monitoring and assessment, and multiple scales (Giebels et al., 2013). In the Houting case, the most important provision of the first characteristic identified *(accumulated data sets providing open access)*, was facilitated through the organization of an international conference. At this conference, knowledge

Table 3.3
Index of qualitative evaluation scores

Evaluation score	Description
A	Application of the principle
NA	Non-application of the principle
++	Application contributed to EBM/Non-application did not undermine EBM
+	Idem, but improvements suggested
–	(Non-) application undermined EBM

generated by the project was shared in a wider community. Participation at the conference was open and free for everybody with an interest. External experts, not directly related to the Houting Project but collecting experience on river restoration itself, also took part. Hence, a sharing of, and learning about, knowledge was facilitated. However, that conference was organized at the end of the decision-making process. Therefore, no direct accumulation of data was actively generated for the decision-making process itself. Most of the river restoration projects were already completed. Consequently, we evaluated the conference as an application of the principle, but in need of improvement (evaluation score A+). The organization of such an event might have been crucial at the beginning of the process and could have been used for the development of an integral knowledge base directly serving decision-making.

Experiments played an important role in the Houting Project. They were crucial to the process, as specific ecological parts of the system could only be known through experimentation, e.g. to know and localize potential nursery areas for the Houting fry. Experiments contributed fully to the EBM approach and therefore were assigned the evaluation score A++. *Interdisciplinary and multidisciplinary cooperation* on the other hand was more difficult to realize throughout the decision-making process. Although attempts were made by organizing round table meetings at the beginning of the river restoration project, not all participants were satisfied with the governance in that part of the process. Biological experts in particular claimed that they were insufficiently involved. In their view, decision-makers took too partial an approach, as only a small number of selected research proposals were approved. According to the biological experts, the quality of decisions taken could have been improved by taking a more comprehensive approach (see for example de Jonge et al., 2012), when decisions were being made about which knowledge parts were still missing. As the same experts, however, evaluated the overall quality of the knowledge applied as good, we decided to assign the evaluation score of A+.

The similar score was assigned to the organization of *long-term monitoring and assessment*. A successful monitoring program was organized but not continued to the very end of the river restoration, or to its aftermath. Hence, there is no full ecological assessment of the overall success of the project. From a procedural perspective, the non-prolongation of the monitoring program was inevitable, as the project and its funding came to an end. However, that shortcoming is partially compensated by the initiation of monitoring of specific parts of the river system in the aftermath of the project. In addition, the fact that Houting can now be caught along parts of the river that formerly were not accessible to the species was used as an indicator of the overall success of the river restoration project. The fish catches indicate that the project has successfully altered the Houting habitat as the species is able to access specific habitat areas again. Before the restoration project, that access was prevented by man-made obstacles. However, the fish catch indicator does not provide information on whether habitat alterations have also been successful in terms of, for example, food supply. Long-term monitoring would be needed to compensate for that shortcoming.

The body of knowledge produced and applied reflects a mixed approach towards *scale* differences. On the one hand, the dominant focus on Houting stocks and population development reflects a reductionist, single-scale approach, aiming to control and predict population numbers. On the other hand, the shift away from the national stocking program towards the habitat approach meant a broadening of the scales applied. Because the habitat approach was adopted, the species was no longer managed as a single commodity; rather, decision-makers tried to understand the species functioning in its habitat. The habitat approach reflects a broadened perspective and hence implies that multiple scales were taken into account. However, a full assessment of the Houting habitat was not conducted. According to involved actors, the success of the EBM approach might have been undermined by that shortcoming. More specifically, it was suggested that the scales of the Wadden Sea and the North Sea should have been taken into account in the definition of the Houting habitat. Both areas are adjacent to the river systems constituting the main Houting habitat, and both have been assessed as actually being part of it. However, due to lack of knowledge on this issue, it is unclear whether and to what extent non-protection of the species in these areas means that the sustainable development of the population is still not guaranteed. During an interview, the issue was raised that unregulated offshore fishing activities might endanger population development. This issue, however, was not settled during our time of evaluation. In sum, we therefore ascribed the evaluation score A+ to that principle.

3.5.2. Knowledge taking account of social complexity

Besides the ecological part of EBM, decision-makers also need to manage the complexities of the social system that they intend to govern. Knowledge that potentially contributes to the successful management of social complexity has theoretically been defined as co-production, value and interest acknowledgement, and facilitation of joint learning (Giebels et al., 2013). As our analysis in section 3.4 reveals, *co-production* has indeed been an important part of the knowledge governance of the project, as reflected in all the interactive links summarized in Table 3.2. As regards the inclusion of co-producing actors, it needs to be mentioned that decision-makers mainly relied on experts when it came to the production of knowledge. Expert-generated knowledge was, however, discussed with citizens during joint decision-making about restoration options that were pre-defined by decision-makers and engineers. The principle of co-production hence has only partially been applied. Especially biological experts and interest groups were critical about the general lack of full co-production. In relation to the round table negotiations described in section 3.4.1.2, biological experts judged the lack of co-production (especially at the beginning of the restoration implementation planning) as an undermining of the EBM approach. An interest group representative claimed that the failure to co-produce was responsible for the decreased quality of several decisions taken. Although that same interest group actively approached decision-makers with the wish to enhance knowledge bases with their own local knowledge about the area, decision-makers did not honor all of their suggestions. As a result, the interest group took juridical actions to contest the lack of quality decisions. Still, the interest group acknowledged that the incorporation of lay knowledge would have meant only an incremental increase in quality. In sum, they were positive about the overall results. Hence, the qualitative score assigned to the application of that principle is an A+.

The second principle, concerning the *incorporation of values and interests*, played a central role in the Houting Project. Concrete river restoration plans were adjusted to individual wishes and preferences. To give an example, the specific location of river slopes and the exact water level were aligned to individual farmer preferences, enabling farmers to still have, for example, sheep grazing on their land. To prevent these adjustments from undermining the EBM approach, specific threshold values were defined and applied as an assaying framework. Actors were excluded from the project where no agreements within the framework could be reached. It needs to be mentioned that this was possible in the Houting Project as enough alternative areas were available to compensate for non-cooperation by e.g. landowners. Also, the economic interest of adjacent fish farms was taken into account. The discharge from these farms was problematic as it reduced river water quality to an intolerable level for the Houting. However, the economic activity of fish farms was not fully prohibited but adjusted by innovative knowledge in such a way that their pollution was reduced to a minimum. In sum, we judged the role of value and interest acknowledgement as a crucial success mechanism of the EBM approach, and therefore assigned the evaluation score A++.

Regarding the last principle, we can conclude that *joint learning* activities were facilitated through a variety of means including site visits, museum exhibitions, public hearings, and coffee-table negotiations (see also all information activities mentioned in Table 3.2). For the application of that principle, we could assign only an A+ however. Participants suggested that improvements could have been made by including more actors in the co-production processes and by increasing the bottom-up learning of decision-makers. The non-inclusion of scientific actors was particularly criticized. At the same time, it needs to be mentioned here that joint knowledge governance was to a certain extent discouraged at EU policy level, which constituted a major part of the project since restoration subsidies had been awarded. These subsidies entailed an application process demanding concrete project proposals. Therefore, it was important that decision-makers were able to propose concrete projects and to assign financial budgets to these projects. The incorporation of too many actors in the design of projects might have prolonged or even distorted the development of concrete plans as such an approach typically entails high decision-making costs (Scharpf, 1988).

3.5.3. Knowledge is mobilized in an adaptive way throughout decision-making

Reaching evidence-based decisions through continuous and long-term interaction between knowledge and decision-making has been defined as an important asset of EBM (Giebels et al., 2013). In the Houting case, we can see only a mixed application of adaptive decision-making. On the basis of the interaction patterns identified and summarized in Table 3.2, we have to conclude that actually none of the knowledge sources was linked in a *long-term* fashion to the decision-making process. Knowledge governance was realized either through short-term linkages or through direct utilization of existing knowledge. Only the long-term monitoring program could be seen as a knowledge source partially satisfying the long-term characteristic. Because of its non-prolongation, it does not, however, qualify as a full application. Participants evaluated the non-application of that principle as decreasing the quality of decisions taken, but overall did not judge it as an undermining characteristic. Therefore, the evaluation score assigned to this governance approach is N+.

Next, regarding the notion that the interaction itself needs to be characterized by an *adaptive* pattern between the knowledge source and the decision-maker to enable flexible and tailor-made results, we indeed see a dominant pattern of adaptation. Decision-makers were able to mobilize a large variety of knowledge sources. Furthermore, they used different linkages for each of the sources. On the basis of our interviews, we can conclude that this approach resulted in knowledge that contributed directly to the decision-making process. However, as already mentioned, biological experts and lay knowledge sources suggested that the pattern could have been improved by organizing more open project planning stages. In sum, we therefore ascribed the evaluation score A+.

The same score was ascribed to the *learning on ecosystem dynamics and established feedback loops*. Because the habitat approach was adopted, ecosystem dynamics played a central role in the EBM approach. As reflected in the National Management Plan (NMP), decision-makers fully updated their Houting policy, deciding on actions needed to restore the species to its habitat. In addition, an evolutionary perspective on the ecosystem and the development of

Table 3.4 Evaluating the knowledge governance of the Houting Project

Knowledge principles	**Empirical manifestation**	**Evaluation/effects of chosen approach**
Ecological complexity Knowledge tries to catch the complex and volatile character of socio-ecological systems by		
a) promoting accumulation of data (open access)	a) facilitation of international conference at the end of the project	a) A+ (timing could be improved)
b) using real-life experiments and reflexive trial-and-error	b) experiments conducted by expert to locate Houting fry in river systems	b) A++ (experiments relevant to process)
c) inter- or multidisciplinary cooperation	c) facilitation through round tables	c) A+ (lack of holistic approach)
d) long-term monitoring and assessment	d) part-term population monitoring	d) A+ (lack of long-term data)
e) giving attention to scale differences	e) tailor-made approaches to different ecosystem scales (e.g. specific attention to fry nursery area)	e) A+ (habitat scale disputed)
Social complexity Knowledge reflects the various values, interests, and ways of knowing of the various actors involved (citizens, stakeholders, experts, bureaucrats):		
a) knowledge is co-produced by experts, citizens/stakeholders, and policymakers, and their different knowledge sources are taken into account	a) applied frequently during process (see all interactive links in Table 2)	a) A+ (choice of actors criticized)
b) values and interests are taken into account in the knowledge process	b) acknowledgement and incorporation of diverse interests	b) A++ (incorporation relevant to process)
c) knowledge is used to facilitate a process of frame reflection and joint learning among actors	c) facilitated through all informing activities mentioned in Table 2	c) A+ (lack of joint approach criticized)
Adaptive decision-making Knowledge production is organized alongside processes of decision-making and implementation:		
a) long-term interaction between scientists, stakeholders, and policymakers is facilitated	a) part-term interaction facilitated	a) N+ (application would have improved results, but non-application did not undermine EBM)
b) adaptive science–society–policy interfaces are installed to enable flexible and tailor-made science–policy interactions	b) science only marginally involved during the process	b) A+ (more adaptive interfaces would have even increased EBM)
c) knowledge enables learning on ecosystem dynamics and facilitates feedback loops to decision-making	c) ecosystem dynamics central to habitat approach, almost all knowledge available (wanted and unwanted) utilized	c) A+ (a few chances of learning neglected)

the species therein was an important factor creating legitimacy for the project (Hansen et al., 2008) when the actual existence of the Houting species became disputed. The NMP, however, was criticized for incorporating too many scientific uncertainties on ecosystem dynamics. Many aspects of the Houting species and its habitat were scientifically unknown when the NMP was launched. Still, the NMP was based on other sources of expertise, including the results of the monitoring program and round table negotiations. Decision-makers deemed this body of knowledge sufficient to plan the restoration implementation. In sum, the evaluation reveals that, although a sound knowledge base was generated, a few opportunities for learning on ecosystem dynamics might have been missed out. Hence, the score A+ was assigned.

3.6. CONCLUSIONS AND DISCUSSION

The case study presented in this paper was conducted to answer the question of whether and how successful EBM approaches are empirically able to create common knowledge grounds and use them as a means to manage a process of ecosystem-based adaptation.

On the basis of all the findings discussed above, we can draw four main conclusions. First, we can conclude that decision-makers indeed succeeded in using knowledge as a resource throughout the complex decision-making process of the Houting case. Our evaluation reveals that all knowledge governance strategies employed reached a minimal score of A+, indicating that the approach chosen enabled the achievement of EBM.

Secondly however, the dominant pattern of + implies that improvements could still have been made. Mainly, more interaction with biological experts and the incorporation of lay knowledge could have meant an increase in the soundness of decisions taken. Biological experts were mainly critical about the lack of knowledge regarding the Houting species, e.g. its living conditions and lifecycle. Decision-makers, however, deemed the level of available information sufficient to realize an adaptive decision-making process. At crucial junctures in the river restoration project, additional technical expert calculations were used to compensate for the lack of biological knowledge. The lack of further incorporation of lay knowledge was also criticized. Lay knowledge could have provided additional information about regional specificities of the river system, improving the design of specific restoration projects. However, the lay knowledge actors interviewed acknowledged that their suggestions concerned minor improvements to the project. Therefore, the lack of lay knowledge incorporation was not evaluated as a factor undermining EBM adaptation. Simultaneously, decision-makers indicated that it was difficult for them to incorporate supplementary knowledge at a stage in the process where projects were procedurally already approved. Hence, our findings reveal that knowledge governance is an issue that should be tackled at the planning stage also. On the assumption that EBM approaches need holistic and integral knowledge sources, incorporating diverse knowledge disciplines to derive most reliable and contextual knowledge (Brunner et al. 2005; de Jonge, 2007; de Jonge et al., 2003, 2012; Meffe et al, 2002), our findings suggest that a common planning of knowledge governance might be as crucial as the generation of common knowledge sources. In order to prevent excessive decision-making costs (Scharpf, 1988), planning that includes the establishment of a knowledge committee, accepting a-priori defined, but openly organized, knowledge input points, might be a viable strategy in order to find a good balance between organizing a complex decision-making process and simultaneously being able to take account of diverging knowledge sources.

Thirdly, and connected to the second conclusion, we found that non-application of a knowledge governance principle does not automatically undermine the EBM adaptation process. Most surprisingly, we found that the long-term interaction between knowledge and the decision-making process was not as essential as expected for EBM adaptation. In relation to our second conclusion, the suggestion can be made that the actual lack of long-term interactions was crucial for the EBM knowledge governance to evolve as a complex decision-making process. Decision-makers were in the lead and could efficiently generate the knowledge they deemed necessary by cooperating with different actors, at different junctures, through different interfaces, effectively creating a decision-making process in a multi-level governance setting. However, although our findings indicate that the involved actors did not judge the lack of long-term interactions as a factor undermining EBM, it remains unclear whether that claim holds true from an ecological viewpoint. Because there is no integral, long-term monitoring of the ecosystem, no ecological evidence can be ascribed to that claim.

Fourth and finally, it is interesting to note that the highest scores in our evaluation were ascribed to the acknowledgement of different values and interests and the use of experiments. Relating this finding to the complex context in which the EBM approach was evolving, we can conclude that both of them have played an important role. To realize a successful interaction between knowledge and decision-making, the adaptive capacity of the project management regime itself seemed to have been crucial. Characteristic of that adaptive management regime was the ability to utilize a high diversity of knowledge sources throughout the decision-making process and the ability to establish effective linkages with each of these sources – for example, by also allowing adjustments to project plans. The same management regime also enabled formal knowledge products, originally written without any connection to the project, to be used in a meaningful way. It was able to handle unexpected and unwanted knowledge claims. Therefore, our findings suggest that the adaptive capacity of the management regime is as crucial to EBM knowledge governance as the development of integral knowledge bases. Because of that adaptive capacity, the utilization of a high diversity of knowledge sources coming along with different parameters of ecosystem measurement and valuation have not jeopardized the successful realization of the EBM approach. The diversity of knowledge sources may even have resulted in a higher rate of innovative knowledge products and a more robust and authoritative knowledge base, making decisions more sound and convincing. Our results indicate that the capability of the management regime to make effective links between many different knowledge sources and align them with the dynamics of the decision-making process was a crucial asset.

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Chapter 4

Towards ecosystem-based management for Mainports: A historical analysis of the role of knowledge in the development of the Rotterdam Harbor from 1827-2008

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ABSTRACT

Ecosystem-based management (EBM) approaches that are appearing in decision-making processes traditionally dominated by economic interests are likely to govern EBM knowledge in a more symbolic than substantive manner, by, for example, emphasizing environmental impact assessments. This article analyzes the development of a more holistic EBM approach for decision-making processes that emerged in the Mainport of Rotterdam, a context traditionally dominated by economic interests. Our historical analysis suggests that holistic EBM knowledge governance was facilitated by factors that included: informal agreements, societal stakeholders who urged for environmental law to be implemented, independent intermediaries who solved deadlocks within the decision-making process, and innovative civil servants that proposed procedural adjustments of the decision-making process that consisted of a transparent process architecture, joint fact-finding, and long-term monitoring. Although these efforts resulted in an overall successful approach, the full potential of EBM knowledge governance has not been realized yet. Based on EBM literatures we propose further decision-making tools that could have improved the approach.

4.1. INTRODUCTION

Ecosystem-based management (EBM) is an environmental management paradigm that handles socio-ecological complexity better than traditional approaches. Lubchenco (1994 in Sherman and Duda, 1999; also Olsen and Nickerson, 2003) identified and described this emerging paradigm as a shift away from incremental problem-solving actions towards a holistic analysis of the entire system, acknowledging and integrating the evolutionary and complex behavior of socio-ecological systems. To do so, EBM adopts three positions:

- Applying multiple, instead of a small spatial scales
- Adopting a long-term, instead of short-term perspective
- Integrating human interventions, such as resource extraction, into the analysis of the ecosystem

A key management strategy for the application of EBM is the continuous generation and adaptive use of knowledge whenever decisions are taken. Knowledge management and governance therefore become an important component of the decision-making process. This search for knowledge is a compelling challenge in itself, because ecological and social systems knowledge has to be integrated so as to capture the system's state, while acknowledging its complex behavior (De Jonge et al., 2012). Specialized experts are often involved to fulfill such demands, by, for example, developing ecological models based on selected ecosystem indicators (Turnhout et al., 2007; Powers and Monk, 2010). Such models work successfully when the selected parameters are easily measureable, and simultaneously reflect an essentially complex system while still facilitating communication with decision-makers.

Since EBM originates from the field of natural resource management, its philosophy originally seemed to be strongly connected and mainly applied to natural areas. Such areas typically are reserves of unique ecological value or exist on an extraordinarily large scale. The management of the Great Barrier Reef in Australia (Sherman and Duda, 1999; Forst, 2009) or the Great Lakes and the Chesapeake Bay, developed in the United States in the 1960s (Olsen and Nickerson, 2003), can be seen as prominent examples of the appeal of EBM. However, EBM approaches will often be applied in more challenging conditions, where one or more competing ambitions hinder its straightforward application. Examples of such contexts include the failed fisheries management study by Garcia and Charles (2008), where administration and institutions were understaffed, poorly trained, had insufficient scientific and enforcement capacity, and lacked support from the fishing sector. But also in regions, where integrated programs are actively developed and implemented, economic primacy (e.g. a focus on GDP for receiving incentives) can undermine the political willingness and financial capacity of, for example, local governments, to implement regionally established EBM targets (Peng et al., 2013).

Such empirical evidence implies that the establishment and development of EBM can also evolve in less straightforward and complex contexts. Such contexts are characterized by "two or more irreducible perspectives or descriptions" (Gallopín et al., 2001: 224) defining the issue under consideration. Case studies reveal that, when making decisions on complex issues, assessment approaches to knowledge governance that are solely characterized by scientific or expert-driven regional assessments, and mainly serve decisionmakers, are likely to fail as they do not consider stakeholder integration and satisfaction (Imeson and van den Bergh, 2006; Hommes et al., 2009). At the same time, for decision-makers themselves, the organization of complex decision-making is a challenging issue. Although the involvement of more participants can improve decision-making due to new actors bringing new solutions and resources (Teisman, 1990), a general pitfall of any joint decision-making process is, that an increase in the number of actors or policy domains leads to unfruitful discussions where no shared decisions can be made (Mintzberg et al., 1996; Benz and Eberlein, 1999). Various actors, whether they are directly involved or only indirectly concerned with a specific decision-making process, are likely to argue with different ways of knowing, implying that additional knowledge management effort is necessary (Van Buuren, 2009).

For these reasons it might not be surprising that our, empirical knowledge on "contexts in which learning and adaptation can occur" is still limited (Leslie and McLeod, 2007) and probably also a rarely experienced phenomenon (Fabricius and Cundill, 2014). The aim of this paper therefore is to present empirical evidence on the decision-making process that took place in a complex EBM implementation process, which was ultimately successful in its attempt to integrate diverse knowledge sources. This case describes the development of one of the biggest harbors in the world, the Rotterdam Mainport. The latest project to extend that harbor, called Maasvlakte 2 (MV2), experienced a high degree of opposition from a variety of public stakeholders. This opposition made Rotterdam harbor development a complex issue (Van Gils and Klijn, 2007), which hindered the straightforward application of knowledge during decision-making. While the involvement of experts was sufficient to satisfy the knowledge demands of decision-makers, they could not satisfy the knowledge claims of public stakeholders. This led to the latter group continue their opposition by using juridical channels to argue for their claims. In turn this triggered managerial attempts to develop more effective knowledge governance among stakeholders. Several procedural innovations and comprehending agreements were needed to establish a context that enabled the harbor authorities and public stakeholders to find a constructive way of exchanging knowledge.

In the following sections, we will present the details of this decision-making process. In section 3, we discuss the changing roles of environmental knowledge that we identified by analyzing the development of Rotterdam's harbor from 1827 to 2008. This time period was chosen to understand traditional harbor management, so that we could then compare it with the current approach to harbor management that is emerging under the umbrella of EBM. Doing so enables us to identify changes that were introduced to facilitate EBM. In total, we identified three knowledge paradigms characterizing Rotterdam harbor development. Environmental knowledge plays a different role in each paradigm vis-à-vis decision-making. Table 4.1 provides an overview of the three paradigms identified. An overview of those historical events we identified as defining events for each knowledge paradigm can be found in Table 4.2. In section 4.3.4 we provide in-depth analysis of the last paradigm identified. The era of this paradigm is characterized by the emergence of EBM policy and legislation, as well as increased societal interest in balancing economic and ecological prerogatives in the Rotterdam region and in national politics. The increased, but at the same time divided societal interest led to the failure of the assessment approach towards knowledge governance. The failure was followed by a period of transformative search for a new balance between stakeholder claims and decision-makers' knowledge bases. Table 4.3 summarizes the development of that period. We furthermore identify several contextual conditions that have been

Table 4.1
Interpretation of shifts in harbor development and the role of knowledge

Historical paradigms of harbor management	**The single quantitative growth approach**	**Quantitative growth 'under conditions'**	**Towards a multiple growth approach?**
Time period identified	1827-1960	1960-1990	1990-2008
Relation between ecology and economy	Growth in terms of quantities is good	Growth disputed in terms of conditions under which it is acceptable	A multiple sustainable growth in the region is acquired
	Ecological dynamics perceived as technical problems	Focus on environmental parameters, no integral perception of ecological value	Ecological paradigm gains importance in environmental law (EU and national)
Characteristics of harbor management	Management is focused on a single goal and direct implemen- tation by better infra- structure and logistics	Management is expanded by a broader assessment framework in which harbor development needs to be evaluated	Expansion still is strong aim, ecological quality and social legitimacy gain higher priority
	Shareholders in the lead Stakeholders not involved	Shareholders in the lead Stakeholders are consulted	Stakeholders actively involved
	A dominant single project orientation	A dominant single project orientation under environmental conditions	Project management is still dominant, but a process-based orientation is added as a support system
Role of knowledge	Expert consultation	Expert consultation Knowledge used according to juridical obligations, Measurement and systematic assessment of pollution	Expert consultation Knowledge used according to juridical obligations, joint fact- finding and long-term monitoring added

necessary to increase the effectiveness of the emerging EBM approach (section 4.4.3). Based on lessons learned from other EBM case studies, we provide several suggestions to further improve EBM in the context of the Rotterdam harbor in section 4.5.

Table 4.2

The changing roles of knowledge in the management of the Rotterdam harbor.

1827-1960 Challenging nature to enable harbor growth

Role of knowledge: Technical problem solving

- Explicitly mentioned first for the excavations related to the Voornse Kanaal (1827-1829)
- Technical feasibility studies, cost benefit analysis and modeling of physical dynamics, also important during harbor extension of New Waterway (Nieuwe Waterweg) (1863) to increase port accessibility endangered by sedimentation processes
- Harbor development needs to solve technical challenges set by ecological dynamic of the harbor area; knowledge utilized by experts on demand, contracted by municipality or other governmental bodies
- Citizens start to perceive lack of green facilities in their city, plans to integrate green into town planning are developed (Bosch- and Parkplan for Kralingen, 1909)

1960-1990 Rise of environmental concerns

Role of knowledge: Measuring, naming and shaming; Decisions on harbor development are assessed by regional working groups within framework provided by environmental policy

- Scientific studies relating the regional population health problems to the decrease of environmental quality in the Rotterdam region
- Since 1964 monitoring of environmental quality of the Rotterdam region
- 1965 installation of a regional emergency council (Raad voor de Milieuhygiene)
- 1970s onwards further harbor development only allowed when industry would not harm environment, e.g. by working group evaluating each new harbor development activity on the basis of established environmental policy (Werkgroep Occupatie Maasvlakte, 1973)
- Environmental pollution is identified, measured and handled on an ad-hoc basis

1990-2008 Integrating environmental concerns and harbor growth

Role of knowledge: Obligatory environmental impact assessments; Stakeholder management; Technical problem solving taking account of juridical obliged ecological parameters (e.g. protected species); Voluntary long-term monitoring on a regional scale

- Measurement of Rotterdam citizens' perception of environmental problems in their own neighborhood using different environmental indicators ranging from dust, stench, oil-, soil-, air- and noise-pollution (e.g. research from Gemeentelijk Bureau Onderzoek en Statistiek, but also research on solution of these problems)
- 1990 Municipality launches integral, non-sectorial plans for the city of Rotterdam and it's harbor; Environment gains position in spatial planning of the harbor; Municipality of Rotterdam launches integral environmental action plan (MAP); Integral platforms to enable discussion and coordination across different governmental institutions
- 1993 Covenant ROM-Rijnmond signed by national, provincial and local government authorities, as well as by business stakeholders; Double aim approach ¼ developing the harbor as well as Rotterdam environmental quality; 1750 ha Rotterdam area claimed for green development
- 1996 VERM procedure (public consultation procedure on MV2 extensions)
- Covenant between the harbor management organization, different governmental layers and NGOs Vision and Courage (May 2000) expanded by Vision and Trust (May 2008) - Joint fact-finding with NGOs
- Diverse environmental monitoring programs since 2005
- Integral and adaptive, long-term policy monitoring scheme installed in 2008

Table 4.3
Events characterizing the development of the Rotterdam harbor from 1990 to 2008

Time	Development of the Rotterdam harbor from 1990-2008
1991	Development Havenplan 2010
1993	ROM Rijnmond − Green Agreement
1994	Responsibility for the Mainport project placed with the national level (after WRR-advice Besluiten over grote projecten)
1996	Assessment procedure VERM (Verkenning Ruimteprobleem Mainport Rotterdam)
Begin 1998	Establishment of PMR (Project Mainport Development Rotterdam) Start of EIA procedure
Oct 1998	Claims uttered that PMR stopped its open and interactive planning process
Begin 1999	Informal gatherings between PMR and environmental interest groups stop as one of the alternative options for MV2 was taken out of the planning process, while no common decision with interest groups has been taken
March 1999	Official commitment of minister to continue the interactive planning process First proposal to develop a process covenant Intervention of intermediary
17 May 1999	First meeting of a council (TOPBERAAD), environmental interest groups claim to the minister a lack of information exchange from PMR
1999	A report is launched by PMR (PMR op Koers) concluding that the alternative harbor extension options are not feasible Environmental interest groups disappointed by lack of involvement and leave the process Another intermediary asked for advice by PMR
End 1999	An informal meeting organized (Haardgesprek) to continue process First intermediary asked for advice again Environmental interest groups put new demands on the process
Nov 1999	First intermediary proposes a renewal of the council (TOPBERAAD nieuwe stijl) Number of actors participating in decision-making process evaluated as too high, reform of the council by decreasing number of members resulting in first covenant (Visie en Durf)
11 July 2001	Decision for MV2, concrete spatial planning (PKB) send to the cabinet, proposals discussed in parliament
Sep-Nov 2001	Public consultation procedure concerning spatial planning starts 26 objections made by stakeholders including citizens, farmers, fishermen
2004	Objections of Dutch Fish Product Board against MV2 at the highest juridical court of the Netherlands (Raad van State) based on EU Habitat Directive
26 Jan 2005	'Raad van State' decision that objections are justified, extension not guaranteed anymore, additional impact assessment conducted
May 2005	Start of fish monitoring (T0 measurements in 2005 and 2007)
2006	Start of benthos monitoring (T0 2006-2008 at 300 different spots across approx. 50 km coastline)
17 April 2008	Formal permit on MV2 issued by responsible ministry (LNV) permit based on additional impact assessment conducted, revealing that MV2 will have no impact on most adjacent natural areas, except Voordelta (Natura 2000 area), but due to compensation still possible
15 May 2008	Second covenant reached (Vision and Trust) including long-term monitoring
1 Sep 2008	Technical start of MV2 extension

4.2. METHOD

We have historically reconstructed the process of harbor development by analyzing documents such as scientific articles, original policy documents and historical literature. All documents we cite in this article are listed under the References. Further documents that were studied, but not cited, are listed under the header *Additional documents studied (not cited)*, and can be found at the end of the article. To improve our understanding of the data and to gather data on the most recent period of harbor development, since few historical documents on that issue were available, we conducted eleven face-to-face interviews. Participants were asked during the interviews to reconstruct their personal involvement in the process. Furthermore, we asked these actors to identify important changes in the evolution of the process, their personal perceptions of the role of knowledge and where applicable the changes they could identify in the role of knowledge. We selected participants with different backgrounds so as to obtain a comprehensive understanding of the process. Our sample included:

- One scientist that participated in the public hearings as a citizen
- One representative of an independent foundation advising on environmental impact assessments in the Netherlands
- One scientist that participated in the second environmental impact assessment
- Two civil servants that held a leading position in the administrative process of the latest harbor extension (the MV2 project)
- One representative of an environmental NGO, that also participated in the joint fact-finding
- One scientist specialized in the historical development of the Rotterdam harbor
- Two scientists involved in the current development of the Rotterdam harbor
- Two members of a non-governmental organization concerned with EBM in the most recent period of Rotterdam harbor development

The study covered the period from 1827 to 2008. Although our dataset also includes information on periods before and after those years, we have not included that information in our historical analysis in the interests of methodological accuracy. However, since our interview respondents mentioned important insights beyond 2008, we elaborate on a few developments beyond the selected period in our discussion section (section 4.5). The analysis of our data (sections 4.3 and 4.4) is based on a mix of a description of historical events, interpretative analysis, ex-post evaluation and causalprocess tracing. To ensure methodological transparency, we mention each method used in the header of each paragraph.

4.3. DESCRIBING THE ENVIRONMENTAL HISTORY OF ROTTERDAM'S HARBOR

For more than a century, the evolution of the port of Rotterdam has been measured mainly quantitatively, focusing on the expansion of infrastructure and logistics facilities. The beginnings of economically driven growth have been traced back to the second half of the 13th century when the Rotterdam fishing village began developing into a prosperous merchant port. By the beginning of the 17th century, the first harbors were constructed. These in turn became important through the increased trading and shipping activities of the Dutch East India Company (Hommes et al., 2009). The quantitative growth paradigm reached a peak at the end of the 1960s, when after numerous expansion projects the Rotterdam harbor was the biggest in the world (Van Gils and Klijn, 2007).

4.3.1. Challenging nature to enable harbor growth (1827-1960)

Due to its on-shore location, however, the Rotterdam harbor has constantly struggled with accessibility problems, caused by sedimentation processes stemming from the North Sea. From 1800 onwards, for example, sedimentation decreased the depth of shipping channels and hindered the ability of large vessels to directly approach the inner city's wharfs. In the second half of 1800, sedimentation increased to such a level that, for example, the Brielse Gat (between Rozenburg and Voorne) and the seaway by Maassluis were not accessible anymore. Commercial ships and warships had to use alternative, slower routes to reach Rotterdam's harbor (Van de Laar, 2000: 65-66).

Various solutions for the sedimentation problem were circulated, discussed and implemented. Knowledge about the ecological dynamics underlying sedimentation processes and the effects of the proposed solutions was developed and consulted as part of the decision-making process. The first solution, supported by the governing commercial elite of Rotterdam, was a canal (Voornse Kanaal,1827-1829) to improve access of the Rotterdam harbor. However, that solution soon became out of date, as further sedimentation occurred and continued hindering direct accessibility of the port (Van de Laar, 2000: 66). An unknown, but recurring, problem in the Rotterdam harbor area was the increased accumulation of sediment due to changes in the circulation patterns of water caused by the excavation of navigation channels (De Jonge and de Jong, 2002).

New solutions needed to be invented. Environmental engineers from the Dutch national infrastructural agency (Rijkswaterstaat) were requested to develop alternative navigational routes. The first plan was developed by engineer F.W. Conrad in 1836, but was not carried out, as it was perceived as being too expensive. Later, another expert, P. Caland, calculated the costs of an engineering design that was derived from England, but his project did not succeed too. On 5th November 1857, a commission was instituted by the national government consisting of the three most important Dutch water experts (Caland, Conrad, and Beijerinck). They were asked to come up with a new solution, and plans for a new navigational route, called the New Waterway, were developed. Caland calculated this route by incorporating intertidal dynamics, hence preventing further sedimentation of the channel (Van de Laar, 2000: 66-67).

However, as the national government, which at that time had final decision-making power for the harbor extension, was not convinced of the necessity of the additional excavation, the implementation of the NewWaterway was not approved. Approval was only received in 1862 (Van de Laar, 2000: 67). A few years later, the intertidal calculations of Caland turned out to be wrong and sand sedimentation again caused accessibility problems. New excavation was necessary and, after debates on whether the national or municipal government would pay for the needed technical adjustments, an agreement was reached in 1883. Technical water experts were then able to start theirwork (Van de Laar, 2000: 70). Rotterdam citizens raised environmental concerns in that period by claiming the loss of valuable recreation areas. However, they had limited impact on the decision-making process (Van de Laar, 2000: 71).

The following period was similarly characterized by minor extensions, which further broadened the harbor and facilitated harbor-related activities (e.g. the development of the Feijenoord harbor complex). Additional land reclamation was planned and discussed (Van de Laar, 2000: 88). From 1880 onwards, the growth strategy was continued and even accelerated as city and port planning were given more prominence, transforming the Rotterdam merchant port into a so-called transito-harbor (Doorvoerhaven). A substantial increase in freight transport to and from Germany supported the growth of the Rotterdam harbor, and was accelerated by the professionalization and mechanization of the harbor's services (Dicke et al., 2007: 14). This strategy was almost completely supported by Rotterdam's governing and commercial elite (Van de Laar, 2000: 92). Typically, technical and financial feasibility studies were used to facilitate the harbor development decision-making process.

It is worth noting that environmental issues were not absent at that time. These issues were discussed in terms of a lack of natural areas in the city of Rotterdam. The environmental concerns were finally taken up by De Jongh, an influential town planner, who developed the Bosch- and Parkplan for the Rotterdam neighborhood of Kralingen in 1909 (Van de Laar, 2000: 288). Environmental assessments of economic activities were already obligatory in that period. The Hinderwet, applied in the Netherlands from 1875 to 1952, assigned decision-making power on the environmental quality of expansions in the harbor area to the Rotterdam municipality. Entrepreneurs were obliged to apply for a permit when planning to build a new factory or installing a steam engine. The municipality, however, could decide on permits without consultation of expert advice (Scholte, 1990: 23-28).

After some interruptions in the growth of the harbor, caused by decision-makers placing more attention on town-instead of harbor-planning between 1920 and 1940, as well as the advent of the Second World War from 1940 onwards, a new period of accelerated development started in 1955. These golden years (1955-1975) were characterized by strong international economic growth, which encouraged the industrialization and expansion of the harbor district (Dicke et al., 2007: 28). Estuaries in the harbor region (Haringvliet and Brielse Meer) were transformed into suppliers of fresh water. This man-made creation of large-scale fresh water supplies motivated the petrochemical industry to set up its facilities in Rotterdam, leading to the creation of the second largest petrochemical complex in the world (Meyer et al., 2012: 84). The fresh water supplies also supported the growth of agri- and horticulture in neighbor areas (clay polders south of Rotterdam; Westland) (Meyer et al., 2012: 84).

4.3.2. Rise of environmental concerns (1960-1990)

From the 1960s onwards, environmental pollution accrued. The spread of industrial activities in the Rotterdam harbor increased the level of industrial emissions, causing environmental problems in the harbor, the city and adjacent regions. The harmful effects of the harbor development became tangible. Air quality worsened, as did the quality of the water in the Rhine and the supplies of Rotterdam drinking water. Scientific studies were published that linked problems of regional population health with the decrease in the quality of the living environment (Van de Laar, 2000: 504-505).

At the same time, the "[…] attention for environmental issues increased and the quantitative growth of the Rotterdam mainport was criticized on a substantial level for the first time. Environmentalists started to voice opposition." (Meyer et al., 2012: 77). Significantly, local environmental interest (from neighbor municipalities such as Hoek van Holland, Maassluis, Vlaardingen and the coastal area of Voorne) organized protests against the dominant position of economic imperatives in the development of the harbor (Van de Laar, 2000: 486). In 1964 regional representation was institutionalized to prevent the further degradation of living and environmental quality in the Rotterdam area (Dicke et al., 2007: 134). In addition, the Council employed scientific capacity, as it generated objective measurements of environmental pollution reported by citizens (Van de Laar, 2000: 504-505).

Pressure groups focused on influencing on Rotterdam's harbor policy emerged in the Rotterdam region, peaking in the 1970-1973 period. Around 1970, a new air pollution law was launched and administrative capacity was transmitted to the provincial regions, decreasing the central position of Rotterdam municipality (Van de Laar, 2000: 505). In that period, it was difficult to obtain approval for further harbor development and extensions. Plans to build new blast furnaces, for example, could not be realized. NGOs, citizens, media, the Rijnmond Council and national politicians uttered their criticism, resulting in the plans being withdrawn. Political primacy was high in that era, lowering the influence of commercial entrepreneurs and harbor administrators on harbor policy (Van de Laar, 2000: 506-507, Dicke et al., 2007: 130-134).

In sum, that period revealed a rise in environmental concerns. Harbor growth had become a topic of dispute, but the harbor itself was still seen as an important economic driver. Plans to develop a forest in one of the harbor extension areas (Maasvlakte) for example did not gain the decisive support of the municipal council. Still, from 1970 onwards, it became more difficult for industrial activities to be carried out in the harbor area. In 1973, for example, a working group (Werkgroep Occupatie Maasvlakte) was established to evaluate whether new harbor development activities complied with environmental regulations (Van de Laar, 2000: 507). The simultaneously emerging oil crisis however meant that environmental concerns became a non-issue for the harbor's growth soon. Further investments in the chemical and steel industries, which dominated Rotterdam's harbor, became unprofitable and the harbor's expansion plans became outdated (Dicke et al., 2007: 138).

4.3.3. Integrating environmental concerns and harbor growth (1990-2008)

The oil crisis called for a new strategy for developing the harbor. That strategy focused on expanding container shipping. Container shipping needs space, and this shift led to plans for expanding the harbor and reclaiming land being drawn up again (Van de Laar, 2000: 507). A new harbor expansion project, MV2, was planned. Unlike previous projects, environmental issues featured significantly in the MV2 expansion. The municipality and the harbor authority (Gemeentelijke Havenbedrijf Rotterdam (GHR)) recognized and accepted that further expansions of the harbor would have to meet social and environmental demands. They jointly presented a new expansion plan in 1991 (Ontwerp Havenplan 2010) (Weggeman, 2003; Dicke et al., 2007: 140). Although not directly related to the new harbor plans, the municipality had simultaneously announced a more integrated approach towards environmental issues, reflecting a shift from expansion and quantity-oriented spatial planning towards more structural and quality-oriented spatial planning (Municipality Rotterdam, 1990: 84).

In 1993, the ROM-Rijnmond covenant, signed by national, provincial and local government authorities, as well as business stakeholders, was announced. It represented a concrete act to establish an integrated approach to planning. It established a forum where the public and private sectors could discuss common issues. Four years later, the official evaluation of

ROM-Rijnmond concluded that the platform supported the attempts of its members to contribute to more integrated regional development. The members identified three sources of added value from the platform: the quicker and smoother processing of procedures, access to finance, and the creation of contacts with partners (ROM-Rijnmond, 1997).

To protect and increase environmental quality, new ways of knowing were introduced, reflecting a more structural and programmatic approach to environmental assessment. Measurements of judgments of environmental issues by Rotterdam's citizens were conducted from 1989 onwards. These environmental indicators included dust, stench, oil-, soil-, air- and noise-pollution (e.g. research from Gemeentelijk Bureau Onderzoek en Statistiek, and the Nederlands Studiecentrum voor Geluid) (Municipality Rotterdam, 1990: 85). In 1990, research on noise pollution was started, with the aim of measuring vessel noise and coming up with plans to reduce industrial noise in the harbor (Municipality Rotterdam, 1990: 90). These changes led to environmental policy gaining a stronger formal position. This position-was called external integration and meant that environmental arguments needed to be taken into account at an early planning stage whenever harbor's expansion and redevelopment were discussed (Municipality Rotterdam, 1990: 92).

In 1993, the plans for MV2 were presented (Van Gils and Klijn, 2007). MV2 was seen as a necessity for the accommodation of growing port activities. The responsibility for the project was assigned to an agency of the national government in 1994 (Weggeman, 2003; also cited in Van Gils and Klijn, 2007). Although the civil servants in charge developed different innovative approaches to pro-actively integrate a wide range of knowledge sources, a period with several decision-making deadlocks occurred. Several procedural adjustments had to be developed, before effective knowledge governance could finally be established. The next section (4.3.4) reports on this part of our historical analysis in more detail.

4.3.4. When the assessment approach to knowledge governance became an outdated strategy: historical development and procedural adjustments to decision-making (1990-2008)

In 1997, several national politicians began arguing for harbor development to be more sustainable. Stemming from parties that formed the government (Liberal Democrats, Social Democrats and Conservative Liberals) these politicians hold a majority in the legislature. The focus on sustainable development resulted in the announcement of a "double aim" approach for harbor development that prioritized both growth as well as improvements in living quality and the environment (Van Gils and Klijn, 2007). Simultaneously, national-level decision-making arrangements changed in 1997, reflecting a more open and interactive style. The so-called VERM procedure was set up to debate the urgency, feasibility, and economic and environmental impact of the proposed harbor extension. The procedure had to facilitate a public consultation process so that citizens, governmental officials, business stakeholders, interest groups, environmental organizations and scientists could participate in decision-making (Weggeman, 2003). Consultation meetings were organized in the region and in regions that were part of the extended harbor system, ranging from Amsterdam, Vlissingen-Terneuzen, Moerdijk, Delfzijl-Eemshaven, Arnhem-Nijmegen to Venlo (Tweede Kamer, 1997).

While the VERM procedure was established to enhance the level of participation in decision-making, Klijn and Koppenjan (1999) concluded that the non-participation of politicians caused problems. Substantive political discussion about whether and how to extend the Rotterdam harbor did not take place in VERM. Participants in VERM also claimed a lack of impact regarding the knowledge gaps that were identified during public meetings. Also civil servants reported non-usability of the resulting reports due to a lack of legitimacy that emerged at the level of political decisionmakers. Summing up, the VERM procedure was helpful in informing stakeholders about the project. Although it promoted deliberation and facilitated knowledge dissemination, integrative knowledge utilization did however not reach its full potential.

A comparable knowledge utilization problem occurred, when a few months later the informal gatherings between harbor authorities (which in the meanwhile had been organized as a project organization called Project Mainport Development Rotterdam (PMR)) and environmental interest groups officially stopped. During that time, PMR took the first steps to arrange the obliged environmental impact assessment (EIA) for the MV2 and stakeholders felt disappointed about not being consulted (Weggeman, 2003). The communication deadlock could be dissolved in March 1999 when a new minister officially reannounced commitment to the necessity of the open and interactive project planning. During that time, the undivided, political support towards the open planning procedure as well as the double aim approach, however, was lacking. As different ministries were involved, administrative participants of the decisionmaking process perceived the lack of political unity as a retarding factor. The decision-making process continued in experiencing problems. Stakeholders once again complained the lack of effective involvement and wanted to leave the common process (Weggeman, 2003). In that same time period, the commission responsible for conducting the EIA concluded that the Mainport plans did not comprehensively examine how nature and living quality would be compensated for (MER, 2013), hence providing further support to the view of stakeholders.

Following these decelerating developments, a mediator stepped into the process and brought the parties back to the negotiation table. He suggested the Top Council as a common consultation platform that brought together representatives of environmental interest groups and public authorities (Van Gils and Klijn, 2007). The chair of that council acted as an independent, mediating force between the interests and arguments of the decision-makers and stakeholders. The government then proposed to continue the decision-making process by coming up with an agreement called a process-covenant. This agreement would describe how interest groups would participate in the decision-making process (Weggeman, 2003). Environmental interest groups, however, were disappointed about the lack of direct impact and refused to sign the covenant. They wanted more decision-making power and decided to leave the process (Van Gils and Klijn, 2007). Their specific complaints were (Weggeman, 2003):

- A split between government and interest groups
- The lack of application of the outcomes of the joint fact-finding exercise
- Authorities perceiving the existing juridical, environmental framework as a hindrance, instead of an opportunity for improvement
- PMR's apparent operation as an arm of the ministry
- The lack of an independent chair

A new mediator was installed by PMR to solve the deadlock in the decision-making process (Weggeman, 2003; Van Gils and Klijn, 2007). The mediator was asked to provide space for and regain the trust of the environmental interest groups (Weggeman, 2003). An informal meeting was organized (called a fire-place conversation), but was unsuccessful. An additional mediator was asked for advice and environmental interest groups decided to put forward new demands. These included (Weggeman, 2003):

- An independent chair
- An independent secretariat
- Clarity about how the input of non-governmental actors would be handled
- The possibility of participating in the planning, contracting and interpretation of research
- A request that common negotiation may not be used as a signal to the government that everything is going well
- The juridical position of the parties to use appeal procedures would not be undermined by their participation in the Council

In addition, they asked for the assessment of an alternative option for the harbor extension as well as a 750-ha nature area to be guaranteed separately from land compensation measures.

At this point, an important organizational change occurred. A new management style was set up, which changed harbor management from a technical and administrative realization of an extension project into a more strategic stakeholder management process. This change was later judged as being part of a crucial strategy for the harbor's development (Van Gils et al., 2009). The municipality of Rotterdam invited three environmental interest groups (Consept, Natuurmonumenten and the Society for Nature and Environment) to negotiate and collaborate (Van Gils and Klijn, 2007). This group managed to reach an agreement, which was called Vision and Courage, including the announcement of harbor extension and environmental compensation projects holding equal priority (Vision and Courage, 2000; Meyer et al., 2012: 78). This enabled decision-making to proceed.

The participation of environmental interest groups also triggered a change in the decision-making process architecture. As our analysis revealed, environmental NGOs stepped out of the process several times, claiming the need for consensus about the definition of the problem under decision, search for solutions that should be guided by perception that all members were equal, and sharing of all information (Weggeman, 2003). To enhance the effectiveness of the knowledge governance approach, PMR introduced structured and transparent process architecture. This architecture entailed the definition of a clear position of each actor participating in the decision-making process. It was defined that the project organization would direct the common knowledge production process as an independent, principal agent, with the aim to produce collective knowledge on the base of which the collective will would be formed and presented to the legitimized authority holding final decision-making power. Figure 4.1 provides an overview of the process architecture introduced.

However, in 2004, new stakeholders began criticizing the body of knowledge that was generated and used juridical ways to claim incompleteness of the ecological knowledge investigations conducted for the MV2 project. More specifically, based on the EU Habitats and Birds Directives, they remarked on the lack of research on the impact of the harbor extension on rare species in the adjacent Rotterdam region, and on sediment and fish larvae transport to the Wadden Sea (an area located 200 km to the north) (Raad van State, 2005; also Meyer et al., 2012). The highest juridical court of the Netherlands justified these claims, and urged additional research. When no significant impact could be proved and the proposed ecological compensations for the ecological damage were judged to be sufficient, the official license for MV2 was issued on 17 April 2008. A similar claim, although issued under national environmental legislation (Flora- en Faunawet), was made by public stakeholders in 2007. They claimed a lack of sufficient research on the impact of harbor development on protected species that were not directly located in the harbor area but the adjacent region (LNV, 2008). Managerial participants of the decision-making process questioned whether these claims were meant to increase ecological knowledge bases of the decision-making process, or whether they were used as an additional means to exert interest influence.

However, on 15 May 2008, another informal covenant called Vision and Trust (Visie en Vertrouwen) was reached between stakeholders and decision-makers (see Picture 4.1, used by permission of Havenbedrijf Rotterdam N.V.). The main changes in the covenant are the inclusion of additional stakeholders and a long-term monitoring program that has to function as an accountability program. It states the various policy aims that have been agreed on and the related targets that should be accomplished to reach these policy aims. Several revision deadlines are included, suggesting time frames in which these aims shall be completed and evaluated (Vision and Trust, 2008). In September 2008, the technical start of MV2 began. To compensate for the actual and expected loss of ecological areas, existing rural areas were proclaimed for new natural areas. That would keep ecological quality stable on the regional level. As an additional compensation measure, new nature areas had to be created in adjacent regions. Picture 4.2 shows new nature area (Spanjaards Duin) created as compensation for MV2 (Picture used by permission of the communication office of the Natura 2000 Beheerplan Voordelta, Rijkswaterstaat Zee en Delta).

In addition, separate monitoring programs have been installed from May 2005 onwards. T0 measurements have, for example, been taken on fish populations at one of the nature compensation areas in 2005 and 2007 (Tulp et al., 2010). Later on, other monitoring programs have been developed, specifically evaluating the environmental effects of MV2 (Port of Rotterdam, 2014). Since the effects need to be measured not only at the project area itself, but also on selected compensation sites, different governmental institutions are responsible, each conducting different monitoring programs. The monitoring organized by the Port of Rotterdam, for example, includes sludge deposit and its effects on food webs, effects of underwater noise caused by dredging ships, effects on currents, as well as monitoring of archaeological and paleontological discoveries. For some parameters first measurements have been taken from 2006 onwards, e.g. the monitoring of benthos (T0 2006-2008 at 300 different spots at ca. 50 km coastline) (Port of Rotterdam, 2012).

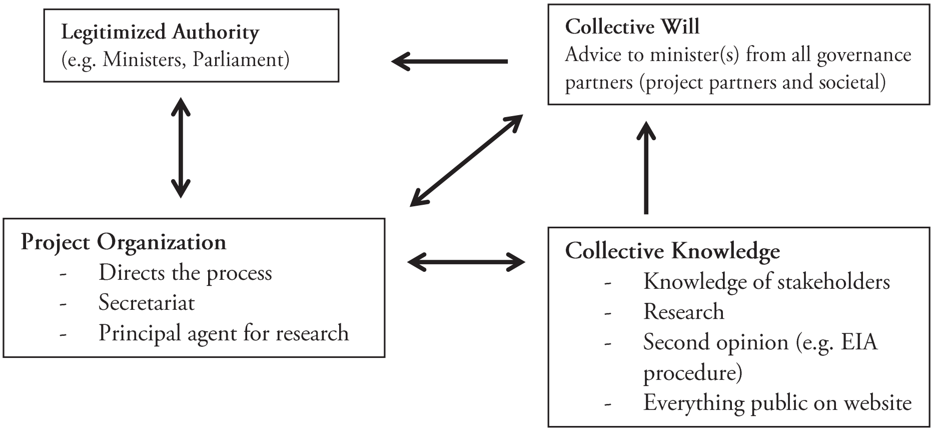
4.4. TOWARDS ECOSYSTEM-BASED HARBOR MANAGEMENT? DESCRIBING AND EVALUATING HISTORICAL SHIFTS IN HARBOR DEVELOPMENT AND THE ROLE OF KNOWLEDGE

4.4.1. Interpretation of historical development from 1827 to 2008

Our comparison reveals shifts in the framing of growth, integrating environmental concerns and the role of knowledge in decision-making. Until 1960, the aim of quantitative growth was not substantially criticized. Land reclamation, the creation of freshwater basins by cutting off the supply of seawater; dredging and allowing more ships and larger containers were accepted techniques to support growth. Narratives on environmental quality existed, but played a marginal role. Ecological issues were mainly discussed as obstacles to economic growth. Environmental knowledge on sedimentation processes was produced to solve technical challenges, such as digging outwaterways. Experts from a technical background and town planners were the central knowledge sources who advised harbor decision-making committees. The key decision-making actors stemmed mainly from public agencies and/or business organizations.

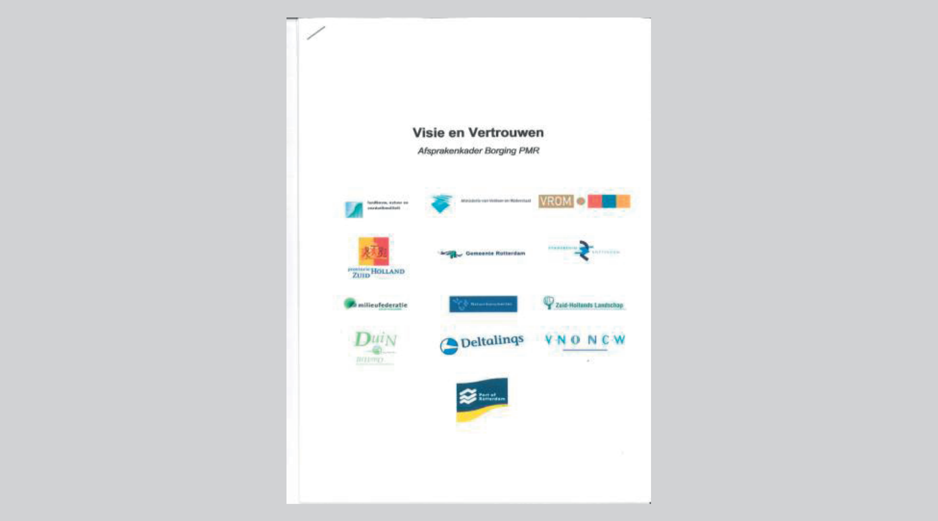
In the 1960s, the context changed. Environmental problems caused by emissions from harbor-related industries became more tangible. New scientific knowledge was produced to systematically and objectively measure and communicate environmental pollution. Reparation measures, however, focused on single issues and were conducted in an ad hoc style. To achieve structural improvements for the environment, new norms around development projects were set up and made compulsory for any harbor development plan. New public organizations emerged that were concerned with environmental damage control. These changes however did not have a decisive impact on harbor management.

Figure 4.1
Process architecture of joint fact-finding process
(Source: reproduced by permission of Van Zwam, 2013, unpublished correspondence)


Legitimized Authority
(e.g. Ministers, Parliament)
Collective Will
Advice to minister(s) from all governance partners (project partners and societal)
Project Organization
- Directs the process
- Secretariat
- Principal agent for research
Collective Knowledge
- Knowledge of stakeholders
- Research
- Second opinion (e.g. EIA procedure)
- Everything public on website

Picture 4.1
New dune landscape ‘Spanjaards Duin’ created to compensate for expected ecological loss caused by harbor extension MV2

Picture 4.2
Covenant ‘Vision and Trust’ V reached on 15th May 2008



Visie en Vertrouwen

Afsprakenkader Borging PMR

VROM

provincie ZUID HOLLAND

Gemeente Rotterdam

milieufederatie

Zuid-Hollands Landschap

DuiN

Deltalinqs

VNO NCW

Port of Rotterdam

Although the increased assessment norms broadened the responsibilities of decision-makers regarding new development plans, the harbor authority proceeded with its economic and technically driven management style. However, a shift towards 'conditioned' harbor development was apparent.

This situation changed again from 1996, when demands from new legislation (e.g. Environmental Impact Assessments, EU Habitats and Bird Directive), Rotterdam citizens and environmental interest groups grew and became institutionalized. The traditional technical problem-solving response of the harbor authority's management was insufficient for making decisions. Although attempts to facilitate stakeholder involvement were initiated (e.g. the VERM procedure), effective knowledge integration did not occur. A few interest groups began using legal channels to claim knowledge gaps in decision-making. New platforms were established to support communication between political decision-makers, the harbor management and interest groups. Integrated plans and innovative procedures, like a joint fact-finding process, and transparent process architecture were introduced. Stronger commitments between environmental NGOs and harbor officials followed and increased the impact of integrative knowledge sources. At a later stage, the production and use of an adaptive monitoring program was added. Table 4.1 summarizes our interpretation of harbor developments. An overview of those historical events we identified as defining events for each knowledge paradigm can be found in Table 4.2.

4.4.2. Ex-post evaluation of knowledge governance from 1990 to 2008

From our analysis in section 4.4.1 we conclude that important shifts have occurred in the management of the Rotterdam harbor that point toward an integrated ecosystem approach in the 1990-2008 period. However, the crucial question remains whether the interplay of economic and ecological interests has resulted in a type of knowledge governance that facilitates EBM over time. To answer this question, we reflect on the empirical manifestation of the EBM approach as observed in the Rotterdam case. We focus on the role of knowledge in decision-making.We analyze whether and to what extent the full potential of EBM knowledge generation and utilization has been reached. We conduct this evaluation on the basis of the principles of EBM knowledge governance, as defined by Giebels et al. (2013). These principles were defined through a literature review that examined the arguments made by scholars of EBM, adaptive decision-making and effective knowledge utilization. Since, EBM was not applied as a conscious management approach in the Rotterdam harbor case, we use these principles as an ex-post evaluation framework. The ex-post evaluation will help us to judge whether established management actions were already sufficient to serve EBM or whether improvements would have been needed.

The EBM knowledge governance principles suggest that knowledge for EBM should consider ecological complexity, social complexity and adaptive management. This means that the knowledge governance realized during decision-making reflects an approach that tries to capture the complex and volatile character of socio-ecological systems, reflects the values, interests, and ways of knowing of the actors involved, and facilitates knowledge production alongside decision-making, enabling adaptive learning and management. We assign a qualitative score to each instance where we identified that a principle was applied. The score reflects whether the principle was applied (A) or not (NA), and whether the (non-) application contributed (++ or +) or undermined (–) the realization of EBM. The score is assigned when the application of the principle contributed to EBM and no improvements could be identified. The + score is assigned when the application contributed to EBM, but improvements could be identified. Table 4.4 reveals an overview of our evaluation matrix. Table 4.5 provides a short description of all principles used for our empirical analysis, as well as the actual evaluation scores assigned.

Table 4.4
Index of qualitative evaluation scores

Evaluation score	Description
A	Application of the principle
NA	Non-application of the principle
++	Application contributed to EBM/Non-application did not undermine EBM
+	Idem, but improvements suggested
–	(Non-) application undermined EBM

4.4.2.1. Knowledge that takes account of ecological complexity

An 'Environmental Impact Assessment' (EIA) has been used as the main policy tool to provide knowledge on ecological complexity. This procedure is strongly expert-driven and assesses the integrated impact of actions that occur as part of important infrastructural projects and other large-scale activities. In such assessments, experts calculate the future effects of planned projects on the environment. We judge the EIA procedure therefore as a manifestation of these EBM principles: a) an accumulation of data and open access, c) inter- or multidisciplinary cooperation and e) pays attention to scale differences. However, as this procedure is meant to calculate the effects before a project is started (Knill and Liefferink, 2007), it becomes clear that using only this procedure does not provide b) real-life experiments and reflexive trial-and-error, or d) long-term monitoring and assessment. From the perspective of EBM, both types of measurement would have been useful to assess the impact of harbor development on the environment. Although added to the process at a later stage, actual measurements of longterm effects were not available within the time period covered by our study. Hence we cannot judge whether their non-application also undermined EBM.

However, since several knowledge gaps were identified by different stakeholders at a very early stage of the decision-making process, but taken seriously only after judicial investigation had taken place, we assign a score of A+ to the application of the EIA, and hence principles a), c) and e). A double + score is not assigned since need for improvement is apparent. For principle b), experiments and reflexive trial and error, we assign the evaluation score NA, since on the base of our collected data no application of experiments could be identified. In terms of longterm monitoring and assessment (principle d), an A+ score was assigned, since an adaptive monitoring program was introduced in 2008. However, the monitoring scheme did not consider an integral ecological assessment, restricting a measurement of the effects of policies to ecosystems. Hence reflecting need for improvement.

Table 4.5
Evaluating the knowledge governance in the period from 1990 to 2008

Knowledge principles	**Empirical manifestation**	**Evaluation/effects of chosen approach**
Ecological complexity Knowledge tries to catch the complex and volatile character of socio-ecological systems by		
a) promoting accumulation of data (open access)	a) EIA conducted before the project was started; monitoring of effects since 2005	a) A+ (open access not applied consistently)
b) using real-life experiments and reflexive trial-and-error	b) not applied	b) NA
c) inter- or multidisciplinary cooperation	c) mainly facilitated through EIA	c) A+ (stakeholders criticize knowledge gaps and push for additional research by juridical means)
d) long-term monitoring and assessment	d) since 2005	d) A+ (lack of integral ecological assessment)
e) giving attention to scale differences	e) facilitated through EIA	e) A+ (stakeholders criticized chosen scale of EIA, assessments of adjacent protected ecosystems, e.g. the Wadden Sea, claimed insufficient)

Social complexity Knowledge reflects the various values, interests, and ways of knowing of the various actors involved (citizens, stakeholders, experts, bureaucrats):		
a) knowledge is co-produced by experts, citizens/stakeholders, and policymakers, and their different knowledge sources are taken into account	a) applied during process by different procedures (e.g. VERM)	a) A+ (choice of actors caused difficulties, participating actors claim lack of impact, but also non-participants utter criticism, while it stays unclear whether a lack of knowledge or general criticism on project is claimed)
b) values and interests are taken into account in the knowledge process	b) need to do so claimed on the national level in the form of ouble aim approach	b) A+ (values and interest of citizens not sufficiently taken into account, resulted into several decision-making deadlocks, double aim approach criticized to be used as an approach to avoid taking unpopular decisions)
c) knowledge is used to facilitate a process of frame reflection and joint learning between actors	c) especially facilitated during joint fact-finding	c) A+ (several adjustments to the procedure and additional informal agreements were necessary to make it effective)
Adaptive decision-making Knowledge production is organized alongside processes of decision-making and implementation:		
a) long-term interaction between scientists, stakeholders, and policymakers is facilitated	a) short-term interaction with scientists through EIA, as well as scientists, stakeholders and citizens through VERM, stakeholders involved through joint fact-finding, since 2005 diverse monitoring and evaluation programs, since 2008 long-term interaction between stakeholders and harbor authorities	a) A+ (earlier application would probably have increased quality of decisions taken)
b) adaptive science–society–policy interfaces are installed to enable flexible and tailor-made science–policy interactions	b) science involved through EIA society-policy interfaces installed at a later stage of the process	b) A+ (earlier interfaces would have even increased EBM)
c) knowledge enables learning on ecosystem dynamics and facilitates feedback loops in decision-making	c) strong emphasis on learning about ecological effects of the MV2 since 2005	c) A+ (VERM procedure criticized for lack of learning, joint fact-finding effective only after redesign, facilitated learning in-between stakeholders and political decision-makers, multi-level governance constellation of responsible authorities periodically restricted learning)

4.4.2.2. Knowledge that takes account of social complexity

The inclusion of stakeholders had a prominent position in the decision-making process. The first attempt to establish a national debate on the utility and necessity of the project was facilitated through the VERM procedure. Later, a joint fact-finding procedure was set up to involve stakeholders on the regional level. Our historical analysis however revealed that both procedures had a difficult implementation process. The data indicate that the VERM procedure did not result into a common debate, as it was meant to do. Similar, the joint fact-finding procedure did not function effectively right away. Several stakeholders left the process, criticizing the lack of actual impact. Several procedural reforms and additional informal agreements were necessary to establish effective communication. Our historical data reveal that participating stakeholders doubted that decision-makers wanted to organize a process that would eventually result into knowledge co-production. The advices conducted by the MER Commission confirm that stakeholder interests were not sufficiently taken into account during the planning of the harbor development project. At the same time, managerial participants of the decision-making process reported that it was difficult to organize a common debate among diverging environmental interest groups. Hence, we conclude that the EBM principles concerning the governance of social complexity are not or only partly satisfied. When the harbor authorities tried to involve stakeholders, it was difficult to find a good structure to include them. In addition, external stakeholders, who were not directly involved in the joint fact-finding exercise, criticized the process. Thus, we assign a score of A+ to the principles of social complexity. While attempts were made to facilitate effective knowledge governance, severe improvements were needed. Since social complexity turned out to be extreme in the Rotterdam case, it however might be questioned whether and which improvements would have been effective. We provide further reflection on the feasibility of potential improvements in the discussion section.

4.4.2.3. Knowledge is organized in an adaptive way throughout decision-making

Researchers have argued that adaptive decision-making is facilitated when a) long-term interaction patters between decisionmakers and knowledge sources are installed, b) when flexible interaction is enabled, and c) when learning is actively stimulated.

The Rotterdam case provided a mixed set of outcomes for this principle. In the beginning of the 1990s, the first attempts were made to implement such a process through the VERM procedure. However, the procedure did not cater for long-term interaction between stakeholders. Moreover, it lacked a flexible interaction pattern because of its large scale. Meetings were held only once to inform the public about project proposals and discuss them. It is unclear whether and by whom learning occurred. Several participants claimed that the knowledge gaps identified during meetings were not taken into account, or only partly so. The selection criteria that decision-makers used to integrate knowledge claims remained unclear to participants. Interestingly, as mentioned in the previous paragraph, the harbor authorities introduced a new tool following the VERM experience to better involve stakeholders, the joint factfinding exercise. Our analysis reveals that this was a better format for establishing effective communication between interest groups and decision-makers. However, it was not working effectively from the beginning. Internal participants claimed that it had little impact. This was especially so when interests on the political level changed and full commitment towards open and transparent planning was not consistently applied anymore. The harbor authorities began running additional project investigations, what was perceived as a pre-defined bias for one of the policy options (building an extension on the sea), instead of commonly assessing three potential options equally. Such actions eventually restricted policy learning. Furthermore the joint fact-finding exercise aimed at establishing common and shared knowledge. This approach therefore logically seems to result in developing a 'common and shared understanding' between participants, neutralizing conflicts, streamlining divergent ideas and perceptions. Our results suggest that this method has the added value of effectively organizing a complex decision-making process, as it supports the involvement of many and diverse stakeholders. On the other hand it might have come along with restrictions of the innovative capacity of the group, because diversity of knowledge was perceived as a problem and not at as a source for innovation. Unfortunately our dataset misses detailed information about the effects of the joint-fact finding. From the perspective of EBM, however, we need to conclude that a full assessment of the ecosystem and available policy alternatives has not been conducted. Furthermore, we conclude that although all of the adaptive decision-making principles have been applied at specific points in time, some have been included at a very late stage of the process. Earlier adaptation would probably have increased the quality of the decisions taken. We therefore assign a score of A+ to the principles applied here. Application is observable, but improvements are deemed necessary.

4.4.3. Causal process-tracing to identify factors facilitating effective EBM knowledge governance

Based on our analysis in the previous sections (4.4.1 and 4.4.2) we can conclude that the most relevant time period to learn about conditions that facilitate effective EBM knowledge governance is the period from 1990 to 2008. Although EBM has not been fully established within that period, we see important elements emerging, together reflecting an EBM approach. We use causal process tracing (see for example Blatter and Haverland, 2012) to analyze the historical storyline developed (see sections 4.3.3 and 4.3.4 for a summary of that storyline) with the aim to identify factors that were necessary for EBM knowledge governance to emerge and to become effective in the Rotterdam case. Our data suggests the interplay of six important factors. To avoid too much repetition of sections 4.3.3 and 4.3.4, we only briefly introduce each factor and their interrelatedness in the following paragraphs.

4.4.3.1. Environmental law

In relation to EBM knowledge governance we can conclude that environmental law was important for EBM to emerge. National as well as international law emerged, introducing an ecological frame to decision-making. The impact of this frame became visible through e.g. decision-makers conducting environmental impact assessments, as well as interest groups criticizing the knowledge base deemed sufficient for decision-making and urging further investigations of environmental impacts in the Rotterdam area.

4.4.3.2. Interest groups

Connected to the variable of environmental law, we therefore identify the active involvement of interest groups as an important driver towards effective EBM. Interest groups however were not united, neither in terms of interest agendas nor organizational form. They used different means to influence the decision-making process. Some of them were willing to unite and participate in negotiations and the joint fact-finding, while others used juridical channels to criticize the knowledge produced and applied by authorities. We therefore need to conclude that the influence of interest groups worked facilitating as well as constraining for effective EBM knowledge governance. A constructive opinion towards finding a balance between environmental quality and economic activities has been reported as an important characteristic of all those groups that participated during decision-making.

4.4.3.3. Informal agreements

Informal agreements (covenants) functioned as a foundation for EBM knowledge governance. The first covenant was reached in 2000 and basically reflected an official announcement of collaboration. In 2008 the covenant was enlarged by the inclusion of additional stakeholders as well as the installation of a long-term monitoring program. Both covenants emerged after a period of decision-making struggles, characterized by unsuccessful cooperation and decision-making deadlocks. Informal agreements therefore, in our view, were important to establish a governable interaction pattern between decision-makers and stakeholders.

4.4.3.4. Independent intermediaries

In addition, independent intermediaries were used several times to solve decision-making deadlocks. They were functioning as mediating links between environmental NGOs and harbor management officials, when interaction between both parties stopped. The causal-process tracing reveals that their intervention was mainly important in 1999, after the first decision-making struggles emerged.

Specific personal and positional characteristics were reported to benefit the effective functioning of one of these chairs (Weggeman, 2003):

- Good listening skills
- Capable to build bridges
- Giving others the feeling that they are important for the process, and considered as fully respected negotiation partners, which also cannot be taken out of the process when necessary
- Direct access to the final decision-maker power in the political system (in this case the minister) and the top-ranking civil servants
- Political broker
- Passion for its position

4.4.3.5. Transparent process architecture, joint fact-finding and long-term monitoring

The participation of environmental interest groups also demanded a change in the decision-making process architecture. As our historical analysis reveals, environmental NGOs stepped out of the decision-making process several times, claiming the lack of impact and the need for procedural decision-making adjustments. Harbor authorities adapted to these demands by the installation of a new leadership style, more progressively trying to establish a joint fact-finding process. Later on, an adaptive feed back loop, in the form of long-term monitoring program was installed. As the governance consortium started to function effectively only after the introduction of these procedural changes, we identify those as important factors for effective EBM knowledge governance.

4.4.3.6. Adaptive and innovative civil servants

Important to note is, that the responsible civil servants introduced the procedural adjustments discussed above on a voluntary base. We therefore identify the influence of adaptive and innovative civil servants as another situational condition for effective EBM to emerge in the Rotterdam case. Our dataset indicates that those adjustments could only be applied in its full potential when simultaneously political decision-makers were undivided supportive and interest groups were constructively participating throughout the process.

4.5. DISCUSSION

Our investigation indicates that in the context of the Rotterdam harbor incremental steps towards EBM occurred, while a full establishment of the management paradigm did not. In the beginning of the process harbor authorities were not reluctant to integrate ecological concerns, but did not develop extensive efforts beyond what were juridical necessities.

Stakeholders, on the other hand, used juridical means to push for further elaboration of ecological impacts. Other empirical work on adaptive governance indicates that effective EBM knowledge governance is characterized by a more active integration of local concerns by, for example, involving scientists, experts and locals to produce knowledge explicitly relevant to the specificities of a regional context (see for example Brunner et al., 2005).

Such an active strategy towards ecological knowledge integration is not apparent in our case, which seems to be more reactive. Nonetheless, our dataset indicates that pro-active strategies were applied during the decision-making process at several stages of the process (e.g. VERM procedure). However, due to societal stakeholders being fragmented as well opponent about harbor development as such, attempts were insufficient to include and integrate all stakeholder concerns made. Unexpected stakeholder interventions jeopardized the decision-making process several times. As a result societal controversies were solved in a continuously emergent negotiation process. In the Rotterdam case, the harbor authority itself became responsible for the management of that process. Hence, knowledge governance and the governance of interests became intermingled during the process. It might be questioned whether such interaction patterns deliver trusted and legitimate knowledge for decision-making. Our historical analysis revealed that the Rotterdam harbor has a long tradition of promoting the growth of the harbor, driven by economic interests. It therefore might have been important to establish a new, truly independent institution to manage what in essence was an interest balancing process.

Lin et al. (2013) identify methods, like landscape pattern analysis and ecosystem service valuation as possible tools to achieve such an integration of interests. Such methods hold the advantage that diversity of values and interests are clarified, made transparent and can be balanced before decisions are taken. Similar, Sherman and Duda (1998: 280) suggest the use of resource stewards, when conflicts arise in integrative attempts. However, since the social dynamics of the Rotterdam case reveal multiple divisions of societal interest, including environmental stakes, local residents and elected politicians, it is doubtful whether integrative tools would have been feasible. Since the Rotterdam harbor development had become a controversial issue, it needs to be questioned whether new management tools should and could have changed divided interests.

Nonetheless, the creation of new nature areas, compensation measures and the planning of technical work in ecologically friendly ways show that a balance between economic and ecological interests could be found. Even in such a complex context as the Rotterdam harbor provides it to EBM. As these achievements could be realized we believe that further incremental expansions of EBM tools might already be sufficient to realize the full potential of EBM philosophy in the Rotterdam harbor. The installation of an ecosystem-monitoring program could for example provide such a tool. As the study of Cappucci et al. (2011) reveals, in the Italian Marina die Carrara Harbor, long-term measurements of sedimentation processes, for example, enabled authorities to understand and better adapt their established dredging practices to the ecological dynamics of their harbor.

Another suggestion would be to further enhance and integrate the monitoring efforts employed in the Rotterdam harbor. As the work of Lam and Notteboom (2014) reveals, environmental management efforts in Rotterdam are fragmented. They are initiated and regulated by different standards, like e.g. the ISO 14001, and are organized alongside harbor specific initiatives, like the carbon footprint measurement. Developing an integral monitoring scheme, fully reflecting ecological dynamics in the region, or even further preceding towards integrating economic and social parameters (see for example De Jonge et al., 2012) could be helpful tools for the further enhancement of ecological monitoring in the Mainport of Rotterdam.

Interesting to note on the Rotterdam case is, however, that a more progressive shift towards sustainability and active knowledge exploitation occurred after 2008. A newsustainability initiative was set up (Erasmus Smart Port, 2010). Further evaluations will be needed to reveal whether and how this initiative also affected the establishment of EBM in the Rotterdam harbor. Also future results of the diverse monitoring programs installed, which unfortunately were not available during the selected time frame of this study, will be needed to fully understand the ecological effects of EBM initiatives taken in the Rotterdam harbor.

4.6. CONCLUSIONS

The analysis of the Rotterdam harbor development case provides interesting results in relation to the (potential) application of EBM to Mainports. From the first part of our historical analysis, we can conclude that the issue of harbor development was defined by economic growth for many decades. Ecological concerns played a marginal role and were perceived as a threat to growth. In the 1960s, environmental concerns arose, and were handled through scientific assessments and ad-hoc measures. In the 1990s, a shift emerges towards integrated approaches, interactive decisionmaking procedures and a search for a balance between economic and ecological interests. These changes have affected the management of the Rotterdam harbor. It has to deal with more procedural duties, such as impact assessments, to prove that growth does not threaten the environment. The management of stakeholder expectations is now essential for generating legitimacy for any expansion plans. Important legislative changes at the national and EU level are further manifestations of the ecosystem-based approach to environmental management. From our detailed analysis of the 1990-2008 period, we can conclude that the assessment style of knowledge governance chosen to handle the increased demands was not sufficient for facilitating EBM. Stakeholders claimed their input had little impact and pushed for the identification and consideration of knowledge gaps through juridical means. Additional management effort and procedural adjustments were necessary to obtain effective knowledge governance. Our research results also imply that, although decision-makers could finally cope with the complex context that harbor development was occurring in, further efforts will be needed to realize the full potential of the emerging EBM approach. Although our general EBM evaluation scores assigned are high (almost all parameters reveal a score of A+) room for improvement is still available. In the discussion section, we provide several suggestions for this.

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Chapter 5

Knowledge governance for ecosystem-based management: Understanding its context-dependency

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ABSTRACT

The governance of knowledge is a crucial element of ecosystem-based management (EBM) and is deemed important for its effectiveness. In this paper we analyze from an empirical perspective how the governance of knowledge in different EBM practices is organized and with what consequences. Based upon four different case studies – all derived from the Wadden Sea – which resemble different contexts (in terms of available knowledge and level of conflict) we reconstruct four different ways of knowledge governance. These four approaches are labeled the database, the alignment, the assessment and the holistic approach. These approaches differ in how the interaction between knowledge production and decision-making is organized. They show different degrees of success, partly related to the extent to which they fit in the context in which they are applied. Understanding the differences in contexts in which knowledge for EBM has to be organized, can help decision-makers to apply the most suitable way of knowledge governance in their specific case. In cases of low conflict and high knowledge capacity a more static, one-directional way of knowledge governance can suffice, while in more complex contexts a holistic approach seems to be necessary.

5.1. INTRODUCTION

In the ecosystem-based management paradigm (EBM), knowledge is meant to function as an important tool for decision-makers to know, understand and evaluate the socio-ecological systems they intend to govern (Lubchenco, 1994 in Olsen and Nickerson, 2003; Knight and Meffe, 1997). Regarding the actual organization of knowledge for EBM, literatures however reflect divided argumentations. On the one hand, there are scholars advocating the need to feed decision-making by ecosystem knowledge that reflects a science-based, holistic decision-making base. Examples constitute approaches like the development of integral models (De Jonge et al., 2012), integral assessment schemes (see for example Borja et al., 2012) and integral science and management conceptualizations (Elliott, 2014). Those approaches stress the need to perceive socio-ecological systems by acknowledging and taking account of their entire complexity. Knowledge, as such, is meant to be at the heart of the decision-making process, guiding actions in primacy to ideologies and political interests (Sanderson, 2002; Radaelli and Meuwese, 2009; Mele et al., 2013).

On the other hand, while still agreeing on the necessity to feed decision-making by knowledge, scholars have put forward more tempered expectations. Sherman and Duda (1999), for example, have emphasized that due to the poor state of current ecosystems, there is also a need for quick action and more pragmatic approaches. Especially under consideration of practical restrictions, like decision-making under uncertainty or lack of funding, it is important to acknowledge that ideal knowledge will never be a given (Sherman and Duda, 1999, p. 275). Many studies provide further evidence to that claim. For the EBM approaches employed in e.g. the Raja Ampat (Indonesia) and Puget Sound (Washington, USA), struggles like time-consuming stakeholder engagement and lack of quality data have been reported (Tallis et al., 2010). Similar results have been observed for river ecosystems (Van Wyk et al., 2008) and reported from large scale EBM, like ocean governance, where next to incomplete scientific information also the management across scales hampers the good implementation of EBM (Ruckelshaus et al., 2008).

Problems with regard to the knowledge process organized, however, go to the expense of the quality of decisions taken. As Liu et al. (2008) summarized, a lack of systematic planning, integral research and comprehensive monitoring, undermine the quality of EBM decision-making. Important to understand then is, what factors shape the context of EBM decision-makers, which actions they take when organizing knowledge for EBM, and whether such actions in the end contribute to the quality of decisions taken or not. Aim of this paper will be to provide a better understanding about the context- dependency of the role of knowledge in EBM. We will do so by comparing the practical application of EBM knowledge governance in four most different contexts. We use the following three research questions to guide our inquiry: (1) How can we characterize the different contexts in which EBM knowledge governance is applied? (2) How do real decision-makers organize knowledge governance for EBM? (3) How can we evaluate the effectiveness of knowledge governance applied in relation to context?

To answer these research questions we present a comparative case study with the aim to test and enhance existing theories in the field (see Section 5.3 for further details). For our approach we will mainly use and further refine the theory on evidence-based practice (EBP) as developed by Jennings and Hall (2011). Building on the variables of scientific capacity and level of conflict, that theory models four different types of context, and matches expectations about the actual use of information by public agencies (see also Figure 5.1 for the matrix developed by Jennings and Hall, 2011). In Section 5.2 we present further details of the theory and show how we have used it for our analysis. After discussion of our chosen method and selection of cases in Section 5.3, we present a brief summary of the cases selected for our analysis in Section 5.4 (answer to research question 2). In Section 5.5 we present the empirical patterns identified at selected public agencies (also referred to as decision-makers) when organizing knowledge governance for EBM (answer to research question 2). Finally an evaluation of the effectiveness of knowledge governance in relation to context is presented in Section 5.6 (answer to research question 3).

5.2. DEFINING THE OPERATIONAL CONTEXT OF PUBLIC DECISION-MAKERS WHEN ORGANIZING KNOWLEDGE FOR EBM

5.2.1. Ecosystem-based management: the search for best available knowledge

The EBM philosophy stresses the need to perceive socio-ecological systems as complex systems. Systems that can only ‘truly’ be understood and managed when guided by integral systems knowledge that incorporates the diversity of all drivers determining the state and development of an ecosystem including social pressures. From that point of departure, we expect knowledge to be created and used as a policy tool helping to understand how and why socio-ecological systems are developing. Knowledge is not selectively treated as an underpinning of ideological arguments or a means to strategically balance political and social interests (see also Sanderson, 2002; Radaelli and Meuwese, 2009; Mele et al., 2013). Knowledge is used as a means to guide and direct the decision-making process in a quest to enable sustainability to be reached for both, the ecological and social systems at hand (Meffe et al., 2002; Brunner et al., 2002, 2005; De Jonge, 2007; De Jonge et al., 2012; Enemark, 2005; Katsanevakis et al., 2011).

5.2.2. How decision-makers fill in the search for best available knowledge

How real decision-makers fill in that search for the best available knowledge, is however, especially in the public realm, expected to depend on decision-makers' operational context (Jennings and Hall, 2011). This context is characterized by fragmentation and social complexity, as different actors and policy levels are involved (Pierre and Peters, 2000; Bache and Flinders, 2004; Paavola et al., 2009). Although many studies reveal that the operational context of decision-makers is an important factor predicting whether or not and how decision-makers are likely to use knowledge, context, however is not an uniformly defined and applied concept (Runhaar and Driessen, 2007). In the field of knowledge utilization, a knowledge gap still exists about which type of factors we need in which type of context (Runhaar, 2009). O'Toole and Meier (2014) furthermore have argued that when it comes to judgment on the influence of context on the performance of public agencies, the variables defining context, potentially are almost endless. A problem that cannot be encountered by single studies, but will need theory building to be resolved (O'Toole and Meier, 2014).

The work of Jennings and Hall (2011) therefore provides an important contribution in the field. Based on results of a survey held across different policy sectors, they expect the level of scientific capacity (availability, relevance and credibility of scientific evidence) on the one hand, and conflict on the other, to explain the emergence of either evidence-based, challenged evidence-based, experiential or symbolic agencies (see also Figure 5.1 for an overview of their theoretical matrix). Decision-makers acting as evidence-based agencies typically operate in a context that encourages the use of evidence, while simultaneously the availability of evidence is high, e.g. Centers for Disease Control and Prevention (Jennings and Hall, 2011). Where political conflicts or government shifts after elections change values or compete existing values, established knowledge claims are likely to be challenged, implying challenged evidence-based agencies to emerge. In turn, where strong consensus comes along with lack of knowledge, agencies are expected to act in an experiential way. And finally, where lack of knowledge meets high contextual disagreement, the role of knowledge turns into a symbolic one (Jennings and Hall, 2011). We think that especially the last categorization is important for EBM emerging in complex settings. Since policy levels and actors are multiple in such settings (Bache and Flinders, 2004) boundary management might be a necessity at any time (Cash et al., 2003, 2006; Bevir, 2007), hence also when e.g. the political system is supportive, but interest groups or citizens are not.

To understand how knowledge is organized in these different contexts, we use the concept knowledge governance to identify and describe all actions that are taken by involved actors to organize knowledge for EBM. We have based this definition on Bevir (2007), who defines the concept of governance as a tool to describe and analyze all patterns of rule. "This general use of governance enables theorists to explore abstract analyses of the construction of social orders, social coordination, or social practices irrespective of their specific content." (Bevir, 2007, p. 365). Put simply, we observe all type of decision-makers behavior in relation to the production and use of knowledge. To further specify what variables need to be observed when studying governance processes, we make use of the governance operationalization developed by Peters (2007). Peters (2007) defines process, outputs, outcomes and norms as important variables to measure governance. We adapt these variables to make them suitable for our specific focus on knowledge governance. We measure process by describing whom the dominant actor is to set the knowledge agenda as well as the frequency of interaction between decision-makers and knowledge sources (=process). We measure output by describing the dominant types of knowledge sources that have been produced and consulted (=output). We measure outcome, by describing how learning among decision-makers and knowledge sources is expected to emerge (=outcome).

Figure 5.1
Jennings and Hall (2011: 261) theory on EBP

		Conflict	
		Low	**High**
Scientific capacity	**High**	Evidence-Based Agency	Challenged Evidence-Based Agency
	Low	Experiential Agency	Symbolic Agency

We will use an earlier developed distinction of EBM knowledge governance practices to identify and describe differences in their organizational patterns. Distinguished are the database, the alignment, the assessment and the holistic approach (Giebels and de Jonge, 2014). In short, the database approach is characterized by strong emphasis on continuous data collection and knowledge production separated from the decision-making process. Data then is interpreted and communicated to decision-making in an on-demand fashion. The holistic approach has been defined in a similar way, while implying that the communication between knowledge sources and decision-makers is more explicitly handled, e.g. through the development of a common communication tool. The alignment and assessment approach foresee less intense connections between knowledge and decision-making. While the alignment approach implies a variety of fragmented knowledge sources being linked in a wherever-deemed-necessary fashion, the assessment approach describes an integral knowledge production being linked as a once-for-the-process advice tool (Giebels and de Jonge, 2014). We use this rather broad distinction to identify which type of knowledge governance prevails within the cases selected for this study. We then add the observations made on process, output and outcome to identify and describe in more detail the dynamics for each approach. By then finally matching the organizational patterns derived with an evaluation of their effects (contextual fit, see next section), we are able to judge upon the effectiveness of each approach in relation to the specific context wherein it was applied. Section 5.6 presents the results of that analysis.

For our research purpose we need to make one additional adaption to the conceptualization of Jennings and Hall (2011). In-stead of using the term scientific, we refer to knowledge capacity. We do so to emphasize that other knowledge sources than scientifically generated potentially can and empirically do matter when creating evidence for EBM (see for example Lee, 1993; Irwin, 1995; Scholz et al., 2006; Edelenbos, 2010; Weber et al., 2010; Edelenbos et al., 2011). Especially for ecosystem-based management non-scientific knowledge sources have furthermore been identified as being vital to know and effectively govern an ecosystem area (see for example Meffe et al., 2002; Brunner et al., 2005; Giebels et al., 2013; Couvet and Prevot, 2015).

5.2.3. Evaluating the fit between knowledge governance conducted and the context wherein it was applied

To finally provide an evaluative analysis (=norms) about the question whether the governance approach applied was effective, we introduce the concept of contextual fit. Contextual fit has especially in implementation studies been proven helpful to explain the interrelatedness between contextual changes and policy implementation; for environmental policy in particular (see for example Zhan et al., 2014), as well as public contexts in general (Horner, 1994; Horner et al. 2014; Petrovsky et al., 2015). Inspired by this line of thinking, we designed the concept of contextual fit for the purpose of our analysis. We did so by building further on conceptualizations of complex decision-making. In complex decision-making the amount and frequency of actor's interactions can imply non-linear and unpredictable dynamics (Teisman, 2000), which can be similar to those of ecosystems (Huisman and Weissing, 2001; Roelke et al., 2003; Scheffer and van Nes, 2007). Many scholars have therefore argued for the need to apply adaptive approaches, enabling adaptation to changed circumstances (Brunner et al., 2005; Folke et al., 2005, 2010; Dekker et al., 2007; Medema et al., 2008; Pahl-Wostl, 2007; Termeer et al., 2010). Accordingly adaptiveness has been identified as an important characteristic of EBM (Meffe et al., 2002; Brunner et al., 2005; Dekker et al., 2007).

For studies that aim to evaluate whether public agencies operated effectively in a complex context, it hence is essential to evaluate the match between their mode of governance conducted and the extent to which it was perceived helpful to organize the knowledge needed for decision-making (Paavola et al., 2009; Driessen et al., 2012). We assume that when knowledge governance organized in complex contexts exists without the need for changes, an equilibrium state has occurred (Gersick, 1988, 1991). A non-equilibrium state is reached when improvements have been identified as being essential (see for a visualization Figure

5.1 in Van der Molen et al., in this issue) or an actual shift toward another governance approach appeared. In this line of thinking we evaluate the contextual fit for each case in a two-step approach. In the fist step we assess, based on the conceptualization of Jennings and Hall (2011), whether with each governance approach applied, the generation of available, relevant and credible knowledge was achieved. We do so to check whether differences in knowledge governance are also related to differences in their capacity to generate the knowledge needed for decision-making. In the second step we evaluate the match between the governance approach applied and its context on a three point qualitative scale. A high match is apparent when no case data indicates that an agency needed to change or adapt its knowledge governance. The approach applied did fit within the context. A medium match is apparent when no major shift was diagnosed, but still (possible) improvements were mentioned, either from decision-makers themselves or external actors. A low fit is apparent when the governance approach applied did not work from the opinion of involved actors and a shift of governance mode appeared.

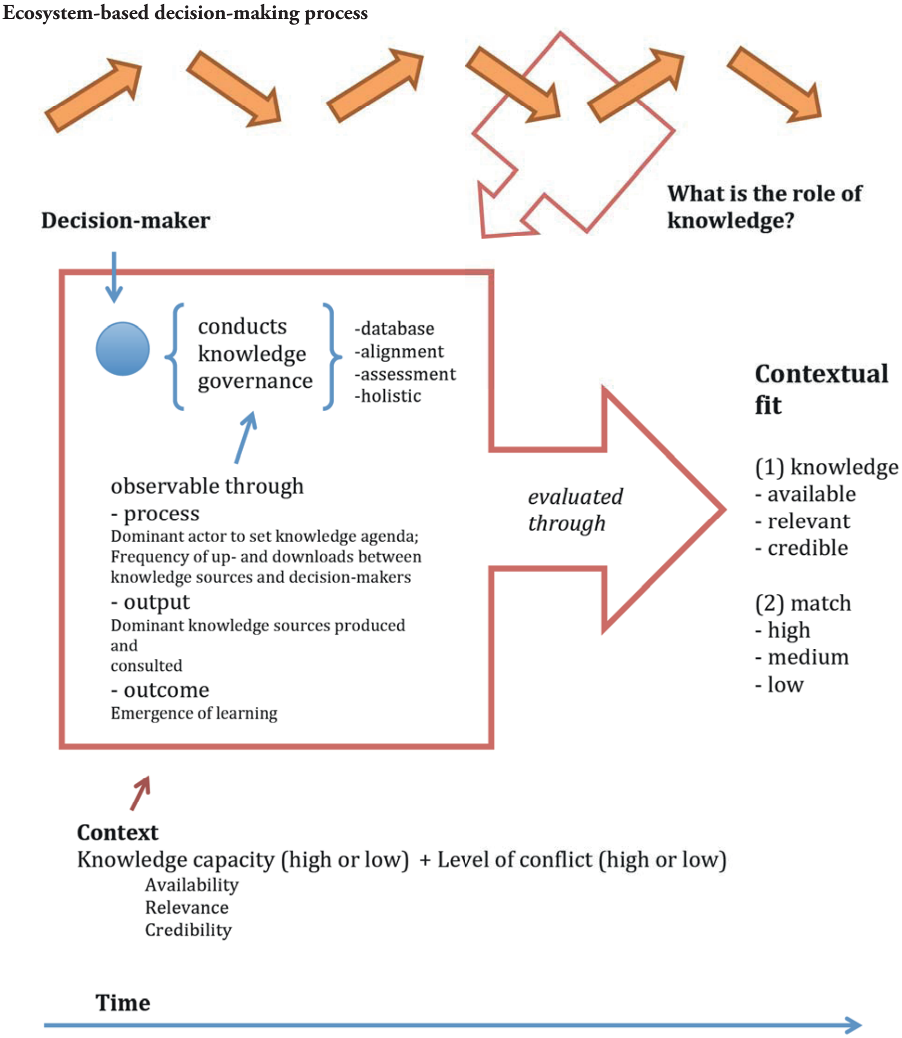
5.2.4. Visualizing our theoretical framework

Summarizing our conceptual definitions described above, we end up with the theoretical framework as pictured in Figure 5.2. We expect that the level of knowledge capacity and conflict define the operational context (visualized through the two non-filled red arrows) of decision-maker(s) (blue spot). Operational context in turn is interdependent to the knowledge governance emerging (how the knowledge process, outputs and outcomes are organized) as well as its contextual fit (whether changes were necessary). The sequence of orange arrows visualizes the ongoing decision-making process wherein a public agency and hence the decision-maker is operating. We use that theoretical framework as an analytical scheme for our case comparison (see also Section 5.3 for further details on methodology).

5.3. METHOD

Using observations we make about “real” decision-makers when organizing EBM knowledge governance in different contexts, we test and develop further on the existing theory of EBP as developed by Jennings and Hall (2011). Mainly we will enhance their theory on evidence use, by adding an empirically derived, typological description (see George and Bennett, 2005) of knowledge governance practices. Compared to Driessen et al. (2012) who develop an ideal, deductively derived conceptualization of governance modes for sustainability, we thus work the other way around; defining governance modes from empirical observation into theory (see also Reynolds, 1971; Lynham, 2002).

Figure 5.2
Theoretical framework used for the analysis of EBM knowledge governance in different contexts


Ecosystem-based decision-making process
Decision-maker
What is the role of knowledge?
conducts knowledge governance
-database
-alignment
-assessment
-holistic
observable through
- process
Dominant actor to set knowledge agenda; Frequency of up- and downloads between knowledge sources and decision-makers
- output
Dominant knowledge sources produced and consulted
- outcome
Emergence of learning
evaluated through
Contextual fit
(1) knowledge
- available
- relevant
- credible
(2) match
- high
- medium
- low
Context
Knowledge capacity (high or low) + Level of conflict (high or low)
Availability
Relevance
Credibility
Time

The case selection has been drawn from data available on different EBM cases placed in or directly related to the Wadden Sea ecosystem[5]. Three cases were identified and selected as most representative, which are the Houting, the Seal and the Mainport case. The Houting

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[5] For in-depth information about these case studies we refer to earlier publications: Giebels et al. (2013) for data on the Mainport case and the seal case; Giebels and Teisman (2014) for data on the Mainport case and Giebels et al. (2015) for data on the Houting case.

case describes the protection of an almost extinct fish species in the Danish part of the Wadden Sea. The Seal case describes the trilateral management of seal populations in the Wadden Sea. The Mainport case describes a harbor development project in Rotterdam, the Netherlands, which although situated in an adjacent region only, was expected to also affect the Wadden Sea's ecology. The Mainport case was separated in two subcases (Mainport old and new style), as an important shift regarding the level of conflict and knowledge capacity appeared throughout the decision-making process (see also Section 5.4.3 for further details). For the Houting case, data consisted of 30 semi-structured interviews, project documents, information from consulted websites and project meetings. For the Seal case available data was taken from 4 semi-structured interviews, scientific articles, original policy documents, consulted websites and a previous conducted study on, among other issues, the relation between science and policy in the Wadden Sea seal management (MESMA, 2012). For the two Mainport cases (old and new style) a historical analysis was conducted based on historical literature, scientific articles, original policy documents as well as additional 11 semi-structured interviews.

Based on all data available a storyline was developed for each case. As some of the cases studied were situated in the past, the interviews mentioned were used as narratives of involved actors to gain observations about the process. Since our aim is to observe behavioral patterns, our inquiry did not explicitly approach personal meaning, which would have been important to develop interpretative theory (see for a discussion Blumer, 1954, McLean, 2001 in Lynham, 2002; Beuving and de Vries, 2015). Where conflict was mentioned frequently during the documents and interviews analyzed, we judge the theme being dominant and in turn the level of conflict high. In a similar way we judged on the level of knowledge capacity and contextual fit. Cases reflecting problems like lack of knowledge as a dominant theme e.g. qualified for low knowledge capacity and vice versa. That theory driven approach minimizes the selection bias of our research (Gerring, 2007; Levy, 2008).

Figure 5.3 presents an overview of the cases selected and their positioning in the EBP matrix. Regarding case selection we need to add two refinements. First, where cases in the matrix appear being on an equal level of either knowledge capacity or conflict, they in practice are not. In the Mainport case, knowledge capacity was in general higher than in the Houting case. Nonetheless, comparing the two time periods studied for the Mainport case, we can distinguish between a phase characterized by low capacity (Mainport old style) and a phase characterized by an increase of capacity (Mainport new style). Secondly, for some cases it was difficult to determine whether the level of conflict was rather high or low. As a matter of fact, for none of the cases conflict was absent. However, we noticed that a distinction between sources and impact of conflict was then helpful to judge upon dominance of a theme. In the Houting case, for example, a high level of conflict was stemming from an unexpected scientific publication that was claiming extinction of the species under protection. While that publication raised a societal discussion about the legitimacy of the project, it however did not affect the governance practice at the decision-making level as such. Authorities set out a new research request to eventually solve the legitimacy conflict. Since the theory of Jennings and Hall (2011) provides explanation about information use of agencies, we deem the measurement of source and impact of conflict on agency level itself logically most important. Especially the seal case shows how important it is to make that distinction. In the seal case many and different types of conflict were traceable. In the Netherlands, for example, much conflict was related to differences in opinion about seal sheltering practices. In Germany an ongoing conflict could be traced among seal hunters and seal protectionists. Nonetheless, judging upon the impact of conflict on practicing authorities, we can observe an ongoing and functioning cooperation at the trilateral public agency level. Under the Wadden Sea Seals Agreement, which coincidently in 2015 celebrated its 25th anniversary, common scientific knowledge is generated and fed back to decision-makers (see Section 5.4.1 for details). An agency that still uses knowledge for decision-making, although conflict is high, thus implies a low level of conflict within the theory of EBP. In this way we judged upon the level of conflict for all cases selected. Detailed motivations as well as a brief introduction of each case selected can be found in the next section (Section 5.4).

Figure 5.3
Selecting four representative cases based on the theory of EBP
(Source: adapted from Jennings and Hall, 2011)

		Conflict	
		Low	**High**
Knowledge capacity	**High**	Evidence-Based Agency (Seal)	Challenged Evidence-Based Agency (Mainport new style)
	Low	Experiential Agency (Houting)	Symbolic Agency (Mainport old style)

5.4. HOW CAN WE CHARACTERIZE THE DIFFERENT CONTEXTS IN WHICH EBM IS APPLIED?

Based on the theory of EBP we have selected four EBM cases, each reflecting a different level of conflict and knowledge capacity. Figure 5.3 shows an overview of the selected cases. Throughout this paragraph we briefly introduce each case and motivate its selection.

5.4.1. The Seal case

The Seal case describes the emergence and functioning of an international governance consortium that was set up to ensure the survival of seals in the North European Wadden Sea. That consortium was set up when, due to a virus infection, the seal population decreased dramatically. Rehabilitation and conservation actions needed to be formulated and agreed on in Denmark, Germany and the Netherlands. The agreements made reflect a strong emphasis on evidence-based decision-making. "According to Article IV of the Seal Agreement the Parties shall develop, on the basis of scientific knowledge, a conservation and management plan for the harbour seal population. [...] The Parties shall keep the plan under review and amend it as may be required, taking into consideration, the results of scientific research in particular." (CWSS, 2014). An important facilitator of that governance structure is the Trilateral Wadden Sea Cooperation (TWSC) formed by the Netherlands, Germany and Denmark. TWSC regularly measures the status of the Wadden Sea ecosystem and defines management actions that should be taken as well as knowledge gaps that should be filled. Within that trilateral cooperation a specific expert group has been formed, called the Trilateral Seal Expert Group (TSEG). Their main tasks are the description and evaluation of the current ecological status of the seal population, the identification of changes in this status as well as possible causes and the identification of emerging issues as well as knowledge gaps (CWSS, 2014).

5.4.1.1. Level of knowledge capacity and conflict

A recent, trilateral study on seal management in the Wadden Sea revealed that the consensus among participating parties is apparent and that the availability of scientific knowledge is impressive (MESMA, 2012). As a matter of fact seal populations have been studied in the Wadden Sea area for several decades now. Especially population recovery and growth have been monitored sine the virus epidemic appeared in 1988 (Reijnders et al., 1997). But also maximal population sizes have been estimated (Ries et al., 1998) and the impact of human modifications of the ecosystem has been investigated (De Jonge et al., 1993; Wolff, 2000). Until today standardized autopsies are conducted on dead-found animals and the potential harmful effects of human impacts like e.g. recreation and fisheries are evaluated (see for example TSEG, 2002; CWSS, 2003). Also we can find studies exploring the effect of chemical emissions on seal populations (Ahrens et al., 2009), as well as changes in pupping seasons (Osinga et al., 2011). While not being exhaustive here in listing all knowledge available, we deem the level of knowledge capacity for that case high.

Judging on the level of conflict however is a more ambiguous exercise for the Seal case. Although generally perceived as a case characterized by consensus, seal management is not free of conflict. While conflict seems to be rather latent at the international level of cooperation, due to the governance consortium established (MESMA, 2012), conflicts still are traceable at national and regional levels. Sources of conflict stem for example from clashes of interest between commercial fisheries and seal protection. Since the seal population has been growing steadily, commercial fishery started to view the seal as a competitor within their fishing grounds. Furthermore, on the regional and national level differences in philosophies about seal sheltering have been and still are sources of conflict (Bosch, 2003). Although conflict especially on the national levels plays a role, it however does not seem to hamper the international protection of seals as such. The number of seals is increasing and its population management is perceived to be successful. In sum we therefore judge the level of conflict being low and the knowledge capacity being high for that case. Compared to the Houting case (next section), we however can place the remark, that the level of conflict is higher in the Seal case than in the Houting case, though less dominant than in the Mainport case (old and new style).

5.4.2. The Houting case

The Houting case describes a project that was initiated to restore the natural habitat of an endangered fish species, the Coregonus oxyrinchus. The original habitat of the Houting was once located across the entire North European Wadden Sea, but became restricted due to man-made alterations like dams and sluices. In addition, commercial fishery meant an extreme decrease of Houting numbers, bringing population sizes near to extinct. Several populations however could survive in the Danish part of the Wadden Sea. Supported by publicly financed stocking programs, population sizes were kept stable. Since stocking programs however meant that the species would not survive without human support, application of EBM philosophy introduced a major change to public policy. Public authorities designed a national management plan, with the ambition to restore important parts of the Houting ecosystem in such a way that the species would be able to survive without any human support.

5.4.2.1. Level of knowledge capacity and conflict

As the Houting species was such a rare species, scientific studies conducted and data available were limited. Scientific knowledge on e.g. the Houting's life cycle and habitat use was not available when authorities started the project. Regarding the knowledge capacity of the project, we therefore judge the Houting case being characterized by a rather low level. To compensate for the lack of scientific knowledge public authorities developed an experiential approach to organize knowledge for decision-making. Based on our data available, this implied public agencies conducted monitoring programs on own initiative, organized working groups and asked experts and scientists to provide specialized advice about identified knowledge gaps.

Regarding the level of conflict, we judge the Houting case being characterized by a rather low level. Authorities across different national policy levels had reached consent about the necessity to restore the habitat. The Houting was referred to as the 'Danish Panther', a species of national interest. When in a later stage of the project, the Houting also became a priority species under EU policy, cooperation on the supranational level could proceed smoothly. Similar, at the local level a high level of agreement to the project could be reached. Public authorities invested a lot of time, effort and money to establish cooperation with local estate owners. Participation of local estate owners was in many areas a necessity, because parts of the habitat were located on or adjacent to privately owned land. Conflict nonetheless became apparent in the project and was due to e.g. several local estate owners not willing to participate as well as local inhabitants protesting against alterations of the landscape. In addition, a major legitimacy crisis of the project emerged when a scientific publication questioned the actual existence of the Houting species, and Danish society heavily discussed the need to invest public money in the conservation of a fish species that did not seem to exist. Nonetheless, since a majority of actors were willing to cooperate, we judge the overall level of conflict not as a dominant theme for the case.

5.4.3. The Mainport case

The Mainport case describes an extension project of the Rotterdam harbor, initiated to accommodate and facilitate growth of container shipping and other economic harbor activities. The case describes the harbor growth in-between the period from 1990 to 2008. That period was characterized by emergence of EBM legislation (on the national as well as EU level) urging harbor authorities to integrate ecological concerns in their attempts to achieve economic growth. The case is divided in two different periods. The first period (Mainport old style) is characterized by harbor authorities accommodating ecological concerns, mainly through the conduction of an environmental impact assessment accompanied by additional technical investigations. The second period (Mainport new style) is characterized by a broadening of knowledge governance, in an attempt to incorporate ecological concerns. That approach is characterized by, for example, joint fact-finding with environmental NGOs, introduction of several monitoring programs, development of ecology-friendly construction practices and compensation measures.

5.4.3.1. Level of knowledge capacity and conflict

Regarding knowledge capacity, we could trace an increasing development across the selected periods. Although, compared to the Houting case, scientific knowledge about environmental impacts of the harbor project was produced before the project started, the actual level of scientific evidence was claimed insufficient. More specific, lack of inclusion of ecological effects on the adjacent ecosystem of the Wadden Sea was criticized. While this claim was taken up and eventually solved by conducting further scientific assessments, these efforts were deemed insufficient by harbor authorities to let the decision-making process proceed. A joint fact-finding program was installed, where environmental interest groups were invited to participate in the development of common and shared facts. In addition, several monitoring programs were installed, continuously measuring the effects of harbor development on adjacent ecosystems. We judge the installment of the joint fact-finding as a break point for the Mainport case, dividing it into two different cases for our analytical scheme. The before joint fact-finding period is referred to by Mainport old style and characterized by low level of knowledge and high level of conflict. In the period afterwards, which is referred to as Mainport new style, we see an increase of knowledge capacity, but still a high level of conflict. The level of conflict, although decreasing over time, seems to be a dominant theme in both parts of the case. Rotterdam citizens fear the further loss and pollution of their living environment. Inhabitants of adjacent regions fear the loss of habitat for several protected species. In the Mainport old style, commercial fishery feared a loss of fishing grounds and alterations of sedimentation and fish larvae migration was feared to have a distortive effect on the Wadden Sea ecosystem. With installation of the joint fact-finding and additional monitoring programs we however see a gradual decrease of conflict and increase of knowledge capacity.

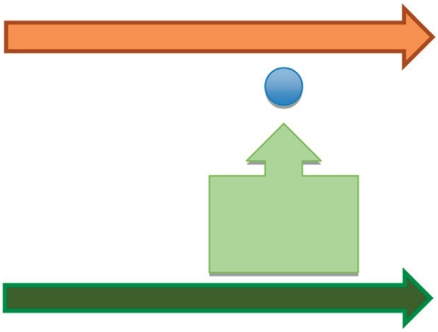
5.5. HOW DO REAL DECISION-MAKERS ORGANIZE KNOWLEDGE FOR EBM?

As already elaborated in our theoretical section of the article (Sections 5.2 and 5.3), we use an earlier developed typology of EBM knowledge governance to identify the significant patterns of rule that characterize each knowledge governance approach. Tables 5.1 and 5.2 provide a summary our results.

5.5.1. The database approach – the case of trilateral seal management

Based on our case description above, we conclude that the Seal case is characterized by low conflict and high knowledge capacity. According to Jennings and Hall (2011) that implies seal authorities are operating as evidence-based agencies. Concerning the organization of knowledge governance, we see an organizational pattern that reflects a strong separation between scientists and policy makers. Scientific capacity has been established through the formation of a trilateral expert consortium. That consortium consists of mainly scientific experts stemming from each of the three participating countries. Those knowledge sources bring different types of expertise together in regular meetings (e.g. counting of dead found animals). They produce common databases, e.g. population development charts. Based on such data, a management plan is drawn each four years. That management plan is presented to national decision-makers through regularly organized trilateral conferences. Decision-makers then announce their commitment to implement the scientific recommendations by formally adopting the seal management plan. Based on that organizational pattern we abstract the general concept of the database approach to characterize the knowledge governance employed in the Seal case (Giebels and de Jonge, 2014). That approach is characterized by a strong emphasis on continuous, scientific data generation. Decision-makers are not involved, but are invited to learn about scientific results and are expected to base their policy and management actions taken on the generated knowledge. The decision-making as well as the knowledge generation process is developing in essence independently from each other. Decision-makers do not intervene directly in the process of knowledge production. Vice versa, the knowledge stream as such, does not directly intervene in the decision-making process. A governance arrangement has been made to regulate the download from knowledge sources to decision-making. Figure 5.4 presents a visualization of that governance pattern.

Figure 5.4
The database approach

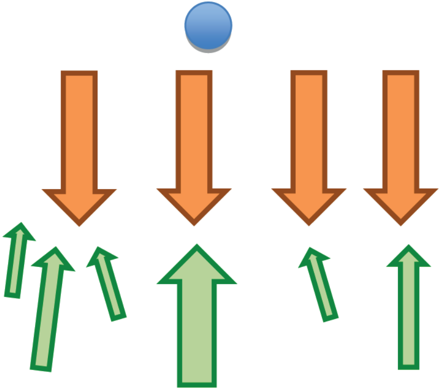


Decision-maker(s) (blue point) operating in an evolving decision-making process (orange arrow) gets knowledge downloaded in an a-priori organized arrangement (light green arrow). That knowledge is generated from a knowledge system (dark green arrow), which is independently developing from the decision-making process.

5.5.2. The alignment approach – the case of the Houting project

For the Houting case we identify the alignment approach to best describe the organization pattern of knowledge governance. That approach is characterized by the utilization of a high diversity of knowledge sources that do not appear in the planning process in a once at a time, concerted fashion. Decision-makers put out separate knowledge requests to experts and ask for ready to utilize solutions. Examples include round table meetings, usage of monitoring programs and expert advice, e.g. to guide the river reconstruction work. Hence it is not the knowledge system that is expected to reach an integral assessment, but the decision-maker who aligns the diversity of knowledge sources to the decision-making process. Figure 5.5 beneath presents a visualization of that approach. Each separate, orange arrow represents one decision-making round, emphasizing that for separate decisions, separate knowledge sources are uploaded. The arrows point to each other, meaning to visualize that knowledge bases are delivered on specific request of decision-makers.

Figure 5.5
The Alignment approach



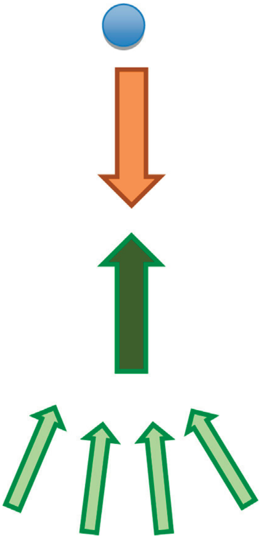
Decision-maker(s) (blue point) puts specified knowledge requests, separated times during the decision-making process (orange arrows) at separated knowledge sources (light green arrows). Orange and green arrows point to each other, visualizing that an upload from knowledge to decision-making occurs.

5.5.3. The assessment approach – the Mainport case (old style)

A common body of knowledge that could have been directly applied to estimate the effects of a harbor extension was absent at the beginning of the Mainport Rotterdam case (old style). Simultaneously the project was still heavily debated and criticized by many societal actors, ranging from members of the parliament, over interest groups to local citizens. That debate was characterized by questions put forward on whether at all a new harbor extension is needed, as well as, where and how to extend the harbor in case an extension would have been needed. At a certain point in time, the public agency responsible for the management of the decision-making process decided to use an environmental impact assessment (EIA) to estimate the effects of one of the three options discussed for potential harbor extension. Conduction of an EIA means that decision-makers ask scientists to estimate the effects of a planned project on the environment. Such an assessment is compulsory by law and made once, before a project is conducted. In addition to the impact assessment, decision-makers also initiated another assessment that was not compulsory by law, but similar characterized by an assessment style of knowledge governance.

Based on our data analysis we therefore judge the first part of the Mainport case to be characterized by the assessment approach to knowledge governance (Giebels and de Jonge, 2014). In abstraction, the assessment approach hence is characterized by an integral, typically science or expert based assessment of environmental impact of decision-making plans. It is organized once in a time, in essence before an important impact decision is taken. In terms of integrality, that planning approach emphasizes the need to reach one integral knowledge product. Crossing different policy sectors, that approach evaluates the expected effects of planned actions within an ecosystem. The interaction needed between participating actors

Figure 5.6
The Assessment approach



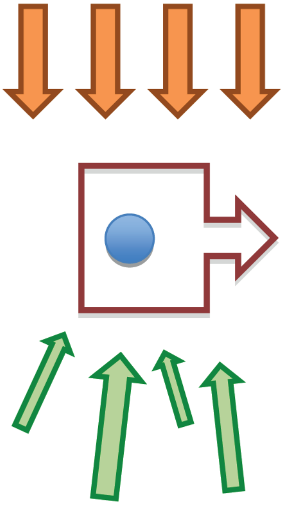
Decision-maker(s) (blue point) puts specified knowledge request, once during the decision-making process (orange arrow) at knowledge system (dark green arrow). Knowledge upload integrally produced based on different knowledge sources (light green arrows). Orange and dark green arrow point to each other, visualizing that an upload from knowledge to decision-making occurs.

is low, since knowledge utilization occurs only once, before the decision to start a project is taken. Figure 5.6 presents a visualization of the assessment approach.

5.5.4. The holistic approach – the Mainport case (new style)

The second part of the Mainport case (new style) is characterized by a gradual enhancement of knowledge capacity, while conflict simultaneously decreased. More specific a joint fact-finding program was installed to organize a joint process of knowledge production (=the facts) among especially environ- mental interest groups. In addition several monitoring programs were installed to measure the impact of harbor development on selected areas. Monitoring areas ranged from compensated habitats of the Natterjack Toad located at the actual harbor area, to the regional monitoring of selected parameters envisioning the quality of Rotterdam's living environment. Based on those changes in knowledge governance observed, we identify the holistic approach to be most representative for the Mainport case (new style) (Giebels and de Jonge, 2014). We use the wording most representative here, to emphasize that the decision-making process was only partially characterized by a holistic style. More specific, the holistic style was developed during the joint fact-finding with environmental interest groups (see also Giebels and Teisman, 2014). As the work of Van Gils and Klijn (2007) reveals, several, separate decision-making arenas were however organized for the decisions to be taken. In an ideal form, the holistic approach, would suggest, that all relevant decision-making actors would need to be organized in one arena. As such the holistic approach foresees a continuous interaction of knowledge sources and decision-makers, including common design of the decision-making as well as knowledge process (Giebels

Figure 5.7
The Holistic approach



Decision-maker(s) (blue point) work together closely (non-filled red arrow) with knowledge sources (light green arrows). Up and downloads occur frequently. Types of knowledge sources are diverse. Although separate decisions occur (orange arrows) those evolve in continuous interaction with similar

and de Jonge, 2014). Enhanced by the observation made from our case, that dynamic is visualized in Figure 5.7.

5.5.5. Differences in social interaction patterns characterizing each knowledge governance approach

Comparing the four cases analyzed we were able to identify and describe four different knowledge governance approaches. Empirically those can be compared along the four different governance measurements as introduced in Section 5.2 (see also Table 5.2 for an overview). First of all, there is a difference regarding the actor that is dominant in determining the scientific agenda. While in, for example the database approach, the knowledge sources are the most important actors to decide on which knowledge is produced, the alignment approach reflects decision-makers being in a leading position. Secondly, regarding the variety of knowledge sources that potentially are applied, we can differentiate governance modes that reflect science-based assessments versus those that allow a mixture of sources. Another important difference lies in the way learning among decision-makers and knowledge actors is expected to emerge. We see a pattern of downloaded oriented culture that prefers knowledge being packaged and presented to decision-makers in a rather undirected manner. The other way around we can trace decision-makers actively putting out knowledge requests, thus uploading knowledge to the decision-making process. In the holistic approach both patterns are observable. Finally, the frequency of up/downloads varies accordingly. While the holistic approach is typically characterized by a high frequency, the assessment approach, for example, foresees a few interaction points only.

Table 5.1
Overview of typological theory developed for EBM knowledge governance in different contexts

Name of the case	Short description of the case	Level of conflict	Knowledge capacity	Characterization of management (after Jennings and Hall, 2011)	Knowledge governance applied (after Giebels and de Jonge, 2014)
Seal	Seal management across nation states	Low	High	Evidence-Based Agency	Database approach
Houting	River restoration project	Low	Low	Experiential Agency	Alignment approach
Mainport (old style)	Harbor extension	High	Low	Symbolic Agency	Assessment approach
Mainport (new style)	Harbor extension	High	High	Challenged Evidence-Based Agency	Holistic approach

Table 5.2
Differences in organizational patterns characterizing each knowledge governance approach

Knowledge governance applied	Dominant actor to set the knowledge agenda	Frequency of up/ downloads	Types of knowledge sources used	How learning among decision- makers and knowledge sources is expected to emerge
Database approach	Knowledge sources	Low (Fixed download arrangements made)	Science	Download (knowledge downloaded to decision-makers)
Alignment approach	Decision-makers	Medium (Several times during a process)	Mixture of expert knowledge and lay knowledge	Upload (decision-makers ask knowledge sources to deliver advice)
Assessment approach	Decision-makers	Low (Beginning of a process only)	Science	Upload (decision-makers ask knowledge sources to deliver advice)
Holistic approach	Decision-makers and knowledge sources balancing each other	High (due to continuous debate)	Mixture (high diversity of knowledge sources)	Continuous up-and downloads

5.6. HOW CAN WE EVALUATE THE EFFECTIVENESS OF KNOWLEDGE GOVERNANCE IN RELATION TO CONTEXT?

In the following we provide further in-depth evaluation of contextual fit. We do so in two steps. First we discuss whether and to what extent our case data suggests that the type of knowledge governance conducted, resulted in available, relevant and credible knowledge for decision-makers themselves. To make our analysis easily accessible we assign a + when our case data suggests that the parameter was achieved. The sign – is applied when it was not achieved, and a +/ – when it was partly achieved. In the second step we judge whether the chosen approach could reach an equilibrium state within the complex decision-making arena. As already introduced in our theory section (Section 5.2), we indicate the equilibrium state reflecting either a high, medium or low fit. Table 5.3 provides an overview of our results.

5.6.1. First step: evaluating availability, relevance and credibility of knowledge

In the Seal case regular management reports are conducted based on all knowledge created about seals in the Wadden Sea. In the Houting case, decision-makers mostly contracted out their specific knowledge requests. In the Mainport case (old style) an environmental impact assessment and additional contracted out assessment studies were conducted, initiated on decision-makers request. In the Mainport (new style) additional joint fact-finding efforts and monitoring programs were installed. Regarding the availability of knowledge, we therefore conclude that in all four cases knowledge governance successfully achieved the production of knowledge, hence availability succeeded. Since all knowledge was also explicitly produced as well as used for an ongoing decision-making process, we judge relevance also to be achieved within all cases. In the Seal case the MESMA (2012) study explicitly reported trust to be an important asset, established among actors involved across the Wadden Sea over time. In the Houting case, trust was also named explicitly. The trust in management as well as involved experts was named several times. Counterfactual, our case data does not indicate knowledge sources have been excluded because of distrust. In the Mainport case (old style) distrust was an important theme, but was not explicitly related to the distrust of knowledge sources by decision-makers. Similar, no distrusting decision-makers could be identified in the Mainport (new style). Credibility of knowledge therefore also receives a + score.

5.6.2. Second step: evaluating contextual fit

Based on our data available, we judge the Seal case to reveal a high match between governance approach and context. Our data indicates that the way knowledge is produced and communicated is perceived to work well. Regular management reports are conducted based on all knowledge created about seals in the Wadden Sea. Although some problems with external legitimacy have been reported (e.g. on the issue of seal sheltering), that problem has not been related to a need for change in knowledge governance.

Table 5.3
Summary of contextual fit analysis

	Availability	Relevance	Credibility	Evaluation of fit
Seal	+	+	+	High
Houting	+	+	+	Medium
Mainport (old style)	+	+	+	Low
Mainport (new style)	+	+	+	Medium

The Houting case reflects a medium fit between context and governance approach. The alignment approach was reported from decision-makers to work well for the organization of a decision-making process across different policy levels, as well as to realize the project on time. However, involved scientists as well as interest groups were critical about the alignment approach. Scientists criticized the lack of integral knowledge bases (e.g. integrating technical with biological knowledge) and argued that a project should only be conducted after knowledge would have been available. Interest groups criticized that their local knowledge was insufficiently taken into account. The same interest groups however judged their own criticism to be on a moderate level. Although they saw room for improvement, they judged the achievements made by public agencies successful and the room for improvement rather moderate. Therefore, in sum we apply the medium score to the Houting case.

For the Mainport case (old style) we need to judge the assessment approach to reflect a low fit between context and governance approach. Although the assessment approach helps to produce knowledge on time, it could not alter the opinion of opponents to the project. A shift toward more interactive forms of knowledge production could be traced afterwards (Mainport new style), indicating that a shift of governance mode was necessary. We thus can conclude that in a context characterized by high conflict and low knowledge capacity, environmental impact assessments are not a good means to bring forward the decision-making process. The joint fact-finding seems to provide a better fit, but also left room for future improvements.

5.7. CONCLUSIONS AND DISCUSSION

Main aim of our research was to develop theory in a quest to better understand the interrelatedness between context and knowledge governance for EBM. More specific we were wondering: 1. How can we know in which type of context EBM knowledge governance is applied?; 2. How do real decision-makers organize knowledge governance for EBM?; and 3. How can we evaluate the effectiveness of knowledge governance applied in relation to context?

Regarding research question 1, we can conclude that our adaption of Jennings and Hall's EBP theory (2011) helped well to identify differences in the operational context of decision-makers. Further refinement of their theory was needed, to judge upon the differences in level of knowledge capacity and conflict. Since we were using a comparative case study approach it was possible to identify such differences by judging whether e.g. conflict was a dominant or rather latent theme. Based on this experience we suggest that for future operationalization cases might benefit from standardized categorization on how decision-makers identify and judge upon level of conflict, as well as level of knowledge capacity.

Regarding research question 2, we could identify four different knowledge governance practices in our cases, which are the database, the alignment, the assessment and the holistic approach (Giebels and de Jonge, 2014). The governance operationalization of Peters (2007) helped much to identify and describe the underlying organizational patterns of each approach in a typological manner (George and Bennett, 2005). More specific the cases reflected differences in the dominant actor to set the knowledge agenda, the frequency of up-and downloads, the types of knowledge sources used and the expectation about how learning among decision-makers and knowledge sources will emerge.

Combining these insights with the evaluation of whether knowledge could be generated (judging upon availability, relevance, credibility), we can conclude that although governance practices differ, all of them were suited to generate knowledge for EBM. Availability, relevance and credibility of knowledge were achieved for all decision-makers involved. However, based on our equilibrium analysis, we need to conclude, that governance approaches reveal a different level of contextual fit. While the database approach seems to fit well in a context characterized by high knowledge capacity and low conflict, the assessment approach did not work out very well in a context characterized by high conflict and low knowledge capacity. Although assessment approaches have been criticized long before for their lack to provide better environmental outcomes (see Gilmour et al., 1999), our analysis shows that in terms of knowledge governance they provide benefits for decision-makers when an upload of knowledge directly to the decision-making process is needed to enhance knowledge capacity. However, when the operational context is characterized by high level of conflict, holistic approaches seem to provide a better fit from the contextual point of view. Nonetheless, as the context configuration of the Houting and Seal case reveals, holism might not be needed in all types of governance regimes. Based on the Houting case we can conclude that the alignment pattern worked to the benefit of reaching decisions quick and on time. Nonetheless, the Houting as well as the Mainport case provide further empirical examples illustrative to the claim that holistic approaches to knowledge governance can be essential for the enhancement of sustainability in our society, but that their practical restrictions are still apparent (Cornell et al., 2013).

In sum, we therefore deem the advanced theoretical understanding of context and its interrelatedness with different types of knowledge governance helpful for future EBM decision-makers to design informed and effective knowledge governance (Van de Ven, 1989; Lynham, 2002). Since our cases have been theory driven, we judge our selection bias minimized and our research results representative (Gerring, 2007; Levy, 2008). Nonetheless we would like to emphasize that we do not perceive our evaluation providing final conclusions about which governance approach should be chosen in which type of context. We still want to be careful about attaching broad generalization to N = 4. Furthermore the results of our evaluation do only describe the experiences made, as we could dissect them from our available data. Hence, restrictions in empirical data might be reflected. Nonetheless, we judge our evaluation to reveal important and typical differences in the variety of contexts decision-makers are likely to come across when empirically applying EBM. Hence, in comparable contexts, the lessons learnt will still provide relevant guidance.

Therefore our findings reveal another acknowledgment of and an important new explanation to the observation made by Fabricius and Cundill (2014), who found that in the implementation of adaptive approaches often governance is not reported as an explicit aim, but an explicit achievement. Our findings show, that knowledge capacity for public decision-makers is directly related to their effort in organizing knowledge governance. The lack of scientific data application during decision-making is therefore not a good indicator for the quality of the knowledge governance process as such. Vice versa, where a lot of scientific knowledge has been generated we do not necessarily arrive at good EBM. For broader EBM literatures this finding suggests that any evaluation study of EBM knowledge governance, also needs to take account of that varying morphology of knowledge governance.

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Chapter 6

Transdisciplinary Knowledge Management: a key but underdeveloped skill in EBM decision-making

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ABSTRACT

The ecosystem-based management (EBM) philosophy draws upon the principle that holistic understanding of the system to be governed needs to guide the decision-making process. However, empirical evidence is growing that knowledge integration is still a main bottleneck for EBM decision-makers. This paper argues that transdisciplinary knowledge management (TKM) is a key competence in achieving knowledge integration, while simultaneously it represents an underdeveloped research area in EBM if understood as a process of human interaction. Based on a literature review, this article summarizes and reflects upon the most recent development in the field of TKM. The paper presents a detailed definition and in-depth description of TKM as a process of human interaction and a diversity of organizational structures that effectuate TKM. Theoretically discussed premises are furthermore illuminated and evaluated by a case study that exemplifies pro-active development and implementation of TKM. Deviating case observations are presented as novel contributions to the field. They suggest new ideas and inspiration for future EBM research and policy agendas.

6.1. INTRODUCTION

Ecosystem-based management has become a globally acknowledged and applied approach in marine policy. It has been introduced as an alternative to traditional, sectorial decision-making, better suited to address marine systems as holistic systems and to ensure their long-term functioning, health and sustainable provision of ecosystem services (Leslie and Mc Leod, 2007; Stelzenmüller et al., 2012; Raakjaer et al., 2014). The notion of holism refers to the need of gaining system understanding that goes further than individual species, small spatial scales, short-term perspectives and management of commodities (Lubchenco; 1994 in Sherman and Duda, 1999; also Olsen and Nickerson, 2003). It aims for deep understanding of the complexity of ecosystems and their interrelatedness with human systems (Mc Leod et al., 2005; UNEP, 2011). As soon as implemented in complex decision-making landscapes, holism also refers to the need of knowledge governance between multiple knowledge sources and decision-making levels, typically represented by scientists, experts, citizens or lay people and administrative-political decision-makers (Giebels et al., 2013; Rodriguez, 2017).

As such, the necessity to understand and govern ecosystems as holistic systems has also raised the need for a broader integration of different bodies and fields of knowledge including data governance and information synthesis (Curtin and Prellezo, 2010; Tallis et al., 2010). In practice, however, the quest for knowledge integration, understood as the integration of all related forms and contents of knowledge relevant to a specific issue area such as marine ecosystems, is an on-going struggle, restricting EBM implementation (Tallis et al., 2010). Studies analysing empirical cases of EBM reveal that related challenges potentially derive from many sources. Those include limitations of data availability and access (Gilliland and Laffoley, 2008; Caldow et al., 2015), the problem of fragmented governance systems (Ruckelshaus et al., 2008; Katsanavakis et al., 2011; Van Leeuwen et al., 2014), and uncertainty introduced by complex problems with non-linear feedbacks, such as climate change, that challenge the possibility to design predictive models to inform decision-makers (Allison et al, 2018).

To approach such challenges many invaluable institutional governance frameworks (see for example Stelzenmüller et al., 2012 on monitoring and evaluation of spatially managed areas or Raakjaer et al., 2014 on nested governance structures) and decision-support tools (see for example Espinosa-Romero et al., 2011 on structured decision-making or Knights et al., 2014 on decision-making under uncertainty) have been developed to assist and facilitate EBM decision-makers in their organizational endeavour of knowledge integration. However there is one crucial challenge that has not gained much attention in EBM research so far. Based on their most recent literature review in the field, Alexander and Haward (2019) conclude that there is a lack of in-depth understanding about how knowledge integration for EBM works as a process of human interaction. It is in particular important to more explicitly disentangle how the human dimension influences processes of e.g. inter-sectorial communication and data-sharing before new governance frameworks and decision-support tools are developed (Alexander and Haward, 2019). In essence, individual decision-makers embedded within institutions as well as wider operational contexts need to arrange common knowledge grounds for EBM to become effective. If they do not succeed in their attempts to arrange data exchanges or to develop frameworks of knowledge integration and commonly shared data interpretation, the quest for holistic understanding has failed.

This paper argues that the literature focusing on transdisciplinary knowledge management (TKM) provides helpful insights and discussions related to these challenges. By merging insights from the disciplines of knowledge management (KM) and transdisciplinarity (TD), TKM combines two important, though different disciplines, both studying how conscious generation and utilization of knowledge works in practice. It provides suggestions on how knowledge integration can be improved and most importantly how it is possible to manage knowledge integration as a group process. With a particular focus on addressing societally relevant problems and their solutions the young field of transdisciplinary research seeks not only to integrate relevant academic disciplinary knowledge (Hirsch Hadorn et al., 2008; Bernstein, 2015), it also calls for the involvement of societal stakeholders beyond adacemia and their respective bodies of knowledge. The rapidly growing body of work in transdisciplinary research (Brandt et al., 2013) developed the notion of collaborative work between researchers and non-academic experts or lay-people further. It calls for problem-focused co-operation of different scientific disciplines together with non-scientific actor groups in different stages of the research process including problem identification and definition, common research and problem-solving processes as well as interactive dissemination and implementation of results (Jahn et al., 2012; Lang et al., 2012). The transdisciplinary knowledge-production process is called upon to open up to civil society groups, holders of local lay knowledge, corporations and other stakeholders and involve them in mutual learning processes (Pohl, 2011; Wiek, 2007).

According to Leenhardt et al. (2015) transdisciplinarity, however, has not been a very popular research strategy in natural resource management, especially marine science. Nonetheless diverse EBM scholars already acknowledged its crucial role in the process of EBM implementation. It has been argued that TD is a necessity to integrate scientific disciplines that would be needed to understand system dynamics like cross-scale linkages, emergent properties, non-linear dynamics, and uncertainty (Allison et al., 2018; Hastings et al., 2012; Leenhardt et al., 2015; Spalding and Biedenweg, 2017) and to develop comprehensive system understanding (Newton et al., 2012; Nguyen et al., 2016). TKM is useful to actively engage with local actors, for example to understand the multiple causes that impact upon and cause change of our coastal systems, to develop co-produced research agendas and to identify tipping points towards ecological system shifts (Newton et al., 2012). As a tool for spatial planning it can bridge governance levels, jurisdictions, and economic uses (Gissi and Suarez de Vivero, 2016) ensuring that those who take decisions about ecosystem resources are also engaged (Ranger et al., 2016, LeHeron et al. 2016). It increases the relevance and practical applicability of scientific research for society and enhances the participation, collaboration and empowerment of stakeholders (Bruckmeier and Larsen, 2008; Brink et al., 2016). It might also be especially suitable in situations where available knowledge is of premature quality (Röckmann et al., 2015).

Therefore it becomes worthwhile taking a deeper look at what most recent research progress in the field has to offer and to learn about the human dimension of integrative knowledge governance. Particular aim of this paper is to identify and describe relevant discussions from state-of-the-art TKM literature, useful to understand knowledge integration within EBM contexts as processes of human interaction. Key question of this paper is to understand how TKM scholars describe TKM as a process of human interaction and through which variables TKM can be studied scientifically.

We do so by first providing a theoretical discussion of TKM based on a systematic literature review. This review dissects variables that define and impact upon TKM as a process of human interaction (section 6.3). In the second step we illustrate this theoretical discussion by providing in-depth case analysis of an empirical application of TKM. This application describes a start-up-phase of a science-driven EBM project, the so called RELEEZE project (section 6.4). Particular aim of the RELEEZE project was to organize a knowledge integration process that would result in a regionally defined and climate-sensitive EBM system perspective. To facilitate this process, a transdisciplinary knowledge integration process was set up among diverse scientific disciplines, fragmented public administrations and different types of coastal zone users. In our case analysis we describe the organizational structure of the applied TKM trajectory (section 6.4.2) and present the results of a process evaluation executed by all scientific project members in the aftermath of the project (section 6.4.3). The process evaluation was structured by the TKM variables derived from literature, to test whether and how those work in practice. As not all variables worked in practice as predicted within theory, deviating case evidence is presented as novel evidence to the field in section 6.5.

6.2. METHODS

Methodologically this paper builds upon the results of a systematic literature review and a participative case study. Literature for the review has been selected via ScienceDirect (sciencedirect.com) using two different and independent search-term combinations. For all search term combinations papers have been classified regarding their relevance concerning descriptions or discussions of transdisciplinarity. For the literature selection only the most recently published articles have been included (2005-2018), as to make sure that the process definition reflects the latest state of the art. It was decided not to include additional classics of transdisciplinarity or TKM, as many of the selected papers already provided this type of discussion and subsequently draw their research design upon it.

The first search term combination used was "knowledge management" AND "transdisciplinarity", to gain an overview about scientific papers that discuss how knowledge management can be used to organize a transdisciplinary process. Secondly the terms "ecosystem based management" AND "transdisciplinarity" have been used to identify papers that discuss transdisciplinarity in the context of EBM. The first search was conducted on 6 March 2018 and revealed 48 papers of which 33 have been identified as relevant. The second search was conducted on 16 May 2018 and revealed 14 papers. All of these 14 papers have been classified as relevant and were included in the review. No duplications have been found. Table 6.1 provides an overview of the total numbers of papers included in this review. In addition, an overview of papers from both search selections is included as an appendix to this article.

To systematically assess the contents of identified papers a Microsoft Excel table was used to archive each article analysis. For all articles, author' names, publication year and journal name were noted. For the TKM literature it was assessed how knowledge management was defined and how the role of knowledge management was described as a human and not (only) technical process. If no definition of knowledge management was provided, alternatively a short summary of the article content was made. Similarly, we provided for all EBM literature articles a content summary, the used definition of transdisciplinarity, and a discussion of how transdisciplinarity was related to EBM in terms of human process.

Table 6.1
Total numbers of papers included in the literature review

Literature search keywords	Total number of papers found	Total number of papers accessible	Total number of papers relevant and included for analysis
“knowledge management” AND “transdisciplinarity”	48	35	33
“ecosystem based management” AND “transdisciplinarity”	14	14	14
Total number of papers	62	49	47

The participative case study was used to set up, design and evaluate a TKM process under the umbrella of the RELEEZE project. The RELEEZE project was financed by the German Federal Ministry of Education and Research (BMBF; Bundesministerium für Bildung und Forschung) within the research program ‘Research for sustainable development (FONA3)’. It aimed at the development of a regional, climate sensitive EBM perspective (see section 6.4.1 for further detail). To generate system knowledge about the RELEEZE project area, TKM was applied to involve relevant experts and decision-makers and to facilitate the knowledge integration between experts, decision-makers and scientists. Applied TKM methods included face-to-face interviews, a digital speed-date and a joint workshop.

Relevant experts and decision-makers were identified through stakeholder analysis following the best practice guidelines of Durham et al. (2014). Accordingly all institutions that affect regional policy making in the RELEEZE research area were approached and invited for an interview. Relevant institutions included different administrative bodies representing the interests of nature protection, coastal defence, farmland use and local as well as regional land use planning. Conducted stakeholder interviews have been guided by a standardized, semi-structured questionnaire. The content of the questionnaire was structured as to understand (i) how individual respondents perceive the socio-ecological system they are operating in, (ii) how they experience or expect it to be impacted by climate change, (iii) whether and how they manage the area in an integrative way, (iv) whether they would like to pose own research questions concerning the socio-ecological system at hand, and (v) what their past experience, future expectations and wishes concerning the further participatory process are. In total 20 experts from 13 organisations have been interviewed. On average each interview took 1 h 45 min.

The results of (iv) have been fed back first to the scientific consortium members in form of a digital speed date and were in a second step transformed into a transdisciplinary research agenda together with experts and decision-makers. To facilitate the digital speed date all stakeholder questions derived from the interviews were content-transcribed and compiled in a Microsoft Excel table. Scientists were requested to indicate for each question whether or not they thought a question could be addressed by academic research. In total 57 research questions have been discussed. While 22 questions could directly be integrated in a joint research agenda, 12 questions needed to be excluded. Two reasons caused exclusion: Either the research question was already handled by a different scientific project in the region or the question was perceived by scientists as being too far away from the core focus of the project. The remaining 23 questions required further discussion. To facilitate this discussion a joint workshop was organized together with all experts, decision-makers and scientists. During this workshop all questions were discussed in detail and a final decision on which questions to include for the transdisciplinary research agenda was made. In addition, the results of (i), (ii) and (iii) were used to draw a first sketch of a transdisciplinary system map. This system map revealed an integrated conceptualization of the socio-ecological system of the project region. It comprehensively reflected scientific state-of-the-art and integrated stakeholder views on system dynamics. A simplified version of the system map is presented in section 6.4.2. Individual results of the stakeholder interviews and the speed date are not included to the manuscript due to word count limitations.

An ex-post reflection was organized in the aftermath of the workshop, in between October and December 2018. The project period itself lasted from June 2017 to May 2018. Inspired by Interpretative Phenomenological Analysis (IPA) (Smith and Shinebourne, 2012), the ex-post reflection aimed to understand how individual participants personally perceived the process of TKM. This method was chosen as the results from the literature review revealed the necessity to conceptualize TKM as a group process. This group process is expected to be effective if all individual participants succeed to evolve throughout a common process. Hence it is important to understand how individual participants perceive the process they have been going through and whether and how their individual perceptions deviate from findings reported from other studies.

To do so all variables derived from the TKM literature review (see Table 6.2 for a summary) were reformulated to statements. Project participants were asked to reflect upon these statements in a written manner. They were asked to indicate whether they agree or disagree to a statement and in case they would disagree to motivate their choice. Motivated disagreements are reported as deviating TKM experience in section 6.4.3. In total 9 evaluations have been filled in, analysed and integrated in this section. Individual evaluation input is indicated anonymously through the capital letter R in combination with a randomly assigned number (R1, …, R9).

It was decided to only invite scientific consortium members for the reflection exercise as only those have been participating throughout all phases of the project. As already mentioned above, it was not possible to organize a fully inclusive TKM process for all project members, due to the restricted timeframe available. A short summary of all findings can be found in Table 6.3. In case no particular elaboration or novel contribution came out of the analysis, this is indicated by the sign ✓ without text in Table 6.3. In case a particular elaboration could be made this is indicated by the sign ✓ followed by text. In case a deviating finding could be identified this is indicated through the use of plain text.

6.3. TRANSDISCIPLINARY KNOWLEDGE MANAGEMENT AS A PROCESS OF HUMAN INTERACTION

In depth study of most recent progress in the discipline of TKM helped to identify variables that define and impact upon TKM as a process of human interaction. In the following sections these variables are elaborated on through resuming and synthesizing the research progress of current debate in the discipline. Section 6.3.1 presents a description of what TKM is if conceptualized as a human process and how it can be organized effectively. Section 6.3.2 resumes on specific actor roles that should be represented in a TKM process and identifies skills needed to execute these roles. Section 6.3.3 zooms in on the crucial role of networks as organizational entities facilitating effective TKM. An overview of all variables that have been distilled from TKM literature to structure the ex-post reflection is presented in Table 6.2.

6.3.1. Defining Transdisciplinary Knowledge Management

Scholars of TKM have described the phenomenon as, in essence, a long-term group interaction and learning process. TKM works cyclical, iterative and participative and facilitates integration across a variety of actors involved (Kragt et al., 2013; Puente-Rodríguez et al., 2016). Included actors typically stem from science or society, public or private sectors (Serna, 2015). They interact through dialogue (Maiello et al., 2011) aiming to deepen and extend established expertise (Puente-Rodríguez et al., 2016). Experts are challenged to leave their institutional comfort zones (Kragt et al., 2013), while group members learn to trust and respect each other through engagement (Kragt et al., 2013; Puente-Rodríguez et al., 2016; Morales Asencio et al., 2017). For that sake the process of interaction is transparent, including fair play rules and commitment of actors to joint goals (Bruckmeier and Larsen, 2008).

TKM differentiates from those processes that see knowledge as a product or a service that can be delivered from producer to user. It explicitly acknowledges the need of knowledge differentiation and integration through reflection and method (Lang et al., 2012 in Barth et al., 2014). Transdisciplinarity implies a dynamic where the communication of knowledge becomes more relevant than its production (Tötzer et al., 2011; Adomβent, 2013). It is an attempt to think about what has been unthought, developing 'what if' techniques to question

Table 6.2

Distilled variables from literature review defining and affecting the social process of Transdisciplinary Knowledge Management

TKM described in the literature	Sources
1. What does a TKM process look like?	
- a group learning process	- Serna, 2015; Gendron et al., 2017; Arnold, 2013; Barth et al., 2014; Brink et al., 2016; Tötzer et al., 2011; Luks and Siebenhüner, 2007; Kragt et al., 2013
- requires complex human skills	- Gurubatham, 2014
- it is about learn how to learn	- Tötzer et al., 2011; Adomβent, 2013; Gurubatham, 2014
- non-routine type of working	- Kragt et al., 2013; Gendron et al., 2017; Klimova and Semradova, 2012
- needs to be organized as a conscious, step-wise process	- Serna, 2015; Laniak et al., 2013; Leischow et al., 2008
- cyclical, iterative, participative	- Kragt et al., 2013; Puente-Rodríguez et al., 2016
- open dialogue, transparent, trusted, non-bureaucratic	- Maiello et al., 2011; Puente-Rodríguez et al., 2016; Morales Asencio et al., 2017; Bruckmeier and Larsen, 2008
- sequentially structured, but also emotional, creative and difficult to predict	- Puente-Rodríguez et al., 2016; Serna, 2015; Le Theule and Fronda, 2005; Gurubatham, 2014; Gendron et al., 2017; Arnold, 2013
- in essence self-directed, but tutored where necessary to prevent isolation of individuals or group-harming behaviour	- Bond et al., 2010; Dlouhá et al., 2013; Tötzer et al., 2011
- needs to be accompanied by boundary work when actors are in conflict	- Bond et al., 2010; Dlouhá et al., 2013; Tötzer et al., 2011
- ideally explicitly facilitated by law and organizational structure	- Bruckmeier and Larsen, 2008; Vie, 2012; Serna, 2015
2. Who is the key actor to convey TKM?	
- not one key actor, but a group process - pre-defined actor roles effectuate the group process	- Tötzer et al., 2011; Puente-Rodríguez et al., 2016; Bond et al. 2010; Maiello et al., 2011; Le Theule and Fronda, 2005; Kragt et al., 2013; Bruckmeier and Larsen, 2008; Raymond et al., 2014; Kyriazi et al. 2013
- universities are most suitable actors to initiate and facilitate TKM	- Luks and Siebenhüner, 2007; Adomβent, 2013; Dlouhá et al., 2013; Sedlacek, 2013; González López et al., 2015; Safaei Fakhri and Talebzadeh, 2011
- explicit organizational embedding e.g. through Centres of Expertise helping to effectuate the role of universities	- Sedlacek, 2013
3. What is the role of networks?	
- TKM can be a tool to build up new networks	- Tötzer et al., 2011; Morales Asencio et al., 2017; Puente-Rodríguez et al., 2016
- TKM as a means to manage existing networks	- Sheate and Partidário, 2010; Le Theule and Fronda, 2005; Vie, 2012; Kragt et al., 2013
- TKM might also use networks to manage	- Le Theule and Fronda, 2005; Serna, 2015; Puente-Rodríguez et al., 2016; Tötzer et al., 2011
- networks are important organizational entities to link actors	- Leischow et al., 2008; Tötzer et al., 2011; Bruckmeier and Larsen, 2008
- networks need continuous negotiation to make them work	- Sedlacek, 2013; Vie, 2012; Puente-Rodríguez et al., 2013; Sheate and Partidário, 2010

the obvious and using hermeneutics and imagination to move beyond mainstreamed ways of theorizing and thinking (Gendron et al., 2017, see also Klimova and Semradova, 2012 for an application to e-learning). As such the concept of TKM has much overlap with and belongs to the family of "sustainability science", "mode 2" and "triple helix" (Bruckmeier and Larsen, 2008; and for in-depth discussion Vie, 2012), however, as discussed throughout this paper TKM forms a specialization within this field, as it is in particular concerned with knowledge integration for complex systems understanding.

Effective organization of Transdisciplinary Knowledge Management

Many TKM scholars associated effective organization of TKM to a process separated into different phases. For each phase clear objectives need to be defined (Puente-Rodríguez et al., 2016). In his TKM maturity model Serna (2015) for example distinguishes in total five process phases with different objectives. In the starting phase (predisposed level) disciplinary knowledge prevails in a group and a lack of abilities to perform knowledge integration is experienced. In the second step (reaction level) the group starts to experiment with methods of knowledge integration. In this stage information starts to flow between disciplines. At the third level (evaluation level) this information flow matures. Participants get a better view on which knowledge should be integrated and how this could be done. Typically agreements are made to further facilitate integrative attempts. In the fourth step (organized level) a clear process architecture has been developed within the group, actively facilitating knowledge integration. The fifth and final step (optimized level) describes an on-going process of knowledge integration. It is characterized by continuous architectural changes to facilitate adaption to new insights and new needs of knowledge integration.

A different process view has been developed for those TKM approaches that chose to develop a modelling process. Laniak et al. (2013), for example argued that, although it is important that all actors work towards a common perspective in a TKM process, they do not necessarily need to evolve through a joint process. The final development of a system model could for example also be outsourced to specialized scientists. This type of process design has the advantage that actor constellations are more flexible and can be changed easily, for example if changing definitions of the problem demand involvement of different expertise (Leischow et al., 2008). Similar, Arnold (2013) argued that in integrated natural resource modelling the knowledge management process should not look like a one-(wo)man-show, like an expert advice nor like a symphony. It ideally provides a playground that makes it possible to develop and combine collaboration within an organization or cooperation with external partners to accumulate knowledge (Arnold, 2013).

A critical view on joint process design has also been developed by Le Theule and Fronda (2005). They argued that a managerial intention to control creativity is inherent to many potential contradictions. Creation needs freedom, it is an emotional process, driven by affection, and it is difficult to predict and put into time frames (see also Gurubatham, 2014 on details of the learning process and stimulating methods for creativity). In organizational terms Le Theule and Fronda (2005) use the jazz metaphor to explain how a creative process in a group can evolve without being strictly steered. They (Le Theule and Fronda, 2005) emphasize that it is a more or less unplanned, very contextual happening, where skilled musicians continuously improvise being simultaneously inspired by their own feelings, colleagues, and the audience. In line with this view Gendron et al. (2017) added that for TKM it is important to not only focus on the classical sources of knowledge, like objective knowledge as it is created by science, or rational knowledge as produced by philosophy; but also on the experiential knowledge as produced by art and literature (Gendron et al., 2017).

The case evidence reported by Bond (et al., 2010) suggests that informal human playgrounds as suggested by Arnold (2013) and Le Theule and Fronda (2005) could be seen as entities that are organized in parallel to highly formalized knowledge generation processes. The development of Environmental Impact Assessments, for example, became effective by actors taking time for frequent knowledge exchange in informal meetings, organized in addition to the formal ones. Through these meetings actors had the possibility to reflect upon and change their vision about the process itself. Negotiation and leadership by a coordinator was important to make this type of knowledge integration effective (Bond et al., 2010).

To effectively organize TKM, it is also important to reckon upon the specific type of disciplines that are represented in a group learning process. Prinsloo's (2018) findings suggest that individual patterns of creative thinking determine how a single actor will experience a TKM process and participate therein. His study reveals that although students of different disciplines show similarities in choosing things they like to analyse, a clear cut difference exists between students of the natural sciences versus students of engineering and music when it comes to the choice of things they dislike (see Prinsloo, 2018 on disfavour-based patterns).

Related to this finding, it is also important to note that TKM requires more complex human skills and "higher level" competencies like the ability to create, evaluate and empathize with stakeholders (Gurubatham, 2014) than traditional approaches of knowledge management do. While general knowledge management can be implemented as a routine activity by recalling and applying pre-learned content or schemes, TKM is typically applied in contexts where established knowledge claims out-date quickly. Accordingly, it becomes much more important to enhance and stimulate the so-called fluid intelligence, enabling an actor to 'learn how to learn' (Gurubatham, 2014).

To effectuate mutual learning, TKM scholars suggested working formats like the experimental learning approach that combines momentum of experience, activity, and reflection (see Kolb, 1984, and Schön, 2009, both cited in Barth et al., 2014) as well as cooperative learning circles, voluntary agreements (Luks and Siebenhüner, 2007) and the learning organization approach (Bond et al., 2010). The development of 'controlled vocabularies' and 'common ontologies' furthermore, can help to bridge language barriers (Kragt et al., 2013). In such settings it is especially for public administrators important to not operate too bureaucratically, as this might cause more distrust instead of trust among participating actors (Bruckmeier and Larsen, 2008).

To let TKM evolve as a successful group process it however also is important to reckon upon potential harmful group behaviour of individual participants. Group management might therefore also urge prevention of individuals getting isolated, the exclusion of non-complying group members or be accompanied by boundary work when actors are in conflict (Dlouhá et al., 2013) and different stakes need to be balanced (Tötzer et al., 2011). In particular boundary work might be suited to support TKM, as it acknowledges and respects that actors hold different and diverging convictions. It does not try to change these convictions, but supports communication and coordination to facilitate integration (see also the discussion in Dlouhá et al., 2013). To reckon upon different and diverging convictions of individual actors seems to be most essential, as it supports individual self-directedness. Self-directedness is an important asset to enable social interaction and learning (Dlouhá et al., 2013). For those TKM processes that entail the participation of actors that did not participate in a TKM process before, it is also important to ensure empowerment of inexperienced actors (Bruckmeier and Larsen, 2008).

Reoccurringly, TKM scholars have also referred to the importance of external factors influencing the success of TKM. Bruckmeier and Larsen (2008) mention that a change of law and the establishment of facilitating institutions would be needed to enable more stakeholder participation and to make participatory approaches fully functioning. Often it are prevailing institutional pressures like career-building paths that prevent TKM to become applied (Vie, 2012; Serna, 2015). But also factors like perception of status and leadership style (Stokols et al., 2008 in Morales Asencio et al., 2017) or the way data ownership is handled (Kragt et al., 2013) can have significant impact. Other studies identified (i) the experience of earlier shortcomings when not managing a system in a transdisciplinary way (Bruckmeier and Larsen, 2008), (ii) the experience of a diversity of viewpoints helping to increase insights (see Gurubatham, 2014), and (iii) the ability of actors to see impact of their efforts in an ongoing process (Tötzer et al., 2011) as important success factors.

6.3.2. Identifying key actors in Transdisciplinary Knowledge Management

Drawing on the definition that TKM in essence is a group process aiming to integrate different bodies of knowledge, it is also important to clarify who should be responsible for its organization. Many of the reviewed articles explicitly addressed this topic. In particular the focal role of universities and the need to explicitly define different actor roles within a TKM process have been discussed.

Universities as key convenors of TKM

Many authors have argued that universities are important key convenors of TKM (Luks and Siebenhüner, 2007; Adomβent, 2013; Dlouhá et al., 2013; Sedlacek, 2013; González López et al., 2015). Scientific disciplines as Ecological Economics have, for example, explicitly defined their scientific agendas through the accomplishment of sustainability goals within society and identified TKM as an important method to achieve them (Luks and Siebenhüner, 2007). By combining many different disciplines in one institution, universities potentially function as important platforms and networks to push for regional and international knowledge dependent initiatives (Sedlacek, 2013). Universities can, for example, introduce innovative management practice, technical expertise, promotion of ideals and critical thinking. They can take the lead in initiating sustainability plans or act as independent monitoring and bridging institutions (Adomβent, 2013).

Other authors have put emphasis on the educational task of universities in this matter. Knowledge management then becomes an important competence students need to learn in order to acquire and create knowledge as well as to critically reflect and judge upon it (Safaei Fakhri and Talebzadeh, 2011). Case evidence suggests that for universities being a key actor to convey TKM, it is important that independently organized coordinating and bridging institutions take over the organizational process behind TKM. For example in the case of the University of Graz (Sedlacek, 2013) a Regional Centre of Expertise was crucial to make TKM effective. The centre acted as an independent coordinator, providing a network that could be used for communication and collaboration. By taking over the multi-stakeholder connection process, the centre prevented the core academic goal of the university not getting under pressure.

Different actor roles

In the process of organizing TKM it is also important to be aware of and ascribe different roles to participating actors. Within the reviewed literature, one important actor role has been assigned to the *facilitator* who is organizing and sometimes also initiating the group learning process. The facilitator acts as a process manager (Tötzer et al., 2011), setting up (Puente-Rodríguez et al., 2016) and if necessary re-evaluating (Bond et al. 2010) knowledge arrangements between participating actors. Case evidence indicates that it is important that the coordinator holds an independent position and has no vested interest in the research itself (Puente-Rodríguez et al., 2016). Independence is important as it enables knowledge brokerage and mediation activities when process deadlocks emerge (Maiello et al., 2011). Le Theule and Fronda (2005) furthermore describe the role of the facilitator as a *translator*. He is not skilled to preach solutions, but to analyse a situation and to assist others in essential activities like reflection to help them finding a solution. A facilitator typically acts like an action researcher or consultant (Le Theule and Fronda, 2005).

Different to the neutral position of the facilitator is the role of the *expert*. Experts are those actors skilled and trained for specific knowledge. It can be the scientific expert (Tötzer et al., 2011) or a technical specialist, trained to translate user needs into characteristics of an integrative model (Kragt et al., 2013). The empirical research of Bruckmeier and Larsen (2008) shows that it depends on specific actor constellations and their perception of the actual conflict or problem at hand, how it is best to proceed in terms of how to characterize what or whom an expert is. Where scientists are working together with experts it can turn out to be useful to proceed with purely scientific methods of knowledge generation and application. However, in case conflicts emerge among participating actors, boundary spanning techniques like joint knowledge production can become more important. Within the TKM community, the added value of a system expert has also been ascribed to its external position. This position is suited to overlook a system in a holistic way, which is often not given for those being involved in and responsible to take decisions (Le Theule and Fronda, 2005). Kragt et al. (2013) provide similar descriptions and definitions of actor roles within the context of integrative modelling.

Resuming TKM processes as group processes it seems also important to realize that group processes do not emerge without initiation. A knowledge generation process to evolve as a group process might urge the activities of an *animator*, someone who is breathing life into the process or acting as a *catalyst* (see Le Theule and Fronda, 2005). These roles could be ascribed as additional activities to the facilitator, but might also be executed by separate actors. Available case evidence suggests that it is advisable to assign different actor roles to specified actors, as otherwise it can be confusing for participants to experience one person in different roles (Tötzer et al., 2011) and to prevent research being experienced as biased (Raymond et al., 2014). However, in case not much funding is available, Kragt et al. (2013) also see the possibility for individual actors fulfilling different roles simultaneously throughout a TKM process.

Maiello et al. (2011) identified a unique position of the *public administrator* throughout processes of TKM. Since typically in transdisciplinary processes many different actors are involved (e.g. citizens, politicians, scientists), it is important that one actor actively manages different knowledge insights and simultaneously assures that the outcome is still serving public interests. According to Maiello et al. (2011) it is the civil servant or public administrator who should take over this role. Maiello et al. (2011) developed this vision after case comparison of governance processes for urban sustainable development in which transdisciplinary approaches failed. An important factor for the lack of transdisciplinarity was that decision-makers tended to separate knowledge streams of experts and lay people.

Maiello et al.'s (2011) study is the only study pointing to this dynamic, although the argumentation of Kyriazi et al. (2013) also underline the need of being sensitive to this issue. In TKM, scientists typically become members of a collaborative network instead of merely being consulted for expert advice. They thus become stakeholders of the decision-making process and hence hold an interest what decisions are taken (Kyriazi et al. 2013). Assigning the role of public-interest keepers to participating representatives of public institutions therefore might be a means to clarify and handle delicate power structures. Equal distribution of power in turn, is essential to create mutual learning (Tötzer et al., 2011).

6.3.3. The role of networks in Transdisciplinary Knowledge Management

The role of networks gained recurring attention in the TKM literature. They have strongly been associated to the effectiveness of systems management. As such they have been discussed from three different angles. First, scholars have argued that it is important to know and understand existing networks to make TKM effective. Secondly, existing networks might be used as a tool to manage through TKM, and thirdly, TKM might by itself be used as a tool to set up new networks.

Manage existing networks, use networks to manage, and build up new networks

In a TKM process the network ties between participants typically are diverse and might be electronically, organisationally, socially, and informally (Vie, 2012). To make TKM work, knowledge exchange needs to be facilitated across all network members (Sheate and Partidário, 2010). Network members need to be willing to share knowledge and to collaborate (Kragt et al., 2013). Individual network members however also need to be understood as being members of already existing networks. Such networks can have impact on the individual as well as the organisational level. On the individual level, interpersonal networks shape the identity of network members as social constructs. They can limit or on the contrary increase individual freedom of expression (Le Theule and Fronda, 2005). On the organizational level networks typically determine the whether and how of knowledge transfer and exchange (Sheate and Partidário, 2010).

Vice versa, a network - if organized in a TKM-like way - can also become a tool of management (Le Theule and Fronda, 2005; Serna, 2015; Puente-Rodríguez et al., 2016). Trough the creation and improvement of space for self-organisation and learning they can provide the necessary organizational entity for knowledge integration (Tötzer et al., 2011). In practice such TKM networks have for example been used to link civil society actors to formal processes of planning and management (Bruckmeier and Larsen, 2008) and to manage geographically wide spread issues like tobacco control and pandemics (Leischow et al., 2008).

Thirdly, TKM can be used to build up new networks (Tötzer et al., 2011), which is a necessity to establish collaboration among researchers (Morales Asencio et al., 2017). Network creation can help to develop and increase the awareness about system knowledge and facilitate reflexive forms of learning (Puente-Rodríguez et al., 2016). Information and communication technologies have been identified as crucial means to effectuate this role of TKM. Particular need for improvement in this domain constitutes effective use of databases. Those are often seized ineffectively due to shortcomings like costly manual updates and expert validations needed for maintenance (Figueiredo and Pereira, 2017).

For all three types of network uses it seems to be important to realize that continuous negotiation is essential to make a network work. Typically, interests between heterogeneous members are not easy to combine. Communication and dissemination of knowledge is then not enough (Vie, 2012). It is also important to articulate actor participation (Puente-Rodríguez et al., 2016) and to apply knowledge brokerage, where it is needed to bridge actor cleavages (Sheate and Partidário, 2010). Independent networking institutions can function as essential linking pins in such dynamics (Sedlacek, 2013). In addition, also the long-term management of networks urges special attention, as networks often have no permanent character, but are project related (Sedlacek, 2013).

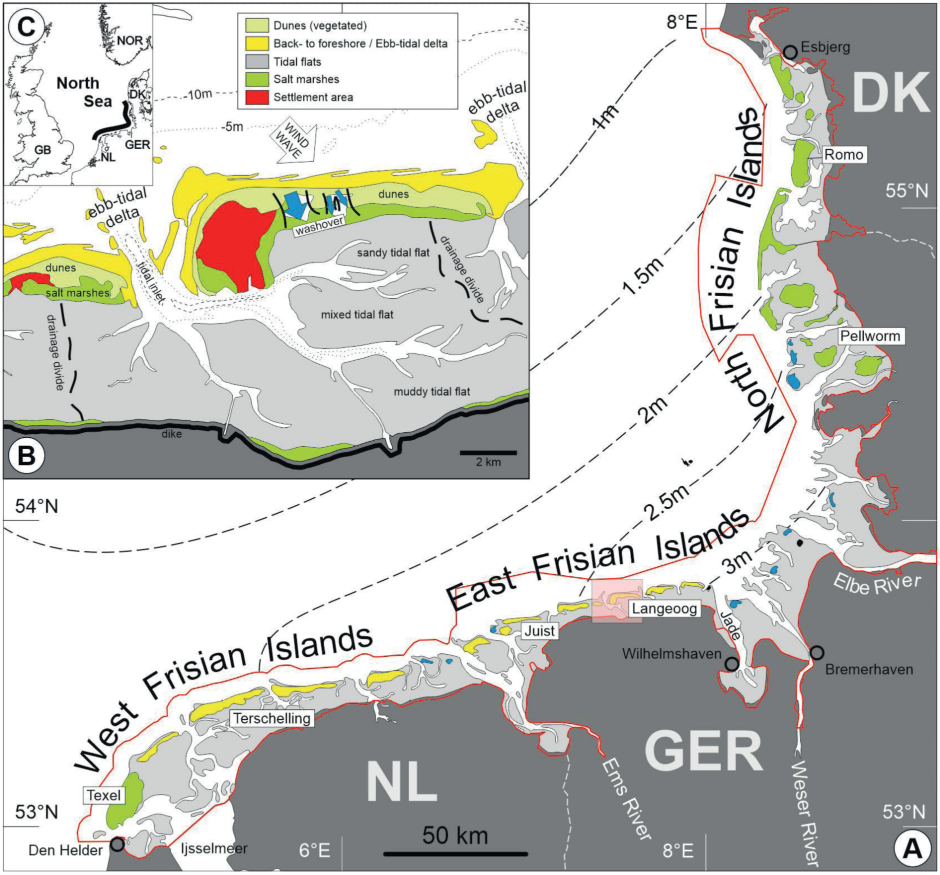
6.4. RESULTS FROM THE CASE ANALYSIS

6.4.1. Introducing the RELEEZE case

The RELEEZE case describes a science-driven transdisciplinary research project that aimed to develop a system perspective of sea level rise-induced changes in a tidal-driven coastal system. The acronym stands for 'RELease from coastal squEEZE', as one of the main aims of the project was to understand and mitigate the process of coastal squeeze. Coastal squeeze is defined as a process where rising sea levels and other factors push the coastal habitats landward, while static margins between land and sea (e.g. dikes) prevent upland migration and thus habitats become squeezed into a narrowing zone (Doody 2004, Pontee 2013).

Geographically, the RELEEZE case was located in the German, East Frisian part of the North European Wadden Sea (EFWS). As a UNESCO World Heritage Site, the Wadden

Figure 6.1
(A) The RELEEZE study was situated at the East Frisian Coast which is part of the trilateral Wadden Sea National Park (red line) ranging from Den Helder in The Netherlands to Esbjerg in Denmark. Most prominent environmental factor are the tides whose range increase from 1.5 m to more than 3.5 m towards the innermost part of the German Bight. Beside the tidal flats (grey) which emerge during lowtide the chain of barrier islands (yellow), geest/marsh islands (green) and highly dynamic sand bank islands (blue) protect the coastal region from strong storm surges. (B) Principle morpho-ecological units of a barrier island and its related tidal basin in the EFWS (for lokation see pink box in (A). Modified after Wehrmann et al. 2014, Wehrmann 2016).



Sea represents the world's biggest tidal flat system and provides a high diversity of coastal habitats and dependent species. Its crucial role of biodiversity provision on a global scale has been internationally acknowledged (WSWH, 2020). The EFWS is part of the UNESCO World Heritage Site and characterised by highly dynamic sedimentary, morpho- and hydrodynamic processes (see Figure 6.1).

It forms part of the southern boundary of the German Bight and is sheltered by a chain of barrier islands, bounded to the mainland by a coherent dike line. It is a mesotidal, mixed energy coastal system (e.g., Davis and FitzGerald, 2004; Hayes, 1979) with semi-diurnal tides ranging from 2.3 m in the west to 3.0 m at its eastern margin. Overall this area is characterized by a shore parallel zonation of sediment belts (Flemming and Ziegler, 1996) with grainsizes decreasing towards the mainland following the decreasing shore normal energy gradient (Antia et al., 1994; Hertweck et al., 2005; Mai and Bartholomä, 2000) with coarse sand (>350 µm) in the inlet gorges and ebb-tidal deltas and very fine sand (88-125 µm) and a local mud content of >30% at the intertidal flats adjacent to the dike (Flemming and Nyandwi, 1994).

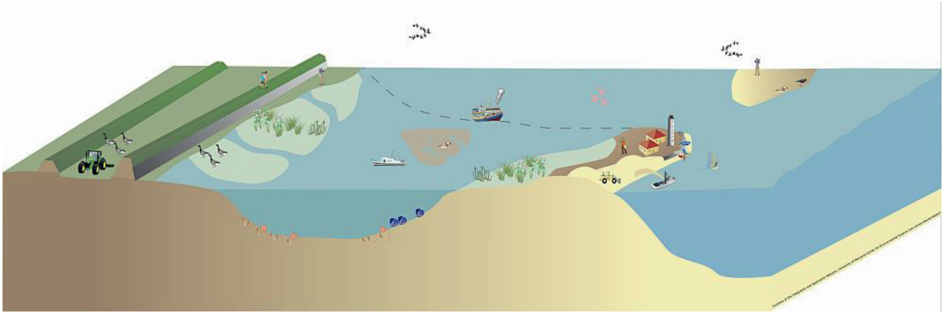
Coastal squeeze can induce a critical tipping point within that system. Man-made fixation of the coastline by dikes on the mainland and maintained dunes on the islands as well as accelerated sea level rise (SLR) interfere with the dynamic equilibrium of the EFWS (Oost et al. 2012) and change the hydro- and morphodynamic regimes (Cheng and Wilson 2008, Mai and Bartholomä 2000). As a consequence, the sediment budget will no longer be balanced, and SLR might exceed sedimentation-driven surface elevation change. The fixed system boundaries prevent natural lateral shifts in ecosystems of the EFWS. The collapse of salt marshes and dunes leading to the loss of the unique flora and fauna of the Wadden Sea might be the consequence. To create awareness and joint understanding of this problem and to eventually develop pathways for solutions a TKM process was initiated under the umbrella of the RELEEZE project, bringing together relevant scientific and societal actors and expertise.

6.4.2. The process of TKM in RELEEZE

TKM within the RELEEZE project was envisioned as a group learning process emerging across diverse scientific disciplines and a representation of local stakeholders. Scientific disciplines included landscape ecology and environmental systems analysis, ecological economics, political science and public administration, coastal engineering, coastal geology, marine sedimentology, ecohydrological modelling, and architecture and urban planning. Local stakeholders included representatives of agriculture, diverse coastal protection organisations, a national park administration, representatives of municipalities, the county administration as well as an overarching regional stakeholder representation board.

Communication pathways were established within the scientific consortium to provide the foundation for appreciation of the respective expertise and to enable high quality knowledge exchange. Exchange and integration of knowledge with local stakeholders was organized in parallel knowledge generation sessions. This was done as the RELEEZE project had a time frame of six month for engagement and integration of local stakeholders. This time frame was deemed too short to develop a commonly joint TKM process. Instead, face-to-face interviews have been used to speed up the process of data collection and generation on the side of the societal stakeholders (see the methods section for further detail). The so generated knowledge was integrated with scientific state-of-the-art in the form of a system map. Figure 6.2 beneath shows a simplified version of this map. It can be divided into three different geographical areas, which bundle different user groups. These are the land behind the first dyke line (left side of the Figure), the Wadden area (middle of the Figure) and the barrier islands (right side of the Figure). The system components and processes that are most relevant for RELEEZE were emphasised by pictograms (e.g. agricultural use, shipping routes, bird feeding areas).

Figure 6.2
Simplified version of the system map used to visualize integration of scientifc and societal knowledge



Courtesy of the Integration and Application Network, University of Maryland Center for Environmental Science (ian.umces.edu/symbols/)

6.4.3. Evaluation of the RELEEZE case: elaborations and novel contributions to the field of TKM

TKM process perception by involved project partners

For the communication between scientists and local stakeholders it was important that an open dialogue was organized in a transparent, trusted and non-bureaucratic way (R1, R2, R3, R4, R5, R6, R7, R8). Trust however is not a given and needs to grow in processes of deliberation and communication. Especially after the workshop some stakeholders felt distrust concerning a scientific bias of the project. Accordingly, an additional stakeholder meeting was organized as to discuss the experienced problems and to provide full transparency about the way the scientific consortium has been working. Establishing trust among all participants was most essential for the success of the RELEEZE project, as the TKM process itself is not facilitated by legal provisions (R1, R2, R3) or other supportive organizational structures (R5, R6, R8). Hence all participation required volunteering commitment. For some participants it was also important to accommodate the emotional and affective drivers of the knowledge creation processes (R1, R2, R4, R6, R7).

Scientific participants experienced the knowledge creation process as such being quite dynamic. Some experienced the process as cyclical, iterative and participative (R1, R2, R3, R6, R7, R8), others regarded it more as a step-by-step process (R4, R5). Cooperation and loyalty have been mentioned as important drivers to make this group process work (R5). Also continuous learning was a necessity (R1, R2, R3, R4, R5, R6, R7, R8), ranging from learning about each other's disciplines, scientific concepts and stakeholder views to learning about organisational practices. One participant perceived this dynamic as explicitly productive, as new lines of thinking could be produced and the discussion was open to new directions (R3). Accordingly, the direction of the entire process was difficult to predict (R1, R2, R3, R4, R6). Self-directedness and tutorship was mostly perceived as a necessary mechanism in the knowledge generation process (R1, R2, R4, R7), though it was not necessarily perceived as a main mechanism of learning.

Tutorship of the group was associated with the need to propose also uncomfortable questions, as those dismantle knowledge integration problems to bring the knowledge generation and integration process forward (R6). The creation of an overarching system map facilitated one of those TKM moments that emerged consciously and in a step-wise manner (R1). As such TKM was helpful to start up and structure the modelling process within the scientific consortium (R2, R5, R7). A delivery matrix was used to discuss issues like data needs and which parameters would define the model. In this matrix each scientific discipline could pose questions and demands about specific data or requests addressed to other members of the consortium.

Furthermore, TKM resulted into the identification of potential user conflicts in the project area. Although the initial project period was too short to fully explore and work on potential solutions for conflicts (R1, R3, R5), it was important to see that TKM helped to identify potential conflicts (R1, R8) and to make them discussable. In particular the description of system dynamics neutralised potentially conflicting system user perspectives. For instance, conflicting interests of e.g. grassland for grazing geese competing with agricultural interests turned out to gain a common dimension in the light of climate change, as rising sea levels might induce a substantial reduction of feeding areas for birds in the project region, irrespective of whether those are grassland, wetland or tidal flat areas. Although this description did not solve the essence of the conflict, which lies in the conflicting land use interests, it established a common ground for discussion about future developments of the area. As such TKM proved its' consensus-building potential (R1, R2, R4, R7) even though generation of new conflicts might accompany this process (R6). "Expliciting the problems, challeng[e] s and potential responses does not mean that different stakeholders will necessarily agree on solutions. They may come to very diverse evaluations, may have believes or different interests, depending on the exposure to the problem." (R8).

Table 6.3

Summary of the case analysis: Transdisciplinary Knowledge Management in the RELEEZE project

TKM described in the literature	TKM perceived by participants of the RELEEZE project
1. What does a TKM process look like?	
- a group learning process	- ✓
- requiring complex human skills	- ✓ important to be open minded for different viewpoints, mindsets and evaluation schemes
- it is about learning how to learn	- more important to learn content-wise from each other about systems functioning and how the dynamics described by different disciplines interrelate and (potentially) effect each
- non-routine type of working	- ✓ being confronted with diverging societal interests; to handle ones own lack of knowledge; taking over representation and argumentation for other disciplines involved
- needs to be organized as a conscious, step-wise process	- ✓ in particular important to enable interest integration
- cyclical, iterative, participative	- sometimes less cyclical and iterative but more chaotic and non-linear development
- open dialogue, transparent, trusted, non-bureaucratic	- ✓ trust-building activities important during the process
- sequentially structured, but also emotional, creative and difficult to predict	- ✓
- in essence self-directed, but tutored where necessary to prevent isolation of individuals or group-harming behaviour	- willingness to cooperate and group loyalty also important drivers - tutorship also entails to propose the uncomfortable questions
- needs to be accompanied by boundary work when actors are in conflict	- ✓ system map worked well to identify boundaries and make them discussable
- ideally explicitly facilitated by law and organizational structure	- lack of facilitation by law or organizational structure makes voluntary commitment essential
2. Who is the key actor to convey TKM?	
- not one key actor, but a group process	- ✓
- pre-defined actor roles effectuate the group process	- pre-defined actor roles can also harm the process by taking out it's dynamic; definition of actor roles also depends on personal character and scientific expertise needed - pre-defined actor roles in particular relevant for the integration of scientific and lay knowledge
- universities most suitable actors to initiate and facilitate TKM	- research institutes or large governmental bodies also suited
- explicit organizational embedding e.g. through Centres of Expertise helping to effectuate the role of universities	- explicit support from the organizational level of University missing

3. What is the role of networks?	
- TKM can be a tool to build up new networks	- ✓
- TKM as a means to manage existing network	- also important to establish links between existing networks
- TKM might also use networks to manage	- ✓
- networks are important organizational entities to link actors	- ✓
- networks need continuous negotiation to make them work	- already existing networks can also operate smoothly without negotiation; interest in participation needs to be a given to make negotiation work

The scientific participants of the TKM process perceived the learning experience of 'learn-how-to-learn' as such not being different to the type of learning required for non-TKM projects (R2, R3, R4, R5, R7). Still it did require complex skills, as it is was important to be open minded for (R2, R3, R7) and curious about (R8) different viewpoints and mindsets as well as evaluation schemes (R2, R5) and to be willing to exchange knowledge (R7). Participants also found it important to learn content-wise from each other about systems functioning and how the dynamics described by different disciplines interrelate and (potentially) affect each other (R2, R3, R4, R5, R7, R8). In that dynamic, one participant observed that it was important to take "nothing for granted and [being willing] to explain one own's disciplines basics." (R1). Also it is important to accept that other disciplines work in different ways and to schedule more time for the development of definitions (R3) and to learn how a transdisciplinary project can be organized and structured (R6). A special learning curve was experienced between the natural and social scientific approaches (R5, R7). Field trips and group meetings (R7) as well as visualization techniques (R8) have been named as a most effective manner of facilitating this part of the group learning process.

The integration of different scientific disciplines for the development of the common system perspective was also experienced as a momentum of changing work routines (R5, R6, R7). For that part it was important to speak to the other disciplines involved (R8), to admit one's own lack of knowledge about parts of the system's functioning if apparent (R1) and to take over representation and argumentation for other disciplines involved when needed (R1, R7). Personal comfort zones were in particular challenged when it came to confrontation with diverging societal interests (R2) and when breaking "down the complexity of the project to one descriptor and to make sure that the common thread [of climate change] is visible in each work package."(R5).

Key actor perceptions of involved project partners

The RELEEZE case is representative for the statement that universities (as well as research institutes) are key actors to initiate TKM (R2, R6, R8), but that the learning process in the end is a group process, which needs to integrate regional interests as well. The specific institutional embedding of TKM therefore seems to be less relevant, as it is more about someone who is actually trying to initiate and to devote time and facilitation (R5). For the initiating organization or person it is important to know about the relevant players in the field and related difficulties, irrespective of whether based at a university, a research institute or a lager governmental authority (R3, R5, R7). As R3 put it "I think it is more about the leading person and not at which institution this takes place. I would not distinguish between universities and research institutes and [...] the initiation could even arise from a ministry etc. The important thing is that the initiating institution knows the players of and difficulties at both sites".

Nevertheless RELEEZE project members experienced universities holding the advantage of being able to bring together different teams of scientists and stakeholders and provide a trustworthy environment for their interaction (R2). They can do so on in principle politically neutral ground funded by public money and not governed by economic interests (R8). As a disadvantage, universities however lack specified facilitation of TKM on the organizational level (R6, R7) what constitutes a critical restrictive factor (R2, R4). One project participant experienced the role of universities as rather neutral in that context as universities as such neither directly provide money for regional development nor have a mandate to take executive decisions (R1).

A division of actor roles has also been essential for the RELEEZE project (R3, R6, R7, R8) and was indeed applied and fulfilled in a non-rigid manner (R2, R4, R8). "Accepting the own role and accepting that others within the group have other roles helped to accept that positions and perceptions differ which caused an openmindedness and openness towards other people's contribution to the knowledge production process. This formed the basis for group learning." (R1). Pre-definition of actor roles was important to ensure that discussions would not become endless (R7). However some participants emphasized that the pre-definition of actor roles might have effectuated cooperation in a negative way, as this would take out the dynamic of the process (R5). Furthermore, it was mentioned that role definitions also depend on personal characters and need to be informed by disciplines involved in relation to what expertise a specific project urges (R8). As R8 put it "[...] even if I was a super dominant leader person, which I may be, I would anyway not be playing that role in the project, because my discipline is planning not geo ecology [...].".

Most important actor roles represented in the RELEEZE project group have been the mediator, the expert and the facilitator. The role of the facilitator was mainly executed by the project leaders. The project leaders were all scientists. They initiated the project and successfully accrued governmental project funds. The expert role was executed by scientists as well as stakeholders. Scientists acted as experts within their respective disciplines (R2, R5, R6, R7). Stakeholders brought in their own interests (R2), delivered relevant local knowledge and observations, provided access to available databases and professional expertise. To let theses process of knowledge generation evolve it was crucial to assign specified responsibilities to specified project participants (R1, R3, R7).

Mediation was essential to manage occurring deadlocks in the integration between scientific disciplines and between science and societal stakeholders. For the mediation process between science and stakeholders an independent mediation expert was contracted. This person acted as discussion facilitator during the joint workshop and was briefed by the information available from the face-to-face interviews and the digital speed date. The mediator was selected as an independent facilitator of the discussion. He had no prior background or institutionalized interest in the policy domain, but was experienced with integrative processes in other sectors. However, his lack of specialized knowledge about marine EBM also implied that mediation needed to be taken over by scientific as well as societal participants whenever detailed project knowledge was needed. Mediation roles within the scientific consortium were not explicitly specified, but taken over by different scientists whenever necessary and mostly depending on the content of the occurring deadlock at hand (R4).

A classical problem occurred in the knowledge integration process between scientific and societal stakeholders. Some scientists assumed that knowledge integration would appear in a top-down fashion. This attitude hindered the knowledge integration between both types of expertise as some of the societal stakeholders expected the process to emerge in an interactive fashion. Partly, this problem was caused by unclear role definitions. Although this lack of role definitions worked well to let participants taking over and functioning in different roles throughout the project, it apparently did not work well for the process of lay knowledge integration.

Network perceptions of involved project partners

The RELEEZE networks were experienced as important organisational entities to make the project work and to link actors. Project participants considered that all three types of network uses that have been described in the reviewed literature also played a role throughout the RELEEZE project (R1, R2, R4, R5). Accordingly, it was important to build up new networks as to connect required expertise (R7), to manage an existing network (R8) and to use networks as a tool to manage, in particular to link individual expert groups internally (R6, R7). One respondent summarized that in particular the use of networks as a tool to manage "[m]ade tasks easier [as] communications [were] less formal and directed." (R6).

Different to the literature discussion, the RELEEZE case exemplifies that alongside the need to build up new networks, it was also important to establish links between already existing networks (R1, R2, R7). Continuous negotiation was important to make available networks work and their integration possible (R1, R2, R4, R5). Some participants perceived continuous negotiation even as a central mechanism (R1, R2), while others however experienced the network working well without a lot of negotiation (R3), smoothly running by itself (R5). However, obviously continuous negotiation was not possible with those potential network members that had no interest in participation (R6).

6.5. DISCUSSION AND CONCLUSIONS

Discussion

Review of recent literature on TKM allowed for the identification of variables that define EBM knowledge governance as a process of human interaction. It provides valuable inputs for all those EBM scholars and practitioners having an interest to perceive, understand, study and improve EBM implementation in general and the human process of integrative EBM knowledge governance in particular.

Still it needs to be emphasized that the insights gained are limited to those experiences made by the scientific participants in the context of the RELEEZE case as well as the selected publications included to the systematic literature review. Both databases present very relevant, but also limited study material. The literature selection could be broadened by inclusion of data sources not included in ScienceDirect. The case experience could be compared across other cases. In future studies such additional data should be used to validate and eventually extend the identified number of variables.

Another limitation of this study was the time frame available to organize stakeholder integration. Within the one year overall project time only six months could be used to identify, analyse and integrate stakeholder knowledge. This time frame restricted the possibility to organize several rounds of knowledge sharing and generation. It also restricted the possibility to include scientific as well as societal project members to the ex-post reflection.

Conclusions

Systematic analysis of state-of-the-art literature makes clear that Transdisciplinary Knowledge Management for EBM, if understood as a process of human interaction, in essence describes a group learning process. This process implies a delicate responsibility for decision-makers as it comes along with contradictive elements, like the need to provide formal and transparent predictability in parallel to free space for emotionally driven creativity. Results of the ex-post reflection uncovered that the design of the group process furthermore needs to reckon upon personnel learning patterns and preferences of individual participants. Regular monitoring of individual participants' perception of process progress might therefore be a necessity for responsible decision-makers as to fully understand how participants perceive and perform throughout a TKM process. Attention towards personal learning preferences could also be facilitated through prior talks with actors before entering an EBM TKM process.

Traditional structured elements of a TKM process, such as the development of a system map are important tools to facilitate and effectuate the knowledge integration process. The RELEEZE case exemplified that such elements were in particular relevant to synthesize and integrate knowledge between scientific and societal experts and to mediate conflicts. Although this is not a novel finding (see for example the structured approaches developed by Espinosa-Romero et al., 2011 or Kragt el al., 2013), it shows that it might be necessary to perceive TKM in the context of EBM as a structured approach that might be sequenced or paralleled by more loosely coupled moments of knowledge creation. In this light, the deviating organizational approaches discussed by Serna (2015) and Le Theule and Fronda (2005) are not conflicting anymore, but become usable for describing and designing different parts of the same process. A structured knowledge generation process that is characterized by a clear process architecture could be comprehended by unstructured creativity sessions. This finding matches with the stakeholder triangle approach developed by Röckmann et al. (2015) who argue that for the organization of EBM it is not a necessity to include all stakeholders throughout the whole decision-making process.

The research findings furthermore suggest that although universities are not necessarily the only key actors that could and should conduct TKM, it is important to highlight their special position. More than up till now experienced within EBM scholarship, scientists could act as entrepreneurs, initiating new knowledge integration processes. Outsourced facilitative support as well as process design that draws on pre-defined, though not rigidly implemented actor roles prevent loss of scientific independence.

Strongly connected to the former arguments, is the necessity to put more focus on the role of networks. Networks have been mentioned frequently as important organisational entities facilitating TKM, in particular as being social constructs facilitating learning. Future research shall put more focus on the identification, functioning and construction of networks that use TKM to foster EBM implementation (Hastings et al., 2012). These findings comprehend the growing body of studies available on network governance and underline the importance of networks to make EBM implementation effective (see for example Smythe et al., 2014; Bodin et al., 2017).

The RELEEZE case evaluation furthermore revealed that next to the conscious management of existing networks and the need to build up new networks, it is also essential to know how to manage *in-between* different, already existing networks. This finding directly connects to the recent debate on nested governance structures that have been deemed essential for EBM to become implemented effectively in particular in the European Union (Raakjaer et al., 2014). The RELEEZE case shows that the development of "tiered, internally consistent and mutually re-enforcing planning and decision-making systems" (Raakjaer et al., 2014) comes along with knowledge integration across already existing, though fragmented knowledge networks. TKM is an important tool to assist this process.

Particularly relevant for TKM processes in the context of EBM finally is to realize that content-wise learning about system dynamics is crucial. The preamble 'learn-how-to-learn' is an important facilitating asset as well, but in itself not sufficient to make TKM in EBM contexts effective. Empowerment of inexperienced actors (see Bruckmeier and Larsen, 2008) might therefore be more essential for EBM approaches than has been discussed within the community so far. The legal or institutional support that was evaluated as an important, but missing factor in the RELEZE case, stresses that current EBM implementation heavily depends on voluntary commitment, willingness to cooperate and group loyalty.

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APPENDIX

Overview of literature review papers [knowledge management AND transdisciplinarity]

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Chapter 7

Discussion and conclusions

Ecosystem-based management (EBM) is conceived as a management philosophy that could be used to manage the complexity of socio-ecological systems. It emerged as a paradigm shift within the domain of environmental protection and resource management when the failure of reductionist approaches became apparent. The growing popularity of EBM is evidenced by the increasing number of locations in which it is being implemented, as well as in the rapid growth of the body of scientific publications.

Despite the popularity of EBM, the application of its principles is far from becoming a common routine. It would be more accurate to refer to the implementation of EBM as an ambitious and demanding organizational operation. In many cases, the intensity of knowledge associated with EBM, including high costs and the time-consuming requirements of data collection, monitoring and analysis, has been identified as a critically restricting factor, which can have a negative impact on the willingness and ability of decision-makers to apply EBM. By neglecting ecosystem structure and function, however, environmental managers run the risk of taking decisions that might lead to even higher costs in the long-term, potentially resulting in the deterioration of ecosystem health and high additional costs of restoration and reparation.

Understanding how successful decision-makers organize the process of knowledge generation and utilization for EBM is therefore an important, but surprisingly not widely employed research focus. The research journey on which this thesis is based has generated an in-depth understanding of the theoretical principles of EBM knowledge governance, in addition to highlighting the organizational approaches that have been developed by decision-makers in the process of implementing EBM. The project involved the exploration, description and evaluation of ways in which successful decision-makers have conducted knowledge governance. The comparison of different case studies enhanced insight into why the variety of knowledge governance approaches should be incorporated into the principles of EBM philosophy. The managerial toolbox available to EBM decision-makers is much broader than traditional EBM might suggest.

Section 7.1 provides a summary of the main research findings of this thesis, along with answers to the main research question and each of the sub-questions. The limitations of the research are discussed in Section 7.2, along with suggestions for future research that could address these limitations. Finally, Section 7.3 presents policy recommendations based on the main findings of this thesis, which are intended to provide important guidelines for EBM decision-makers in their attempts to organize future knowledge governance within the context of EBM. Taken together, these insights enhance existing understanding about the ways in which decision-makers perceive, argue and decide about EBM. It provides a theoretical foundation for modifying future applications of EBM in order to maximize the full potential of EBM knowledge governance.

7.1. CONCLUSIONS

The primary research topic of this thesis is summarized by the central research question: How can EBM knowledge governance be organized successfully? To investigate this question, several research ventures were developed, guided by four sub-questions. In this section, the answers to these sub-questions are presented. The section concludes with an overarching reflection and conclusion, thereby providing the answer to the main research question.

Sub-question 1. Which knowledge requirements does EBM philosophy impose on decision-makers?

The EBM philosophy envisions decision-making based on knowledge that captures socio-ecological complexity. As revealed by a consultation and review of key literature from the EBM community, combined with relevant social scientific literature, including the disciplines of public administration, environmental management and science and technology studies, the decision-making task can be broken down into three distinguishable, albeit partially overlapping dimensions. With regard to the first dimension, it is important to understand the structure and functioning of the ecological elements of the underlying system. The resulting knowledge requirements for decision-makers entail the accumulation of data, the use of real-life experiments and reflexive trial-and-error, interdisciplinary or multidisciplinary cooperation, long-term monitoring and assessment and recognition of differences in scale.

With regard to the second dimension, it is important to understand the values, interests and ways of knowing that typically define and trigger complexity within the social part of the system. The co-production of knowledge has been elaborated as an important means of approaching social complexity. Co-production is usually organized amongst experts, citizens, stakeholders and decision-makers by considering their diverse sources of knowledge, as well as their values and interests. Frame reflection and joint learning are required in order to effectuate the process of knowledge co-production.

With regard to the third dimension, EBM requires knowledge to be mobilized in an adaptive manner throughout the decision-making process. Given that complex systems tend to be characterized by non-linear developments and a high degree of uncertainty regarding system behaviour, it is important for knowledge to be organized continuously alongside decision-making, thereby enabling learning on system dynamics. To this end, interaction patterns between involved actors should be adaptive, flexible and customized. Interaction is inherently characterized by continuous feedback loops and long-term planning.

Sub-question 2. How do EBM decision-makers respond to knowledge requirements in practice, and how do they create common knowledge grounds in order to manage ecosystem-based adaptation?

Arriving at an answer to Sub-question 2 required investigating the behaviour of EBM decision-makers in practice. The use of case studies has proven most helpful for this purpose. First, a scoping study was conducted to identify a variety of cases reflecting the application of EBM in or in relation to the North European Wadden Sea. Cases were identified through desktop research and field trips into the 'Wadden Sea scene' by asking participants at conferences and meetings to identify complex yet successful EBM cases. The final selection of cases was deliberate, with the goal of reflecting complex decision-making processes, as characterized by multiple decision-making sectors, levels and actors, while maintaining an explicit ambition to implement EBM. To be included, the cases were also required to be identified as successful, in the sense that the decision-makers involved in them were able to achieve EBM goals. For example, in the Houting case, EBM success was defined according to the goal of restoring the Houting habitat in such a way that the species would be capable of surviving on its own. In the Mainport Rotterdam case, success was defined as having enabled a harbour expansion project while explicitly integrating the needs of environmental quality and ecosystem health.

In the second step, the cases were described through document analysis. For some of the selected cases, additional material was collected through interviews. This was important, in order to obtain detailed data on the behaviour of decision-makers when organizing knowledge governance for EBM. Taken together, the variety of cases identified, selected and analysed, reveal two main conclusions. First, the comparison of document-based cases revealed that decision-makers interpret the task of EBM knowledge governance in different ways. For example, while the seal case involved the development of a periodic management plan based on scientific data, the knowledge governance in the Houting case reflected the systematic alignment of a wide range of knowledge sources, including scientific, expert and lay advice.

Although most of the knowledge requirements derived from theory play an important role in practical implementation, not all of them seem to be necessary for success in knowledge governance. In all selected cases, the non-application of knowledge requirements was observed. For example, in the Mainport Rotterdam case, no experiments or reflexive trial-and-error processes were used throughout the project period examined. As revealed by the analysis of the cases, however, non-application of knowledge requirements did not appear to undermine the quality of knowledge governance.

The research results further indicate differences in the operational freedom that decision-makers have to interpret the task of EBM knowledge governance. The Mainport Rotterdam case qualified for an infrastructural project of national interest, thereby requiring an Environmental Impact Assessment (EIA). It was only after the EIA failed to achieve effective EKG that the decision-makers developed a different approach to knowledge governance, facilitated through joint fact-finding. In the Houting case, although the possibility of applying an EIA procedure was considered, the decision-makers deemed it redundant. Accordingly, the decision-makers in the Houting case had more operational freedom in organizing the decision-making process than did the decision-makers in the Mainport Rotterdam case. This dynamic indicates that, in practice, the theoretical knowledge requirements implied by EBM philosophy are at least partly dependent on context. The specific administrative-political contexts in which decision-makers operate thus play a decisive role in determining whether and how knowledge requirements should be assessed as compulsory or redundant.

Sub-question 3. Can the success of EBM knowledge governance be explained by the administrative-political contexts in which decision-makers operate and, if so, how?

Inspired by the findings elaborated under Sub-question 2, a qualitative case comparison was conducted in order to allow a more detailed investigation of the ways in which the administrative-political contexts of EBM decision-makers explain the relative success of knowledge governance. To this end, existing public administration theory was used to identify and define differences in administrative-political contexts. Based on this theory, the most suitable cases were selected from the available case-study material. This material was analysed through qualitative comparison to test whether and how differences in administrative-political context can be related to differences in the success of applied knowledge governance.

Analysis of the case material revealed four different types of knowledge governance: the database approach, the alignment approach, the assessment approach and the holistic approach. Briefly stated, the database approach describes a process of long-term, science-driven expert advice, as derived from the trilateral cooperation organized in the Wadden Sea for the management of seals. The alignment approach is illustrated by the approach to knowledge governance as applied in the Houting case, evolving as a systematic alignment of relevant and highly diverse types of knowledge sources. The assessment and holistic approaches were both applied in the Mainport Rotterdam case. The assessment approach assumes integrated, short-term expert advice aimed at taking a specific decision. The holistic approach is characterized by long-term interaction between decision-makers and knowledge sources, thereby facilitating and integrating joint reflection on frames.

The relative success of each of the four approaches to knowledge governance was evaluated separately, in relation to four different types of context. Differences in context were defined by either a low or high level of conflict, combined with either low or high knowledge availability. The results of this case comparison indicate that the relative success of knowledge governance is indeed related to both, the level of conflict and the level of knowledge, that defines the operational context of decision-makers. As clearly demonstrated by the results, for decision-makers aiming to conduct an EBM-implementation process within a context of low knowledge availability, it is possible to align knowledge systematically within an evolving decision-making process, as long as the level of conflict is low. In contrast, assessment approaches are not successful in contexts of low knowledge availability and a high level of conflict. In such contexts, it is more advisable to develop holistic approaches to knowledge governance, with a focus on mechanisms of joint frame reflection. Such mechanisms are needed in order to specify diverging interests and values before available knowledge can be used as a decision-making tool.

At the same time, however, the holistic approach seems to be the most difficult for decision-makers to realize. None of the cases analysed reflects a fully developed holistic approach. Although the joint fact-finding that was developed to facilitate the holistic approach in the Mainport Rotterdam case worked well for purposes of establishing social legitimacy and producing a commonly accepted body of knowledge, it was not linked to the development of integrated bodies of knowledge measuring ecological complexity. This finding inspired the fourth sub-question, which directs a particular focus on the further refinement of the holistic approach, along with the mechanisms that enable its implementation.

Sub-question 4. How can transdisciplinary knowledge management assist decision-makers in their attempts to organize holistic EBM knowledge governance successfully?

Answering Sub-question 4 required returning to what is known about holistic knowledge governance in theory. To this end, the literature on transdisciplinarity and knowledge management were systematically reviewed to generate a profound theoretical understanding of the knowledge-integration process and to identify mechanisms that enable its implementation. The review revealed that, if organized in practice, a holistic approach to knowledge governance is defined as a participative group-learning process. In essence, this process is self-directed in order to enable individual learning, although it may require tutoring to prevent individual isolation or behaviour that is detrimental to the group. Pre-defined actor roles might therefore effectuate the group-learning process. For example, it might be important to assign a mediator in advance to assume conflict management if necessary. If this is likely to be perceived as detrimental to the dynamic of group interaction, however, it could be important to work without pre-defined actor roles.

In general, it can be concluded that the group-learning process can be organized in two different styles: a sequentially structured or a chaotic pattern. The sequentially structured pattern (e.g. as described in the maturity model developed by Serna, 2015) regards group interaction as a process of professionalizing the integration of knowledge. It starts with unexperienced actors reflecting on the process from within their disciplinary backgrounds. Through evaluation and re-organization it evolves towards an optimized level, characterized by a clear yet flexible process architecture for knowledge integration. In contrast, the chaotic style does not assume any clear process architecture, instead approaching group learning as being analogous to a jazz concert (Le Theule and Fronda, 2005). In this pattern, group learning occurs spontaneously throughout a process of continuous improvisation. Individual participants need to be skilled, but act in a process of inspiration based on their own feelings, colleagues, and the audience.

For both styles, it is difficult to predict the evolution of the process, as it is typically accompanied by a heavy load of emotions. It therefore requires complex skills of participants, who must engage in content-learning with each other, while also empathizing with various interests and being open to differing viewpoints, mindsets and evaluation schemes. These characteristics make both types of group learning particularly well suited for application in complex decision-making processes, which are inherently characterized by a high diversity of viewpoints, mindsets and evaluation schemes. The chaotic style of organization nevertheless seems more feasible for participants who are able to draw on past experiences of knowledge integration.

Participation in holistic governance processes urges participants to conduct non-routine types of working, e.g. due to the need to identify and describe knowledge gaps. The process typically emerges through open dialogue that is transparent, trusted and non-bureaucratic. It must be accompanied by boundary work when actors are in conflict, in addition to being organized as a conscious, systematic process particularly aimed at enabling the integration of interests. Universities have been identified as the most suitable actors for initiating and facilitating holistic governance approaches, although research institutes or larger governmental bodies might be suited as well. Networks play an important role in the realization of group-learning processes, as they play an essential role in linking actors. Transdisciplinary knowledge management can be used as a tool for building new networks, as well as for managing and linking existing networks or for using networks to manage the knowledge-integration process.

Main research question: How can EBM knowledge governance be organized successfully?

Knowledge requirements formulated within and derived from EBM philosophy and related disciplines define the task of knowledge governance that emerges alongside the need to capture both ecological and social complexity and to organize adaptive management. Investigation of the behaviour of decision-makers in the successful organization of EBM reveals that decision-makers apply a variety of approaches to achieve successful implementation of EBM knowledge governance. The analysis identified four different approaches: the database approach, the alignment approach, the assessment approach and the holistic approach.

The approaches differ in terms of the type of dominant actor setting the knowledge agenda, the frequency with which knowledge is uploaded and downloaded, the diversity of knowledge sources included and the manner in which learning is expected to emerge between decision-makers and knowledge sources. The alignment approach is characterized by a knowledge agenda driven by decision-makers, who literally align the most diverse of knowledge sources (including scientific, expert and lay) to the decision-making process. They typically upload knowledge requested as advice from knowledge sources at several steps during an ongoing decision-making process. In contrast, the database approach assumes a strong science-driven approach to decision-making, in which scientists download knowledge packages to decision-makers in a sequence of interaction moments. This approach is similar to the assessment approach, with the difference being that, in the assessment approach, it is the decision-maker who sets the knowledge agenda and requests knowledge sources to deliver a packaged knowledge base for the sake of taking a particular decision. Finally, and different from all other approaches, the holistic approach to knowledge governance is characterized by a high frequency of uploads and downloads between decision-makers and knowledge sources. In the holistic approach, neither the decision-maker nor the knowledge source takes a dominant position in the decision-making process. Instead, they attempt to balance each other. The knowledge sources that are included can be quite varied, and learning emerges through a continuous series of uploads and downloads.

The exploration, identification and description of these governance approaches help to fill an important knowledge gap in the EBM literature. To date, questions concerning whether and what type of knowledge governance approaches are applied by decision-makers in order to effectuate EBM have remained unclear. Qualitative comparison made it possible to unravel and describe the different organizational structures that characterize these approaches. The results clarified the organizational settings in which learning can occur.

Another novel result from the research is that the *a-priori*, theoretically derived knowledge requirements are important, but not necessarily compulsory elements of the defined approaches to knowledge governance. Success is more likely to be related to differences in the administrative-political contexts within which these approaches are applied. In particular, the level of conflict and the availability of knowledge together explain whether a particular governance approach has or has not been successful. In a context characterized by a high level of knowledge availability and a low level of conflict, it is possible to develop a strongly science-driven approach to EBM knowledge governance, using decision-making advice based on data. Low knowledge availability and low conflict combine to provide a fertile breeding ground for decision-makers seeking to develop a more experimental approach as described by the alignment approach. In contrast, assessment approaches are unlikely to work well in contexts characterized by high levels of societal conflict, as they are not suited to function as boundary mechanisms. In such contexts, holistic approaches are more likely to result in successful knowledge governance.

Although all of the various approaches to knowledge governance considered in the research have been applied successfully, it is important to stress that the full potential of EBM knowledge governance is not easily achieved in practice. Each of the cases reflected a need for further improvement. For example, as applied in the Houting case, the alignment approach worked well for organizing an effective decision-making process, but it fell short of achieving an overarching integration of the best knowledge available. This lack of integration hindered the development of deeper insight into the dynamics of the ecosystem. As a result, biologists were particularly sceptical about the long-term sustainability of some of the decisions taken during the process. The joint fact-finding applied in the Mainport Rotterdam case worked well to establish social legitimacy by streamlining conflicting knowledge. However it also did not work well for developing a knowledge base that could capture ecosystem dynamics.

The most recent developments within the field of transdisciplinary knowledge management provide important suggestions for redressing these shortcomings. The TKM literature has accrued essential knowledge concerning the ways in which integrated and legitimate knowledge can be created as a group-learning process. The study of such processes is relevant within that context, as EBM inherently emerges across multiple decision-making sectors, levels and actors. The TKM literature provides descriptions of competences that participating actors need, along with a variety of organizing styles and suggestions for individual actor roles and group compositions for effectuating group learning. This body of literature also highlights the particular role of networks as important organizational entities for drawing links between learning actors.

The TKM case studied throughout this thesis revealed a diversity of experiences with regard to the operation of group learning when applied within the context of EBM. These experiences are presented as novel contributions to the field. One point that can be distilled from them is that, for EBM, mutual content-based learning about the function and dynamics of systems is more important than the methodological understanding of how learning works. In practice, the EBM learning process is not structured as either maturing or chaotic, instead evolving in sequenced blocks of cyclical and iterative moments, interspersed with chaotic and non-linear ones. Willingness to cooperate and group loyalty are important drivers of the process, as the lack of legal embeddedness or institutionalized support makes voluntary commitment essential. The proposition that pre-defined actor roles can help to effectuate group learning was particularly confirmed with regard to the integration of scientific and lay knowledge. At the same time, however, the cases suggested that pre-defined actor roles could potentially harm the process by eliminating its creativity supporting dynamics. It became clear that the definition of actor roles depends on personal character of participating actors, and that it should depend on the specific expertise needed. The mentoring of group-learning processes entails addressing uncomfortable questions, in order to help individual participants reflect upon and break out of their own comfort zones. The traditional role of universities in the initiation and fostering of group-learning processes has been questioned for cases in which explicit university-level institutional support is lacking. Research institutes or large governmental bodies have been proposed as equivalent alternatives. With regard to the role of networks as essential organizational entities for effectuating TKM, the case material examined in this study reveals that, in addition to the necessity of managing networks, it is equally essential to establish links between existing networks. If they are operating smoothly without negotiation, existing networks do not necessarily need much management. As highlighted by the reported case evidence, however, interest in participation amongst the members of the group is required for the proper functioning of negotiation in networks.

Taken together, the findings of this thesis contribute to a more profound practically and theoretically informed understanding of the successful organization of knowledge governance within the context of EBM. The details concerning the description, explanation and evaluation combine to generate a body of knowledge that enhance the principles of EBM philosophy.

7.2. REFLECTIONS AND OUTLOOK

The conclusions formulated at the end of this thesis research should be considered in the light of several limitations. First, the need to generate detailed data for the case analysis came at the expense of the total number of EBM cases that could be included in the study, thereby restricting the general applicability of the results. Nevertheless, the cases were deliberately selected according to specific *a-priori* research criteria. This selection strategy makes it possible for other researchers or decision-makers to assess the similarity of their own operational contexts to those described for the cases examined in this study. Although the general applicability of the results might thus be limited to specified contexts, it is possible to specify the contexts to which they do apply.

A second limitation of the study is that the case selection relating to the Wadden Sea might be biased, due to the long tradition of EBM in the region. Given the availability of many initiatives and funding possibilities, the selected cases might reflect the most favourable conditions possible for the emergence of successful knowledge governance. For this reason, the results and conclusions of this study might prove neither helpful nor easily applicable for EBM in areas characterized by less favourable conditions. For example, decision-makers in geographical areas that are structurally dominated by economic development interests or in countries where the public-administration sector is confronted with problems like corruption or bankruptcy could be expected to face different challenges when attempting to implement EBM. Effective knowledge governance might not be of the highest priority in such contexts. To address this limitation of the research, future EBM studies should focus on the implementation of EBM in research areas outside the context of the Wadden Sea. Possible research routes could include, but should not be limited to contexts of developing countries, within which EBM is introduced as a novel approach to environmental resource management.

Studying EBM knowledge governance implies an understanding of the behaviour of decision-makers, as it occurs in emerging processes. Given that decision-making also entails elements of power, communication throughout or about a decision-making process can serve as a tool for increasing, decreasing or providing protection from power. The tension between using communication for research and the use of communication in the power play could easily compromise the reliability of research data. Throughout the research journey of this thesis, the combination of document analysis with semi-structured interviews to construct story lines that could be used to arrive at an *ex-post* reconstruction of the decision-making process has proven effective in preventing non-informative or unreliable communication. Key actors were invited to participate in interviews that provided space for personal and informal reflection on the decision-making process. The participants were explicitly requested to share their own perceptions of the process. Taken together, all of the individually reported and constructed narratives resulted in a detailed, yet overarching process narrative. Participants were also not reluctant to report group dynamics that caused problems during a given process. As a result, the reported narratives provide a rich and comprehensive base for analysing the various cases.

Furthermore it is important to emphasize that, throughout the research conducted for this thesis, it was not possible to arrive at an objective operationalization of ‘success’. A subjective indication of success was gained by asking internal participants and external actors whether particular projects had been successful. Selected cases qualified as having been successful in the realization of EBM knowledge governance if the project goals had been achieved. This selection method proved most helpful for identifying adequate EBM cases, coming into contact with key actors and generating interest for participation in the interviews, as well as for gaining access to important documents. At the same time, however, the selected cases do not reveal whether the projects were also successful in terms of the ecosystem. For example, at the time at which the Houting case study was conducted, it remained unclear whether the restoration means had been sufficient to ensure the sustainable resettlement of the Houting species. It will be up to future studies to determine the relative societal and ecological success of particular management practices with regard to the realization of the project goals. As indicated in the research conducted by Jensen et al. (2015 and 2017), the study of habitat requirements and migration patterns of the Houting species might highlight the need for managerial adaptations to the original project goals.

The Houting case also highlights a structural problem of EBM implementation that applies to all European marine and coastal areas. Although current European Union legislation supports the ecosystem approach, the actual measurement of ecosystem state is not operational. The measurement of ‘Good Environmental Status’ – as promoted by the Water Framework Directive (WFD, Article 2, Paragraph 21) (EC, 2000) and recently re-emphasized under the Marine Strategy Framework Directive (MSFD) (EC, 2017) – is still under development. An objective measurement that includes the long-term monitoring of ecosystem status would be an important asset for the evidence-based understanding of the success of EBM implementation in general, in addition to contributing to the specific understanding of knowledge governance. In the course of this thesis, the only way to evaluate whether knowledge governance had been successful in the realization of EBM implementation was by asking for the subjective evaluations of individual participants. No objective measure of ecosystem status was available for the cases that were studied. The development of transdisciplinary evaluation frameworks (see e.g. Borgström et al. 2015) or ecosystem measurement tools based on network modelling (see e.g. de la Vega et al., 2018) are promising approaches to addressing this knowledge gap. It will also be important to link such evaluation frameworks or network models to the measurement of economic systems, in order to enhance understanding of the complex functioning of specific socio-ecological systems (for an example, see Haraldsson et al., 2020).

7.3. RECOMMENDATIONS FOR THE ORGANIZATION OF KNOWLEDGE GOVERNANCE FOR FUTURE EBM CASES, BOTH IN GENERAL AND SPECIFIC TO THE WADDEN SEA REGION

7.3.1. Climate change as a trigger of complex system behaviour: The need for more holistic approaches

As indicated by the results of the current study, knowledge governance for purposes of EBM can be organized in a variety of ways. The daily EBM routines within the context of the Wadden Sea area are defined by classical modes of knowledge governance (characterized by scientists giving advice to decision-makers), as well as by more interactive modes, which envision scientists, decision-makers and other stakeholders as engaging in a process of mutual learning (see also the discussion on Mode 1 and Mode 2 science in e.g. Gibbons et al., 1994; Nowotny et al., 2001). These modes are implemented and combined throughout evolving decision-making processes, ultimately amounting to different types of governance approaches, as typified in terms of the assessment, alignment, database and holistic approach. Different modes seem to fit different research needs, and their effectiveness can be related to the operational contexts of decision-makers.

As suggested by the literature reviewed throughout this thesis, the holistic approach to knowledge governance is particularly likely to become more important to the EBM community in the future. Climate change and the global biodiversity crisis re-acknowledge and re-emphasize the importance of this approach in relation to the *raison d'être* of EBM. The application of holistic knowledge governance could generate understanding of systems and enhance the ability to understand and deal with complex systems (Hastings et al., 2012; Newton et al., 2012; Nguyen et al., 2016). At this point in the development of the discipline, however, the holistic approach is apparently applied only rarely.

As suggested by the literature reviewed in Chapter 6, the lack of application of the holistic approach to knowledge governance is largely attributable to institutional pressure. For example, scientific excellence continues to be achieved primarily in disciplinary communities (Vie, 2012) or, as formulated by Brewer (1999) in a call for greater interdisciplinarity, 'The world has problems, but universities have departments'. The case evidence discussed throughout this thesis suggests that this problem is also characteristic of the Wadden Sea area. Interdisciplinary, multidisciplinary and transdisciplinary cooperation is not easily achieved in emerging decision-making processes.

These findings imply that increasing the implementation of EBM in the future will require explicit institutional support for knowledge governance. For example, a centre of EBM science could be established for the Wadden Sea area. Such a centre could facilitate pure scientific as well as more co-productive forms of knowledge generation. In this regard, it will be important for scientific achievements to be accounted for in the curriculums of universities or research institutes, while being simultaneously embedded within the political-administrative decision-making system.

Case evidence further suggests that the effectiveness of such knowledge governance at the regional level will depend on its embeddedness in existing policies and programmes (Tötzer et al., 2011). Knowledge governance between scientists, decision-makers and stakeholders can become effective because the decision-making process already provides an opening for it. Such regional embeddedness could offer an effective solution for decision-makers who are seeking new knowledge-generation methods or specific knowledge input other than what has been available thus far.

7.3.2. Enabling EBM on a larger spatial and temporal scale: The need to specify the structure of decision-making

Although it was not the main research focus of this thesis, it was interesting to see throughout the research process that a lack of a clearly defined decision-making structure also seemed to cause problems in the Wadden Sea area. As such, the EBM approach in the Wadden Sea should be characterized as a fragmented and scattered movement. In many cases, the approach is manifested as partial nature protection or restoration, often in the short term and at a low scale (see also Olff, 2015). Decision-making structures are thus not necessarily institutionalized, but an emergent property within short-term and loosely coupled project organizations.

Case studies reporting on the implementation of successful EBM practices make repeated references to clear decision-making structures, in particular organizational links that have been established between the actors delivering system-knowledge updates and those mandated to take the decisions. For example, the EBM case involving the Elkhorn Slough estuary, as reported by Wasson et al. (2015) elaborates on a conceptual diagram that explicitly structured the decision-making process. The system consisted primarily of a strategic planning team (composed of decision-makers) and a science panel (which informed the decision-makers), along with the expert working groups and community stakeholders. The EBM developed by the Gulf of Mexico Alliance (GOMA) reports an explicit priority issue team (the ‘Ecosystem Integration and Assessment Priority Issue Team’) that emerged amongst Florida, Alabama, Mississippi, Louisiana and Texas after two intense hurricane seasons. This Alliance was supported by a federal workgroup coordinated by the US Environmental Protection Agency (EPA), the Department of Interior, and the National Oceanic and Atmospheric Administration (NOAA) (Carollo and Reed, 2010).

As particularly emphasized in the latter case, institutionalized decision-making structures are also beneficial to the generation of adaptive management. Crises typically introduce unexpected changes into systems. After a crisis, there is a need to generate sound and quick understanding of the changes that have occurred, in addition to being able to adapt existing policies quickly. It would therefore be advantageous for decision-making structures to be clearly established and well-functioning, while still allowing for the integration of new knowledge in a flexible and customized manner.

The case evidence elaborated throughout this thesis reflects similar results. Within the trilateral seal-management consortium, a scientific advisory committee was institutionalized to provide continuous knowledge updates to decision-makers. This decision-making structure was established when a virus infection threatened the entire seal population with extinction. In the Mainport Rotterdam case, decision-making became effective through the development and ratification of a decision-making structure that clearly defined how knowledge would be generated throughout the process, how stakeholders would be integrated and who would be mandated to take the actual decisions.

To enable EBM on a larger spatial and temporal scale, the case evidence reported in the EBM literature and throughout this thesis suggests a need to reconsider existing EBM decision-making structures within the context of the Wadden Sea. Centralization accompanied by institutionalized decision-making seems to be a necessity. The centralization of research agendas – as recently organized under the umbrella of the trilateral Wadden Sea Cooperation (CWSS, 2018) – is a promising step in this direction. Whether these measures will be sufficient for the further maturation of EBM implementation remains to be seen.

7.3.3. No evidence without power-free zones: The need to separate knowledge production from decision-making

In addition to clear decision-making structures that benefit EBM knowledge governance, a clear-cut separation between knowledge production and decision-making also seems to be a necessity. Separation means that the knowledge-generation process should not be used as a means of organizing pre-determined decisions or to legitimate particular choices. As a form of natural resource management, EBM must address issues of resource restrictions, which are manifested through the loss of single species or the collapse of entire ecosystems. To a certain extent, resource restrictions can be governed by political motives (e.g. values, beliefs or individual/group interests). The actual amount of 'existing' resources remains a limiting factor, however, as many resources are not endlessly available.

'Evidence' is needed to calculate and indicate resource limits. The creation of this evidence will require the facilitation of pure knowledge processes emerging within power-free zones.

Such zones are essential to enabling mutual learning between scientists, experts and other knowledge sources. As indicated by the literature reviewed in this thesis, effective knowledge governance can emerge if the actors involved have balanced their interests and hold equal power within the process (Bruckmeier and Larsen, 2008; Russel et al., 2008; Barth et al., 2014; Brink et al., 2016; Tötzer et al., 2011). As also discussed in greater detail in Chapter 6, mutual learning is essential to the establishment of systems perspectives for EBM. The organization of power-free zones is thus an important condition for the effectiveness of EBM knowledge governance.

This does not mean that EBM cannot benefit from the interactive modes of knowledge governance that provide close and frequent interaction between knowledge and power, thereby effectuating complex decision-making. As applied in the Mainport Rotterdam case, joint fact-finding worked well in the creation of knowledge reflecting social complexity, while simultaneously creating social legitimacy. As also became clear, however, one reason for the success of this process apparently had to do with the fact that decision-making power was centralized at the level of the responsible minister. The installation of power-free zones thus implies a need to pre-define interaction points between knowledge and decision-making, in order to prevent a lack of transparency and the emergence of distrust.

It is particularly interesting to note that EBM is often presented as a community approach (Meffe and Carrol, 1997 in Meffe et al., 2002: 70), based on consensus (Carollo and Reed, 2010) and characterized by collaborative decision-making (Wasson et al., 2015). As revealed by the diversity of decision-making patterns observed in the Wadden Sea, EBM decision-making can also be a matter of pushing for interest (see the Mainport Rotterdam case, as reported in Chapter 4) or of splitting up different interests (see the Houting case, as reported in Chapter 3). Accordingly, although collaboration can be an outcome of EBM, it is not necessarily a defining element of the concept. Where collaboration is not a given, it is important to create political legitimacy first.

7.3.4. Facilitating knowledge governance throughout various stages of maturity: The need to understand EBM as an emergent decision-making process

Finally, for future EBM cases in general, as well as specifically with regard to the organization of EBM within the context of the Wadden Sea, it will be important to assess the appropriateness of particular types of knowledge governance in relation to the actual maturity stage of EBM. The work of Tallis et al. (2010) and UNEP (2011) provide relevant conceptualizations to this end. These two studies conceptualize EBM as a phenomenon that can emerge in different evolutionary stages. Tallis et al. (2010) distinguish poorly developed and developed governance contexts in which EBM can be implemented through different means. In addition, UNEP (2011) describes phases of low, incremental and comprehensive EBM. Each of these descriptions is defined by a varying degree of available system knowledge and decision-making power.

This conceptualization implies two interesting ways to proceed for future EBM research. First, existing models, methods and tools are in need of further refinement in order to generate high-quality knowledge for those EBM approaches that are in or entering a maturing stage. Examples include the work aimed at fine-tuning the measurement of ecosystem health through the combination and operationalization of selected ecosystem indicators, as recently proposed by the OSPAR commission (Safi et al., 2019). Second, it will be important to develop a new focus on low and incremental forms of EBM. Understanding is needed from the perspectives of both decision-making and science with regard to the emergence of transition processes from low to poor, incremental and comprehensive EBM. This understanding must be linked to questions concerning whether and how the different types of knowledge governance can be useful for different stages of maturity. Such research avenues could further broaden, improve and innovate the toolbox of ecosystem-based decision-making. Most importantly, they could deliver important insights into whether and how knowledge governance can be used to further increase the implementation of EBM. They also summarize and emphasize the main message of this thesis: knowledge can enrich ecosystem-based management from two different angles, as either a package or a process.

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SUMMARY IN ENGLISH

The ecosystem-based management (EBM) paradigm was introduced as a renewal for traditional approaches to natural resource management. It emerged in the 1930s and 1940s, when fragmented and sectorial driven management of natural resources were resulting in resource depletion. To overcome the fallacies of established practices, EBM promoted the ecosystem as a focal entity of decision-making. It argued for the need to create a holistic understanding of natural systems utilized by humans, in order to achieve the adequate alignment between resource extraction and the carrying capacity of ecosystems. It would not be until the 1980s, however, that the approach would gain popularity. Since then, it has experienced remarkable growth, resulting in an increasing number of applications throughout the world.

Scientifically, the EBM approach continues to lack conceptual maturity. In particular, social scientific understanding is lacking, as the philosophy has been promoted and researched primarily by natural scientists. As a result, the conceptualization of the ecosystem approach within the context of policy implementation and organizational change has not attracted much research attention. The quest to base decision-making on holistic systems understanding has been interpreted largely according to the need to develop scientific system conceptualizations and instruction manuals for decision-makers. Studies focusing on the actual work that decision-makers do when creating and utilizing knowledge in the process of organizing EBM decision-making processes has not received any structural attention.

The lack of conceptualization is problematic, as current EBM philosophy has no tools with which to understand, study and eventually improve the dynamics of implementation. The improvement of these dynamics is nevertheless a pressing issue for mandated decision-makers, as it has become apparent that, despite the growing popularity of EBM, decision-makers continue to struggle – and often fail – to bring EBM ambitions into practice. The increased popularity of EBM has also resulted in efforts to apply EBM in unfavourable settings. Such settings are typically characterized by a lack of funding, the dominance of economic interests and fragmented decision-making levels, which do not necessarily assign legitimacy to ecological concerns.

In light of the issues outlined above, the main focus of this thesis is on creating a social scientific view on the ecosystem approach. Rooted in, but not solely informed by the social scientific disciplines of public administration and political science, the thesis takes on the decision-maker as an object of study. It advances the research interest of how mandated decision-makers take up and interpret their knowledge-governance tasks when implementing EBM. For this study, the art of knowledge governance has been identified as an important defining element of EBM as a special type of decision-making. It assumes that decision-makers regard knowledge as the most important tool in the process. Theoretically, therefore, the generation of new knowledge and the utilization of existing knowledge becomes an important means of organizing a decision-making process and, ultimately, taking 'ecologically correct' decisions.

In practice, the task of knowledge governance is accompanied by various complications, including high costs and the time-consuming requirements of data collection, monitoring and analysis. It has therefore been identified as a critically restricting factor, negatively affecting the willingness and capability of environmental managers to apply EBM. Although EBM nevertheless continues to be implemented successfully, issues of whether and how decision-makers are able to achieve success in the implementation of EBM remain unclear. The primary objective of this thesis is therefore to create a conceptual understanding of the ways in which decision-makers are able to achieve success in organizing knowledge governance for EBM. Accordingly, the central research question of this thesis is formulated as follows:

How can EBM knowledge governance be organized successfully?

To formulate an answer to this question, the research approach starts by developing a theoretical conceptualization of the knowledge requirements that the ecosystem-based management philosophy imposes on decision-makers. A literature review that selects and merges relevant literature from environmental management with specialized social scientific literature concerning the role of knowledge in decision-making, is used to formulate three main types of knowledge requirements faced by decision-makers. First, decision-makers must create and utilize knowledge that resembles the complex and volatile character of socio-ecological systems. Typical activities should focus on, but not be limited to long-term monitoring and assessment or the use of real-life experiments and reflexive trial-and-error. Second, they must consider the social complexity of their systems. Co-productive approaches to the generation and utilization of knowledge that can facilitate reflection and joint learning amongst actors have been identified as most fruitful ways to create knowledge that reflects the diverse values, interests and ways of knowing held by the various actors involved. Third, and finally, it is important for decision-makers to organize knowledge in an adaptive manner. Within this context, adaptive refers to the creation of knowledge that enables learning on ecosystem dynamics and that facilitates feedback loops for purposes of decision-making.

The literature review yielded a catalogue of principles that conceptualize and define the art of knowledge governance that mandated decision-makers are expected to practice when implementing EBM. This catalogue was used to describe and evaluate the knowledge-generation and knowledge-utilization activities employed by actual decision-makers when implementing EBM. For this analysis, several case studies were selected from the research area of the North European Wadden Sea. The world's largest tidal flat system, the North European Wadden Sea has received international recognition for its ecological value under the UNESCO World Heritage Programme. Given that the EBM paradigm has enjoyed legitimacy in this area for decades, the selected cases reflect decision-making practices that are highly relevant to the research of this thesis. The relatively large scale on which EBM has been implemented within the area provides material showcasing the difficulty of implementing EBM in decision-making settings that have typically been characterized by diverse and fragmented decision-making levels and actors.

Describing and evaluating decision-makers practice in successful cases from the North European Wadden Sea

Cases from the Wadden Sea region were selected by approaching decision-makers through participation in publicly organized meetings and conferences, as well as through direct contact by telephone or email. In-depth case studies were conducted for the two most representative cases of EBM implementation in complex settings. The first case focuses on a Danish river-restoration project that was initiated to restore the ecosystem of a nearly extinct fish species – the Houting – whose habitat encompasses part of the Wadden Sea area. The second case focuses on the latest extension of one of Europe's largest harbours, the Rotterdam Mainport. This extension (Maasvlakte 2), involves the seaward extension of the harbour area into the North Sea. It was planned to increase shipping access. The extension was directly connected to the Wadden Sea ecology, as the planned construction in the North Sea was accused of having a negative impact on the migration of fish larvae to the Wadden Sea.

In both cases, the generation of new knowledge and the utilization of existing knowledge played an important role for decision-makers when organizing the decision-making process. As revealed by an in-depth evaluation of decision-making practice, however, not all of the knowledge-governance principles derived from literature have proven relevant. One surprising result of the evaluation was that some principles were very important, while others were not and, in many cases, the non-application of particular principles was not deemed problematic to the quality of EBM decisions taken. More surprisingly, however, the decision-makers tended to apply different, yet constant patterns for the generation and utilization of knowledge. Four different types of governance approaches were distilled from the case material collected from the Wadden Sea area.

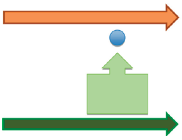
The choice for the decision-maker: Alignment, assessment, holism or database?

The four governance approaches have been designated as the 'alignment approach', the 'database approach', the 'assessment approach' and the 'holistic approach'. The alignment approach was identified from the Houting case. It is characterized by a process in which decision-makers link the most diverse and most segregated knowledge sources to a sequence of individual decisions. The database approach was derived from the seal-management practice in the Wadden Sea. It is characterized by a strong division between knowledge sources and decision-makers. Organized as an ongoing process of knowledge generation within a permanent group of scientists, it provides feedback to decision-makers at formally planned and annually reoccurring points in time. The assessment and the holistic approach were both derived from the Mainport Rotterdam case. The assessment approach describes EBM knowledge governance as being characterized by a one-time assessment of environmental impact of a planned project or activity. Finally, the holistic approach describes a very time-intensive approach to knowledge governance, characterized by frequent interaction between decision-makers and diverse knowledge sources, in order to enable joint frame reflection.

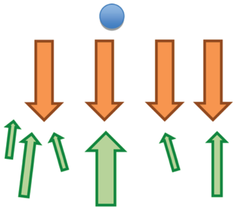
In terms of learning, the holistic approach could best be described as an evolving process of learning, in which decision-makers and knowledge providing actors enjoy similar legitimacy in setting the knowledge agenda. The alignment and assessment approaches are characterized by a knowledge agenda determined by decision-makers. Learning occurs in the form of download at the request of decision-makers. In contrast, the database approach is characterized by the upload of knowledge and a research agenda determined by scientists.

Description of these governance approaches corresponds to an important knowledge gap in the literature of EBM, as they unravel the types of organizational patterns through which EBM knowledge governance can be organized and the ways in which learning can emerge. To provide a quick overview of these main findings, Figure S.1 presents a visualization of the governance approaches, and Table S.1 summarizes the organizational patterns that characterize each knowledge-governance approach.

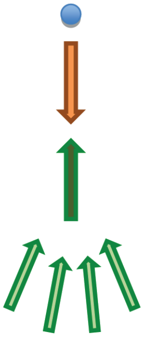
Figure S.1
Visualizaton of knowledge governance approaches



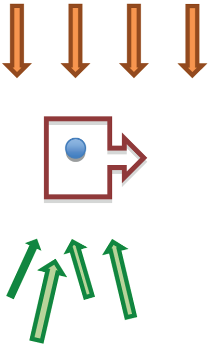
The Alignment approach
Decision-maker(s) (blue point) puts specified knowledge requests, separated times during the decision-making process (orange arrows) at separated knowledge sources (light green arrows). Orange and green arrows point to each other, visualizing that an upload from knowledge to decision-making occurs.



The Database approach
Decision-maker(s) (blue point) operating in an evolving decision-making process (orange arrow) gets knowledge downloaded in an a-priori organized arrangement (light green arrow). That knowledge is generated from a knowledge system (dark green arrow), which is independently developing



The Assessment approach
Decision-maker(s) (blue point) puts specified knowledge request, once during the decision-making process (orange arrow) at knowledge system (dark green arrow). Knowledge upload integrally produced based on different knowledge sources (light green arrows). Orange and dark green arrow point to each other, visualizing that an upload from knowledge to decision-making occurs.



The Holistic approach
Decision-maker(s) (blue point) work together closely (non-filled red arrow) with knowledge sources (light green arrows). Up and downloads occur frequently. Types of knowledge sources are diverse. Although separate decisions occur (orange arrows) those evolve in continuous interaction with similar knowledge sources.

Table S.1
Differences in organizational patterns characterizing each knowledge governance approach

Knowledge governance applied	Dominant actor to set the knowledge agenda	Frequency of up/ downloads	Types of knowledge sources used	How learning among decision-makers and knowledge sources is expected to emerge
Database approach	Knowledge sources	Low (fixed download arrangements made)	Science	Download (knowledge packaged and presented to decision- makers)
Alignment approach	Decision- makers	Medium (several times during a process)	Mixture of scientific, expert and lay knowledge	Upload (decision-makers ask knowledge sources to deliver advice)
Assessment approach	Decision-makers	Low (beginning of a process only)	Science	Upload (decision-makers ask knowledge sources to deliver advice)
Holistic approach	Decision-makers and knowledge sources balancing each other	High (due to continuous debate)	Mixture (high diversity of knowledge sources)	Continuous up-and downloads

To gain a deeper understanding about whether and how each governance approach was successful, a qualitative comparison was conducted across the cases studied. The comparison indicates that, although all of the approaches have resulted in successful decision-making for EBM, the most suitable approach for a given application depends on the operational context of the decision-maker. The level of conflict and the availability of knowledge emerged as particularly important variables explaining which governance approach should be applied in which context. The alignment approach works well in contexts characterized by low levels of conflict and knowledge, while the database approach is most suitable for situations characterized by low levels of conflict and high availability of knowledge. Contexts characterized by high levels of conflict typically benefit from either the assessment or the holistic approach. The assessment approach is apparently most fruitful if a large volume of knowledge is already available, while the holistic approach works well at low levels of knowledge availability.

The results of the in-depth case studies further reveal that, although generally perceived as successful, the knowledge-governance approaches that have been applied have failed to achieve the full potential of EBM knowledge governance. In the Mainport case, the application of a joint fact-finding approach worked well to accommodate conflict, but did not result in an overarching knowledge integration that would assess ecosystem dynamics. Similar, in the Houting case, the lack of an overarching ecosystem evaluation resulted in several decisions that failed to integrate ecological concerns. The final chapter of this thesis therefore zooms in on the successful implementation of the holistic type of knowledge governance, which is deemed the most fruitful in realizing the full potential of EBM knowledge governance. In line with that aim a participative case study was used by the author of this thesis to set up, design and evaluate the holistic approach to EBM knowledge governance.

Effectuating the holistic approach: How to manage networks, transparency and emotion at the same time

Literature specialized on transdisciplinary knowledge management (TKM) was used to develop an evaluation scheme for understanding, studying and evaluating holistic knowledge governance. Based on the literature that was reviewed, TKM was identified as a delicate task for mandated decision-makers, as it entails a group-learning process characterized by contradictory elements. It must be organized in a predictable and transparent manner, while also evolving in an unpredictable and unstructured manner, thereby supporting creativity.

The results of the case study indicate that holistic knowledge governance is most fruitfully organized through a process architecture that combines classic structured elements of knowledge integration with the use of non-structured knowledge generation. For example, the co-production of system maps that reflect socio-ecological complexity could be organized parallel to informal meetings. Throughout the entire process, it is important to consider individual learning patterns and preferences, as well as to monitor the perceptions of participants about process development. Network management plays an important role in effectuating holistic knowledge governance for EBM. The management of existing networks, the creation of new networks and management between existing networks are all necessary to the effectuation of holistic knowledge governance.

Towards the end: Successful EBM knowledge governance uncovered

In the final part of this thesis, four recommendations are formulated to foster and support future EBM implementation. The first recommendation argues that meeting the challenges of climate change and the global biodiversity crisis will require increasing the implementation of the holistic type of knowledge governance. This type is particularly suited to enhance the creation of understanding and management of complex systems behaviour that is likely to emerge more often. To facilitate holistic knowledge governance, it is important to design a clear process architecture for EBM decision-making within the context of the Wadden Sea. The architecture should explicitly specify when and how knowledge is generated and utilized during a decision-making process and identify the mandated decision-makers. The *ad-hoc* structure that characterizes the current administrative-political landscape of the Wadden Sea comes at the expense of decision-making quality. Available knowledge is scattered and difficult to utilize. Although the centralization of EBM knowledge is organized through individual research projects, long-term institutional embeddedness is lacking. As a result, individual research efforts and results are likely to get lost, as learning is restricted to social learning, in which actors learn from each other. It will be important to facilitate institutional learning in order to construct a heritage of knowledge. Institutional forms like the Common Wadden Sea Secretariat and National Parks might be suitable organizational entities with which to realize institutional learning.

Clear institutional embeddedness is also important to the realization of the second recommendation, which is to ensure that any type of EBM knowledge governance should be characterized by an explicit organisational link between knowledge sources and decision-makers. As suggested by the case evidence generated and studied throughout this thesis, such institutional embeddedness is necessary in order to effectuate the knowledge-governance process. It can be facilitated through a variety of organizational entities (e.g. a science panel or an Ecosystem Integration and Assessment Priority Issue Team).

The third recommendation is to structure institutional embeddedness in such a way that knowledge generation is separated from the actual decision-making moment. In current EBM practice, it is too easy to use (or abuse) knowledge as a means of power, given that knowledge is typically carried by individual actors participating in a decision-making process. Whenever EBM knowledge is explicitly requested for decision-making, it should be clear who is to take the final decision in that process and how and when knowledge will be utilized. The separation between knowledge and decision helps to create power-free zones, which are necessary in order to establish evidence or, if knowledge is too uncertain, conjunctions of evidence. Such evidence is urgently needed, in order to build a body of knowledge that adequately reflects ecosystem states and resource limitations.

Finally, it will be important to differentiate current EBM practices within the context of the Wadden Sea according to level of maturity. While EBM seems to be in the early phases in some places, it has already been implemented for years at others. This implies that EBM decision-making will require further refinement of the available knowledge in more mature settings, while knowledge generation accompanied by conflict resolution will be of greater value in settings that reflect low or incremental types of EBM.

The recommendations also provide suggestions for future research avenues, needed to further improve our theoretically and practically informed understanding of knowledge governance within the context of EBM. Improvement of this understanding will be crucial as to assure EBM implementation will increase in terms of both, quantity and quality.

ABOUT THE AUTHOR

Originating from Germany, Diana Giebels moved to the Netherlands in 2003 to study Political Science at the University of Amsterdam and Leiden (cum laude). During her study she started to focus on sustainable development, environmental policy and policy implementation. After obtaining her master's degree she worked as a research assistant at the University of Amsterdam/ Amsterdam Medical Centre for a project promoting sustainable development on the municipal level. In 2011 she started her PhD at the department of Public Administration at the Erasmus University Rotterdam.

Her thesis focuses on the implementation of ecosystem-based management in European marine waters. Main research area was the North European Wadden Sea, including the adjacent countries of Denmark, Germany and the Netherlands. Her research specialized in the role of knowledge in ecosystem-based decision-making. Her particular interest was to understand whether and how knowledge governance improves implementation of ecosystem-based management.

During her PhD research Diana also assisted in teaching. She was involved as a tutor at the Bachelor programme of Public Administration at the Erasmus University and designed a teaching module for Master students at the Alfred-Wegener Institute in Germany under the umbrella of the Partnership for Observation of the Global Ocean. In 2017 and 2018 she also worked as a researcher in Germany, at the Ecological Economics department of the University of Oldenburg. In her project she got the opportunity to design and execute an ecosystem-based knowledge governance process from scratch.

With the beginning of 2019, Diana continues her work on ecosystem-based management, now focussing on land use. She does so as a researcher at the department of Landscape Architecture and Spatial Planning of the University of Wageningen. With an interdisciplinary team she develops an agent-based model to understand and evaluate ecosystem-based land use. Particular aim of this model is to understand the effect of farmers (not) taking decisions to improve soil ecology.