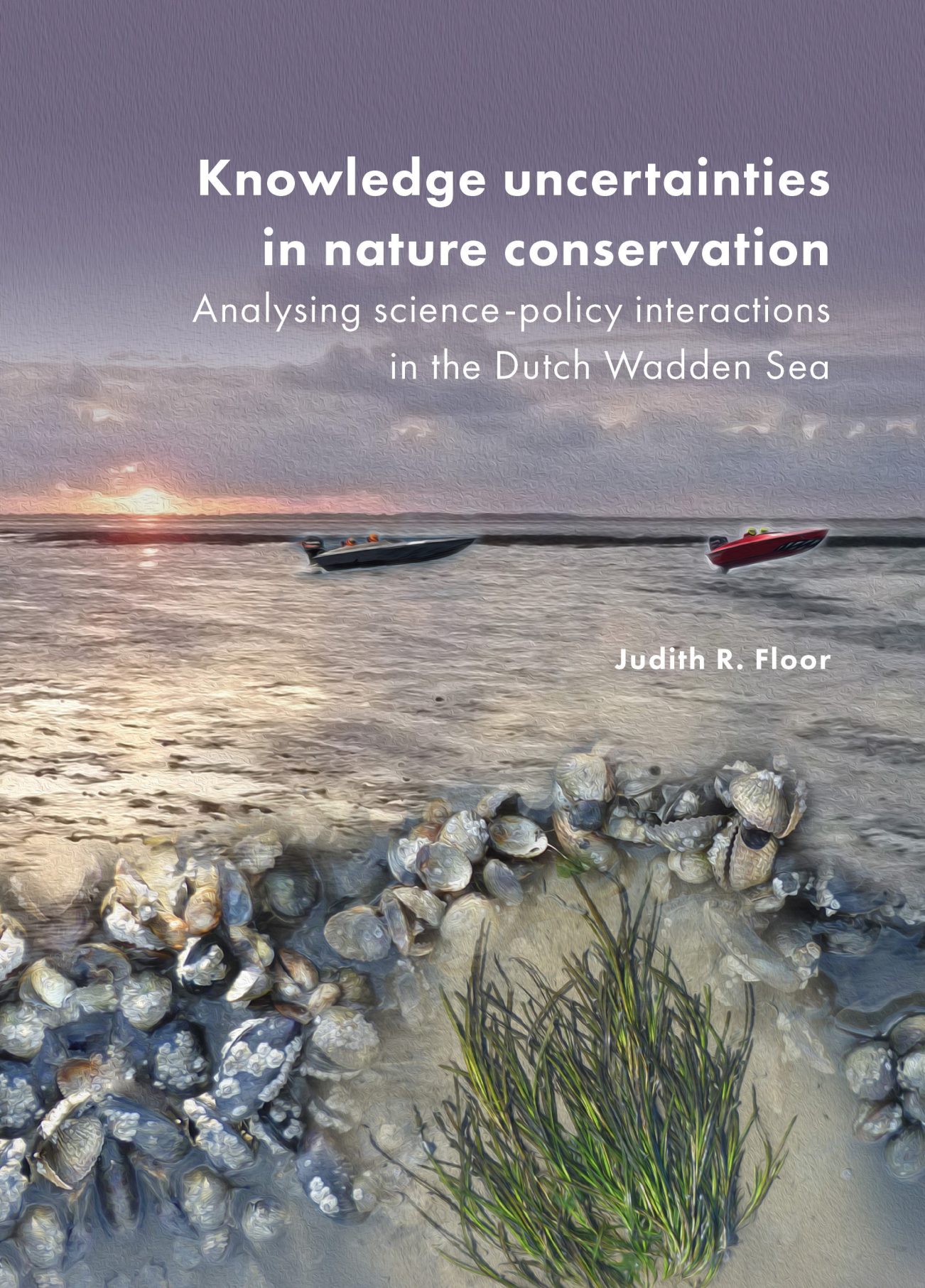
Knowledge uncertainties in nature conservation

Analysing science-policy interactions in the Dutch Wadden Sea



Judith R. Floor

Propositions

1. Knowledge uncertainties do not undermine but amplify the role of scientific knowledge and science-based experts in the governance of nature conservation. (this thesis)

2. The myth that more knowledge gives better regulation decisions is a threat for nature conservation. (this thesis)

3. Whereas in quantum mechanics unpredictability of a position disappears by observation, the unpredictability of effects from economic activities on nature areas is not reduced by monitoring.

4. Climate change is not a tragedy of the commons problem.

5. With the introduction of English as the only language in the BSc-programs at Dutch universities the Dutch context-specific content will get lost.

6. Home-made cake is a crucial commodity in social relations.

7. A PhD thesis based on articles is just the tip of the iceberg, most insights are not turned into explicit knowledge.

Propositions belonging to the PhD thesis, entitled 'Knowledge uncertainties in nature conservation - Analysing science-policy interactions in the Dutch Wadden Sea'

Judith R. Floor

Wageningen, 13 April 2018

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Judith R. Floor

Thesis

Submitted in fulfilment of the requirement for the degree of doctor
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Chapter 1

Introduction


1

1.1 Nature protection of coastal areas

Coastal areas are important not only as natural areas but also as economic hotspots. Most of the human population lives in coastal areas, where they conduct a large number of economic activities, including fishery and fossil fuel exploitation. This human pressure on coastal areas results in resource overexploitation and habitat loss. Simultaneously, there are legal protections and management policies that recognize the natural values of coastal areas all over the world. This combination of economic use and nature protection is a major challenge for the conservation of coastal areas. Legal protection is not always sufficient to prevent the deterioration of coastal areas. For example, the Great Barrier Reef in Australia is nationally and internationally recognised as a marine protected area; however, the reefs have still been disturbed by harbour expansions for the coal industry (Morrison 2017).

Decisions about human activities in protected nature areas fall within the field of governance. Coastal areas are governed in relation to nature protection in the sense that decisions are made regarding what is allowed in the area and which activities are undertaken to preserve and improve the natural value of the area. These political decisions are connected to what is valued most and to beliefs about how different interests should be balanced. These decisions are often officially made by the responsible governmental actors; however, market and civil society players also influence the decision-making process. To emphasize that decision-making and implementation of policies are shaped by multiple actors, the term governance is used in this PhD thesis. The use of this term follows the broad definition of Van Assche et al. (2015), according to which governance is "the taking of collectively binding decisions for a community in a community, by governmental and other actors" (Van Assche et al. 2015, p.20).

Knowledge plays an important role in decision-making processes. Knowledge claims are used to legitimize decisions about whether to continue or change human activities, especially with regard to nature protection (Beunen and Duineveld 2010; Turnhout et al. 2015; Wesselink et al. 2013). Nature protection can be supported by very different and complementary arguments, such as aesthetic and ethical considerations or the need to preserve resources for future generations (Van Koppen 2000). However, these arguments are often combined with knowledge components to emphasize their scientific basis (Stone 2012). Scientists have played a key role in putting nature protection on the political agenda, both historically – at the start of the nature conservation movement – and presently. The general trend in political decision-making is the increasing importance of scientific expertise (Weingart 1999).

The important role of knowledge-based decision-making has triggered a new challenge: knowledge uncertainties. When decisions need to be legitimised by a knowledge base, the certainty of this knowledge can become an issue in itself. The marine aspect of nature in coastal areas makes knowledge generation difficult. 'Invisible' nature that is under water, as well as dynamic water flows, contribute to ecosystems that are difficult to study (Owens 2008). These aspects contribute to a large

number of knowledge uncertainties concerning coastal areas. Furthermore, the involvement of diverse stakeholders – with their own knowledge interpretations – also contributes to knowledge uncertainties, as is shown in several empirical studies on governance processes (Pellizzoni 2011; Sarewitz 2004; Turnhout et al. 2008).

This PhD thesis will explain the role of knowledge uncertainties in decision-making processes focused on the nature protection of coastal areas. The importance of science-based expertise in nature protection of coastal areas is recognised by a large number of scholars (Seijger 2014; Stange 2017; Van Buuren and Edelenbos 2004; Van der Molen 2017; Van Tatenhove 2013; Wesselink et al. 2013). Although knowledge uncertainties challenge the legitimacy of science-based decisions, scientific expertise continues to dominate decision-making processes. To unpack this puzzle, I selected the Dutch Wadden Sea as case study to analyse the role of knowledge uncertainties in the governance of this coastal area.

1.2 The Dutch Wadden Sea

The empirical insights of this thesis are based on the governance of the Dutch Wadden Sea. This coastal area is selected as a case to study the role of knowledge uncertainties in the governance of protected marine nature. Here, I will highlight the factors that contributed to the decision to study this area. First, the Dutch Wadden Sea is recognised as an important nature area. The Wadden Sea is a shallow estuarine sea lying along the north coast of the Netherlands to the west coast of Denmark, see Figure 1.1. The main characteristics of this area are its tidal mudflats. As a result of high tidal dynamics, large areas of the Wadden Sea fall dry during low tide. These mudflats contain high numbers of shellfish and worms that provide a feeding ground for many birds. The area is especially renowned for migrating birds; each year, millions of water birds use the Wadden Sea as a foraging and resting place (Boere and Piersma 2012). These natural values have contributed to the international recognition of the Dutch Wadden Sea as an important nature area. The Dutch Wadden Sea is, for example, protected as a wetland area under the Ramsar convention, as a Natura 2000-site under the European Bird and Habitat Directive, and as a World Heritage site by UNESCO. These designations have contributed to the national legal protection of the area under the Dutch Nature conservation act (in Dutch 'Wet Natuurbescherming' in 2017), which, for example, regulates the permit procedures for activities in the area. The aim of the Dutch nature protection legislations is not only the preservation of current natural values but also the restoration of lost natural values, such as seagrass fields (PRW 2015). Hence, the Wadden Sea is both scientifically and legally recognised as an important nature area.

Secondly, the governance of the Dutch Wadden Sea is an exemplary case of a continuous struggle between nature protection and economic activities. The struggle started in the 1960s with protests against large-scale embankment plans. This triggered the establishment of the Wadden Society (in Dutch 'Waddenvereniging'), which

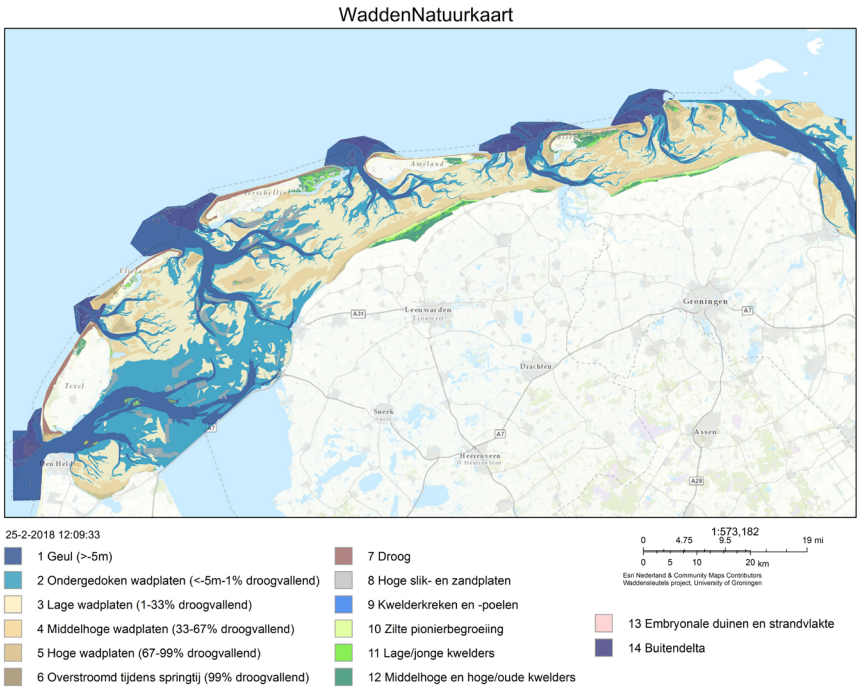

Figure 1.1. The Dutch Wadden Sea, with mudflats in brown, salt marshes in green and the grey rectanggles indicate the mussel cultivation plots (map from WaddenSleutels, 2018).

is currently a prominent NGO in Wadden Sea governance. During the same period, the Wadden Sea Working Group was established by a group of concerned scientists (Wolff 2013). Ever since, the human use of the area has been a topic of debate, even though the Wadden Sea area was recognised as a nature area by the national government in the 1970s and embankment plans were cancelled. The different interests of the stakeholders and the resulting tensions become particularly clear in conflicts about gas mining, cockle fishery and mussel fishery. Scientific knowledge, scientists and uncertainties have played an important role in these conflicts over nature protection versus economic activities. There is a large Dutch scientific community, connected to several research institutes and universities, currently studying different aspects of the Wadden Sea. This research started in the 19th century with marine laboratories, the predecessors of the Royal Netherlands Institute for Sea Research (NIOZ). Active advice from scientists started in 1965 with the Wadden Sea Working Group and was institutionalized in 1975 into the Co-ordination Group for Research and Management of the Wadden Sea area. The research and an advisory role was taken up by research institutes and universities in the 1980s (Wolff 2013). The knowledge of these science-based experts has been used by actors at opposing ends of the conflict; furthermore, some scientists themselves have played crucial roles in conflicts over human activities (Steins 1999; Turnhout et al. 2008).

Thirdly, there is a willingness on the part of Wadden Sea professionals to learn about science-policy interactions. In particular, the conflicts in 2004 on gas mining and cockle fishery triggered a discussion about the role of scientists and scientific knowledge. This resulted in reflections by several key actors regarding the use of knowledge. For example, the Dutch ministry of Agriculture, Nature and Food Quality commissioned an evaluation of a research project conducted on the effects of fishery policy in the Wadden Sea (1999-2003) in order to learn about the science-policy interactions (Hanssen et al. 2007). This led to several questions about how the use of knowledge for policy could be improved and how policy-makers could address knowledge uncertainties and risks. This interest in science-policy interactions was incorporated into a large-scale research program on the Dutch Sea and Coast; this project was called 'NWO-ZKO' and supported this PhD research. Furthermore, the topic of science-policy interactions was recognised by the scientific network organisation known as the Wadden Academy. The Wadden Academy organised several symposia for both scientists and policy-makers, and science-policy interactions were included as one of the topics. This shows that in addition to funding for science-policy interaction research in the Wadden Sea, there is also the potential to actually contribute to science-policy interactions in this area.

1.3 Science-policy interactions

Science-policy interactions are studied within the fields of knowledge utilisation, science and technology studies, sociology of knowledge, and predominantly within the field of environmental management. This PhD thesis will contribute to these fields of literature with new empirical and conceptual insights into the role of knowledge uncertainties in decision-making processes based on the Dutch Wadden Sea case study. In this section, I will first introduce three theoretical perspectives on science-policy interactions. Secondly, the conceptual framework of boundary objects is introduced as a tool to identify and study how science-policy interactions take place. Finally, I describe the challenges for the use of knowledge in decision-making through the processes of scientification and politicisation. These processes highlight how knowledge uncertainties can challenge the legitimacy of science-based decisions.

In this thesis, science-policy interactions are perceived as interactions between knowledge producers and knowledge users in the context of policy-making. Often, public policy-making is associated with governmental decisions and procedures that guide appropriate actions in the public domain. However, the governance perspective of this thesis makes clear that a vast number of actors are involved in the field of policy formulation and implementation, including such stakeholders as nature organisations and economic entrepreneurs. Furthermore, scientists are not the only knowledge producers. The concept of science-policy interactions highlights that the analytical focus of this study is on the role of knowledge processes, including knowledge production, exchange, transformation and use.

1.3.1 Different conceptualisations of science-policy interactions

There are different theoretical understandings of science-policy interactions. I will distinguish three ways of conceptualizing science-policy interactions, similar to Janssen (2015). The first perspective is based on a clear distinction between a science world and a policy world. This conceptualisation of 'Two-Communities' emphasizes that knowledge producers of the science world live in a world separated from the knowledge users of the policy world, with their own values, reward systems and language (Caplan 1979). For example, the different worlds can be characterised as scientists looking for the truth based on sound scientific methodology, whereas policy-makers are looking for power and fast solutions. Roughly stated, the science world deals with facts and the policy world with values. In line with the traditional perspective of the Enlightenment, the role of scientific knowledge in decision-making should be 'speaking truth to power' (Hoppe 1999). From this perspective, the issue of knowledge in decision-making is problematized as underutilization, explained by the gap between the science world and the policy world. Approaches within this strand of literature often focus on bridging this gap between science and policy, for example with participative approaches that bring together knowledge producers and knowledge users (Van Koningsveld 2003).

The second perspective on science-policy interactions criticises this conceptualisation of two clearly divided worlds and instead highlights the intertwinements of the science and policy worlds (Beck 2011; Carter 2013; Van Buuren and Edelenbos 2004; Van der Molen 2017; Wesselink et al. 2013). This conceptualisation of 'Intertwinement' emphasizes the socially constructed nature of science and knowledge production. The social process of knowledge production is stressed: "science is not the objective procedure by which facts are uncovered, but the way of life in which facts are made" (Van Buuren 2009, p.291). Furthermore, the boundary between science and non-science is perceived as changeable and context-dependent. This active process of drawing the boundary between science and non-science is called boundary work (Gieryn 1999). Moreover, from this perspective, science has no exclusive status as the appropriate knowledge provider for decision-making. Often, the broader term of expertise is used to highlight the various sources of knowledge that are used in policy-making (Janssen 2015; Wesselink et al. 2013). Additionally, the multiple uses of knowledge in policy-making are stressed. Knowledge can be used not only instrumentally but also conceptually and strategically (Hisschemöller 2005; Wesselink et al. 2013). Additionally, the performative aspect of knowledge is addressed, highlighting the entwinement of power and knowledge (Turnhout et al. 2016; Van Assche et al. 2017). Several empirical studies have shown the blurred character of the division between the science and policy worlds. In particular, the study of Jasanoff (1994) on the role of policy advisors has been very influential in this field. This study revealed the political role of scientific experts in the policy-making process. This supports the conceptualisation of science-policy interactions as a two-way process between knowledge production and decision-making (Wesselink et al. 2013). Based on the intertwined con-

ceptualisation of science-policy interactions, the issue of knowledge in decision-making is analysed from the perspective of how science-policy interactions take place. The challenge is not the underutilization of knowledge but rather finding the most appropriate science-policy interactions (Turnhout et al. 2008). The aim is to find the correct balance between the extremes of negotiated nonsense and superfluous knowledge (Janssen 2015).

The third perspective is based on a similar conceptualisation of science-policy interactions as that used in the intertwinement perspective, acknowledging that there is not a clear boundary between the science and policy worlds. However, it adds the perspective of multiple coalitions that interact in a decision-making process. This conceptualisation of 'Knowledge Coalitions' emphasizes that groups of people see the world in different ways. Each group or coalition has its own particular type of knowledge, fosters different knowledge production processes and gives different interpretations to research results. These knowledge coalitions can include actors from both the science and policy worlds who share a common perspective (Janssen 2015). This approach was triggered by research on conflict situations: the presence of different knowledge coalitions was identified as cause for lack of knowledge utilization (Van Buuren 2009; Van Buuren and Edelenbos 2004). Another term for this model of science-policy interactions is Ways of Knowing (WOKs). Van Buuren (2009) describes the aforementioned model as follows: "Different WOKs give rise to different understandings of precisely which factual knowledge is valid and relevant; they feed different world views, problem perceptions, and values" (p.209). Analytically, groups that share a way of knowing can be identified as coalitions. Based on this perspective, the focus of studies on knowledge use expands towards the interactions between different coalitions instead of the science-policy interactions that can be observed within a coalition. For example, in current debates on flood protection, a coalition with a safety perspective and a coalition with an ecological perspective can be distinguished. These coalitions both use and produce knowledge to support their positions in favour of or against the building of new dams (Janssen 2015). According to this perspective on science-policy interactions, the problem of knowledge use in decision-making is not at the science-policy boundary but at the boundary between different knowledge coalitions. The aim is to facilitate cooperation between these coalitions that have different ways of knowing. The three conceptual models of science-policy interactions described above are summarized and visualized in Figure 1.2.

1.3.2 Boundary objects

Although the three models of science-policy interactions described in the previous section emphasize different perceptions of science-policy interactions, they share the conceptualisation that people from different social worlds interact. The boundaries between these worlds are drawn in different places, either between the science and policy worlds or between different coalitions. Still, the question remains, how do these people interact and cooperate? This question of cooperation between people in diverse intersecting

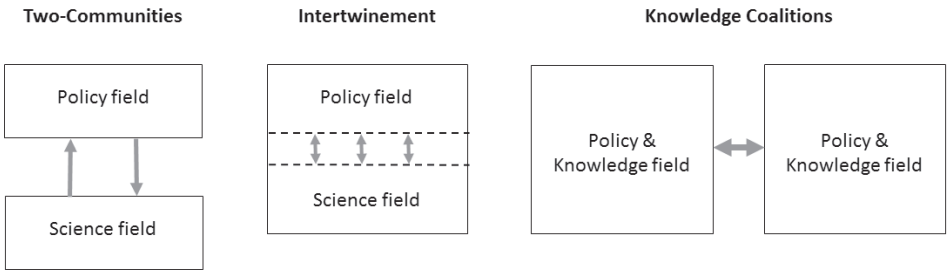

Figure 1.2. Visualisation of three conceptual models of science-policy interactions, based on Janssen (2015).

social worlds initiated the research of Star and Griesemer (1989), who developed the concept of boundary objects to explain how to overcome the tension between diversity and cooperation. Their starting point is that "consensus is not necessary for cooperation nor for the successful conduct of work" (Star and Griesemer 1989, p.388). Without eliminating the differences between different social worlds, cooperation can be facilitated by boundary objects. They describe boundary objects as:

> "objects which are both plastic enough to adapt to local needs and the constrains of the several parties employing them, yet robust enough to maintain a common identity across sites. They are weakly structured in common use, and become strongly structured in individual site use. These objects may be abstract or concrete. They have different meanings in different social worlds but their structure is common enough to more than one world to make them recognizable, a means of translation" (Star and Griesemer 1989, p.393).

The concept of boundary objects is used to study a diverse range of interactions, e.g., to identify and study how science-policy interactions take place (Stange 2017; Star 2010; Turnhout 2009). A crucial aspect of a boundary object is its interpretative flexibility. The boundary indicated in the concept of boundary objects is often placed between the science and policy worlds. However, in this study, I will not base my analysis on the assumption that the main boundary is between the policy and science worlds; the main boundary could also be between knowledge coalitions with their own ways of knowing. For this reason, I will take an open approach and observe empirically between which groups of people interactions are facilitated by boundary objects.

1.3.3 Scientification of politics and politicisation of science

In relation to knowledge use in decision-making, a trend of scientification of politics and politicisation of science is described by Weingart (1999). This trend is indicated by the increased role of scientific expert advice in policy decision-making since World War II. This is a general trend for all policy fields but has received particular emphasis in the environmental field, which is historically driven by scientists. This 'scientification' of na-

ture conservation and environmental issues indicates that scientific experts dominate the decision-making process as "the ones in charge of defining and assessing environmental problems as well as providing the knowledge and solutions to solve them" (Wesselink et al. 2013, p.2). In this way, decisions about nature conservation are transferred to the domain of scientific expertise, whereas the 'politicisation' of science and expertise refers to the contestation of science-based knowledge in public debates (Mouffe 2000; Pellizzoni 2011). In the words of Pellizzoni, politicisation is "the opening, broadening or restoring of a public space of discussion" (Pellizzoni 2011, p.711). The opposite process of depoliticisation implies that an issue is taken out of the public domain and, for example, into the domain of scientific or bureaucratic expertise (Behagel 2012). A clear example in which science has become a topic of debate is climate change (Beck 2011; Pielke 2004).

The process of the politicisation of science is especially perceived as a problem by those who hold the 'Two-Communities' perspective on science-policy interactions, as it would diminish the objectivity and independence of scientific experts (Pellizzoni 2011). Whereas from the 'Intertwinement' perspective, the political aspect of scientific knowledge is the starting point. Knowledge production involves all types of social factors, including political choices. From this perspective, the scientification of politics is criticised, as the perception of apolitical experts can hide the political choices that are made in the decision-making process (Pellizzoni 2011; Wesselink et al. 2013).

However, from both perspectives, an important challenge that is acknowledged is that of uncertainty (Pellizzoni 2011; Pielke 2004; Weingart 1999). With the scientification of politics, science-based knowledge becomes essential for decision-making. However, this becomes problematic when the knowledge is questioned because of uncertainties. The politicisation of science implies that there is a debate between experts, increasing the uncertainty about which knowledge should be the basis of decisions. This challenge – of both the increased importance of scientific knowledge and the recognition of uncertainties – triggered the decision to focus my research on knowledge uncertainties.

1.4 Knowledge uncertainties

The main focus of this thesis is on knowledge uncertainties. However, what are knowledge uncertainties? Within the literature, there is an abundance of definitions. Important for my research are uncertainty concepts that enable me to analyse the role of uncertainties in decision-making processes. Often, uncertainties are positioned as opposites of knowledge: as unknowns or ignorance (Funtowicz and Ravetz 1990; Gross 2010). In this way, uncertainties are connected to what knowledge is. In this thesis, I will use the broad definition of knowledge as justified true belief that is connected to a purpose or use (Elder-Vass 2012; Gross 2010). In this way, scientific knowledge is the type of knowledge justified through a scientific method or the authority of a scientist. However, uncertainty is not only the lack of knowledge but also the

lack of coherence among competing knowledge claims (Sarewitz 2004; Stirling 2010).

Several studies have shown that knowledge uncertainties play a central role in environmental controversies. Shackley and Wynne (1996) have shown that for a decision-making process, it are the uncertainties that are constructed in a particular setting that are important, not the multitude of potential uncertainties. This issue is addressed in the relational approach of Brugnach et al. (2008): "The definition of a problem and what is uncertain about it depends not only on scientific or expert understanding, but on the knowledge, views, and preferences of the decision-maker in relation to those of other actors with whom the decision-maker interacts to make sense of the situation" (Brugnach et al. 2008, p.5).

To acknowledge the different types of knowledge situations and the relational character of uncertainties in decision-making processes, I will distinguish three types of uncertainty. Building on Brugnach et al. (2008) and Van den Hoek (2014), I conceptualise uncertainty as incomplete knowledge, unpredictability and ambiguity, see Figure 1.3. In my approach, the uncertainty of incomplete knowledge refers to expressions of knowledge imperfections: to what is unknown at the moment but could be made available with additional research. The uncertainty of unpredictability refers to what is seen as unknowable: certain elements of complex systems are unpredictable. For example, the current state of science is unable to give predictions about several aspects of marine ecosystems that are characterised by chaotic dynamics. The uncertainty of ambiguity refers to the situation of actors presenting diverging knowledge claims, with ambiguity defined as "the existence of two or more equally plausible interpretation possibilities" (Dewulf et al. 2005, p.116). This perception of ambiguity is closely linked to the perception that there are different ways of knowing, which I presented in the conceptual model of Knowledge Coalitions, see paragraph 1.3.1 (Armitage et al. 2008; Folke et al. 2005; Holling 2001; Janssen 2015; Van Buuren and Edelenbos 2004).

These different types of uncertainties also imply different strategies for addressing uncertainties in decision-making. When the uncertainty is perceived as incomplete knowl-

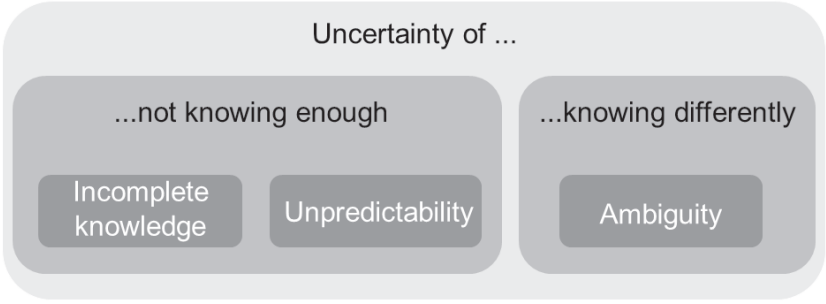

Figure 1.3. Schematisation of types of uncertainties based on Van den Hoek (2014).

edge, one strategy could be to invest in more research or collect better data. In this case, the expectation is that the new knowledge will improve the understanding of the situation. This perception can be used to postpone a decision, or the research can be seen as input for future decision-making. However, more research could also reveal new uncertainties and make the decision-making process more complicated (Brugnach et al. 2008; Sarewitz 2004; Turnhout et al. 2008). When the uncertainty is perceived as unpredictability, this implies that not knowing is accepted. Strategies to address this uncertainty often focus on risk reduction, for example through capacity-building to anticipate several possible scenarios. A decision-making approach that starts from the acknowledgement of not knowing enough, which can be both incomplete knowledge and unpredictability, is adaptive management. This approach is based on the learning capacity of decision-makers and the need to respond to unpredicted surprises (Armitage et al. 2008; Brugnach et al. 2008; Folke et al. 2005; Gross 2010; Holling 2001).

In contrast, the uncertainty of ambiguity implies that there are multiple, conflicting interpretations among the actors involved in the decision-making process. This can result in conflict situations; either a cold conflict, in which actors distance themselves from each other and avoid confrontation, or a hot conflict, in which actors explicitly criticise the opposite camp. Strategies that seek to address this uncertainty of knowing differently often focus on the relations between and perceptions of the actors involved, for example through participative and deliberative approaches (Brugnach and Ingram 2012). However, another response of a decision-maker can be to support one of the camps and ignore or discredit the alternative perspective (Turnhout et al. 2008).

This typology of uncertainties as incomplete knowledge, unpredictability and ambiguity will be used to analyse how uncertainties played a role in the decision-making processes in the Dutch Wadden Sea. Although the interrelated character of these uncertainties is recognised (Van den Hoek et al. 2014) in this study, the classification of different types of uncertainties will be used to analytically make the distinction between different understandings of uncertainty and different reactions to these perceptions of uncertainty. Together, the explicit acknowledgement of uncertainties and the implicit implications of strategies that address uncertainties will serve as a starting point to analyse the role of knowledge uncertainties in the decision-making processes.

1.5 Research objective and questions

As stated, this thesis analyses the challenge of knowledge uncertainties in coastal nature conservation decision-making. Although the legitimacy of science-based decisions is questioned by knowledge uncertainties, this has not reduced the dominance of scientific expertise in nature governance. This puzzling combination is also known as the paradox of both the scientification of politics and the politicisation of science (Weingart 1999). The aim of this thesis is to explain this paradox and understand the role of knowledge uncertainties in decision-making processes. To this end, the Dutch Wadden Sea was se-

lected as a case study in order to achieve an in-depth understanding of knowledge uncertainties in decision-making processes about coastal nature conservation. The first objective of this thesis is to clarify science-policy interactions in the Dutch Wadden Sea, both theoretically and empirically. Science-policy interactions are perceived as the location in which the meaning of knowledge uncertainties for governance processes is formed. The second objective is to describe the role of knowledge uncertainties in decision-making processes about the use and restoration of the Dutch Wadden Sea. For this analysis, a relational approach to knowledge uncertainties is used, based on the concepts of incomplete knowledge, unpredictability and ambiguity. The third objective is to understand and explain the role of scientific knowledge and experts in decision-making processes in which knowledge uncertainties are expressed. Based on the insights of the Dutch Wadden Sea case, the paradoxical stable domination of scientific expertise in nature governance within a context of knowledge uncertainties will be explained.

Given the research objectives of this thesis, the research questions are as follows:

1. *How to understand science-policy interactions in the governance of Dutch Wadden Sea nature?*
2. *How do knowledge uncertainties play a role in decision-making about the use and the restoration of Dutch Wadden Sea nature?*
3. *What does this analysis of knowledge uncertainties in decision-making processes in the Dutch Wadden Sea reveal that can explain the role of science-based expertise in nature conservation governance?*

1.6 Research approach

In this section, I will elaborate on my ontological and epistemological research position and describe my research design. My relational approach of knowledge uncertainties suggests particular theoretical perspectives on science-policy interactions and specific ontological and epistemological viewpoints, which will be clarified in this section.

First, ontology is the study of being and centres around the question of "what exists in the human world that we can acquire knowledge about?" (Moon and Blackman 2014, p.1169). Different positions are identified within philosophy, and a central concern is whether an external reality exists independent of human beliefs and interpretations. These positions range from realism, which states that there is only one reality, to relativism, which states that multiple realities exist (Ritchie et al. 2014). A middle position is critical realism, which states that there is an external reality independent of humans; however, this reality is only knowable through socially constructed meanings. This connection between meaning and being is emphasized in social constructionism: "the ways in which we collectively think and communicate about the world affects the way that the world is" (Elder-Vass 2012, p.4).

Secondly, epistemology explores how we can know and how we create knowledge. Two opposing views can be identified as positivism and interpretivism. Whereas positivism is based on the discovery of objective truth, interpretivism emphasizes that researchers and the social world impact each other. The interpretative approach highlights a double hermeneutics for social science – knowledge is not only created by the interpretations of the researcher but also by the understandings of the people connected to the studied phenomena (Toonen 2013; Yanow and Schwartz-Shea 2006).

In the following subsections, I will position myself as having a critical constructivist perspective with an interpretative approach. My research objectives connected to these ontological and epistemological positions have shaped my research design, which consists of a case study approach based on interviews, observations and document analysis.

1.6.1 Critical constructivist perspective

My research approach is in line with a critical constructivist perspective, which implies "a critical stance towards the object of study and the perception that this object of study is socially constructed" (Behagel 2012, p.27). My main objects of study are knowledge uncertainties, which I study from a relational perspective. This relational perspective focuses on the different meanings actors attribute to knowledge uncertainties in a decision-making context. Especially with the concept of ambiguity, I acknowledge that there are multiple constructed realities. For example, the mass mortality of birds can be perceived as a natural phenomenon or as a human-caused catastrophe. These different realities do not differ in their view that there is an external world with birds. However, they give the event a different meaning, and in this way, they change what the event is, indicating the constructed nature of knowledge and knowledge uncertainties. As explained by Van Assche et al. (2015), knowledge "does not mirror a pre-existing order or an external reality, but it is always an active discursive construction of that reality. It cannot be detached from the historical and cultural context in which it is produced and performed" (p.20).

Furthermore, my critical constructivist perspective on knowledge uncertainties includes the acknowledgement that knowledge and knowledge uncertainties are connected to power relations. Some perceptions are included in the decision-making process, whereas others are excluded. Moreover, I critically challenge the naturalness and self-evident nature of scientific knowledge in decision-making processes by emphasizing the historical and contingent roots of power and knowledge. I emphasize the political choices that are made in decision-making processes, even though these choices can be hidden in knowledge argumentations. This is consistent with the conceptual models of science-policy interactions called Intertwinement and Knowledge Coalitions, as described in paragraph 1.3.1. My starting point is that I criticise the conception of the science and policy worlds as having a fixed nature. However, at the same time, I acknowledge that the Two-Communities model has empirical relevance as a dominant view of science-policy interactions (Carter 2013).

1.6.2 Interpretative approach

To analyse the construction and use of knowledge uncertainties in decision-making processes, I will use an interpretative approach. I acknowledge the value-laden aspect of knowledge production, both in the knowledge production processes regarding the Dutch Wadden Sea, which I studied empirically, as well as in my own knowledge production process that has led to this PhD thesis. My own values, interests and historical trajectory from a natural to a social scientist have shaped this research in several ways, for example, in my connection to some of my interviewees. Instead of aiming to present objective truth in this thesis, my knowledge production objective is to provide a trustworthy account of the empirical events I have studied, as well as new conceptual insights into knowledge uncertainties that can have practical implications for future decision-making processes. To support the trustworthiness of this research, I will give an account of how I collected my data and analysed the meanings and interpretations of actors in the decision-making processes I studied. Furthermore, I used informant feedback to check whether my interpretations of the processes were recognizable to people with direct experiences in the cases I studied (Hajer 2006; Wagenaar 2011; Yanow and Schwartz-Shea 2006).

To structure the analysis of the different meanings and interpretations of knowledge uncertainties in the decision-making process, I used a discourse approach. Here, I use the definition of Hajer (1995) of discourses as "a specific ensemble of ideas, concepts and categorizations that are produced, reproduced and transformed in a particular set of practices and through which meaning is given to physical and social realities" (p.44). Actors that share specific discourses can form coalitions around specific issues. These discourse coalitions construct different realities. Although the concepts originate from different strands of literature, discourse coalitions can be seen as a way to analytically operationalise the Knowledge Coalition model[1], see paragraph 1.3.1.

The discourse approach is used to structure and understand the interpretations and relations of actors in my case studies. Through the lens of discourse analysis, different storylines of actors can be distinguished with specific framings of problems and solutions that are relevant to the decision-making process. Although the aim of this study is not to explain the emergence of specific discourses and storylines, the contingent and changing nature of discourses and storylines is acknowledged: "The articulation of a discourse is always non-necessary or contingent: it could have been articulated otherwise" (Behagel 2012, p.32). A specific historical path has led to specific discourses and governance arrangements (Van Assche et al. 2015). For this reason, the stability and flexibility of interpretations are best perceived through historical analysis, which contributed to the decision to analyse long time periods in most of my case studies.

[1] Another way to operationalize this conceptual model of science-policy interactions is with knowledge arrangements that consists of 4 dimensions, including discourses (Janssen 2015).

1.6.3 A case study approach

My research design can best be described as a qualitative case study approach that fits well with my critical constructivist perspective and interpretative approach to understanding knowledge uncertainties in nature conservation governance (Ritchie et al. 2014; Yanow and Schwartz-Shea 2006; Yin 2014). A qualitative case study design supports my goal of studying meanings in a specific context (Yin 2014). As I am interested in the different meanings people attach to knowledge uncertainties and the role of those uncertainties in marine governance processes, a concrete and specific decision-making process should be studied to acquire new insights. The selected nature conservation governance setting for my research is the Dutch Wadden Sea. However, there are several parallel and interconnected decision-making processes within the field of nature conservation of the Dutch Wadden Sea. To obtain in-depth insights, additional concrete case studies were selected. This case selection took place through an iterative process, combining theory and empirical observations to find interesting research puzzles (Wagenaar 2011).

The first cases that were studied are the activities of cockle fishery and gas exploitation within the Dutch Wadden Sea. These two cases formed the cornerstone of the review I undertook in order to build upon the insights of social science research regarding science-policy interactions in the Dutch Wadden Sea. Cockle fishery and gas exploitation started in the 1950s and 1960s. Their regulations were connected in 2004 by a governmental decision to use gas revenues to ban mechanical cockle fishery from the Dutch Wadden Sea. The controversies over these activities not only triggered complex decision-making processes in the 1990s and 2000s, in which scientific ecological knowledge became part of the controversy, they also triggered several social science studies of the resulting science-policy interactions. The review of this literature is presented in chapter 2.

One of the insights of my review was the important role that court rulings had played in decision-making processes. Furthermore, my explorative interviews with key actors indicated the dominance of Natura 2000 and the assessment of effects on decisions regarding the Dutch Wadden Sea. This led to the selection of two cases: the controversy over the 2006-spring permit for the mussel seed fishery and the 2011 permit for the planned World Championship powerboat races. The mussel seed fishery case was selected because it played a crucial role in shaping the position of nature conservation NGOs in the Wadden Sea; the court ruling in 2008 considerably changed the power field of the governance setting. Additionally, the very different activity of a planned power boat race within another political context was selected to give in-depth insights into the different roles that knowledge uncertainties can play in permit and juridical processes. These empirical insights are presented in chapter 3.

During the analysis and writing process on the mussel seed fishery controversy, more interesting elements were observed than could be addressed in the scope of the permit and juridical process study. This led to the re-examination of the mussel fishery case for a longer time period, spanning from 1990 until 2016. In this study,

the linear science-policy model – and its assumption that research can resolve regulation debates – is criticised. I observed this expectation of knowledge production for decision-making in my interviews and during meetings I attended – even though that expectation did not correspond with my observations of the policy process. Through an in-depth analysis of the mussel fishery case, the persistence of the high expectation that research projects could resolve the conflict is explained in chapter 4.

Complementary to the controversies over human activities in the Wadden Sea, which can be characterised by the policy discourse described by Runhaar (2009) as "Human activities within ecological limits" (p.206), I observed another dominant policy discourse – "Hands on: restore the Dutch Wadden Sea". This perspective was articulated by nature conservation organisations in a restoration plan in 2005 (Van der Eijk 2005), and the restoration aim was institutionalised in the Programme Towards a Rich Wadden Sea ('Programma naar een Rijke Waddenzee' in Dutch). Since 2010, nature organisations and the government have cooperated within this restoration programme to enhance nature restoration of the Wadden Sea (PRW 2015). To address this different governance setting for nature protection, the seagrass restoration case was selected to analyse the science-policy interactions in a more collaborative setting. The decision-making process surrounding the restoration of seagrass fields in the Dutch Wadden Sea is studied for the period 1989-2017; this analysis is presented in chapter 5.

These selected cases all contributed to my understanding of the role of knowledge uncertainties in decision-making processes in the Dutch Wadden Sea. These cases all met the overarching case selection criteria that knowledge uncertainties should play a key role in the analysed decision-making processes. The insights obtained about the different roles of knowledge uncertainties in the power boat case, the mussel fishery case and the seagrass restoration case have led to the conclusions presented in chapter 6.

1.6.4 Data collection methods

This thesis builds on qualitative data collected from documents, interviews and observations (Crag and Cook 2007; Ritchie et al. 2014). A wide range of documents on general issues of the Wadden Sea, as well as specific documents for the selected case studies, were collected. Both primary and secondary literature was used. Data were gathered from research reports, governmental documents, project plans, websites of stakeholders, blogs, newspaper articles, scholarly articles and PhD theses within the ecological and social science fields. Especially for the reconstruction of the mussel fishery and seagrass restoration case studies, newspaper articles retrieved from the LexisNexis database gave useful insights into the positions and perspectives of actors some decades ago.

A crucial source of data was a set of semi-structured interviews with key informants from scientific institutes, nature organisations, national and provincial governments and the mussel fishery sector. In total, I conducted 28 interviews, for a list of the interviewees, see Appendix I. Potential interviewees were selected based on ex-

isting contacts; document analysis provided the names of key actors, and the snowball method was used to identify more relevant interview candidates. Most of the interviews took place face-to-face with the interviewee at their work location or their home. Only the first four interviews involved groups. These interviews were conducted in co-operation with Chris Seijger, a colleague PhD researcher from the NWO-ZKO research project. Additionally, there was one interview that took place via telephone and one via e-mail. The interviews were guided in a semi-structured way: a specific interview guide was prepared for each interviewee; open-ended questions were used to start the conversation; followed by probing questions to deepen and steer the topics that were discussed. Almost all interviews were recorded (with permission of the interviewees) and later transcribed for analytical purposes. One interview took place spontaneously during the coffee break of a workshop, and detailed notes were taken.

In addition to the documents and interviews, observations during meetings, symposia and conferences have been valuable for this research. These sites of interactions provided me with the opportunity to have informal conversations with key actors. Holding conversations with such key actors, as well as other event participants, enabled me to gain insight into many more opinions and ideas than I could have accessed through interviews exclusively. Furthermore, I could observe the interactions between the actors and develop an idea of their relationships. I visited several public meetings, which were often organised by the Wadden Academy; for an overview of attended meetings, see Appendix II. In addition to these more general observations, I also participated in the seagrass restoration efforts of autumn 2015. For three days, I was part of the team that executed the introduction of seagrass seeds at intertidal areas near Uithuizen and Schiermonnikoog. This gave me in-depth insights into the practice of seagrass restoration and allowed me to have long conversations with the persons involved in executing the project.

These three methods of data collection were used to complement each other. In some instances, interviews triggered the discovery of documents crucial to the decision-making process, whereas at other times, insights based on document analysis shaped the probing of in-depth interview questions. The data collection took place in an iterative process parallel to the development of the case study selections. In the first phase of the research, a broad scoping approach was used, starting with explorative interviews with key actors in the science-policy field and a broad literature overview. In a later phase, the documents and interviews became more specific to the selected case studies.

1.6.5 Data analysis

This research is based on an interpretative approach, which means that I am interested in the different understandings and meanings people have. This approach is applied in different ways for each of my four studies. In my first study, the different understandings of science-policy interactions in the Dutch Wadden Sea in social science literature are analysed. Here, the different perspectives of scholars on science-policy interactions are

the objects of analysis. Whereas in my other studies, the understandings of science-based experts, nature organisations, governmental actors and economic entrepreneurs are the objects of analysis. In my second study, two empirical controversies are analysed – focussing on the different interpretations of significant effect and knowledge uncertainties. To structure this analysis, discourse coalitions were distinguished as opposing each other in the controversy, with a discourse coalition understood as "a group of actors that, in the context of an identifiable set of practices, shares the usage of a particular set of story lines over a particular period of time" (Hajer, 2006, p.70). Documents, interview transcripts and notes were analysed to categorize the arguments and expressions of knowledge uncertainties provided by each coalition. Furthermore, the assessment of significant effect was approached as a boundary object to identify where and how interactions took place. In my third study, the debate on mussel fishery is re-analysed, building on the previous distinction of two discourse coalitions. Here, a more historical analysis is conducted in which four periods are distinguished. These periods are based on the analysis of the mussel fishery regulation and the storylines about regulation and knowledge uncertainties expressed by the discourse coalitions. In the fourth study, the focus is on the storylines of seagrass restoration. Here, the storylines structure the analysis of the different understandings: the reasons for restoration, the role research should play and how knowledge uncertainties should be addressed. This is, again, a historical analysis in which changes and stability are highlighted through the distinction of three episodes.

To support the trustworthiness of my analysis, interactions took place with key actors in the field. Feedback was provided on draft versions of manuscripts, and I presented my research findings not only at international conferences to scholars in my field but also to Wadden Sea professionals during symposia and conferences, see Appendix II. This led to interesting and insightful conversations about my research results. These interactions not only supported my views but also highlighted the different perspectives on science-policy within the Dutch Wadden Sea context. Furthermore, the collected data are archived for potential audits. Copies of data, including interview transcripts, documents and observer notes are stored at the Environmental Policy Group of Wageningen University.

1.7 Outline of the thesis

This thesis has been compiled in a publication-based format, which means that chapters 2-5 are written as articles for peer-reviewed journals. These articles are written with co-authors. However, I was the main researcher who conducted the data collection and analysis. The outline of this thesis is as follows. This introduction provides an overview of the research topic, the conceptual framework, the research objectives and questions, as well as my methodological position. In chapter 2, a review of the social science literature on science-policy interactions in the Dutch Wadden Sea is presented. This research provides lessons learned about science-policy interactions in the Dutch Wadden

Sea. This chapter addresses the first research question on understanding science-policy interactions in the Dutch Wadden Sea. In chapter 3, the permit and legal procedures on the mussel seed fishery and a planned powerboat race are analysed. Furthermore, this chapter explains how science-policy interactions are shaped through the boundary object 'significant effect'. In chapter 4, the mussel fishery case is re-examined. A typology of depoliticisation mechanisms is used to describe the decision-making processes and explain the persistent belief that more knowledge can resolve controversy. In chapter 5, a more collaborative context is examined in the analysis of the seagrass restoration case. This chapter shows the impact of storylines and knowledge uncertainties on decisions concerning restoration action and research. The empirical case studies on the use and restoration of the nature of the Dutch Wadden Sea contribute to answering the second research question on the role of knowledge uncertainties in decision-making processes. In chapter 6, the conclusions of this thesis are presented. The empirical findings are discussed, and conclusions are drawn based on the insights into knowledge uncertainties presented in the empirical chapters. Furthermore, chapter 6 presents a reflection on the politics of knowledge uncertainties and the broader contributions of this PhD thesis.

Chapter 2

A review of science-policy interactions in the Dutch Wadden Sea
– The cockle fishery and gas exploitation controversies

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Abstract

The potential ecological effects of cockle fisheries and gas exploitation in the Dutch Wadden Sea and their implications for policy and management have been the topic of vigorous societal debates. Ecological science has played crucial but controversial roles in these debates. Several social science studies have been dedicated to analysing these roles and making recommendations for the improvement of science-policy interactions. In reviewing these studies, this article aims to draw lessons for (ecological) scientists and policy-makers on how to understand and guide the interactions of science and policy in Wadden Sea management. Studies addressing science-policy interactions in the Dutch Wadden Sea can be grouped into three main perspectives, emphasizing the social and economic dynamics of resource management, the role of nature views and discourses in controversies, and the influence of science dynamics in policy and management debates. The review demonstrates that ecological knowledge and ecological scientists have played important roles in the controversies on cockle fisheries and gas exploitation. However, scientific knowledge was not always the most important factor in the decision-making process, and scientific insights were not always used as expected by the scientists. How scientific knowledge is used and interpreted by stakeholders was dependent on their interests, their nature views and on the dominant policy discourses. Ecological knowledge and scientists themselves became part of the policy debates, e.g. in discussions on uncertainty and reliability. The position of scientists in policy debates was strongly influenced by the policy setting and by changes in this setting, e.g. by the operation of mediators or by new interpretations of legal rules. A lesson to be drawn for scientists is that they should reflect on the sort of position - e.g. independent outsider, or engaged stakeholder - they take in a debate. They should also be aware that this position cannot be chosen at will: it is strongly influenced by the policy context. For government and other stakeholders, an important lesson is that by shaping adequate policy settings they can contribute to more productive and effective interactions with science and scientists.

2.1 Introduction

The Dutch Wadden Sea is a dynamic ecosystem, but also a dynamic and conflictual social arena. There have been vigorous debates on the possible effects of economic activities on the ecology of the Wadden Sea, which in the last 10-15 years mainly concentrated on shellfish, in particular cockle fishery, and on gas exploitation. In these controversies scientific knowledge and scientists not only had substantial influence but also became subject of controversy and debate themselves. Central to this article will be this disputed involvement of natural science in social and political conflicts.

Nature conservation plays a very important role in the management of the Dutch Wadden Sea, recognised as an important nature area, especially for birds. Main legislations are the Dutch Key Planning Decision, the EU Birds and Habitat directive, the Dutch Nature Protecting Act and the Trilateral agreements between the Netherlands, Germany and Denmark. Together with the diverging economic and nature conservation interests in this area, these different regulatory frameworks constitute a complex and multi-level governance context to the science-policy interactions in the Dutch Wadden Sea. Many different actors are involved, including governmental bodies (municipalities, three provinces, several ministries, Germany, Denmark and the European Union), environmental organisations (particularly the Wadden Society, in Dutch 'Waddenvereniging', an NGO with a large number of members that aims to protect the nature of the Wadden Sea), economic entrepreneurs (fishermen, tourist organisations, sand/shells/salt/gas extraction companies), as well as scientists. The ecological research on the Dutch Wadden Sea is undertaken by research institutes and universities, especially NIOZ (Royal Netherlands Institute for Sea Research), IMARES (Institute for Marine Resources and Ecosystem Studies) and the University of Groningen. These different actors come together during official and unofficial negotiations, but also meet each other in courts, such as the 'Raad van State', the supreme administrative court of the Netherlands.

The policy processes of cockle fishery and gas exploitation have attracted the attention of several scholars that took an interest in the science-policy interactions in this dynamic arena of the Dutch Wadden Sea. Applying insights from international strands of science-policy studies (e.g. Gibbons 2000; Halfmann and Hoppe 2004; Jasanoff 1994; Star and Griesemer 1989), these scholars have explored how ecological knowledge and scientists played a role in the policy-making for the Wadden Sea. This article aims to review these studies to assess how they can contribute to our understanding of science-policy interactions, and also to draw lessons for (ecological) scientists and policy-makers on how these interactions can be improved in coping with the challenges the Wadden Sea is faced with.

The literature reviewed for this article was limited to peer-reviewed articles and PhD theses of the last 15 years with a focus on the Dutch Wadden Sea. Based on these criteria five PhD theses and ten articles of social research on the Dutch Wadden Sea have

been selected for review. Almost all of this research has focused on the decision-making process around the activities of cockle fisheries and gas exploitation. This review aims to combine their different insights to give an overview of the current knowledge on this topic. However we will first give a brief historical overview on the cockle fisheries and the gas exploitation conflict and their governance context.

2.2 Historical overview

2.2.1 The cockle fishery and gas exploitation conflicts

A timeline of governmental decisions and important events for the cockle fishery and gas exploitation in the Dutch Wadden Sea is given in Figure 2.1. The next two sections present them in more detail.

2.2.2 Cockle fishery

Two shellfish species in the Wadden Sea are fished commercially: cockles (*Cerastoderna edule*) and mussels (*Mytilus edulis*). The mechanical cockle fishery has been the most controversial. This type of fishery started in the 1950s. It uses a hydraulic suction dredge alongside a ship to systematically harvest the shellfish from the tidal sand flats. Before, the cockles were harvested manually during low tide. In 1973, the mechanical cockle fishery became regulated through a license system (Van Nieuwaal 2011; Verbeeten 1999).

Since the 1980s, research on the possible impact of mechanical cockle fishing on the ecosystem of the mud flats and the availability of the shellfish for birds, started to play a role (De Vlas 1982; Dankers & de Vlas 1992; RIN 1987). This research became highly relevant when in 1988 and 1989 an extremely low spat fall of cockles and mussels was observed. After a request of nature organisations to reserve the low amount of shellfish for the birds, the ministry of Agriculture, Nature and Food Quality (in Dutch 'LNV') decided to partly close the Dutch Wadden Sea for shellfish fishing in 1990. However, this decision was successfully opposed by the fishermen at the Raad van State, which resulted in the fishing of the cockles and mussel banks in 1990. This was followed by large protests of the nature organisations in the media, blaming the fishermen for the large mortality of birds in the winters of 1990-1991 and 1991-1992 (Imeson and van den Bergh 2006; Verbeeten 1999). In reaction to this conflict, the ministry of Agriculture, Nature and Food Quality came in 1993 with new regulations in the form of the Sea and Coastal Fisheries Policy: 26% of the Dutch Wadden Sea area became closed for mussel seed and cockle fishing and enough cockles and mussels should be left to satisfy 60% of the food requirement of the bird populations (LNV 1993). Also the fishermen came up with new initiatives, such as fishing plans, logging their activities through black boxes, and organising themselves in a Producers Organisation (Steins 1999).

This did not stop the controversy on the impacts of the mechanical cockle fishery. The outcomes of research on the effects of the fishery on the ecology were interpreted differently by the fishermen and the nature organisations, which resulted in

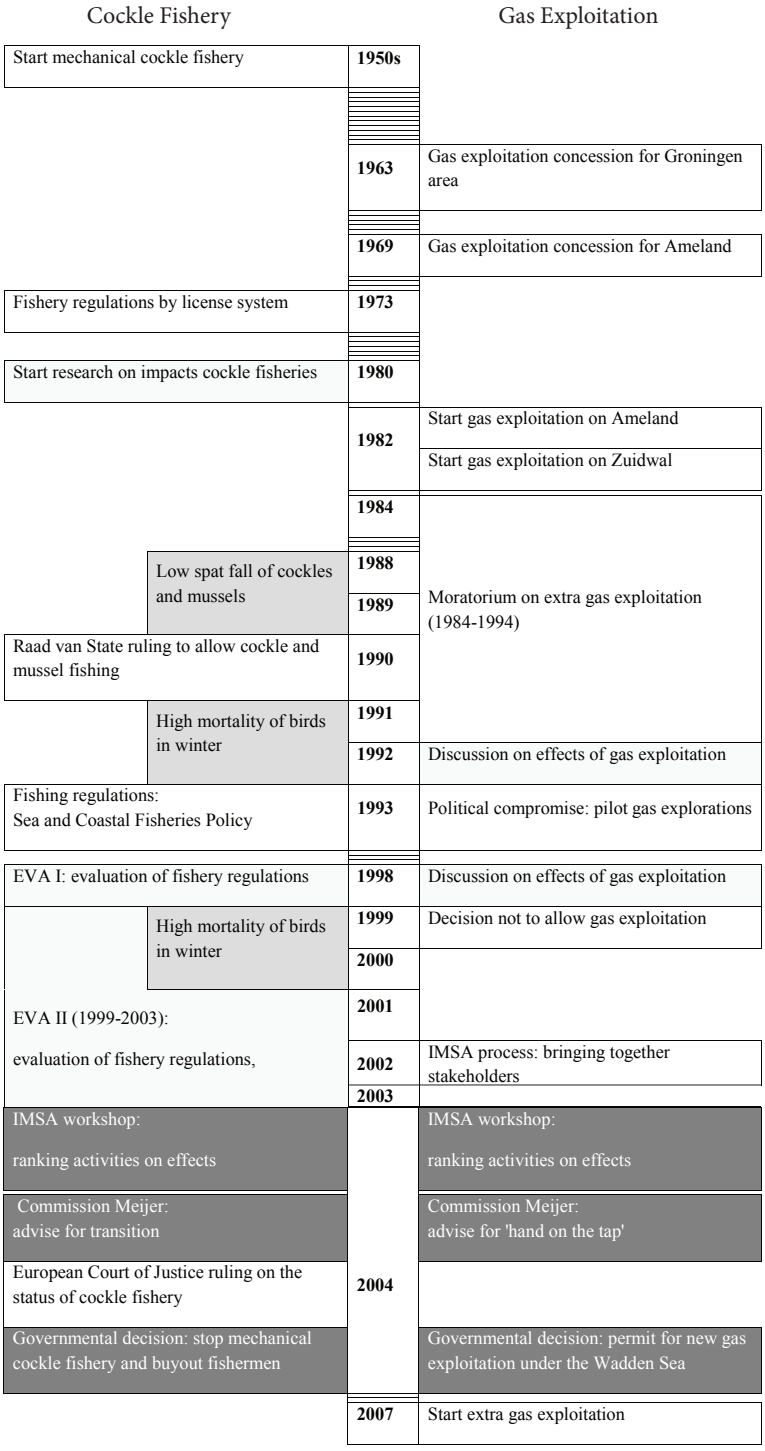

Figure 2.1. Timeline of important events and decisions for the cockle fishery and gas exploitation case, with major ecological events in light grey and the policy connection in 2004 in dark grey.

commissioning their own research (Nomden et al. 1999). In 1998, an ecological evaluation program (EVA I) assessed the impact of the restrictive fishing policy, but the results were inconclusive, there was insufficient data to make strong conclusions (LNV 1998). A debated NIOZ report, however, stated there were long-term negative effects (Piersma & Koolhaas 1997), this rapport was criticised for not being scientific, until it was put into an academic publication (Piersma et al. 2001). Based on EVA I, the minister of Agriculture, Nature and Food Quality planned a more thorough evaluation (EVA II) for the period 1999-2003 (Ens et al. 2004). During this period there was a large disagreement over the effects of the cockle fisheries. Research outcomes were used as arguments in this controversy, and some researchers took an active stance in the conflict (Swart and Van Andel 2008; Turnhout 2003). The observations of high mortality of Eider ducks in the winters of 1999-2001 intensified the debate (Camphuysen et al. 2002; Ens 2000; LNV 2000;). The dispute on cockle fishery was also taken to the Raad van State, but every year the fishermen won and got a permit to fish (Hanssen et al. 2009; Swart and Van Andel 2008). The EVA II reports were finalized in December 2003.

Before the EVA II process was finished, however, a new policy dynamic came into play, connecting the cockle fisheries with gas exploitation. This was influenced by the activities of the environmental research and consultancy company IMSA, which became a mediator in the controversy on gas exploitation (see also section 2.3). During the mediation activities, IMSA connected the cockle fishery - which was perceived as major threat to the ecological quality of the Wadden Sea – to possibilities for new gas exploitations. During an expert workshop organised by IMSA in 2004, in which ecological experts ranked the impacts of existing activities, cockle fishery came out as having the largest negative effects, much more than gas exploitation (Runhaar 2009).

Another important factor in the controversy was the Commission Meijer which was installed by the Dutch government to explore possible policies for gas exploitation, shellfish fishing, and conservation of the Wadden Sea nature. Supported by EVA II results and researchers, in 2004 this Commission, together with its advice on gas exploitation, proposed a 7 year transition period for the cockle fishery to develop sustainable fishing methods, and advised to use part of the revenues from gas exploitation for a fund supporting restoration, conservation and research in the Wadden Sea area (Meijer et al. 2004).

In September of the same year, and perhaps most influential of all developments in 2004, the court ruling of the European Court of Justice stipulated that the cockle fishery should be handled as a project for which an appropriate assessment is required. The appropriate assessment should establish whether the cockle fishery has negative significant effects on the nature values of the Wadden Sea (European Court of Justice 2004). The Court's ruling also implied that the precautionary principle should be applied for the cockle fishery, which put the burden of proof with regard to effects on the ecosystem with the fishermen. Against this background the national government decided to stop mechanical cockle fishing in the Dutch Wadden Sea and to buy out the cockle fishermen.

This was the end of the mechanical cockle fishery in the Dutch Wadden Sea. Manual harvesting cockles continued and was intensified (Runhaar 2009; Swart and Van Andel 2008).

2.2.3 Gas exploitation

In 1963, the NAM (Dutch oil and natural gas producer) obtained the gas exploitation concession for the area of Groningen (including Slochteren and part of the Wadden Sea) and in 1969 it got an additional concession for the area around the island Ameland. The NAM intended to start gas exploitation on Ameland in 1971, but was delayed by protests of the local municipality, the Wadden Society and the province. In another area, the Zuidwal (in the west part of the Wadden Sea), a concession was requested in 1971 by the private company Elf Petroland. Finally, in 1981 the national government decided not to give this concession to Elf Petroland, because of possible negative effects on the Wadden Sea nature, but was forced to give the concession on the basis of a court ruling of the Raad van State in 1982. In that year gas exploitation started on Ameland and Zuidwal. Against this background of controversies, for the period of 1984-1994, a moratorium on further gas exploitations in all parts of the Dutch Wadden Sea was agreed on between the government and gas exploitation companies (Van Nieuwaal 2011; Verbeeten 1999).

In 1992 the discussion on gas exploitation started again when the Dutch government made clear that it wanted to prolong the moratorium, while the gas exploitation companies declared that they wanted to start with new gas exploitations. A compromise was reached in December 1993, by allowing pilot gas explorations (Lindeboom 1993; Verbeeten 1999). In 1998 the discussion on gas exploitation in the Wadden Sea gas was reopened, with again an important role for scientific knowledge on the impacts of gas exploitation, specifically the effect of subsidence and coastal erosion. The discussion focussed on the question whether sedimentation in the Wadden Sea could keep up with subsidence, in which case hardly any actual decrease of the intertidal area and thus effects on the ecosystem would occur (Dijkema 1997; Oost et al. 1999). However, scientific reports that stated that the effects of exploitation would be negligible were contested because they were commissioned by the NAM (Eysink et al. 1995; Eysink et al. 2000). Greenpeace commissioned a contra-expertise rapport in which the economic effects were calculated for the hypothetical case of large subsidence (Van Wetten et al. 1999). In November 1999 a political crisis emerged when the government decided to allow gas exploitation and the parliament rejected this. After a debate about the reliability of no-effect predictions, the government decided against gas exploitation in the Wadden Sea (Turnhout et al. 2008).

A new dynamic started when the issue of gas exploitation became connected with cockle fishery, as described in the previous section. In the period of 2002-2004 IMSA carried out a project to bring stakeholders and politicians together, financed by the NAM. In April 2004 the Commission Meijer (a governmental advice commission) concluded that gas exploitation without significant ecological effects appeared to be possible and

advised the 'hand on the tap' method. This method implies structured monitoring for unwanted effects: to prevent irreversible effects to occur, the amount of gas exploitation per year is restricted (Meijer et al. 2004). This advice was taken up in the governmental decision in 2004 to allow gas exploitation (Runhaar and van Nieuwaal 2010). The protest against this decision was fought out in court, and was settled in 2007 with the Raad van State deciding that the gas exploitation would be allowed (Raad van State 2007).

2.3 Review of the social science literature on the Dutch Wadden Sea

2.3.1 Structuring the literature

The selected review publications can be clustered around three main themes based on their different perspectives on the Wadden Sea controversies, see Figure 2.2. The theme 'resource management' refers to studies that deal with science-policy issues within a perspective of stakeholders in the management of the Wadden Sea as a common resource. The theme 'nature views & discourses' deals with science-policy interactions from a perspective in which different interpretation frameworks are key structuring factors. Finally, the publications in the theme 'science dynamics' take the science-policy interactions as the main topic of their research.

In reviewing the publications, we particularly focus on science-policy interactions and pay less attention to other arguments presented. We have tried to stay close to the authors' interpretation of success and failure in the controversies described. It is obvious that in these much-debated conflicts there are diverging views on the policy processes and outcomes. When describing the arguments of the authors, we do not claim that these arguments are beyond dispute.

2.3.2 Resource management

In one of the earliest studies on science-policy interactions, Verbeeten (1999) investigated the cases of gas exploitation and cockle fishery from a perspective of policy-oriented learning. In this perspective, the role of new knowledge and insights in changing policy is central to the analysis. Regarding the cockle fishery Verbeeten looked at the period 1950-1998, with the license system decision of 1974 and the fishery regulations of 1993 as landmarks. The process towards the decision on fishery regulation in 1993 was characterised by conflicting views on the ecological effects of mechanical cockle fishery. In the 1980s there had been large uncertainties in the knowledge about the impacts of mechanical cockle fishery and effects were generally considered to be low. In the 1990s, however, new research concluded that there was a causal relationship between mechanical fishery, benthic food availability and negative trends in bird populations (Dankers & De Vlas 1992; De Vlas 1982; RIN 1987). This information was contested and strategically used by stakeholders: nature organisations emphasized the negative effects, while fishermen claimed these effects were exaggerated and tried to show this by commissioning more research. Although there were differences of interpretation, there was a dialogue between

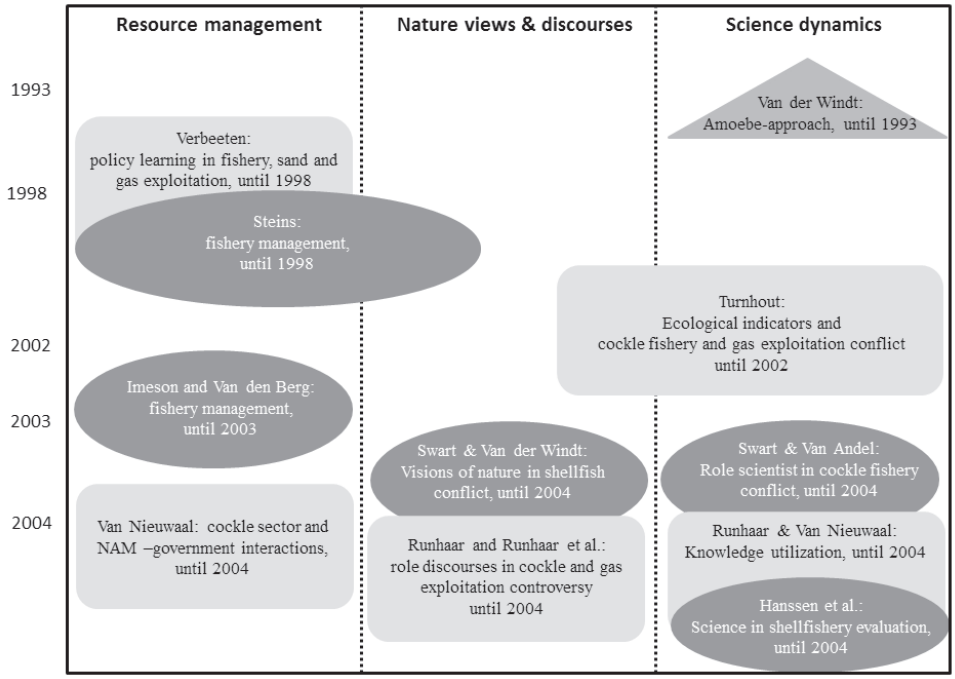

Figure 2.2. Visual representation of the reviewed literature, with authors, research themes and last year of their research period. The research in the ovals focused on the fishery conflict, research in the rectangles focused on both the fishery conflict and the gas exploitation, the research in the triangle did not focus on either of these conflicts.

the actors involved about the research outcomes. Moreover, since 1992 the fishermen, nature organisations and the government acknowledged their mutual dependence and the new policies of resource conservation were considered legitimate by them. According to Verbeeten, these circumstances made it possible for policy-oriented learning to take place. This means that due to new knowledge and insights the definition of the policy issue, the policy goals and the policy instruments changed in a way that maintained or even improved the legitimacy of the policy.

Regarding gas exploitation Verbeeten looked at the period 1960-1998, distinguishing two decisions that changed the policy direction: the moratorium on gas exploitation in 1984 and the decision in favour of pilot gas explorations in 1993. Verbeeten interpreted the moratorium decision as a result of policy-oriented learning. For the process towards the political compromise that allowed gas exploration in 1993, however, she concluded that there was no policy-oriented learning. The new policy was not broadly supported, but rather the result of a power play, in which economic considerations were most powerful. Learning through new knowledge occurred, but the opponents of gas exploitation contested the validity of this knowledge. Rather than disputing the

knowledge on scientific grounds, they questioned the legitimacy of the knowledge, because all the research on the effects of gas exploitation was commissioned by the NAM.

While Verbeeten stressed the importance of policy-oriented learning, she also added that the economic context and the relations between relevant parties are very important in influencing the policy-making process. To improve policy-making, she recommends regular interactions between parties, with a focus on knowledge sharing. Here Verbeeten sees an important role for science, under the condition that scientists and scientific information are experienced as independent.

In contrast to Verbeeten, Steins (1999) focused more specifically on the resource (co-) management of the shellfish fishery in the period 1993-1998. After some voluntary measures by the fishing industry in 1991, the Sea and Coastal Fisheries Policy (SCFP) in 1993 meant a shift from the situation of complete freedom for each fisherman with a licence, towards common property fishing. This entailed that the Producers Organisation was responsible for dividing the fish quota and fishing days between the fishermen. According to Steins the aim of this policy was to integrate shellfish fisheries and nature values through a multi-party process, encompassing the government, the shellfish industry, nature conservation groups and scientists. This process was partly successful, and there were indeed official negotiations between the main stakeholders. On the other hand, however, there were sharp conflicts about the mechanical cockle fishery and there was only limited trust between the different parties. There was disagreement on when and where fishing took place, however, this was settled by the black boxes that monitored the fishermen's activities. Steins stated that the unsuccessful functioning of this management process was influenced by several factors: initially not all cockle fishermen's were part of the agreed regulations; no common rationality was developed because of the strategic participation of nature conservation organisations; and there was limited interaction between the stakeholders, only during periods in which policies were designed or evaluated.

An unlucky accident in the process was the fishing of the scientific research plots just after implementing the SCFP. This was probably a mistake caused by an incorrect map in the SCFP on which the research plots were not designated as closed areas. Nonetheless, it had a negative influence on the relationship between fishermen and scientists, particularly for the scientists that Steins calls 'political biologists': the biologists that advocated nature protection and publically claimed that there were negative effects of cockle fisheries. Steins also asserts that the different positions of the stakeholders in the management process are related with their nature views.

According to Steins, science was important in the management process, however differently for each stakeholder. The government used scientific knowledge to justify their policy. Nature organisations used scientific knowledge that proved the negative effect of the (cockle) fishery to support their position against the fishery practice. Fishermen were dependent on the scientific inventory of the shell-

fish stock and on the development of new fishing techniques. In addition, fishermen commissioned new scientific research to show there were no adverse effects.

Like Steins, Imeson & Van den Bergh (2006) analysed the fishery management process, but their research scope expanded until 2003. They investigated the impacts of the Sea and Coastal Fisheries Policy (SCFP) on the objectives of the various stakeholders and the implications of this policy for establishing a sustainable fishing practice. The stakeholders they distinguished were the government, the conservationists, the fishing sector and researchers. In doing so they categorized scientists as actors having a stake in the outcome of the process: "scientists can be considered a stakeholder group because their research can benefit from the establishment of areas permanently closed to fishing" (Imeson and van den Bergh 2006, p.499). The authors concluded that the SCFP could not realize the different objectives of the stakeholders. Explaining factors for this were the lack of communication between stakeholders, the lack of a common objective shared by all stakeholders and disagreement about which policies were appropriate. Imeson & Van den Bergh criticised the national government for inconsistently applying the precautionary approach for the Wadden Sea. According to them the fishing practices were tolerated until it would be proven to be a threat to the sustainability of the ecosystem, whereas gas extraction in 1999 was not allowed because the absence of effects could not be guaranteed.

Van Nieuwaal (2011) brings in a new perspective to the resource management theme: that of the economic entrepreneur. Van Nieuwaal analysed the cockle fishery and gas exploitation cases as firm-government interaction process and investigated the institutional survival path of the cockle fishery sector and the NAM. These survival paths were structured by controversies in which actions were mobilised. With regard to the cockle fishery, Van Nieuwaal analysed several controversies over the period of 1973 to 2004. In his view, the central controversy for the cockle fishery is on the ecological effect of mechanical cockle fishery, specifically the effects on bird populations. While other controversies, such as the one on fishing rights, were settled, the central controversy on the effects on the ecosystem has not been settled according to Van Nieuwaal, at least not for the fishermen. However, the controversy ended with the buyout of the fishermen in 2004.

Van Nieuwaal showed that knowledge played a central role in this controversy. Uncertainty of knowledge was an issue of dispute, but also the question whose knowledge is more valuable: the practical knowledge of fishermen or scientific knowledge. With the decision of the European Court that the mechanical cockle fishery should be considered as a project for which the precautionary principle applied, the direction of the discussion changed, putting the burden of proof on the fisherman. The mobilisations of the fishermen were insufficient to prevent the buyout of their enterprises in 2004. They relied too much on their position as an established activity and on following the rules without being pro-active. For example, they did not invest

in technological innovation. At the same time, there was a strong counter-mobilization from nature organisations, especially the pressure group 'the Wild Cockles' (in Dutch 'De Wilde Kokkels') that protested against all their permits in court. In public media, the arguments of the fishermen that they would not ruin their own resources was not convincing enough against the images of death birds and disturbed sediments.

Also in the gas exploitation case, Van Nieuwaal regards the effects on the ecology of the Wadden Sea as the central controversy. According to him, this controversy was only temporarily settled in 1999 by the parliamentary decision against gas exploitation. Van Nieuwaal posits that through strategic mobilisation of the NAM, gas exploitation came back as a potential option, especially after the link with the cockle fishery and the IMSA session on ranking activities on their effects. The ranking workshop by ecological experts facilitated a shift in environmental attention from gas extraction to another activity that was now perceived as more harmful: mechanical cockle fishery. Van Nieuwaal claimed the strategy of NAM to have IMSA facilitate interactions between stakeholders was very successful. In their facilitation of interactions not only natural science insights were used, but also lessons from social science. The remaining doubts on gas exploitation were met through the 'hand on the tap' method.

Resource management conclusions

The review of the resource management literature leads to the following conclusions. Firstly, scientific knowledge - mainly with regard to the ecological effects of activities within the Wadden Sea - played a very important role in resource management. Here science was used as source of information. Secondly, the scientific knowledge itself became problematic. The legitimacy of knowledge was contested, depending on who commissioned or carried out the research, and information was strategically used by stakeholders. Thirdly, next to the role of (new) scientific knowledge in resource management, other factors such as economic interests, the perception of uncertainties, power relations, and the shifts in burden of proof by the application of the precautionary principle, had an impact on how and when knowledge was used. Finally, science was not only a source of information, but some scientists ('political biologists') took an active role. Thus, to some extent, scientists acted as stakeholders with specific interests in the policy outcomes, although their interests did not play a substantial role in the conflict.

2.3.3 Nature views and discourses

Focusing on nature views, Swart & Van Der Windt (2005) specifically looked at the views of nature incorporated in the different perceptions of sustainability that clashed in the shellfish conflict until 2004. They analysed the nature views of the shellfish organisations, the national government and the Wadden Society. According to this analysis, the shellfish organisations perceived sustainability mainly in terms of 'economically profitable' and 'ecologically sound', drawing on their traditional knowledge of the sea and their own interest to sustain their resource. The Dutch government gave priority to both human welfare and

human duties towards nature. In policy documents both human welfare and the intrinsic value of nature were stressed. The Wadden Society emphasized the intrinsic value of nature, as well as the mutual dependency of humans and nature: they perceived the Wadden Sea as a last wilderness, but also saw the traditional hand-catchment of cockles as a sustainable way of dealing with nature. With their approach, Swart & Van der Windt illustrated that the conflicts not only involved different interests but were also connected with diverging deeper beliefs and ideas. They argued that these deep beliefs are very hard to change on a short term, and concluded that it is therefore unlikely that deliberation and communication between the Wadden Society and fishery organizations will result in consensus.

In contrast to the research of Swart & Van der Windt the analysis of Steins (1999) does not start with the conflict, but with the co-operation between fishery organisations and the Wadden Society in the co-management of the shellfish fisheries in the period 1993-1999. Although Steins also concludes: "of crucial importance for the relationship between nature conservation groups and the shellfish industry, and therefore for resource use negotiation, are the images both groups have of nature and each other" (Steins 1999, p.139). With regard to the images of nature she found similar differences between the shellfish industry and the nature conservationist as Swart & Van der Windt: while the shellfish industry agreed with a need for sustainable ecosystems, they saw the Wadden Sea at the same time as a production area. Nature conservationists perceived the Wadden Sea first and foremost as a nature monument in which natural processes should take place without interference for purposes of human use. These different views explain why the proposal of cockle fisherman to rotate the closed areas was not an option for the nature conservationists. For the nature conservationist this nature should be without human intervention, for the fishermen the nature could only be seen in combination with human activities.

Extending the scope of Swart & Van der Windt and Steins, who focused on the nature views of the fishermen and the nature organisations, Turnhout (2003) also analysed the nature views of scientists involved in the policy process. She based her analysis on three ideal types of nature: nature as resource, as a pastoral idyll and as wilderness. In the nature policy of the Wadden Sea, she observed an increase of the wilderness view, linked to an upcoming trend of nature development with a focus on dynamic natural processes. This trend is shown in her analyses of the trilateral expert workgroup in 1994, whose aim was to develop ecological targets for the Wadden Sea. These ecological experts "perceived the Wadden Sea as a robust and dynamic nature area" (Turnhout, 2003, p. 80), which made it undesirable or even impossible to develop fixed quantitative targets. However, because of policy requirements also elements of the pastoral idyll view were added, in particular by including concrete species as nature conservation targets. Turnhout's analysis illuminates the role of different nature views in interactions between scientists and policy-makers in the policy-making process.

Adding a new dimension to the views of the previous researchers, Runhaar (2009) investigated the policy process from the perspective of policy discourses, which he defined as "the frames through which groups of actors give meaning to aspects of the world" (Runhaar et al. 2010, p.339). In his analysis he looked specifically at discourses on human-nature relations in the Wadden Sea area and observed a change in the dominant policy discourse over the period of 2000-2004, from 'Hands off the Wadden Sea!' to 'Human activities within ecological limits', implying no new activities in the Wadden Sea towards a discourse that implies that activities that do not harm the ecosystem should be allowed. Runhaar made an explicit link between the dominant discourse and the use of knowledge: "the use of environmental knowledge depends on the degree to which environmental knowledge fits into the dominant discourse" (Runhaar 2009, p.207). For example, he explained the change in use of the scientific knowledge on the effects of gas exploitation on the ecosystem in 1999 and 2004 as follows. In 1999 the statement that the effects of gas exploitation were minimal was not a convincing argument for the Dutch parliament, because within the dominant discourse 'Hands off the Wadden Sea!' the normative position of no additional human activities was dominant. With the change towards a discourse in which human activities are allowed within ecological limits, the emphasis shifted to the scientific analysis of ecological effects and limits, which in this case strengthened the power position of the actors in favour of gas exploitation.

From his perception that discourses are very important in decision-making, Runhaar recommends discourse articulation and reflection for better understanding in decision-making processes. Acknowledging the structural and implicit elements of discourses, which makes change very difficult, Runhaar et al. (2010) explore the conditions for discourse reflection, connecting it with concepts as reframing and policy learning. According to these authors, important factors for discourse reflection are the malleability of discourse, the openness of actors involved, the role of a mediator as a neutral party and exogenous factors, like court rulings. They state that when the dominant discourse is incongruent with environmental assessment outcomes, these outcomes will likely not be used in decision-making. To increase knowledge utilization discourse reflection can be encouraged. For the Wadden Sea case these authors describe IMSA as an important mediator that helped to change the dominant discourse. Runhaar et al. (2010) recommend scientists in environmental assessments to collaborate with mediators to encourage discourse reflections and recommend scientists to reflect on their own discourses.

Nature views & discourses conclusions

From the literature with the nature views & discourses perspective, the following conclusions can be drawn. First of all, conflicts of stakeholders were connected to their different nature views. Secondly, the nature views of scientists had an impact on their policy advices. Thirdly, which knowledge is used and how scientific knowledge is interpreted in the policy process depended on the dominant discourse. Finally, it was recommended

for scientists to enhance knowledge utilization by facilitating discourse reflection, for example by collaborating with mediators.

2.3.4 Science dynamics

In one of the first studies of science-policy dynamics in the Wadden Sea, Van der Windt (1995) focused on the Amoeba-framework in the Wadden Sea policy development. This is a tool to visualise the quality of an ecosystem, see Figure 2.3. The debate on the effects of economic activities on the ecosystem is connected with the ecological quality of the Wadden Sea. In 1989, the Amoeba-framework was used for the Wadden Sea to show its ecological quality. The Amoeba-framework was developed by 'Rijkswaterstaat', part of the ministry of Transport, Public Works and Water Management. Van der Windt analysed the Amoeba-framework as a boundary object, bridging different worlds that could connect through this object. It connected different ministries, policy-makers and scientists. The object could be used from a technical water quality view and a nature protection view. In its target species also commercially fished species were included, combining the view on the Wadden Sea as a production area and as a nature area. The visualisation of target species and their states against reference values made it possible to discuss nature goals and policy measures. The strength of the approach was its clearness, however the choice for target species meant also a simplification of the ecosystem. The development of the Amoeba-framework stimulated more research to underpin the target parameters, while at the same time it was criticised for not being scientific enough. The Amoeba-framework showed the mixing of science and policy-making and the close relations between (some) scientists and policy-makers in the Wadden area, which made it possible to establish new policy measures.

Within the same line of thought on boundary objects and close science-policy interactions, Turnhout (2003) studied the development of ecological targets for the trilateral policy of the Netherlands, Germany and Denmark by an expert working group in the period 1992-1994. In that case the Amoeba-framework was not used, but new targets were formulated that can be described as qualitative open-ended ecosystem objectives. At that moment the Amoeba-framework could no longer work as a boundary object. The strict quantitative targets in the Amoeba-framework were not politically feasible and its rigid aspect and historical reference were contested by scientists (Turnhout 2003; Turnhout 2009).

Reflecting on ecological indicators as boundary objects between the science and policy domain Turnhout (2009) emphasized the need of a common culture between the parties involved for boundary objects to be effective. After a reflection on knowledge utilization in Turnhout et al. (2007), where the authors start with the paradox that science is aimed to close the debate but only exacerbates it, they recommend to include stakeholder perspectives in the development of ecological indicators to be effective boundary objects.

Next to the role of ecological indicators as boundary objects, Turnhout

(2003) examined the science-policy interactions and the role of scientists in the cockle fishery and gas exploitation controversies in the period 1998-2002. She perceived both controversies as debates between two knowledge coalitions: Pro Nature and Pro Fisheries/Gas-exploitation. Scientific uncertainty and knowledge gaps were used to undermine knowledge claims. In the cockle fishery controversy the claim that the fishery had long-term negative effects was questioned in a scientific debate. In the gas exploitation controversy the claim that there were no significant effects was questioned, the Wadden Society started the discussion to what extent you can prove there will not be an effect. According to Turnhout the science-policy boundary was used to "undermine the claims of the other coalition. Within coalitions, the boundaries between science and policy were not contested" (Turnhout, 2003, p.92).

According to Turnhout et al. (2008) the role of scientists is connected with the type of policy problem. These authors distinguish well-structured problems with science as *problem solver*, unstructured problems with science as *problem signaller*, badly struc-

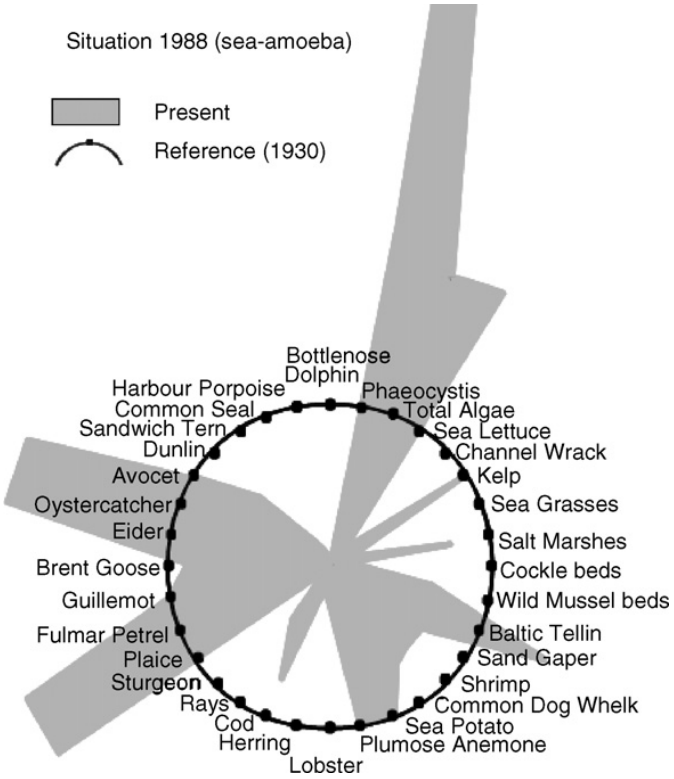

Figure 2.3. The Amoeba-framework shows the quality of a water ecosystem by presenting the present values of parameters against reference values that are set on 100% plotted in a circle (from Turnhout et al. 2007).

tured problems with science as *accommodation* and moderately structured policy problems with science as *advocacy*, see Table 2.1. The scientists involved in developing the ecological targets in the trilateral working group were seen as accommodating the process by depoliticizing the sensitive issue, while scientists on ecological effects of cockle fishery and gas exploitation were (willingly and unwillingly) part of advocating a specific position. Based on this analysis Turnhout et al. (2008) conclude that there are different science-policy structures, and these structures can change in the process from policy development to policy implementation. These authors criticise the general claim that science and policy should cooperate more closely. Instead, to avoid endless debates between competing knowledge coalitions, they recommend to recognise more unstructured problems in decision-making, and to enable more open dialogues.

Table 2.1. Science-policy typology from Turnhout et al. (2008).

Policy problem:	Well structured	Unstructured	Badly structured	Moderately structured
Policy process	Rule	Learning	Compromise	Negotiation
Role of scientist	Problem solver	Problem signalling	Accommodation	Advocacy
Knowledge	Data	Perspectives of intervention	Concepts	Arguments

Also focusing on the role of science in the debate on the Wadden Sea, Swart & Van Andel (2008) specifically looked at the controversy on cockle fishing between 1990 and 2004. Based on the changing roles of scientists, these authors distinguish four episodes. The first episode, 1990-1998 was characterised by the fishery measures and its first evaluation (EVA I) by ecological research institutes (LNV 1998). The second episode, 1997-1999, witnessed the intensive public debate on cockle fishery, triggered by a report of NIOZ (that was not part of EVA I) that stated that cockle fishery had long-lasting negative effects (see Piersma & Koolhaas 1997). The validity of this research was questioned as it was not academically published and scientists were criticised as behaving as conservationists rather than independent scientists. In the third episode, 1999-2003, the second evaluation study (EVA II) was carried out with a supervising steering committee with representatives from different stakeholders groups and an independent audit committee. At the same time there was the public debate on cockle fisheries, in which some (NIOZ) scientists, nature organisations (particularly the aforementioned 'Wild Cockles') and cockle fishermen took positions. In this period the research of NIOZ was published in reviewed literature (Piersma et al. 2001). After several postponements the EVA II research was finished (Ens et al.2004). In the fourth episode, 2003-2004, after some debate on the statement in the public summary about the role of the reduced nutrient load on the carrying capacity of the Wadden Sea, the dominant conclusion was that there were negative effects of mechanical cockle fishery. This episode also featured the advice of the Meijer commission to give the cockle fishery a 7 year-transition period, which was criticised by scientists for not

reacting fast enough on the scientific insights that there were negative effects. The debate stopped with the EU-court rule and the decision to buyout the cockle fishermen in 2004.

According to Swart & Van Andel, this process can best be described as societally contextualised science, where "contextualization implies the involvement of societal players in the research process by which the difference between scientific and societal statements may become less clear" (Swart and Van Andel 2008, p.86). In the public debate it was often unclear whether biologists were speaking as scientists, citizens or stakeholders. Swart & Van Andel used the concept of boundary work and boundary objects to describe these tensions.

According to Swart & Van Andel one way to deal with social contextualization is trying to cool down the public debate by stressing the necessity to wait for final scientific results. This approach failed for the EVA II research because the debate was heated up by external players. They propose another approach: extended accountability for (ecological) scientists, with a focus on sound ways of interacting and communicating with society. Therefore, scientists should accept that public controversy may arise, should have an open scientific debate, should consider seriously competing rationalities, should present scientific results in publicly accessible texts, and should scientifically evaluate political decisions based on research results.

The EVA II process between 1999 and 2004 was also evaluated by Hanssen et al. (2009). According to these authors the EVA II process had several shortcomings: the exclusion of the NIOZ, the limited time for deliberations, and the reduced scope of the research during the process. The Ministry of Agriculture, Nature and Food Quality reduced the EVA II scope with the decision to postpone the questions on the legal robustness of the fisheries regulations and the involvement of stakeholders and scientists in designing new regulation options. Hanssen et al. criticise both the unrealistic expectations of policy-makers that more research will quickly reduce uncertainties, and the unrealistic expectations of scientists that if they tell policy-makers what science reveals, correct policies will simply follow.

Hanssen et al. analysed the EVA II process as a failed pacification strategy of policy-makers. Within the pacification strategy it is assumed that scientific uncertainties can be reduced by doing more research, and this should bring parties together, see Figure 2.4. According to Hanssen et al., uncertainties were not successfully reduced in the EVA II process, due to a lack of an open dialogue between conflicting points of view, because of insufficient time to reach scientific consensus, and because of inherent uncertainties of the complex Wadden Sea nature.

As a reaction to this failed strategy, Hanssen et al. propose a facilitation strategy, with the aim first to reduce societal dissent, and then scientific uncertainties. Within this facilitation strategy, policy-makers should find shared ambitions by confronting and eliciting stakeholders perspectives to minimize polarization, and should use stakeholders' knowledge to maximize knowledge utilization. Scientists should involve stakeholders and policy-makers in knowledge production and scientists should participate

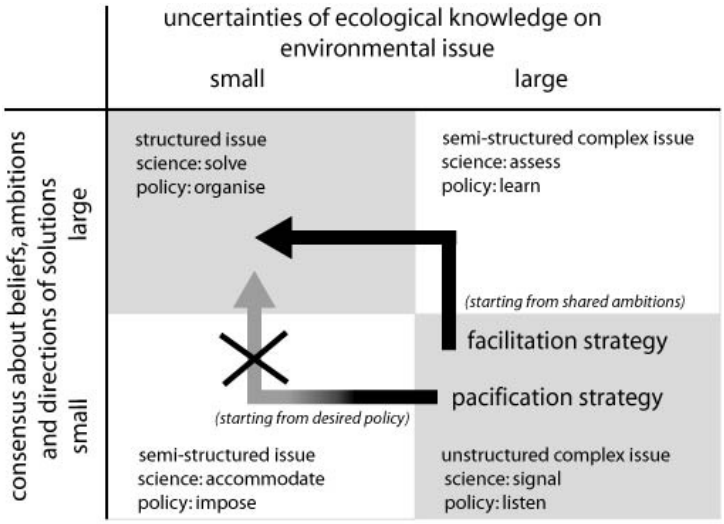

Figure 2.4. The facilitation and pacification strategy of policy-makers to structure the policy problem (from Hanssen et al. 2009).

in policy formulation and evaluation. These scientists should facilitate such participative processes by providing facts as well as educated guesses to evaluate policy plans.

Hanssen et al. claim that contesting beliefs and divergent directions of solutions should not be neglected. Scientific claims are always interpreted from different viewpoints. Accepting these limitations of scientific research for policy-making, ecological scientists can play their necessary explanatory role to understand the ecosystem complexity, without having an advocacy role which leads to scientific uncertainties used by vested interests.

In reaction to the analyses of Swart & Van Andel (2008) and Turnhout et al. (2008), that mainly focused on the role of scientists, Runhaar and Nieuwaal (2010) tried to explain the change in science utilization in 2004 by including the role of stakeholders. In their analysis they built on the earlier insights of Runhaar (2009) on the important role of mediator IMSA. Runhaar and Nieuwaal start with a reflection on science, arguing that "science and scientists generally are not value-free" (Runhaar and van Nieuwaal 2010, p.241) and that research that insufficiently reflects values of stakeholders is often ignored or contested. According to them the following science conditions are important for knowledge utilization: knowledge should be scientifically sound, research should be structured to search for policy options, research should have a broad focus, analysis should be trustworthy, analysis should bridge interests, assessment should have a legal requirement, the research and decision-making processes should be aligned, and the research should have sufficient resources. Based on these conditions Runhaar and Nieuwaal identify two different science-policy interfaces in the Dutch Wadden Sea debate on ecological effects: before 2000 a science-dominated science-policy practice and between 2000-2004 an in-

teractive science-policy practice with IMSA as a key mediator. According to these authors, the main reasons for not utilizing the research on the ecological effects on cockle fishery and non-effects of gas-exploitation in policy decisions before 2004 was the lack of interactions of scientists with decision-makers and stakeholders, and the narrow focus of research activities. Through the involvement of IMSA, with a focus on ecological effects of multiple activities and stakeholder participation, a reframing of the problem took place. However, crucial for this change in knowledge utilization in the decision-making was the sentence of the Court of Justice on the cockle fisheries. Referring to knowledge utilisation Runhaar & Van Nieuwaal stress the important role of mediators that encourage interaction with stakeholders and can facilitate reframing of problems and objectives.

Science dynamics conclusions

The following conclusions can be made based on the science-policy interactions analysed in the science dynamics perspective literature. First, there have been flexible boundaries between the domains of science and policy. Communication between these domains could take place through boundary objects. Secondly, within the conflicts on cockle fishery and gas exploitation the crucial boundary was the one between different knowledge coalitions, each consisting of actors from both the policy and the science domain with a shared position and interpretation of information. Scientists were willingly and unwillingly part of these coalitions. This advocating role of scientists within the management conflicts was seen as problematic. A proposed reaction, by Swart & Van Andel (2008), on this is an extended accountability of scientists. Thirdly, the EVA II process was perceived as a failed policy strategy to pacify the debate, both scientist and policy-makers had unrealistic expectations. A suggested alternative policy approach, by Hanssen et al. (2009), is the facilitation strategy: starting with the societal differences and an explanatory role for scientists. Fourthly, there have been different science-policy interfaces which are dependent on the policy problem and amount of interactions with stakeholders, resulting in different roles for scientist: from accommodating to advocating. Finally, mediators can play a crucial role in science-policy interactions to increase knowledge utilization.

2.4 Discussion

2.4.1 Shifting analytical perceptions of science

A shift can be observed in the way science is perceived in the three themes that we distinguished in this review. In the resource management literature, the role of science was mainly analysed as scientific information that was used as a resource in the management conflicts. In the nature views & discourses literature the role of beliefs, viewpoints and dominant frameworks on the interpretation and use of scientific information became important. In the science dynamics literature, the role of scientists and the flexible boundaries between the science and policy domain was central to the analysis.

These different interpretations of science-policy interactions can be connected with the analytical perception of what science is. We can roughly make a division in two approaches: a traditional realist perception, and a constructivist perception. Within a traditional view of science there is a clear distinction between the political and scientific domain, between values and facts. Scientific knowledge is obtained through asking methodologically sound questions which can be objectively answered. Within the constructivist view of science, on the other hand, there is contextualised knowledge: the political and scientific domains are intertwined, their boundaries are context dependent, and social processes co-determine the stabilization of scientific knowledge (Van Buuren & Edelenbos 2004).

Comparing the three described perspectives on the science-policy interactions a shift towards a more constructivist view can be observed. The reviewed literature within the theme resource management stays close to the traditional view of science, with scientific information as a resource for stakeholders, for example in the strategic use of information identified by Verbeeten (1999) and Steins (1999). They emphasized that stakeholders use scientific knowledge to legitimize their position. The focus was on the use of the knowledge, there was some attention on the role of scientist, but not on the scientific knowledge production process.

This is in contrast to the reviewed literature of nature views & discourses, where science is mostly approached from a constructivist view. For example by Turnhout (2003), who describes the role of nature views on the development of targets by ecological experts. And also by Runhaar (2009), who emphasized the role of dominant discourses on knowledge utilization, and explained the new interpretation of the same scientific information with a discourse change. In these publications, the policy frameworks and nature values were seen as connected to the understanding and production of knowledge.

The reviewed literature on the science dynamics perspective shows even more constructivist elements. Van der Windt (1995), Turnhout (2003) and Swart & Van Andel (2008) used the concepts boundary objects and boundary work between the science and policy domain, based on the assumption that these boundaries are actively formed. For example in the knowledge coalitions of Turnhout (2003), there was a difference between what a scientist could say and do inside a coalition and outside this coalition. Runhaar and Van Nieuwaal (2010) clearly express a constructivist point of view with their reflection that in general, science and scientists are not value-free. However, at the same time the traditional view of science has not disappeared. For example in the mixed position of Hanssen et al. (2009), in their recommended facilitation strategy they stress the legitimacy of stakeholder's knowledge, but also put emphasis on fact finding and the independency of scientists.

2.4.2 Normative perception of science

Within the reviewed literature there are also differences with regard to the normative perspective on science-policy interaction: on how scientific knowledge *should* be pro-

duced and what role scientists *should* play in the decision-making process. The general position of the reviewed publications is that involvement and commitment of all parties are very important, including scientists.

Not all authors have made explicit recommendations. With regard to knowledge production and interpretation, the following recommendations were made. Swart & Van der Windt (2005) recommended that different nature views should be acknowledged as a source of conflict and different interpretations of information. According to Runhaar (2009), reflection on the dominant discourse should be encouraged among scientists and other stakeholders. Mediators could be helpful for this purpose, although it should be acknowledged that dominant discourses are hard to change. Next to this, the involvement of stakeholders in the knowledge production process is recommended by Hanssen et al. (2009).

With regard to the role of scientists in decision-making, Hanssen et al. (2009) recommended an explanatory role, in which independent scientists provide facts and evaluate policy plans. Also Verbeeten (1999) stresses that scientists should be perceived as independent. At the same time, several authors recommended that scientist should interact more with stakeholders and the government. According to Swart & Van Andel (2008) scientists should aim for transparency through good communication, they should bring their scientific results to society and play a role in decision-making by evaluating political decisions. The advice of Runhaar and Van Nieuwaal (2010) to scientists is to take an active role by cooperating with mediators and involve policy-makers and stakeholders in the knowledge production process in order to bring together multiple perspectives on a broad research problem. They propose a form of co-production of knowledge. However, according to Turnhout et al. (2008), the role of scientists is connected to the policy problem, and closer science-policy interactions will not always be the best solution.

As some of the studies have demonstrated, the advocating role of scientists in the cockle and gas cases have been problematic. When scientists are perceived as independent authorities who can provide valid knowledge claims and this knowledge expresses stakeholders views, their knowledge claims will more easily be used in the decision-making process. To successfully address these challenges of independence ánd involvement, careful and deliberate choices have to be made with regard to the different modes of co-production of knowledge and the involvement of different parties in the knowledge production processes. In doing this, we can learn from the problems and successes in the EVA II process, and the influential contributions of mediators as IMSA.

2.4.3 The role of the government

The reviewed studies pay varying attention to the role of the government in the science-policy interactions. In the resource management studies, the government was the crucial player. In Steins (1999) and Imeson & Van den Bergh (2006), the fishery regulations in 1993 by the government was the starting point of their analysis. In other studies, particularly that of Verbeeten (1999) and Van Nieuwaal (2010), the government

was analysed as an actor structuring the process. In structuring the process, the government played a very important role as user of scientific knowledge to legitimize its decisions. In addition to these roles, the government was also very important as commissioner of research. For the EVA II process the role of the government, and more specifically the ministry of Agriculture, Nature and Food Quality, was analysed in more detail by Hanssen et al. (2009). The ministry initiated the EVAII research process and decided which research institutes were involved, when research results could be communicated and to what extent stakeholders could participate in the research process. Next to this, the ministry initiated another advisory commission with scientists involved, known as the commission Meijer. Remarkably, however, these active roles of the government in initiating and structuring the science-policy interactions were usually described as context factors, and not analysed as thoroughly as the role of scientists.

Moreover, the very important court rulings were positioned as context. All reviewed studies after 2004 acknowledge the crucial role of the European Court of Justice in the cockle fishery case with the ruling that the precautionary principle should be applied. The roles of the different stakeholders, governments on different levels and scientists in the process towards this court ruling are unfortunately not analysed.

2.5 Conclusions

This review has shown that ecological knowledge and scientists have played a very important role in the cockle fisheries and gas exploitation controversies of the Dutch Wadden Sea. In the cockle fishery case, ecological scientists signalled a possible negative relation between mechanical cockle fishery and birds populations. This was used as legitimation to regulate the fishery. The causal relation between the fishery and a long-term negative impact was however disputed. In the debate, the uncertainty and reliability of the ecological knowledge were discussed. Different scientific interpretations were strategically used by the government and stakeholders to legitimize their position. During EVA II (1999-2003), two parallel debates took place, inside the official scientific evaluation process and in the media by stakeholders and scientists who were not part of EVA II. The independence of scientists became criticised, as scientists were willingly or unwillingly placed in the coalition in favour or against the activity. In the gas exploitation case, the possible negative ecological impacts of subsidence of gas exploitation formed the argument to (temporally) prohibit the activity: in the decision for a moratorium (1984-1994) and the compromise to allow only pilot gas explorations in 1993. The scientific claim in 1998 that there would be negligible ecological effects was discredited as research financed by the NAM and politically contested by highlighting the uncertainties. The two controversies were settled in 2004 after the connection of cockle fisheries with gas exploitation was made. Crucial events were the EVA II process, the ranking of the impacts of different activities by ecological experts organised by IMSA, the advice of the committee Meijer and the European court ruling on the cockle fisheries.

These science-policy interactions have been analysed in the reviewed literature from three main perspectives. Central in the resource management perspective analysis was the strategic use of scientific knowledge in the policy process. In the perspective of nature views & discourses, the structuring influence of these views and discourses on the interpretations and use of knowledge was exposed. Finally, the science dynamic perspective highlighted the flexible boundaries between the science and policy domains and the role of scientists in the debates.

Summing up, the following lessons can be drawn from this review:

- Scientific knowledge is only one of the influential aspects in decision-making, next to e.g. economic interests and power relations.
- How scientific knowledge is used and interpreted by stakeholders depends on their nature views and on the dominant policy discourses. Different interpretations of knowledge explain why producing more scientific knowledge is in itself insufficient to find consensus between stakeholders. Reflection on nature views and discourses can be helpful to increase learning and resolve deadlocks. Independent mediators can play an important role in these difficult processes, but it should be acknowledged that dominant discourses can be very persistent.
- The science-policy interactions are structured by the policy setting. In the Wadden Sea context, the policy rules were mainly shaped by decisions of the national government, EU directives and court rulings. Next to the legal rules, the decision-making setting of who is involved with what kind of responsibilities, structures the science-policy interactions. Also the policy expectations influence these interactions, there are different relations when policy-makers expect first to reduce uncertainties (pacification strategy) or first to reduce the societal dissent (facilitation strategy). These policy settings are formed by the stakeholders, with an important role for the government. However, also other actors can influence the decision-making setting, as the mediating intervention of IMSA aptly illustrates.
- When scientific knowledge is an established condition - juridical or otherwise - for legitimate policy argumentations, this has a strong impact on the structure of the policy-science interactions. In the cockle fishery and gas exploitation controversies scientific knowledge was a pre-condition to make a legitimate claim in the debate. As a result, the focus was directed to the scientific knowledge itself, making it the topic of debate.
- In controversies there are roughly two positions in how a scientist can be perceived: as independent outsider or as connected to a societal position. How scientists are perceived only partly depends upon their own behaviour; in the cockle fishery controversy scientists became willingly and unwillingly part of a coalition. Scientists can actively emphasize their independent position or take up an extended accountability and acknowledge their connections with the societal field.

- Scientists can play different roles in science-policy interactions, from problem signalling, accommodation, to advocacy or a more explanatory role. These roles are framed by the policy setting, however scientist also influence their own role. One choice scientists have to make is to what extent there is co-operation with stakeholders in the knowledge production. With co-production of knowledge multiple perspectives, scientific and societal, are taken into account. This can increase the relevance of the knowledge for the decision-making process, but can also reduce the independent status of the research.

2.6 Epilogue

In this review article the emphasis has been on the cockle fishery and gas exploitation controversies. These controversies were largely settled in 2004. Since then new controversies on ecological effects of activities in the Dutch Wadden Sea emerged, for example on the mussel fisheries in 2008, and currently around Energy plants near Delfszijl. Future policies and projects, among which prominently the new Delta-program, will not fail to generate new and equally arduous debates on nature protection in relation to safety and other societal interests, not just in the Wadden Sea but also in other parts of the Netherlands, such as the South-West Delta. Scientific knowledge will remain a crucial and disputed factor in conflicts between environmental organisations, local residents, economic interest groups, and the government. The lessons from the cockle fisheries and gas exploitation cases, as they were presented in this review, may help to better structure the science-policy interactions in these new controversies. This will not likely prevent the conflicts, but it may help to find better and more timely solutions, with a broader legitimacy among the stakeholders involved.

Chapter 3

Uncertainties in the assessment of "significant effect" on the Dutch Natura 2000 Wadden Sea site

– The mussel seed fishery and powerboat race controversies

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Abstract

Natura 2000, the nature network based on the European Bird and Habitat Directives, is explicitly grounded on ecological science. To acquire a permit under the Dutch Nature Conservation Act, an appropriate assessment of significant effects must be conducted based on the best available scientific knowledge. In this way the scientific and policy world are directly linked. This article focuses on 'significant effect' as a boundary object to analyse how science-policy interactions shape the meaning and assessment of significant effect and how these interpretations influence the decision-making process. To this end, two conflicts over significant effect are investigated: the conflict over the 2006-spring permit for the mussel seed fishery, and the 2011 permit for the planned World Championship powerboat races. In both cases nature organisations started a court process against the government-granted permits in protest to the "no significant effect" claim, stating that there was insufficient certainty for this conclusion. These conflicts are approached as controversies between discourse coalitions with different interpretations of the ecological knowledge. We show how significant effect became a focal point in the controversies, limiting the debate to ecological arguments and science-based expertise, but also creating options for parties to advance their protest by articulating uncertainties. Only uncertainty of incomplete knowledge was explicitly addressed, excluding ambiguity of values and unpredictability of the actual ecosystem. We suggest that acknowledging the value aspect in disputes on significant effect would leave more space for effective solutions of the problems under debate.

3.1 Introduction

Determining which human activities are allowed, or more precisely, which effects of human activities are acceptable, is a central issue in the regulation of protected nature areas. In the discussions about effects of human activities scientific reports and uncertainty arguments often play a major role (Floor et al. 2013). Regulatory frameworks are set up to structure and guide these discussions over what is acceptable. In the EU, the main legal framework to protect nature areas is Natura 2000, based on the Bird Directive (79/409/EEC) and Habitat Directive (92/43/EEC). This legislation is science-based. Permits for human activities are dependent on the assessment of 'significant effect'. According to the Habitat Directive:

> "Any plan or project not directly connected with or necessary to the management of the site but likely to have a *significant effect* thereon, either individually or in combination with other plans or projects, shall be subject to *appropriate assessment* of its implications for the site in view of the site's conservation objectives" (article 6.3, Habitat Directive 92/43/EEC, emphasis by the authors).

The aim of this procedure is to prevent adverse effects on the protected habitats and species under the EU directives.

As a consequence, controversies over what is allowed in nature areas have transformed into disputes over the assessment of significant effect (Beunen 2006; Beunen et al. 2013). Although there is no fixed definition of what significant effects are in this legal context[2], it can be characterised as "a change in the conditions affecting the conservation objectives of a site to an extent which is considered unacceptable" (Opdam et al. 2009, p.913). This element of acceptability of effects falls within the tradition of environmental impact assessments (EIA). Ehrlich and Ross (2015) show in their overview of EIA academic literature that value judgement is an important part of such significance determination. According to them, the assessment of significance is open for multiple interpretations by actors from both the policy and the science world and is not a deterministic scientific outcome (Ehrlich and Ross 2015). However, these interpretations of significant effect are not arbitrary. Interpretations are context specific and shaped by the European legal origin, the national implementation and the course of the assessment process (LNV 2009).

An important aspect in the acceptability of an effect is the certainty of the knowledge used. This aspect of uncertainty has become very explicit through the EU case law on cockle fishery in 2004. In this case, the EU Court of Justice emphasized the precautionary principle and ruled that the authority could only permit the activity if "no reasonable scientific doubt remains as to the absence of such effects" (ECJ 2004, paragraph 61). This EU court decision became the benchmark for the role of scientific knowledge in permit procedures all over Europe, and opened the discussion on uncertainties,

[2] It should be noted that 'significant', in this context, has not the same meaning as the well-defined term significant used in statistical testing

which nature organisations effectively used to stop planned activities (Beunen 2006).

Several studies have been conducted on the implementation of Natura 2000 and the technical aspects of the assessment of significant effects (Beunen 2006; Beunen and De Vries 2011; Opdam et al. 2009; Söderman 2009; Therivel 2009). While these studies underline the importance of science-policy interactions and the pivotal role of assessment procedures, detailed empirical studies into science-policy dynamics are limited (Hommes et al. 2009). This is where our study contributes to existing literature on the European nature policy. As we will elaborate in the next section, we analyse 'significant effect' as a boundary object, to unpack the science-policy interactions that take place in the implementation of the EU legislation. The aim of the article is twofold. First, to give insight in the different meanings and interpretations of significant effect by scientists, policy-makers, and interest groups. Second, to explain how different interpretations of significant effect and uncertainties affected the decision-making process.

To this end, we selected the controversies over the 2006-spring permit for the mussel seed fishery and the 2011 permit for the planned World Championship powerboat races. These are two different activities with different political contexts, which will enable us to give in-depth insights on how science-policy interactions shape the meanings and assessments of significant effect. In both cases, the controversy was centred around the effects on the Dutch Wadden Sea. The Wadden Sea is a shallow estuarine sea, stretching from the Netherlands to Denmark, and is an important feeding ground for birds. The management of the Wadden Sea area is characterised by a continuous struggle of nature organisations against economical activities, a struggle in which scientific knowledge and scientists play an important role (Floor et al. 2013). Also in our cases, the credibility and legitimacy of the knowledge used for the assessment of significant effect was disputed, but the need for ecological knowledge, and the salience of this knowledge was not contested (Van Enst et al. 2014).

The article is structured as follows. In Section 2, we elaborate on our analytical framework of boundary objects and a typology of uncertainties. In Section 3, we explain the permit process and the steps in the assessment of significant effect. In Section 4, we describe the mussel and powerboat cases. In Section 5, we reflect on significant effect at the science-policy boundary. In Section 6, we draw conclusions on the science-policy interactions and the role of ambiguity in the decision-making processes over significant effect.

3.2 Science-policy interactions around a boundary object: discussing uncertainties

The assessment of significant effect shows the importance of scientific knowledge and expertise for nature regulation. Within the assessment knowledge of what will probably happen is combined with a value judgements on what is allowable. The first is traditionally seen as the scientific aspect, the latter as the policy or political aspect. In our

research, we do not assume prescribed boundaries demarcating the science and policy worlds (Gieryn 1999; Jasenoff 1994; Turnhout et al. 2008; Weingart 1999; Wesselink et al. 2013). In the field of policy advice "the traffic between the institutional domains of politics and science is rather dense" (Wesselink et al. 2013, p.2). However, the perception of scientific advice as value-free is still very dominant (Carter 2013), also within the set-up of the Habitat Directive and within guidelines aiming to assess significance in an objective way (Alphandéry and Fortier 2001; Opdam et al. 2009). To analyse the science-policy interactions around the assessment of significance, we use the concepts of boundary objects and uncertainty.

3.2.1 Significant effect as boundary object

In this paper 'significant effect' will be perceived as a boundary object. Crucial for a boundary object is its interpretative flexibility. It should be "plastic enough to adapt the local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites" (Star and Griesemer 1989, p.393). Boundary objects have been used in many studies analysing co-operation between actors from different social worlds (Iorio and Taylor 2014; Mattor et al. 2014; Star and Griesemer 1989; Star 2010; Swart and Van der Windt 2012; Turnhout 2009). For the assessment of significant effect, actors from research institutes, governmental departments and nature organisations, with different perspectives and daily activities all contributed their interpretation of what significance means. We use the concept of boundary object as an analytical tool to analyse a conflict situation, in contrast to the more common use of boundary objects as a way to bridge boundaries or even as a design tool to facilitate co-operation (Hegger et al. 2012; Swart and Van der Windt 2012). In our case studies the assessment of significant effect is not functioning in the way that it brings people together to work on a common goal, as with Swart and Van der Windt (2012). However, even in conflict situations, boundary objects can focus people towards the same topic and facilitate sharing of knowledge (Iorio and Taylor 2014; Turnhout 2009). In this way, the assessment of significant effect gives insight in interactions between different actors in structured conflicts, based on formal rules of the game, such as consultation and legal protest. However, boundary objects can also reinforce existing power structures and perform as a barricade that excludes people (Oswick and Robertson 2009). In the analysis of the debates which are centred around this boundary object, we will focus on this role of inclusion and exclusion. In the permit and juridical processes we analyse who was able to get access and which arguments were perceived valid.

3.2.2 Uncertainties in the significance of effects

The aspect of uncertainty has become crucial in controversies over activities in Natura 2000 sites. Especially since the EU case law demands certainty that activities not adversely affect the integrity of a Natura 2000 site (ECJ 2004). We perceive uncertainties as relational and constructed in particular situations (Shackley and Wynne 1996;

Van den Hoek 2014). Much can be uncertain in the assessment of significant effects, such as which protected species could be affected, the prediction of impacts, and the assessment to what extent this would influence the site's conservation objectives (Opdam et al. 2009). However, these uncertainties only become meaningful when they are acknowledged and expressed by actors involved in the decision-making process.

With the term uncertainty different knowledge situations can be addressed. We distinguish three types of uncertainty: incomplete knowledge, unpredictability and ambiguity, see Figure 3.1. The uncertainty of incomplete knowledge refers to imperfection of knowledge: to what is unknown at the moment but could be available with additional research. The uncertainty of unpredictability refers to what is seen as unknowable, for example the unpredictable chaotic dynamics of the Wadden Sea ecosystem. This uncertainty cannot be taken away by more research. The uncertainty of ambiguity is about actors knowing differently. Opdam et al. (2009) relate such ambiguity mainly to a lack of quantitatively defined indicators in the policy formulation of objectives. However, we will use a broader definition of ambiguity as "the existence of two or more equally plausible interpretation possibilities" (Dewulf et al. 2005, p.116). This classification of uncertainty will be used to distinguish how uncertainties are used in debates over significant effect.

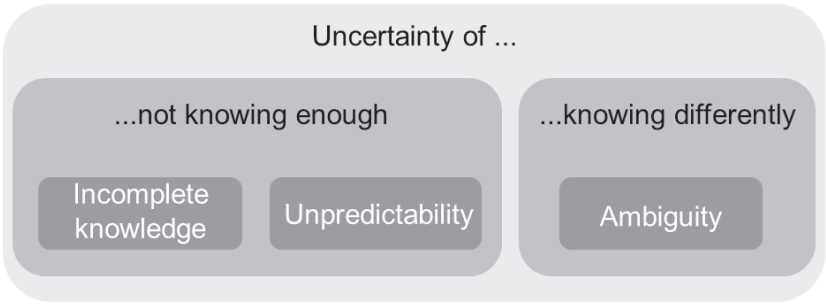

Figure 3.1. Schematisation of types of uncertainties based on Van den Hoek (2014).

3.2.3 Methodological approach

We use an interpretative approach to analyse the science-policy interactions in the controversies we selected (Yanow and Schwartz-Shea 2006). Interpretative approaches focus on the construction of reality by people "in a hybrid of social, political and scientific practices" (Beunen and Duineveld 2010, p.325). We structure our case studies by identifying discourse coalitions (Hajer 1993; Hajer 2006; Wagenaar 2011). A discourse coalition is "a group of actors that, in the context of an identifiable set of practices, shares the usage of a particular set of story lines over a particular period of time" (Hajer 2006, p.70). In conflicts over knowledge interpretations, these coalitions can consist of both scientists and policy-makers (Turnhout et al. 2008; Van Buuren and Edelenbos 2004).

In our analysis, we focus on the storylines about what should be part of the assessment of significant effects, including the use of knowledge and articulation of

uncertainties. For each case, we analysed reports, court rulings, newspaper articles, parliamentary proceedings, stakeholder websites and meeting notes. In addition, 17 semi-structured interviews were carried out to explore the role of Natura 2000 within the Wadden Sea area and reconstruct the relations between actors. In total 18 persons from scientific institutes, nature organisations and the national and provincial government were interviewed. Furthermore, observations and informal interactions with actors during 7 symposia and workshops contributed to our understanding of the Wadden Sea context. As a final step we confronted our key respondents with our findings, to check if our analysis was recognisable by actors with close experience of the cases (Hajer 2006).

3.3 Permit procedure within the Netherlands

Based on the European Habitat Directive, member states are required to implement the appropriate assessment procedure for significant effects, resulting in a variety of legal translations and assessment practices (Alphandéry and Fortier 2001; Beunen et al. 2013; Söderman 2009; Therivel 2009). In the Netherlands, the implementation of this European legislation has led to a large number of court cases (Beunen 2006; Beunen et al. 2013), among which Wadden Sea cases have been prominent. The combination of active nature organisations protecting the nature values of the Wadden Sea, a large group of researchers investigating the area, and important economical functions of the Wadden Sea has been a recipe for several conflicts over nature protection (Floor et al. 2013). Jurisprudence from the court cases has shaped the interpretation of European legislation, not only in the Netherlands, but also on a European level. A perfect example is the aforementioned ruling on scientific doubt in a Wadden Sea case for the European Court of Justice in 2004 (ECJ 2004).

Since 2005, the assessment of significant effect is part of the permit procedures under the Dutch Nature Conservation Act. The aim of this procedure is to protect the nature area as expressed in conservation objectives. For this, every initiator planning a potentially harmful activity must provide the permit authority with an assessment of significant effects on the Natura 2000 site's conservation objectives. Often the initiator of an activity commissions this appropriate assessment to science-based experts. The assessment of significant effect consists of determining the relevant conservation objectives and conservation status, and predicting the impact caused by the planned activity on the site conservation status. Finally, the value judgement has to be made whether a negative effect is significant, taking into account the vulnerability of the affected species, and the conservation objectives ranging from conservation to restoration (LNV 2006; LNV 2009), see Figure 3.2.

The permit authority should decide whether the initiator has provided an authoritative and comprehensive assessment report (Opdam et al. 2009). A permit can be granted if there is an assessment of no significant effects, possibly supported by mitigation measures to counteract possible adverse effects. As extra risk reduction measurement, the obligation of monitoring under the hand-on-the-tap principle can be part of

the permit. Originating from the case of gas mining in the Wadden Sea, this adaptive management approach implies stopping an activity when adverse effects are measured (Raad van State 2007). Legally, activities with significant effects can be allowed, however, under strict conditions and with compensatory measures. Within the Dutch permit system, there are formalised moments to protest against a permit. Firstly, stakeholders have the right to see the permit before it is given, and react on it. The reactions are collected and taken into consideration by the permit authority. Ultimately, stakeholders can protest at the 'Raad van State', which is the supreme court of Justice (Beunen 2006).

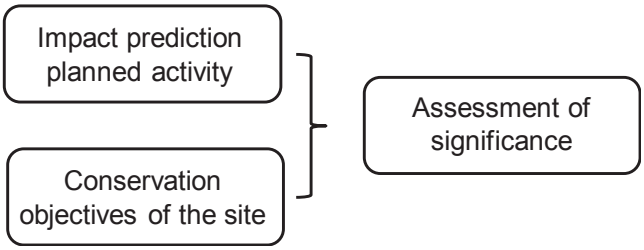

Figure 3.2. Representation of the three main steps in the assessment of significant effect, based on Opdam et. al (2009).

3.4. Interpretations of significant effect in two controversies

In this section the conflicts over the assessment of significant effects in the cases of the mussel seed fishery 2006-permit and the powerboat race 2011-permit are described and analysed. These two cases are shortly characterised in Table 3.1.

3.4.1 The mussel seed fishery controversy

In March 2006, the producer organisation for the mussel sector requested a permit for the spring mussel seed fishery (*Mytilus edulis*). This type of fishery is part of a production cycle from mussel seed towards consumption mussels. The mussel seed, which are juvenile mussels, are brought from wild mussel banks to cultivation plots in the Wadden Sea. This fishing practice, which is regulated since 1993, takes place two times a year on areas that are constantly covered with water (Ens et al. 2004). In autumn, fishery is only allowed on newly formed 'unstable' mussel banks, which are expected to disappear in winter through storms or star fish predation. By restricting fishery to these unstable banks, sufficient mussels should be left as food for birds in winter. In spring, the remaining mussels may be fished (Van Stralen and Sas 2006). However, this fishing practice is highly controversial, especially since the nature organisations blamed fishermen for the high mortality of eider ducks in the 1990s, resulting in several juridical procedures against shellfish fishery by nature organisations (ECJ 2004; Raad van State 2005). From 2005 on, the fishermen were obliged to demonstrate that there is no significant effect before they can obtain a permit. For the autumn-2005 permit, the ministry of Agriculture, Nature and Food Quality (in Dutch 'LNV') commissioned research in-

stitute Alterra to make an appropriate assessment. Their conclusion of 'no significant effect' was mainly based on their interpretation that significance means stable mussel banks would be affected. Since in the autumn period fishing was only allowed for unstable mussel banks, there could be no significant adverse effect. Fishing these mussels and transporting them to culture plots could even increase the biomass of mussels and food availability for birds in the Wadden Sea. By the same argumentation, however, mussel seed fishing in spring, on mussel banks that by definition have the potential to become stable mussel banks, could potentially generate significant effects (Alterra 2005).

In 2006, the producer organisation commissioned the consultancy MarinX instead of Alterra for the appropriate assessment. In this period, meetings took place between mussel fishery organisations, nature organisations and scientists. However, the nature organisations were afraid the fishing practice would not change, and therefore contested the permit to put more pressure on the process towards sustainable fishing. The juridical procedure took 2 years and resulted in a nullification of the permit by the Dutch supreme court of Justice, the 'Raad van State', in February 2008. For an overview of the process, see Figure 3.3.

Table 3.1. Characteristics of the two case studies.

	Mussel case	**Powerboat case**
Activity	Spring mussel seed fishing, two weeks in May 2006, part of the long term activity of mussel cultivation.	World Championship, planned for 5-7 August 2011
Permit authority	Ministry LNV (Ministry of Agriculture, Nature and Food Quality)	Province of Noord-Holland
Permit process	February-May 2006	November 2010-July 2011
Juridical process	May 2006-February 2008	8-25 July 2011
Main issue	Sufficient food for birds	Disturbance and noise of the powerboat race
Political support	Yes, national support since the activity started in the Wadden Sea in the 1950s	Mixed, supported by the municipality Den Helder, criticised by the municipality Texel, position Province only on legal framework
Consensus within scientific community	No, historical disagreement on long-term effects	Yes, new short activity that was assessed as having no significant effect on the conservation objectives, based on expert judgement

We identified two discourse coalitions in the discussion over 'significant effect' of the mussel seed fishery in spring 2006: "*Mussel fishery belongs in the Wadden Sea*" and "*No damage to the seabed*". The discourse coalition of "*Mussel fishery belongs in the Wadden Sea*", was constituted by the mussel farmers, the ministry LNV and parliamentary members. The activities of the mussel sector in the Wadden Sea have been supported by the ministry since the start of mussel farming in the Wadden Sea in 1950 (Van Ginkel 2007). In 2004, when mechanical cockle fishery was banned, the Dutch government continued supporting the mussel sector. The ministry LNV stated in their new policy towards sustainable fishing: "there is a future for the mussel culture" (LNV 2004, p.6).

This vision of a future for the mussel sector in the Wadden Sea was questioned by some nature organisations that were part of the discourse coalition "*No damage to the seabed*". This coalition consisted of several nature organisations (the Wadden Society, Bird Protection NL, Wad foundation, and Fauna protection), whereas some wished to ban mussel fishery completely from the Wadden Sea, others wanted to secure a sustainable practice. However, they shared concerns for the bird populations in the Wadden Sea and concerns about negative effects on the ecosystem by disturbance of the seabed.

To some extent scientists can also be placed within these discourse coalitions. Historically, research institutes have been leaning to the fishery perspective or the nature conservation perspective (Turnhout et al. 2008). Research findings on effects were interpreted differently by scientists from different institutes. For example within the large evaluation research EVA II (1999-2003) on the effects of shellfish fishery there was a debate on what was causing the decline of cockles, natural fluctuations or fishery (Ens et al. 2004; Hanssen et al. 2009). Another outcome of this research was a realisation of a lack of ecological knowledge on wild mussel banks and mussels on culture plots. For this reason the PRODUS research-project was set up. In the debate on the 2006-spring permit this research-project was put forward as an adaptive management approach by the discourse coalition "*Mussel fishery belongs in the Wadden Sea*". Whereas scientists from other institutes were commissioned by nature organisations for an audit of the MarinX assessment report.

During the permit process (February-May 2006) significance of effects were interpreted at three moments: within the appropriate assessment-report of MarinX, within the consultation of the nature organisations, and within the argumentation of the ministry for the permit. MarinX assessed 'no significant effects', based on the calculation that mussel seed fishery has a positive effect on the amount of mussels in the Wadden Sea and the adaptive management approach of the PRODUS-project that addressed the uncertainty of incomplete knowledge on constantly covered mussel banks. The nature organisations disagreed and claimed that significant effects were possible on two bird species with a restoration objective, based on their interpretation that significance means certainty of no effects on protected birds. They addressed uncertainties in the form of ambiguity: on how to interpret the precautionary principle, on how much food should be reserved for birds and on the hypothesis that mussel cultivation would increase mus-

sel biomass. In the argumentation for the permit, the ministry made clear they had the expert judgement to make an assessment of significant effects. They concluded that the monitoring of PRODUS as part of an adaptive management approach was sufficient to address uncertainties, resulting in the conclusion of no significant effects. They interpret significance as permanent effects, which according to their assessments were prevented through an adaptive management approach (LNV 2005). For more details see Table 3.2.

The juridical process (May 2006-February 2008) was started by the nature organisations. In May 2006 the Raad van State made the preliminary decision to only allow 2/3 of the fishing, stating that the appropriate assessment could be insufficient (Raad van State

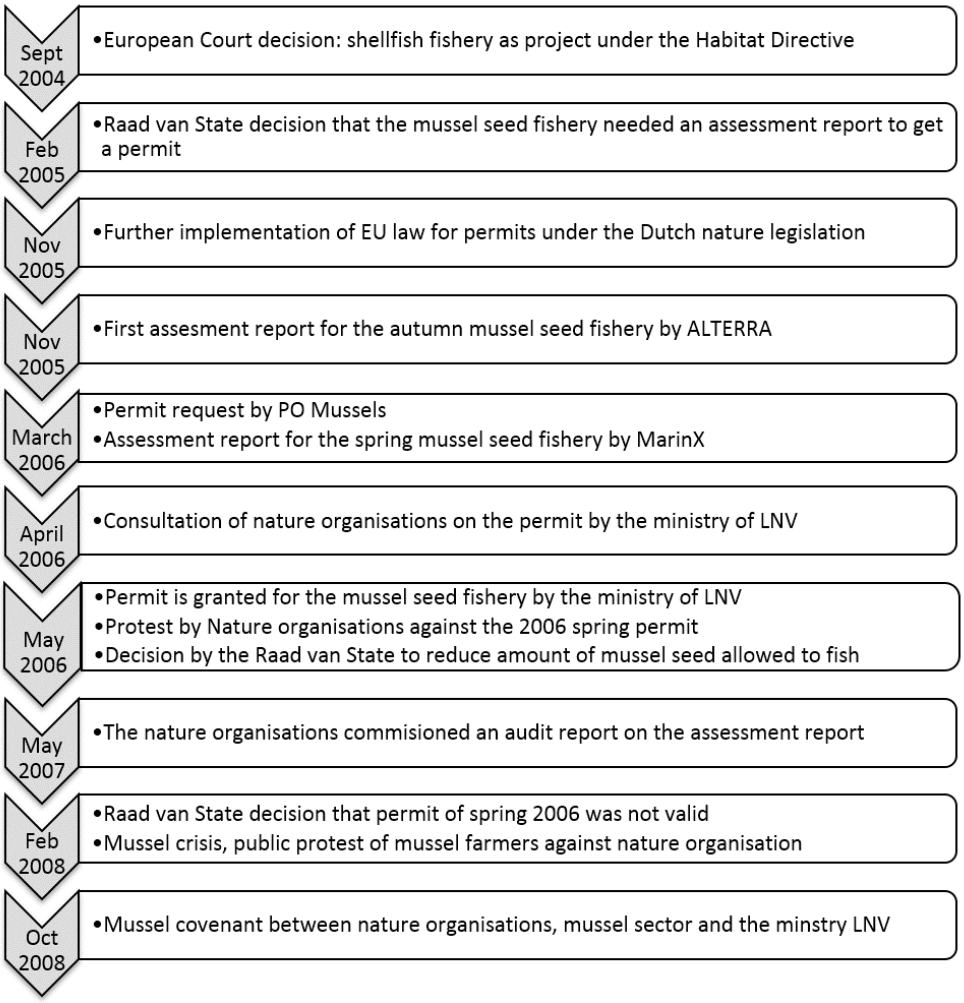

Figure 3.3. Overview of the crucial moments in the conflict over the spring-2006 permit.

2006). To support their position against the permit, the nature organisations commissioned an audit report to ecological researchers (Ens et al. 2007). In this report, the researchers claim there could be significant effects through the disturbance of the seabed. They explicated uncertainties of incomplete knowledge on constantly covered sandbanks, unpredictability of effects caused by the complexity of sedimentation in the Wadden Sea, and ambiguity on the assumption that culture plots have a similar nature value as wild mussel banks. Using the appropriate assessment and the audit report the two discourse coalitions explained their positions towards the Raad van State, as summarized in Table 3.3. On 27 February 2008 the Raad van State made its final ruling on the spring-2006 permit, stating that the permit was not properly based on the best scientific knowledge available and was therefore not valid (Raad van State 2008). This ruling resulted in a crisis for the mussel sector because the minister concluded this had consequences for the future permits for the mussel sector. After an intense media protest of mussel farmers against nature organisations and scientists, a covenant was made for a transition to sustainable mussel fishery between nature organisations, the mussel sector and the ministry LNV in October 2008 (Van der Molen et al. 2015).

The two crucial decisions in this case, the ministry granting the permit and the Raad van State's nullification, can be explained with the different interpretations of significant effect and its uncertainties. The ministry was part of the same discourse coalition as the fisherman and had the same interpretation of the ecological knowledge to conclude no significant effect, even though they acknowledged a large uncertainty caused by incomplete knowledge. However, the nature organisations were powerful in their interpretation of possible significant effects. They could claim scientific doubt because the scientific community disagreed on the possibility of harmful long-term effects. This ambiguity was convincing for the Raad van State, who judged there was too much uncertainty to claim no significant effect.

3.4.2 The powerboat race controversy

In November 2010, the organisation the Grand Prix of the Sea announced that it would organise the World Championship powerboat racing. This race was planned for 5, 6 and 7 August 2011 near the harbour of Den Helder, which is situated at the border of the Wadden Sea. The plan was to have high speed races for 15 m long boats with speeds over 200 km/h, and an accompanying event for the public such as a fireworks show. The race organisation needed a permit under the nature protection law from the province of Noord-Holland. To acquire the permit, the race organisation contracted the ecological research institute IMARES Wageningen UR to assess significant effects of the planned activity. The permit process started with the screening phase of significant effects and lasted half a year because the province of Noord-Holland was not content with the appropriate assessment. The debate ended with the announcement the race was cancelled due to organisational problems, even though the Raad van State judged the permit as valid. See Figure 3.4 for an overview.

Table 3.2. Interpretations of significant effect in the permit process of the mussel seed fishing controversy

	Interpretation of significant effect	**Addressing uncertainty**
March 2006 Permit request, supported with appropriate assessment by MarinX (Van Stralen and Sas 2006)	No significant negative effects: -The adaptive management approach of simultaneous research in the form of the PRODUS research-project will prevent permanent effects. -Mussel seed fishery has a positive effect on the amount of mussels in the Wadden Sea. -Not all mussels are fished away (only feasible above 0.15 kg/m^2).	Incomplete knowledge -Insufficient knowledge on the nature values of mussel banks and habitat type 1110, and on the effect of fishing on these nature values. → To deal with this the research project PRODUS has been set up. Ambiguity Nature protection of mussel banks in the form of reefs (habitat type 1170) are not protected.
April 2006 Consultation as part of permit process of nature organisations (Bird Protection NL, Wadden Society and Wad foundation)	Possible significant effects: On two duck species with a restoration goal: -On common eider (*Somateria mollissima*), they have a preference for grown mussels -On scaups (*Aythya marila*), there is no research on how they are affected.	Ambiguity -On the interpretation of the precautionary principle and dealing with uncertainty. In case the research has not been conducted the project should not be granted. -On how much food should be reserved for birds, more food is necessary based on restoration values. -On the hypothesis that mussel cultivation increases biomass of mussels in the Wadden Sea.
May 2006 Permit granted by ministry	No significant negative effects: Based on best available knowledge and an adaptive management approach (monitoring by PRODUS) that will prevent permanent effects.	Incomplete knowledge -Impact of fishery on future mussel seeds. -Insufficient knowledge on the nature values of mussel banks and habitat type 1110, and on the effect of fishing on these nature values. → To deal with the uncertainty the research project PRODUS has been set up. Ambiguity No scientific consensus if mussel cultivation increases food supply for shellfish eating birds.

We identified two discourse coalitions in the dispute over the planned powerboat race: "*The Wadden Sea is not only for birdwatchers*" and "*Power boat races don't belong in the Wadden Sea*". Besides these coalitions the province of Noord-Holland played a crucial role, not as part of one of these coalitions, but by setting the stage for the discussion. They actively expressed that human activities without significant effect are allowed and limited the decision-making to the legal framework.

The controversy started with the race organisation planning the World Championship. Supported by the municipality of Den Helder, they formed the discourse coalition, "*The Wadden Sea is not only for birdwatchers*". Our naming of the coalition is almost literally from a newspaper statement by the initiator: "The Wadden Sea is not only for nature and 15 birdwatchers" (Leeuwarder Courant 2011). The race organisation commissioned IMARES for a short assessment and used the assessments of IMARES to support their claim of no significant effects (Baptist 2011).

The initiative of a World championship of powerboat races provoked astonishment by people cherishing the Wadden Sea as an open and quiet nature area.

Table 3.3. Summary of interpretation and uncertainties in mussel seed fishery conflict.

	Mussel seed fishery, Spring 2006	
	Pro	**Against**
Discourse coalition	*Mussel fishery belongs in the Wadden Sea*	*No damage to the seabed*
Interpretation of significant effect	No significant negative effects: -Adaptive management approach will prevent permanent effects. -Mussel seed fishery has a positive effect on the amount of mussels in the Wadden Sea.	There can be a significant effect: -There is inadequate understanding on the effects of mussel seed fishery on the seabed. -Mussel seed fishery can have a negative effect on the amount of mussels in bad years: not enough food for birds.
Main Uncertainty issue	Incomplete knowledge On effects on seabed ecosystem. → Addressed through adaptive management.	Incomplete knowledge On effects on seabed nature values. Ambiguity Different perspective on long-term effects.
Raad van State decision	**Permit not valid**: Inadequate understanding of the effects on the seabed nature values to asses no significant effect without reasonable scientific doubt.	

Their point of view was expressed by the discourse coalition "*Power boat races don't belong in the Wadden Sea*", which consisted of nature organisations (the Wadden Society and 'Landschap Noord-Holland'), the municipality of Texel, and some provincial and national parliament members. They perceived the planned powerboat race as "noisy activities that don't belong in a nature area" (Noordhollands Dagblad 2011). Because the debate options were limited by the province to arguments over significant effects, the nature organisations criticised the assessment of significant effects and protested at the Raad van State. They used an external ecological consultancy as science-based expert to support their claim that the assessment was insufficient. In addition to the provincial procedures, the Wadden Society used several other strategies to stop the races. For example, they had a public campaign against the powerboat race on their website and in the media, with strong metaphors as "a blender in an aquarium" to describe the disturbing effects of a power boat race (Leeuwarder Courant 2011).

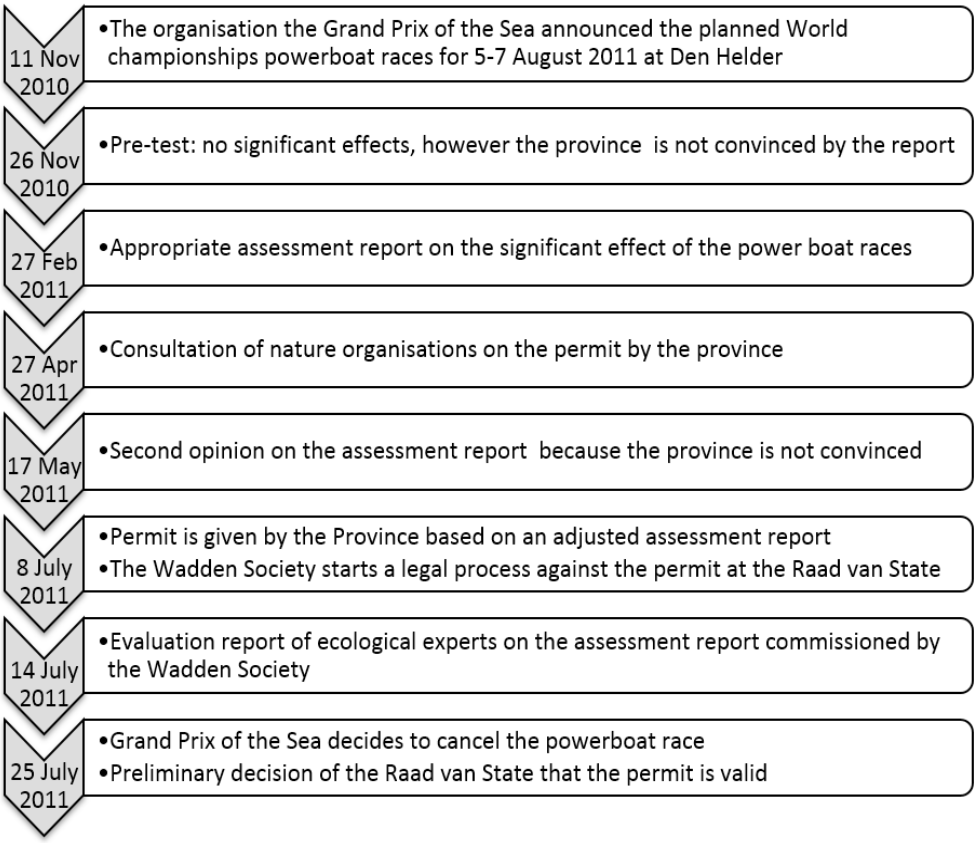

Figure 3.4. Crucial events in the powerboat case.

During the permit process (November 2010-July 2011), the most important interpretations of significant effect were expressed within the appropriate assessments of IMARES and within the critique of the province of Noord-Holland on these assessments. According to the pre-test and appropriate assessment of IMARES there was no significant effect on the site's conservation objectives, based on their interpretation that significance means long-term effects on population sizes. The uncertainty of incomplete knowledge on the effects of power boat races was acknowledged, especially the effects of underwater sound on seals. However, the expert judgement of IMARES was that species would move away, protecting themselves from long-term effects. Initially the province of Noord-Holland was not content with this assessment. According to the province there was no certainty there would be no significant effect, because of incomplete knowledge through a lack of data to support conclusions and ambiguity in how to judge very small effects on species with a restoration goal. This type of ambiguity to judge very small effects is also acknowledged by scientists:

> "There is an effect, but whether you can call this significant, there are different sides to it. If you are very strict, you have to conclude it is significant, there is a negative effect on a restoration objective. However you can also reason the effect is so small you will not be able to measure it in practice, so no significant effect" (ecological researcher).

To improve the assessment the province demanded more details: expert judgement alone did not suffice and data support was necessary to come with valid and authoritative claims in a potential court process. The province even commissioned an evaluation by an external ecological consultancy. These consultants concluded that the IMARES report would be insufficient in a juridical procedure (Strijkstra and Bruinzeel 2011). The province gave the initiator a second chance to improve the report. Based on a more elaborate report in June, the province granted the permit in July. This permit was granted for 5 years, with a monitoring obligation to assess potential effects to deal with the uncertainty of incomplete knowledge. For more detail see Table 3.4.

During the juridical process (8-25 July 2011), different interpretations of significant effect were brought forward by the province of Noord-Holland and the nature organisations. The nature organisations used the critique that the province had expressed during the permit process and an evaluation of an external ecological company to criticise procedural and content aspects of the appropriate assessment (Gyimesi and Krijgsveld 2011). The uncertainty of incomplete knowledge over the effect of underwater sounds caused by the powerboats was expressed by all actors involved. Uncertainty in the form of ambiguity was also expressed. Firstly, in how to judge miniscule effect of NOx deposition on species in dune areas with a restoration goal. Secondly, in how to judge the reference situation for the assessment of the powerboat race. According to the appropriate assessment within the activity area there are already 45000 ship movements a year. Compared to this disturbance the short-term event of a powerboat race would not

Table 3.4. Interpretations of significant effect at crucial moments in the permit process of the powerboat controversy.

	Interpretation of significant effect	Addressing uncertainty
27 February 2011 Appropriate assessment by IMARES	No significant negative effects: Some small effects were expected but were perceived as not significant with regard to the site's conservation objectives. -The NOx effects on the conservation objectives of dune areas were assessed as not significant because it was not detectible against background levels. -Possible effects on birds and seals were assessed as not significant because these species could move to other areas and this was not a vulnerable period for reproduction, which meant no long-term effects on population sizes.	Incomplete knowledge Limited scientific information on the effects of power boat races. → To address this uncertainty IMARES included a model calculation for NOx deposition and literature research on underwater sound effects in other contexts.
May 2011 Province of Noord-Holland	No certainty there will be no significant effects Incomplete basis of the appropriate assessment to make conclusions and incorrect information in permit request.	Incomplete knowledge Conclusions and judgement are made in the appropriate assessment without stating the concrete data and information that supports these conclusions. Ambiguity Different interpretation is possible for the judgement of effect of NOx and underwater sound. A relative small effect can be significant, more argumentation is necessary to make a conclusion.
8 July 2011 Province of Noord-Holland	No significant negative effects: -No effects on quantity habitat types, NOx effects are not measurable. -Effects on quality habitat types by sound, light and NOx is not significant. -No effect on the population size of protected species, no direct deaths are expected and they can move to other areas and are not in a vulnerable period.	Incomplete knowledge Limited scientific information on the effects of power boat races. → Addressed through monitoring obligation during the activity.

give significant effects. According to the nature organisations, the already existing disturbance of the area implied that accumulation of effects can take place. Even when the effects of the powerboat race on its own were not significant, all activities together could have a significant effect. For more detail see Table 3.5.

The debate on significant effects ended on 25 July 2011 with the decision of the initiator of the powerboat to cancel the power boat race, stating they had insufficient time left for the organisation. On the same day the Raad van State stated its preliminary conclusion that the permit of the power boat race was valid under the nature conservation law. In the Raad van State hearing the judgement of no significant effect was discussed in detail with ecological experts. The need for data and not just expert judgement was stressed by the Raad van State judge in her ruling that the nature organisations had not provided "concrete objective data" that contradicted the statements of the appropriate assessment (Raad van State 2011).

The two crucial decisions in this case, the province granting the permit and the Raad van State judging the permit as valid, can be explained with the different interpretations of significant effect and its uncertainties. Although the province was very critical towards the assessment of no significant effect, after the inclusion of more data they did grant the permit. The province did not take a position with one of the discourse coalitions, but stated that they based their judgement only on ecological judgement, and that the conclusion of ecological science-based experts was no significant effect on the conservation objectives. The ambiguity on how to interpret a small effect of NOx, was eventually dismissed as immeasurable. Also the Raad van State was not convinced there was scientific doubt, resulting in the preliminary decision that the permit was valid. However, the debate over the permit augmented the organisational problems for the race initiator to such an extent that the race was cancelled.

3.5. Reflection

Our case studies showed the analytical use of a boundary object in controversies, even though boundary objects are commonly used for analysing more co-operative situations. The approach of a boundary object enabled us to analyse the mechanisms of inclusion and exclusion. Specifically the way the interpretation of significant effect limited the debate to ecological arguments and science-based experts, focusing on uncertainties of incomplete knowledge and ambiguity, while excluding unpredictability. A boundary object can facilitate constructive interactions during a conflict through facilitating learning processes. Resulting in a constructive conflict in which learning takes place because different perspectives are made explicit (Cuppen 2012). However, in the analysed cases the relations between the actors became so distorted and expressions of value differences supressed by the legal procedure, resulting in no constructive effort. In these cases the permit procedures and assessment of significant effect only pacified the conflict into professional disagreement on scientific arguments, excluding explicit

Table 3.5. Summary of interpretation and uncertainties in powerboat race conflict.

	Powerboat race 2011	
	Pro	**Against**
Discourse coalitions	*The Wadden Sea is not only for bird watchers*	*Power boat races don't belong in the Wadden Sea*
Interpretation of significant effect	No significant negative effects: -The activity takes place in an already largely disturbed area. -The possibility of the animals to move away from the activity prevents long-term effects.	There can be a significant effect: -Procedural: the appropriate assessment is unclear and missing information. -Possible cumulation of effects, this activity ads up to other disturbing activities in the area. -Insufficient knowledge on the possible effects of the underwater noise of power boat races on seals.
Main Uncertainty issue	Incomplete knowledge On underwater sound effects. → Addressed through assessment vulnerable species would move away. → Addressed through monitoring obligation.	Incomplete knowledge On effects underwater noise Ambiguity -On relevance small NOx effects and cumulation of effects. -On effects on individuals instead of populations. -On the assessment of the reference situation.
Raad van State decision	*Preliminary decision*: **permit valid**, no objective information that the assessment of potential effects is not correct.	

normative debates (Hanssen et al. 2009). The absence of such a constructive influence explains why the significant effect procedures did not contribute much to the closure of the controversies. In the mussel case, this closure was achieved in the negotiations leading to the covenant; in the power boat case, it was forced by the cancelling of the race.

The science-policy boundary in our case studies was perceived as a clear demarcation. Based on this demarcation science-based experts had the authority to give advice, both in the permit procedure and the juridical procedure. The boundary of the science world and the policy world was perceived concrete in the sense that most science-based experts were involved through contract research, formalising their role as scientific experts. However, this aspect of contract research also formed questions of independency, as expressed by a nature organisation: "the payer decides", a clear questioning of the credibility and legitimacy of the knowledge. This remark contrast the ideal of a clear bound-

ary between facts and values, science and policy. Still, the importance and authority of science-based experts to assess significant effects was supported by all actors involved. For example, by the use of contra-expertise in the legal procedures by the nature organisations. However, the task division of responsibility to make the judgement of significance was less clear: scientists or the governmental permit authority. In practice this responsibility was shared and was formed by the specific context. In the mussel case the government stated in their permit argumentation they have the authority and sufficient expertise to make their own expert judgement on the effects of mussel seed fishery. In the powerboat case the government focused more on the quality of the appropriate assessment and pushed the responsibility of a good judgement on significant effects towards the science-based experts. According to a marine ecologist: "the governmental authority wants us to make the judgement". In this technocratic perspective "politics is replaced by a scientifically rationalised administration" (Weingart 1999, p.154). A contrasting perspective is that the governmental authority has the formal responsibility to make this judgement: "based on the report, the authority will decide whether the predicted impact is significant" (Opdam et al. 2009, p.916). Our findings suggest that in cases where the government was in favour of the activity they take the responsibility to judge significance, while in other situations governments push the responsibility to science-based experts.

3.6 Conclusions

The mussel case and the powerboat case were selected to show the interpretative flexibility of significant effect as boundary object in different contexts. In this section we draw our conclusions.

3.6.1 How science-policy interactions shape the assessment of significant effect

The interpretations of significant effect within science-policy interactions took place in the permit and juridical processes. In the permit process, the benchmark for the interpretation of significant effect was formed by the science-based experts that wrote the assessment report. In the assessment report the scope of significant effect was set by the selection of relevant effects and relevant species and habitats. These selections were shaped by existing research on the activity, the conservation objectives that were set by the government, and jurisprudence on significant effect. The appropriate assessment report was also influenced by practical factors, such as time limitations for the researcher resulting from the contract with the initiator. Secondly, interactions with the permit authority could influence the assessment of significant effect. In the mussel case, the Ministry agreed with the assessment based on its own expert judgement, thus precluding other interpretations of significant effect. However, in the powerboat case the province initially disagreed and by asking critical questions during the writing of the assessment-report, the province expanded the scope of significant effect to more activities of the race event and more detailed argumentations. Thirdly, lower governments and nature organisations

could influence the assessment of significant effects, particularly during consultations for the permit. Within our analysed cases these consultations did not result in changing the significant effect assessment, however, uncertainties in the form of incomplete knowledge and ambiguity were made explicit and different interpretations had to be addressed by the permit authority.

In the juridical process which is more focused on procedural aspects, the different interpretations of significant effect became the focal point of debate. The significance interpretation of the nature organisations was strategically supported by counter-expertise, influencing the perception of the significant effect assessment. Eventually the Raad van State judge had to decide if the interpretation of no significant effect from the government was sufficiently supported. Due to the emphasis on scientific doubt in this phase science-based experts became core actors. They were the first to make incomplete knowledge explicit, although the government and nature organisations were the actors that could put scientific ambiguity forward to mark a different interpretation of significance and acceptability of uncertainty. The mussel case showed the Court draw a different line then the government in how much incomplete knowledge as uncertainty is acceptable.

3.6.2 How significant effect shapes the decision-making process

Significant effect as a boundary object structured both the decision of the government to grant the permit and the decision of the Raad van State to judge the validity of this permit. In both decisions the technocratic view on the assessment of significant effect as science-based dominated the process. This precluded a wider normative debate on the activity; the only option was to discuss the assessment of significant effect with scientific arguments.

This limitation caused frustration, for example for the nature organisations, who preferred discussions on the terms for a permit, when and where an activity could take place, instead of restricting the debate to "a black-and-white framework" of significant effects (interview nature organisation). The strict legal framework excluded the normative arguments of the nature organisations on which activities belong in the Wadden Sea from the debate. Legally, the distinction of significance marks the boundary for what is allowed. The socio-economic arguments of parties were also excluded, for example the economic revenues of the powerboat race, or the need for mussel seed to sustain mussel enterprises. Even though these arguments were expressed in the media and were the driving forces to contribute in the debate, officially these normative aspects were irrelevant. The province of Noord-Holland was very clear on this aspect, their only official framework of reference were scientific arguments, not political considerations. Not acknowledging the valuation aspect of an appropriate assessment.

This focus on scientific arguments also excluded actors without ecological expertise to directly contribute in the permit process. The initiators were only involved through the science-based experts that they contracted to write the assessment reports.

And even though, the government and nature organisations had themselves ecological expertise, they also contracted external expertise because external experts were seen as having more authority in the legal procedure. This made science-based experts highly influential players in the debate. Especially in the mussel case, where ambiguity in interpretating the incomplete knowledge of effects on the seabed divided the scientific community.

The assessment of significant effect based on the 'best available knowledge' also excluded unpredictability. In the two analysed cases we saw that uncertainty in the form of incomplete knowledge and ambiguity were frequently expressed, however unpredictability was only mentioned ones in the mussel case. Apparently the element of not being able to know something does not fit within the framework of significant effect, even though the dynamic nature of the Wadden Sea ecosystem is very unpredictable.

Although the specific interpretation of significant effects limited the discussion options, the interpretative flexibility of this boundary object and the inherent uncertainties in the assessment also created options to protest. Through the consultation process and the juridical procedure the nature organisations were able to express their alternative interpretation of significant effect with the aim to stop the activity. The juridical framework of "no scientific doubt" based on the precautionary principle created the powerful option for nature organisations to protest against the permits, claiming there was too much uncertainty. This is a strong way to uphold the aim of nature protection, because the initiator is responsible to show it is not planning an harmful activity instead of the nature organisations showing it is harmful.

3.6.3 Dealing with uncertainty

Within the two controversies over significant effect uncertainties played a crucial role. In the juridical debates, the Raad van State decided if there was scientific doubt, limiting uncertainties to incomplete knowledge. In the permit process uncertainty of incomplete knowledge and ambiguity were expressed, however, only incomplete knowledge was incorporated by suggesting monitoring measurements. Consequently, ambiguity was not addressed. Monitoring and more research is not sufficient to address ambiguity, because more information can be interpreted differently based on different value-perspectives. So with more knowledge, the debate on the credibility and legitimacy of the knowledge would not disappear, because the different value-perspectives were the drivers of the conflict. And the strict focus on scientific arguments within the assessment of significant effect does not mean that value differences disappear, instead these differences become absorbed in scientific discussions over uncertainties (Linke and Jentoft 2014; Sarewitz 2004).

Together with Opdam et al. (2009) we conclude that uncertainty caused by different valuation frameworks is a structural element of the assessment of significant effect. We propose to acknowledge this value-laden aspect of the Natura 2000 regulations that

should be discussed as part of a political process. We also suggest that a broader approach for permits is necessary to effectively deal with ambiguities over impacts and their assessment. An option is to broaden the debate on permits to include more elements than only the assessment of significant effects. For example for the mussel case, with the transition covenant the discussion was transformed in how and where the fishing could take place instead on what the exact effect would be (Van der Molen et al. 2015). This form of co-operation between initiators, nature organisations and the government can be effective to deal with activities with debated uncertainties, because it opens up more options on which actors can agree.

Nonetheless, the legal option to stop activities based on uncertainties continues to be a powerful tool for opponents. Through the EU legislation and its implementation with significant effect assessments the limit for activities is made clear, no activities that harm the conservation objectives. Even though it is an improvement for nature protection that initiators are obliged to show they will not unacceptably affect conservation objectives, this paper has shown that with the technocratic approach of significant effect the value-differences have not disappeared. Instead of a political debate the value differences became expressed in legal settings.

Chapter 4

Knowledge uncertainties in environmental conflicts: how the mussel fishery controversy in the Dutch Wadden Sea became depoliticised

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Floor, J. R., van Koppen, C. S. A., & van Tatenhove, J. P. M. Knowledge uncertainties in environmental conflicts: how the mussel fishery controversy in the Dutch Wadden Sea became depoliticised. *Environmental Politics.*

Abstract

Policy-makers and scientists often expect that controversies in public policy can be solved by gathering more knowledge, even though this linear model of expertise is widely criticised in social studies of science. To shed more light on this, the role of scientific uncertainties in the controversies on mussel fishery in the Dutch Wadden Sea (1990-2016) is investigated. The analysis shows that mussel fishery regulation decisions were primarily based on government authority, not on scientific knowledge. Expectations of policy-makers and scientists on conflict resolution by more research were not met, because the knowledge debate was politicised over ambiguous knowledge claims. The controversy was depoliticised by a political covenant between the conflicting parties. The case study confirms that science-based knowledge fails to guide policy-making as expected in the linear model, but also demonstrates how science plays important strategic, procedural and instrumental roles in structuring interactions between stakeholders in nature protection conflicts.

4.1 Introduction

Policy-makers and scientists often expect that scientific knowledge will conclusively solve conflicts in public debates. The underlying assumption is that, with the right knowledge, the decision to take should be clear. This linear model of expertise has become a dominant perception among scientists, policy-makers and advisors (Hanssen et al. 2009; Pielke 2007; Sutherland et al. 2017). In the field of protected nature areas, science-based knowledge has become essential for decision-making (Beunen and Duineveld 2010; Floor et al. 2016; Turnhout et al. 2015). By analysing the debates concerning the mussel fishery in the Dutch Wadden Sea (1990-2016), this article critically assesses the linear expectation that additional knowledge will solve conflicts in public debates. The mussel fishery case is an exemplary case of high expectations of scientific knowledge and simultaneously contested expertise. Several scholars have analysed the role of expertise and knowledge in the governance process of shellfish fisheries in the Wadden Sea region (see for an overview Floor et al. 2013; Van der Molen et al. 2015). Our research builds upon this work and focuses on the expected depoliticising role of knowledge from 1990-2016.

This article contributes to the existing literature on knowledge use in environmental decision-making (Huitema and Turnhout 2009; Jasanoff 1994; Weingart 1999; Wesselink et al. 2013). We contribute to the existing critique on the linear model of expertise by specifically focusing on the expectations of knowledge production for decision-making processes. The assumption of the linear model of expertise is that science will provide policy actors with the knowledge required to solve controversies (Beck 2011). The main criticism towards this dominant model is that there is not a clear boundary between science and policy (Beck 2011; Carter 2013; Wesselink et al. 2013). This has resulted in a conceptualisation of science-policy interactions as "multiple, two-way and dynamic interactions between processes of knowledge production and decision-making" (Wesselink et al. 2013, p.2). The aim of this article is to critically reflect on the assumption of the linear model that knowledge can reduce and end controversies, by using the concepts of politicisation and depoliticisation. Politicisation refers to the confrontation of different positions about a human activity in the public debate (Mouffe 2000; Pellizzoni 2011). With politicisation, a shift takes place from a situation in which a human activity was perceived as necessary, private, and requiring no regulation toward a situation in which the human activity is a topic of public debate. This process of politicisation can be triggered by claims of interest groups and knowledge claims of science-based experts. In the words of Pellizzoni, politicisation is: "the opening, broadening or restoring of a public space of discussion. An issue (or part of it) is politicised to the extent that it is released from necessity and duty: different positions can be confronted in the public arena" (Pellizzoni 2011, p.711). Depoliticisation refers to the process of ending controversies, by removing these conflicting issues out of the public debate and defining them as non-controversial. The controversial issue is then taken out of the public domain and,

for example, into the domain of scientific or bureaucratic expertise (Behagel 2012). Furthermore, controversy can exist within several debates simultaneously. Therefore, we distinguish two interconnected and parallel debates: the regulation debate and the knowledge debate. In the case of nature protection, the regulation debate is about which human activities are allowed in a nature area and under what conditions. Whereas, the knowledge debate is about what is known and whether there is sufficient knowledge to make decisions. In this paper, we study the expectations based on the linear model of expertise that assumes first the knowledge debate needs to be closed to end the regulation debate (Beck 2011; Hoppe 2005). In the next section, we present our conceptual framework of depoliticisation mechanisms and different types of uncertainties. We use this framework to describe and analyse the mussel fishery controversy and draw our conclusions.

4.2 Analytical framework

4.2.1 Depoliticisation mechanisms

Several decision-making mechanisms can reduce the public debate on a controversial issue. In this paper, we distinguish four depoliticisation mechanisms based on Van Koppen (2002), see Table 4.1. This typology includes the traditional demarcation between the decisionist and technocratic models, based on the primacy for political power or the primacy for science-based expertise (Hoppe 2005; Weingart 1999). To highlight the current role of the civil society and the market in governance process, the participatory and market models of political reasoning are also included in the typology. We approach these decision-making mechanisms as ideal types. In decision-making processes these types are often combined. To function as depoliticisation mechanism, the type of decision-making should be accepted as legitimate by the actors involved to reduce the scope of the public debate. Furthermore, decision-maker(s) should also reach consensus on the decision.

Table 4.1. Decisionist, technocratic, participatory and market depoliticisation mechanisms (Based on Van Koppen 2002).

	Depoliticisation mechanism
Decisionist	'Let the authority handle it', transfer to political hierarchy. Decisions are justified by the political position of the decision-maker.
Technocratic	'Let the experts handle it', transfer to the science-based expertise domain. Decisions are justified by scientific consensus.
Participatory	'Let the stakeholders decide', transfer to the semi-private stakeholder domain. Decisions are justified by an agreement between all relevant actors.
Market	'Leave it to the market', transfer to the private domain. Decisions are justified by the perception that market forces serve the common good.

These depoliticisation mechanisms are based on different types of legitimacy and knowledge use. The decisionist mechanism is based on the legitimacy of the governmental authority to make decisions. Within a democracy, this authority can be elected politicians or appointed officials. Knowledge can play a supporting role, through knowledge workers in bureaucratic state institutions or through advise from research institutes (Hoppe 2005). The technocratic mechanism relies on the legitimacy of experts and their scientific arguments to justify decisions (Weingart 1999). Knowledge is the main factor to guide decisions. In radical technocratic decision-making, scientists replace politicians, in a less radical version: "experts hold *de facto* power in the day-to-day business of administration and politics because scientific knowledge and its corresponding technical-practical tools have colonized the administrative and political worlds" (Hoppe 2005, p.209). The participatory approach is based on the premise that affected actors should make decisions. The perception that all relevant stakeholders are included is crucial. Knowledge can play a supportive role, both specific stakeholder knowledge and science-based knowledge, depending on the stakeholders' perceptions. The market mechanism is based on the ideology that market forces serve the common good, transferring the issue of decision-making to individuals collectively (Van Koppen 2002). Knowledge that informs market players can play a role, such as the information on product labels.

In our analysis of the mussel fishery decision-making, we focus on the legitimation of decisions and the role of knowledge production in these decisions. We consider that knowledge has a role in all depoliticisation mechanisms but is most prominent in the technocratic approach.

4.2.2 Knowledge uncertainties

In all depoliticisation mechanisms, the role of knowledge is complicated when knowledge uncertainties are considered. According to the linear model, experts have or can obtain the knowledge required, which would contribute to depoliticisation. However, when the certainty of a knowledge claim becomes disputed, this knowledge claim can become controversial within a knowledge debate. We analytically distinguish three types of uncertainty perceptions: incomplete knowledge, unpredictability and ambiguity, see Figure 4.1 (Floor et al. 2016; Van den Hoek 2014). The uncertainty of incomplete knowledge addresses expressions of knowledge imperfection: what is currently unknown but could be available with additional research. The uncertainty of unpredictability addresses unknowable knowledge, and this uncertainty cannot be reduced by the current state of science. The uncertainty of ambiguity concerns actors' knowing differently rather than not knowing enough. We use the definition of ambiguity as "the existence of two or more equally plausible interpretation possibilities" (Dewulf et al. 2005, p.116).

These different types of uncertainties mark different knowledge debates: on sufficient knowledge or on correct knowledge. Disputes that question if there is sufficient knowledge to support decision-making are triggered by perceptions of not knowing

enough, either incomplete knowledge or unpredictability. Whereas disputes that question knowledge claims are triggered by knowing differently, the uncertainty of ambiguity. Ambiguity is frequently not recognised and is often perceived as a lack of the correct knowledge. The desire of coalitions to strengthen their position with better knowledge arguments, imply high expectations for research. Although additional research will not change the underlying value differences (Sarewitz 2004). We use our classification of uncertainties to understand the knowledge debates and the extent that knowledge production can resolve them.

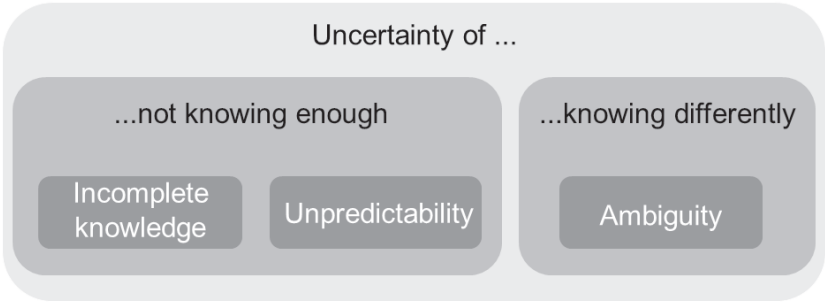

Figure 4.1. Schematisation of types of uncertainties based on Van den Hoek (2014).

4.2.3 Linear model of expertise

We use our concepts of depoliticisation mechanisms and knowledge uncertainties to characterise the linear model of expertise. The linear model of expertise is based on the assumption that with sufficient and appropriate knowledge, uncertainties are reduced and decisions can be made (Beck 2011; Hoppe 2005; Wesselink et al. 2013). These elements correlate with the technocratic depoliticisation approach and the view of uncertainty as incomplete knowledge. These elements led to the following expectations of the regulation and knowledge debate. First, when a human activity is politicised, the regulation debate should be depoliticised in a technocratic manner, with experts providing the required knowledge for policy-making. This is the simple model of 'Speaking truth to Power' (Beck 2011). This model is however complicated when uncertainties result in politicisation of knowledge. At that moment, also the knowledge debate should be addressed. Based on the linear science-policy expectation, a second step of depoliticisation in a technocratic manner is required. When uncertainty is perceived as incomplete knowledge, research should provide the necessary knowledge to end the knowledge debate. Lastly, the linear model prescribed the expectation that with the ending of the knowledge debate it should become clear how to regulate the human activity. In this way, ending the knowledge debate becomes a condition for ending the regulation debate. This linear expectation from research for decision-making is summarized in Figure 4.2. Our mussel fishery case study will show a different relation between the knowledge and regulation debates that contrasts this linear expectation.

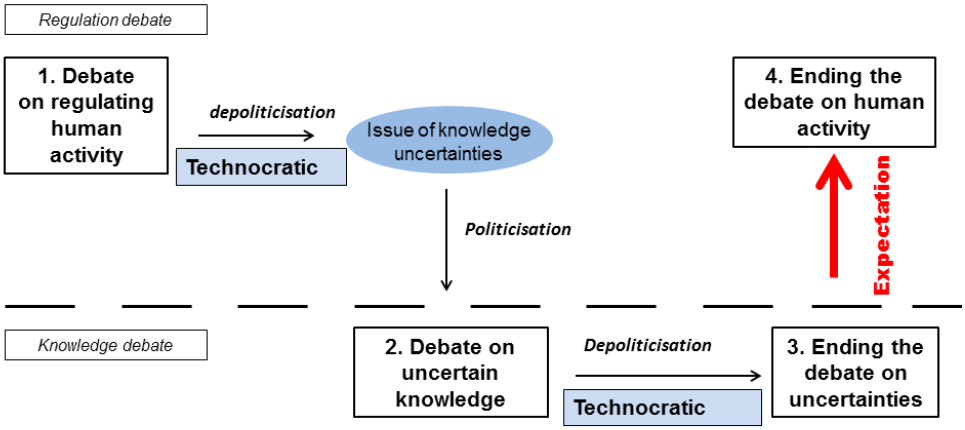

Figure 4.2. Visualisation of the linear expectations of research for closing knowledge and regulation debates, based on the perceptions of technocratic depoliticisation and uncertainty as incomplete knowledge.

4.3 Methodological approach

We use an interpretative approach to understand the mussel fishery controversy (Yanow and Schwartz-Shea 2006). Interpretative approaches focus on different constructions of meaning as 'people will interpret the social and material world in various and sometimes conflicting ways' (Beunen and Duineveld 2010, p.325). These differences between people form the basis of regulation and knowledge debates. Following Mouffe (2000), we view these debates as a result of conflicting positions between 'us' and 'them' that have different perspectives. We describe these different positions as discourse coalitions: 'a group of actors that, in the context of an identifiable set of practices, shares the usage of a particular set of story lines over a particular period of time' (Hajer 2006, p.70). These coalitions can be viewed as having their own way of knowing (Janssen 2015). In the mussel fishery case, nature and fishery discourse coalitions can be identified (Van der Molen 2015).

In our analysis, we distinguish four periods in the mussel fishery case (1990-2016) that are separated by crucial decisions that depoliticised the public debate to a certain extent and changed the regulation of mussel fisheries. The starting point of 1990 is based on the first politicisation of mussel fisheries in reaction to high bird mortalities. The analysis ends in 2016, corresponding to the end of our data collection. Our case study is empirically informed by interviews, participatory observations, field trips and document analysis of the role of science-policy interactions in the Dutch Wadden Sea[3].

[3] The 28 semi-structured interviews were conducted in January 2011 to July 2016 as part of a PhD project on the role of science-policy interactions in the Dutch Wadden Sea. In the same period, observations and informal interactions with actors took place during symposia, field trips and workshops. For the full list of interviews, see Appendix I. Quotes from the interviews have been translated to English by the authors.

Twenty-eight semi-structured interviews on science-policy interactions in the Wadden Sea were conducted, nine of which specifically focused on the mussel fishery case with persons from scientific institutes, nature organisations, the mussel fishery sector and the government. We analysed case-related research reports, governmental documents, stakeholder documents, court rulings, parliamentary proceedings, stakeholder websites, meeting notes and newspaper articles (using the Lexis Nexis database). For each period, we analysed the data on articulations of uncertainties and legitimations of decisions to identify depoliticisation mechanisms and knowledge expectations.

4.4 Mussel cultivation and fishery in the Dutch Wadden Sea

The Wadden Sea is a shallow estuarine sea, renowned as a feeding ground for birds. The high tidal dynamics of the system are characteristic of the Wadden Sea. During low tide, large portions of the Wadden Sea fall dry, which are called the littoral areas. The areas of the Wadden Sea that are constantly covered by seawater are the sublittoral areas. Another characteristic of the Wadden Sea is the occurrence of mussel beds, which are clusters of blue mussels (*Mytilus edulis*) attached to each other that are perceived as biodiversity hotspots (Dankers and Zuidema 1995). There are naturally growing mussel banks and mussels on mussel cultivation plots. This human activity of mussel cultivation in the Dutch Wadden Sea began in the 1950s, with mussel farmers renting seabed areas from the national government to cultivate mussels. The mussel cultivation practice in the Netherlands originated in the Eastern Scheldt in the Zeeland province. In the 1950s, the mussels in Zeeland declined severely due to a parasite infection, which was the reason that cultivation in the Dutch Wadden Sea was initiated by fishermen from Zeeland (Van Ginkel 2007). The mussel fishermen describe their cultivation practice as farming in the water (Van der Molen et al. 2015). As input for their cultivation practice they need 'seeds', the spat fall of juvenile mussels. These juvenile mussels form banks on the seabed by attaching themselves to old shelves and to each other. The main input for cultivation are the juvenile sublittoral mussels, which are fished in autumn and in spring and relocated to cultivation plots. Littoral mussel banks can also be used for harvest of juvenile and grown mussels. The cultivation plots are in the sublittoral area of the Wadden Sea and are not visible because they are constantly covered by water. The mussels grow to consumption size in two to three years, after which they are brought to the mussel auction in Yerseke in Zeeland for sale.

In the mussel fishery controversy, two stable discourse coalitions can be identified based on a mussel fishery perspective or a nature conservation perspective (Van der Molen et al. 2015). The fishery discourse coalition can be characterised as *Mussel fishery belongs in the Wadden Sea*, articulating the historical and future place of mussel fisheries and cultivation in the Wadden Sea (Floor et al. 2016). The main actors in this coalition are the mussel farmers, represented since 1992 by the Producers Organisation (PO) Mussel Culture (Verbeeten 1999). For them, mussel fishing and cultivation is not in conflict with nature protection. Instead, they perceive mussel cultivation as enriching

nature. The mussel sectors position has largely been supported by the ministry responsible for fishery and nature protection. This ministry is known under the acronym LNV[4] in Dutch. Science-based experts are also part of the fishery discourse coalition (Imeson and van den Bergh 2006; Turnhout et al. 2008). Historically, fishery biologists have taken the mussel fishery activity as a starting point, for example within research on improving fishing efficiency. During debates, scientists were explicitly placed in the fishery coalition, for example researchers from the RIVO research institute that is currently part of Wageningen Marine Science (Floor et al. 2016; Turnhout et al. 2008).

In opposition to the fishery coalition, the nature discourse coalition can be characterised as *The Wadden Sea is first and foremost a nature area*, articulating that human activities should not harm this unique nature area (Floor et al. 2016; Van der Molen et al. 2015). Several nature organisations have expressed this nature perspective and criticised the potential harmful role of mussel fisheries in the Dutch Wadden Sea since the 1990s. The main actors have been the Wadden Sea Society, the Society for the Protection of Birds, Fauna Protection and the WAD foundation. Although these nature organisations have different perspectives on the extent that fisheries should take place in the nature area, they share concerns for bird populations and seabed disturbance in the Wadden Sea. Their position is strongly rooted in ecosystem ecology and the interrelations of species in the Wadden Sea. Many employees of nature organisations have science-based ecological expertise (Van der Molen et al. 2015). Science-based experts from research institutes are also placed within this discourse coalition, such as researchers from NIOZ, the Royal Netherlands Institute for Sea Research. The Dutch government is also aligned with this discourse coalition, with increased recognition of the nature value of the Wadden Sea in international and national policy documents.

4.5 The mussel fishery controversy (1990-2016)

This section describes the politicisation and depoliticisation process and the role of knowledge in four periods that distinguish different regulations of mussel fisheries. For an overview of the main events and a summary of the analysis, see Figure 4.3 and Table 4.2.

4.5.1 Debate on restricting mussel fishery areas (1990-1993)

The high mortality of birds and disappearance of all littoral mussel banks triggered the politicisation of mussel fishery in the 1990s. In 1990, nature organisations supported by scientists attempted to limit cockle fishery[5]. However, governmental regulation was

[4] LNV represents the ministry of Agriculture, Nature and Fishery, which was renamed the Agriculture, Nature and Food Quality in 2003. Between 2010-2017, this ministry was part of the ministry of Economic Affairs.

[5] In this period, the fishery debate included cockle and mussel fisheries. This article focuses on the mussel fishery debate; for an overview of the cockle fishery debate, see Floor et al. (2013).

stopped by the Council of State ('Raad van State' in Dutch) because there was no legal basis for limiting shellfish fisheries. This triggered a regulation debate between nature and fishery coalitions, which can be characterised by the positions of *Reduce fishery areas!* versus *No limitations of fishery areas!*. The main topics were if and where areas should be closed to fisheries, predominantly littoral areas to leave enough food for birds. Fishermen emphasized that they had also difficulties in the early 1990s due to limited mussel spat and intensified eider duck predation on their cultivation plots. The nature organisations stated that nature needed to be protected from fisheries, blaming fisheries for the disappearance of the littoral mussel banks and eider duck mortality. In response, fishermen stressed the role of natural fluctuations on mussel banks and bird populations. According to a fishermen: 'natural mortality of birds caused by cold, ice, storms and other catastrophes has much more impact than our activities' (Den Hollander 1991). These differences resulted in a knowledge debate: *Harmful fishery* versus *Natural fluctuations*. In 1993, the Ministry formulated a compromise between the nature and fishery positions. Mussel fishery regulation became part of the Sea and Coastal Fisheries Policy: restricting 26% of the Dutch Wadden Sea area from shell fish fisheries, limiting fishing to leave sufficient cockles and mussels to satisfy 60% of the food requirement of the bird populations and restricting fishing of littoral mussel banks if their surface coverage is below 2000 ha. Furthermore, a science-based evaluation was planned to be ready in 1998, on which the policy was to be adjusted to restrict additional areas or re-open them for fisheries (LNV 1993).

During this period (1990-1993), observations of bird mortality and contestation of fishery effects politicised mussel fisheries. Knowledge played an important role in politicisation of the issue, and scientific experts could not depoliticise the issue as expected from the linear model of expertise. Both the nature and fishery coalitions acknowledged that knowledge of the fishery effects should be the basis for mussel fishery regulation. However, there was ambiguity on the fishery effects, especially about the causes of the high bird mortality and loss of the mussel banks. The ministry acknowledged this uncertainty by formulating a compromise to keep areas open for fisheries and simultaneously protecting nature with food availability limitations. Although knowledge topics influenced the crucial decision in 1993, this decision was not legitimised by expertise. Instead, this decision was legitimised through the governmental authority of the ministry, a decisionist mechanism to depoliticise the debate. A technocratic approach was proposed to guide further decision making. Research was perceived as necessary to evaluate the effects of restricting areas for fisheries and to reduce the uncertainty on fishery effects. Expert knowledge was viewed as a requirement for future legitimate decisions, expressing high expectations for research results in future decision-making processes (LNV 1993).

Main events and decisions			Research projects
No restriction of cockle and mussel fishery		1990	
	Almost all littoral mussel banks disappeared		
	High bird mortality in winter	1991	
		1992	
Crucial decision: Sea and Coastal Fisheries Policy (SCFP): 26% of the Wadden Sea restricted from fishery and 60% food reservation for birds		1993	
		1994	EVA I (1994-1998): evaluation of fishery regulation
		1995	
		1996	
		1997	
Adaptation SCFP: additional littoral areas closed		1998	
	High bird mortality in winter	1999	EVA II (1999-2003): evaluation of fishery regulations and fishery effect research
		2000	
Shellfish sector vision on sustainable fishery (ODUS)		2001	
		2002	
		2003	
European Court of Justice ruling: shellfish fishery as a project under the Habitat Directive		2004	
Government decision: ban on cockle fishery and permit for gas mining			
Crucial decision: Support sustainable mussel fishery, no more food reservations for birds instead autumn fishery restricted to instable mussel banks			
Workshops and meetings between fishermen and nature organisations until spring 2006		2005	
		2006	PRODUS project (2006-2013): fishery effect research on sublittoral nature values
Council of State procedure against mussel seed fishery spring 2006 permit			
Heldoorn informer began to bring nature organisations, fishermen and ministry together		2007	
Council of State ruling: spring 2006 permit invalid		2008	
Crucial decision: Transition covenant between nature organisations, fishermen and the ministry			
Permanently closing 140 ha sublittoral mussel seed banks		2009	
Additional closing of 70 ha sublittoral mussel seed banks		2010	
		2011	
		2012	
		2013	
Additional closing of 9090 ha sublittoral mussel seed banks		2014	
		2015	
		2016	

Figure 4.3. Overview of important events, research projects and crucial decisions in the mussel fishery controversy (1990-2016).

4.5.2 Continuation of debate on sufficient bird protection (1993-2004)

The Sea and Coastal Fisheries Policy of 1993 and the slow restoration of littoral mussel banks restricted the mussel fishery practice to only sublittoral mussels. In 1998, the EVA I evaluation research showed that the restoration of littoral mussel banks was very limited (Ens 2004). However, there were insufficient data to make strong conclusions on fishery effects, and the Ministry of LNV initiated the EVA II evaluation project. Although this technocratic approach using evaluation research to guide decision-making restricted the debate to knowledge arguments, the regulation debate on shellfish fisheries continued. Nature organisations contested cockle and mussel fishery permits in court, claiming that the fishery regulation was insufficient to protect nature. The littoral mussel bank restoration was very slow, and high bird mortality occurred in the winters of 1999-2001 (Floor et al. 2013; Raad van State 2005). Fishermen claimed that the regulation to restrict fishery areas hampered sustainable fishery innovations. In 2001, the shellfish fishery sector published a sustainable fishery vision, which included an alternative method of juvenile mussel collection to innovate mussel fishery and cultivation. These mussel seed collectors should reduce seabed disturbance and create a more stable mussel seed input using ropes in the water column on which juvenile mussels can attach themselves (ODUS 2001). However, in 2002, mussel fishermen also requested a permit to fish on natural littoral mussel banks, which was unmentionable for nature organisations and was not granted by the Ministry (Raad van State 2004). This mussel fishery regulation debate can be characterised by the positions of *More regulation!* versus *Less regulation!*

The positions of the nature and fishery coalitions were supported by knowledge claims on fishery effects. The main concern of the nature coalitions was bird protection. The removal of mussels would effectively reduce food availability for birds, especially in years with low numbers of juvenile mussels. In contrast, the fishery coalition claimed that the overall effect of mussel fishery and cultivation was positive for nature. The transportation of juvenile mussels to cultivation plots would increase the number of mussels in the Wadden Sea because of the better surviving conditions for mussels on cultivation plots, increasing also the number of mussels available for birds. The coalitions had their own interpretations of the research results of EVA I and II, and science-based experts contested different fishery effect interpretations. For example, model calculations in the EVA II project showed that the cultivation practice increased the number of mussels in the Wadden Sea. The fishery coalition perceived this as a confirmation of their position. The nature coalition, however, emphasized that, in years with low numbers of juvenile mussels, the actual effects for bird populations could still be negative. Furthermore, the nature coalition proposed changing the norm of food availability to reach bird restoration goals. This knowledge debate triggered by ambiguity on fishery effects can be characterised by the positions of *Potentially harmful fishery* versus *Positive effects of mussel fishery and cultivation*.

Table 4.2. Overview of regulation and knowledge debates and depoliticisation mechanisms in mussel fishery decision-making (1990-2016).

Period	Regulation debate on mussel fishery regulation	Knowledge debate on uncertainties of effect claims	Depoliticisation mechanisms & role of knowledge uncertainties
1990-1993: Start politicisation of mussel fishery, focus on littoral mussel banks	Reduce fishery areas! vs. No limitations of fishery areas!	Harmful fishery vs. Natural fluctuations	▪ Decisionist: government decision to regulate fishery. ▪ The policy included a compromise to address ambiguity on fishery effects for birds. ▪ Knowledge as requirement for future decisions, initiating EVA I.
1993-2004: Technocratic debate on fishery effects	More regulation! vs. Less regulation!	Potentially harmful fishery vs. Positive effects of mussel fishery and cultivation	▪ Decisionist: government decision to support mussel fishery. ▪ No scientific consensus on effects, ambiguity on interpretation of EVA II research results. ▪ New research to address incomplete knowledge of sublittoral effects.
2004-2008: Restricted debate on permits, focus on sublittoral mussel banks. After Council of State verdict, increased public debate	Only mussel fishery without damage to the seabed vs. Mussel fishery and cultivation is already sustainable	Too much incomplete knowledge to assess effects vs. Sufficient knowledge to assess no significant effects	▪ Legal decisionist: Nullification 2006 permit based on incomplete knowledge of sublittoral fishery effects. ▪ Increased politicisation of the issue, reducing incomplete knowledge with research was unattainable. ▪ Participatory: transition covenant enforced co-operation to end mussel fishery crisis in 2008.
2008-2016: Co-operation within mussel transition covenant	Pacified debate, redirected to semi-private sphere of covenant partners	Pacified knowledge debate, agreement to ignore ambiguity on fishery effects	▪ Participatory: co-operation in transition covenant. ▪ Ambiguity in fishery effects is ignored by covenant partners. ▪ Knowledge required to support covenant decisions.

Although the EVA II research project was undertaken to guide decision-making on shellfish fisheries, other processes became more influential. First, the debate on gas mining in the Wadden Sea had begun to influence the shellfish fishery debate (Floor et al. 2013). In addition, the ruling of the European Court of Justice in 2004 that the European Habitat Directive permit procedures also applied to shellfish fisheries was a very influential change in the legal setting (EuropeanCourtofJustice 2004). This decision implied that the burden of proof was on the fishermen to show that there were no negative significant effects on the Wadden Sea's nature value (Raad van State 2005). Against this background, in 2004, the Dutch government decided to support sustainable mussel fishery and support alternative mussel seed collection experiments, whereas mechanical cockle fishery was banned from the Wadden Sea (LNV 2004).

In this period (1993-2004), knowledge did not contribute to depoliticising the controversy. Even though knowledge arguments structured the regulation debate, ambiguity on fishery effects amplified the knowledge debate. The high expectation that the EVA I and II evaluation projects could reduce the debate on fishery effects was not met. In contrast, science-based expertise became part of the debate on fishery effects as contested expertise. Again, the main uncertainty was the ambiguity on fishery effects. The fishermen also noted the unpredictability of the natural dynamics of the Wadden Sea: "not everything can be described or explained" (ODUS 2001, p.14). Still, the fishermen were actively involved in the EVA II project. This project structured the debate on mussel fisheries. For example, the debate on eider duck protection occurred with ecological arguments on food availability calculations. However, the ambiguity on the EVA II research results enhanced the debate instead of the expected depoliticisation. Furthermore, the acknowledgement of incomplete knowledge on sublittoral nature effects triggered new research: the PRODUS project ('PRoject Onderzoek DUurzame Schelpdiercultuur' in Dutch). This project aimed to support sustainable fishery and included research on the effects on sublittoral nature by comparing the biodiversity of fished and unfished plots. The ministry expressed high expectations for this research: "Knowledge and facts are seen as an opportunity to bridge the divide of standpoints and visions" (LNV 2004, p.8). Again, a technocratic approach was proposed for future decision-making. However, the crucial decision to support sustainable mussel fishery (and not cockle fishery) in 2004 was based on a decisionist approach, legitimised through the authority of the government. Although the ministry legitimated this decision with their interpretation of the EVA II results and advise commissions, it was not technocratic in the sense of being prescribed by science-based experts.

4.5.3 Debate on mussel seed fishery permits (2004-2008)

In 2004, the Ministry of LNV decided to support mussel fishery and cultivation in the Dutch Wadden Sea, whereas mechanical cockle fishery was banned from the Wadden Sea (LNV 2004). As a result, the fishery practice on sublittoral mussel seed banks could

continue in spring and autumn[6], although fishermen now needed a permit under the European Habitat Directive (92/42/EEC). After a period of low spat fall and no fishing, the first fishing activity under this obligation was in autumn 2005. For this permit, the ministry of LNV commissioned research institute Alterra to write an appropriate assessment (Alterra 2005). They concluded that there were no significant effects based on the condition that only instable mussel banks were fished. For the spring 2006 permit to fish mussel banks that survived the winter[7], the Producer Organisation (PO) Mussel Culture commissioned the consultancy MarinX, who assessed that there were no significant effects (Floor et al. 2016; Van Stralen and Sas 2006). In 2005 and 2006, several workshops and meetings took place between nature organisations, the PO Mussel Culture and science-based experts, organised by the Ministry of LNV, which had an aspiration of co-management. Although they agreed that fishermen needed transition time to adopt new practices, they disagreed on the meaning of sustainable fishery and how quickly innovations should be realised. These differences between the fishery and nature coalitions' positions characterise the regulation debate: *Mussel fishery and cultivation is already sustainable* versus *Only mussel fishery without damage to the seabed*.

In March 2006, these differences led to discontinuation of the regular meetings. Instead, nature organisations began legal procedures against the spring 2006 fishing permit from the Dutch government. These legal procedures redirected their differences toward a debate on the assessment of significant effects and the certainty of knowledge claims, triggered by the European Court of Justice condition of "no reasonable scientific doubt" (EJC, 2004. Paragraph 61). This knowledge debate can be characterised as *Too much incomplete knowledge to assess effects* versus *Sufficient knowledge to assess no significant effects*. The nature coalition questioned if the assessment of no significant effects could be made. Based on the precautionary principle, they claimed that there was insufficient knowledge to grant a permit. The incomplete knowledge of the effects of fisheries on sublittoral nature values implied that there could possibly be significant effects. In addition, they challenged the knowledge claims on mussel cultivation effects in bad years and food availability for birds with a restoration goal, whereas the fishery coalition claimed that an assessment of no significant effects could be made. The effect uncertainties on sublittoral nature values were addressed with an adaptive management approach; if the PRODUS results showed negative effects, the fishery practice would be changed. Furthermore, they stressed the positive effect of an increase of mussel

[6] Regulation on bird protection changed in 2004. Instead of yearly food availability assessments, fisheries were restricted to instable mussel seed banks in autumn and an administrative requirement was introduced to record mussel transports to keep 85% of the fished juvenile mussels in the Wadden Sea for the winter.

[7] These mussel banks have the potential to become multiple-year-old wild mussel banks, see Floor et al. (2016) and Alterra (2005) for details.

biomass by relocating mussels to cultivation plots. In 2007, in parallel with this legal conflict, the ministry commissioned an independent facilitator to initiate meetings between nature organisations, the mussel sector and the ministry to support co-operation.

In February 2008, the Council of State ruled that the spring 2006 permit was invalid, stating that there was inadequate understanding of effects to assess no significant effect without reasonable scientific doubt (Raad van State 2008). This triggered a mussel crisis. Fishermen feared for their future, according to them without new permits the Dutch mussel sector would be finished. In response, the fishermen began an intensive media campaign, 'stop the green lie', against nature organisations and scientists that claimed mussel fishery was not sustainable. Initially, the minister expected that the PRODUS research could be accelerated to provide the required scientific basis for new fishery permits. However, a scientific audit revealed that this was impossible. The ecological research needed much more time to make valid conclusions on effects, and the auditors remarked that it would be unlikely that the results could reduce the controversy (Herman 2008; Van der Molen et al. 2015). In response, the Ministry intensified the process seeking co-operation using an independent facilitator (Heldoorn 2008). In October 2008, this resulted in the Transition Mussel Sector and Nature Restoration Wadden Sea Covenant, signed by nature organisations[8], the PO Mussel Culture and the Ministry. This covenant implied a step-by-step replacement of traditional mussel seed fishery with alternative mussel seed collection in 2020 and a nature restoration program for the Wadden Sea[9]. This covenant is in line with a broader trend in Dutch governance, in which covenants between NGOs and market parties are used to pacify conflicting issues.

In this period (2004-2008), knowledge production did not depoliticise the debate, instead the legal decision on the knowledge debate of significant effect assessment even triggered intensification of the debate. The knowledge dispute on whether there was sufficient knowledge to grant a permit was decided upon by the Council of State in 2008, who stated that there was incomplete understanding to assess no significant effects. This can be viewed as a legal decisionist mechanism to close the knowledge debate in which the court judged between different expert interpretations. However, this decision triggered further politicisation of the regulation debate. After the Council of State's ruling in 2008, the public debate on the mussel sector increased, with intensive discussions in the media and the Dutch parliament. The relations became very tense between fishermen and nature organisations. It became clear that the technocratic mechanism based on the PRODUS research results would not provide a timely answer. Instead, the ministry em-

[8] The covenant (Convenant Transitie Mosselsector en Natuurherstel Waddenzee in Dutch) was signed by the following nature organisations: the Society for the Protection of Birds, the Wadden Sea Society, the WAD Foundation and the Society for the Preservation of Nature Monuments in the Netherlands.

[9] The nature restoration 'Program towards a Rich Wadden Sea' (PRW, Programma naar een Rijke Waddenzee in Dutch) was established to facilitate the mussel fishery transition and nature restoration.

phasized co-operation. This 'forced marriage' between the nature organisations and fishermen in the transition covenant aimed to prevent further court cases on fishery permits and guarantee a transition process to innovative and more sustainable fishery practice. The mussel transition covenant was legitimised by the involvement of the most relevant stakeholders, a participatory mechanism.

4.5.4 Co-operation within the mussel transition covenant (2008-2016)

The mussel transition covenant made it possible for the fishermen to obtain a permit to fish in spring 2009, excepting the newly closed sublittoral areas. Investments in mussel seed collectors were also made, up-scaling the technical innovation to gradually increase the intake of juvenile mussels from the water column. Additional areas were permanently closed for mussel seed fishery in 2010 and 2014 (PRW 2015). The impact of mussel seed collectors and natural development in the closed areas are monitored. In addition, research on the restoration of mussel banks was initiated.

The covenant depoliticised the debate on mussel fishery regulation by transferring the issue from the public domain of government to the semi-private domain of the covenant partners. Although the differences between the stakeholders did not disappear, the regulation debate became pacified. The permits are no longer opposed by nature organisations in court. According to a nature organisation: "all the issues that were first debated, are now documented, so the permit procedure is different". Moreover, interactions between the actors changed; instead of enforcing their own perspectives and using knowledge to enhance their positions, they must work together to shape the transition process. For example, nature organisation and mussel fishermen had to work together to formulate a policy for juvinale mussel transportantion. This is a controversial issue for nature organisations because of the invasive exotic species risk when transport takes place from the south of the Netherlands to the Wadden Sea (Van der Molen et al. 2015). Through shared fact-finding, a monitoring program was set up in a participatory manner by a workgroup of fishermen and nature organisations, based on the input of science-based experts on species inventories.

With the depoliticisation of the regulation debate, the transition covenant pacified the knowledge debate on fishery effects. The co-operation between the covenant partners depoliticised this dispute because the covenant partners decided that their contesting knowledge claims on fishery effects are not relevant for the co-operative process. This is very clear in the reaction to the PRODUS results in 2013, this research indicated both temporarily negative effects of mussel seed fishery in spring and high biodiversity of mussel cultivation plots (Smaal *et al.* 2013). After the covenant was signed, interest in the PRODUS research declined. According to a researcher: "the agenda of the covenant partners was dominated by other issues than what we could address with PRODUS". Contrasting the initial high expectations of the government and fishermen for this research, the PRODUS results had no impact on mussel fishery management in the cove-

nant. To avoid a new debate on knowledge uncertainties, the covenant partners decided to ignore the results. An interviewee from the mussel sector remarked: "We did not discuss it properly, nobody was interested". Nevertheless, the release of the PRODUS results in 2013 triggered scientific disagreement on the correct interpretation of the results. The original press release was criticised for being too positive to mussel fishery by scientists from the NIOZ research institute, resulting in a new press release that emphasized the limitations of the research (IMARES 2013a; IMARES 2013b). However, this ambiguity was not used or expressed by stakeholders to change mussel fishery regulations.

The debate on knowledge uncertainties of fishery effects was pacified in this period (2008-2016). Instead, knowledge was instrumentally used to support decisions to implement the transition of mussel fishery practice based on an adaptive management approach of 'learning by doing'. There was no resolution within the knowledge debate on fishery effect uncertainties, however, the public debate on knowledge uncertainties of fishery effects disappeared because the regulation debate was depoliticised; decisions on mussel fishery management were made between covenant partners. To give legitimacy to their decisions as covenant partners, they continue to rely heavily on science-based expertise. The transition is based on 'learning by doing', expressing incomplete knowledge and unpredictability, which should be addressed with monitoring and research projects. Furthermore, the interactions between the nature organisations, mussel fishermen and science-based experts changed. Instead of coalitions enforcing their own perspective and using knowledge to enhance their position, they began to work together to shape the transition process. However, this could be a temporary end to the controversy. First, the legitimacy of the covenant can be questioned by excluded actors. Some important outsiders to the covenant such as shrimpers and recreational organisations[10] have criticised the covenant, even though without repoliticising the issue. Second, the covenant partners themselves can withdraw from the co-operation. The current consensus is threatened by the continuation of opposing views, the limited feasibility of a complete transition to mussel seed collectors and the formal end date of the covenant in 2020. However, all actors still perceive collaboration as mutually beneficial.

4.6 Conclusions

4.6.1 No linear relation of knowledge and policy in the mussel case

Our research was triggered by the persistent belief in the linear model of expertise which assumes that appropriate knowledge results in legitimate decisions. In the case of knowledge uncertainties, the linear model states that the knowledge debate must first

[10] Shrimp fisheries have experienced a decrease in their fishing grounds due to increases in mussel seed collectors and restricted areas. Recreational organisations are primarily concerned with the aesthetics of the open Wadden Sea landscape that is disturbed by mussel seed collectors that are in the Wadden Sea for several months.

be resolved to end the regulation debate, see Figure 4.2. However, our mussel fishery case study showed a different relation between the knowledge and regulation debates. Mussel fishery regulation decisions were primarily based on government authority, with knowledge as a requirement for future decisions. The large EVA I, EVA II and PRODUS research projects were planned with the expectation that their results would prescribe future decisions on mussel fishery. But these technocratic expectations were hampered by knowledge ambiguity. Also the legal process at the Council of State did not end the knowledge debate on fishery effects. The ruling stated there was inadequate understanding of effects, which initially increased the expectations research should solve the controversy. However, research could not provide timely knowledge to address the incomplete knowledge on effects. Instead, the mussel fishermen politicised the issue even further by attacking what they called the 'green lie' of nature organisations and scientists that mussel fishery was harmful. It was the 2008 covenant between the conflicting parties, made under high political pressure from the government, which pacified the controversy and enforced a participatory approach. Thus, the pacification of the regulation debate circumvented knowledge controversies. Although the covenant partners still diverged in opinion, they set aside the knowledge ambiguity on fishery effects, see Figure 4.4, which made the knowledge debate on fishery effects irrelevant. We conclude that knowledge consensus was not a prerequisite for decision-making in the case of mussel fishery in the Wadden Sea. Instead, decisions were justified through the decisionist and participatory depoliticisation mechanism. In spite of the high expectations that future decisions could be based on research results, a scientific consensus on fishery effects was not reached. Therefore, we criticise the assumption of the linear model of expertise that knowledge will resolve environmental controversies. Rather than scientific clarity putting an end to policy controversy, we found that a political closure of the regulation debate ended the knowledge debate.

4.6.2 High expectations of scientific knowledge explained

Even though we criticise the linear model of expertise to describe the role of science in policy-making processes, we conclude that the linear model of expertise is essential to understand the high expectations of research in the decision-making process. Our distinction of a knowledge debate and a regulation debate, and the analytical concepts of knowledge uncertainty and depoliticisation mechanisms help explain the high expectations of scientific knowledge to resolve controversies.

First of all, knowledge uncertainties were predominantly perceived as incomplete knowledge, indicating that the uncertainty should be tackled with research. This assumption that more knowledge can resolve a knowledge debate is a key aspect of the linear model of expertise. It is widely found in our case study, even though our analysis of the mussel case showed that ambiguity on fishery effects was the main knowledge uncertainty in the decision-making process. Instead of acknowledging ambigu-

ity on fishery effects, research projects were conducted with the expectation that the results would provide clarity on effects. This expectation for research was enforced by the technocratic conditions in the European Habitat Directive. Also the Council of State ruling in 2008, while not ending the knowledge debate on fishery effects, did enforce the perception of uncertainty as incomplete knowledge. Thus, even when the research projects did not result in consensus among science-based experts, knowledge uncertainties were predominantly interpreted in terms of incomplete knowledge.

Secondly, we observed a firm belief in the linear model of expertise among the conflicting parties in the mussel fishery case. Both camps acknowledged scientific knowledge as condition to make legitimate arguments in the debate. Furthermore, there were high expectations that new research projects would support their position in the controversy. Only during the mussel crisis in 2008, it became clear to the stakeholders involved that they are mutually dependent upon each other and that the strategic use of scientific arguments was no longer an option to strengthen their position. This crisis resulted in sufficient political pressure to depoliticise the regulation debate through a participatory approach that resulted in the mussel transition covenant. This pacification of the regulation debate stopped the knowledge debate because the knowledge uncertainties on fishery effects addressed by different discourse coalitions became irrelevant to the policy-making process. Still, the belief in knowledge for decision-making processes continued in the 'learning by doing' approach.

Thirdly, our analysis of the mussel fishery case showed that expectations in line with the linear model can reinforce depoliticisation through regulatory mechanisms. For example, the legitimacy of the participatory mechanism was enforced by a proposed technocratic approach for further decisions. The legitimacy of the covenant was based on the participation of the relevant stakeholders and on their proposal to base their decisions on an adaptive management approach of 'learning by doing'. In a similar manner, the legitimacy of the governmental decisions in 1993 and 2004 were supported by research projects. This shows that the technocratic mechanism played an important role in the legitimation of decisions by indicating that future decisions will be based on new information. Actors involved anticipated that new research results would resolve the knowledge debate, and by consequence also soften the controversies in the regulation debate. Even though the actual research projects did not provide this clarity, the expectations for future research persisted.

These findings have a broader relevance, as it is likely that the three processes observed - a dominant perception of uncertainty as incomplete knowledge; the belief of actors in the controversy that more knowledge will support their position; and the expectation that future policy decisions can be based on research results - also occur in other nature conservation controversies. Simply criticizing the linear model of expertise will not have an impact on controversies of such kind. Instead, we propose, there should be better acknowledgement of ambiguity and more reflection on the expected outcome of research

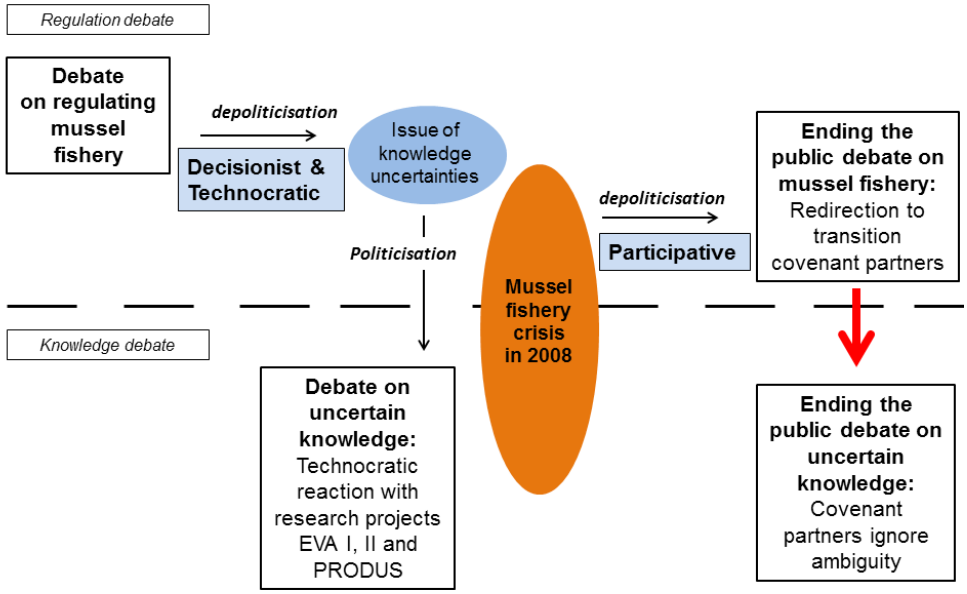

Figure 4.4. Visualisation of the depoliticisation of the regulation debate in 2008 with the transition covenant that triggered closure of the knowledge debate.

projects. Indicating there is a social problem and not just a technical problem can redirect the controversy to the regulation debate where political choices need to be made.

4.6.3 The role of knowledge production in decision-making processes

The mussel fishery case study has shown that knowledge played an important role in the decision-making processes, although knowledge development did not lead to the end of the mussel controversy. Research projects played a strategic role by postponing final decisions, a procedural role as an arena for interaction between different actors and an instrumental role by providing increased understanding of specific topics. All actors used research as a strategic tool. The nature organisations and mussel fishermen expected that additional knowledge would support their positions, resulting in research projects to find 'better' knowledge. Although additional knowledge could not reduce their ambiguity, research results increased the complexity of their scientific arguments. In addition, the Ministry used research in a strategic manner. Instead of supporting either fishery or nature interests, they made scientists jointly responsible for permit decisions supported by the expert-driven European Habitat Directive regulations. Furthermore, research projects served a procedural role as an important meeting ground for the discourse coalitions. Especially in the EVA II project, those with different perspectives had to work together. In the covenant, workgroups based on the 'learning by doing' approach facilitated interactions between different perspectives. Finally, not all knowledge produced in the research projects was contested. For example, the raw data of mussel calculations

and bird counts were not disputed and were used instrumentally. These uncontested data formed the basis of the co-operation within the covenant setting. To conclude, knowledge structured the decision-making process though it did not solve the controversy. Knowledge and research can play crucial strategic, procedural and instrumental roles in decision-making processes, but to resolve controversies that are characterised by knowledge ambiguity other depoliticisation processes are required.

Chapter 5

Science, uncertainty and changing storylines in nature restoration:
The case of seagrass restoration in the Dutch Wadden Sea

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Abstract

Marine areas have been heavily affected by human activities, resulting in current attempts to both conserve and restore nature. In decisions about nature restoration, ecological knowledge plays a crucial role and is closely linked to nature preferences and political views. In this study, the empirical case of seagrass (*Zostera marina*) restoration in the Dutch Wadden Sea (1989-2017) is analysed. The impact of storylines and uncertainty perceptions, together with socio-political context factors, on decisions concerning restoration action and research are investigated. This case illustrates the difficulties of establishing seagrass fields and the dynamic process in which meaning is attributed to nature restoration. Two basic storylines – authenticity and the ecological function of ecosystem engineers – supported the restoration efforts. Three different episodes are distinguished based on different views of research in restoration efforts. The dominant perception of uncertainty was incomplete knowledge, and this perception resulted in research projects. Furthermore, the unpredictability of the success of restoration efforts and the ambiguity regarding the feasibility of restoration also influenced decisions. Two concepts – ecosystem engineer and pilot project – facilitated collaboration among science-based experts, NGOs and governmental organizations.

5.1 Introduction

Over the past few decades, nature restoration – in addition to nature preservation – has become an important component of nature protection. At the moment, increasing efforts are being made to restore marine and coastal areas, which involve more 'invisible' nature compared with terrestrial areas. In the face of on-going degradation of marine areas and loss of biodiversity, attempts are being made to restore species or even to develop new natural habitats. While nature preservation mainly aims at safeguarding existing nature values, the aim of nature restoration is to change a particular natural environment, transitioning it towards an envisioned restored state (France 2016; Light and Higgs 1996). In many respects, this makes restoration an even more complex process than preservation. Ecological knowledge is crucial in guiding this process, and scientists play a key role in restoration activities, from initiating restoration projects to operationalizing restoration techniques. The emergence of restoration ecology as a new subdiscipline of biology reflects this development (Choi 2007; Gross 2010; Higgs 2005; Light and Higgs 1996). Science alone, however, is not sufficient to cope with the challenges of restoration. As several authors have noted, restoration is intertwined with political choices and cultural preferences, which significantly influence the potential aims and outcomes of restoration projects (Baker and Eckerberg 2013; France 2016; Light and Higgs 1996). In addition, the complexities of restoration entail persistent uncertainties about interventions and their consequences to the ecosystem. In combination with the urgency of making ecological improvements and the limits of available funding, these uncertainties may lead to conflicts between taking immediate action versus gathering more knowledge through ecological research (Allison 2007; McDonald-Madden et al. 2010).

Restoration, in sum, is subject to a dynamic interplay of different factors: socio-political context, ecological knowledge, uncertainties, and action-research dilemmas. While several studies (Baker and Eckerberg 2013; France 2016; Gross 2010; Light and Higgs 1996) have identified and investigated these factors, few have analysed how they interact with one another in restoration projects. This article contributes to the literature on the social and political aspects of nature restoration (Baker and Eckerberg 2013; France 2016) and the literature on science-policy interactions in environmental issues (Wesselink et al. 2013).

We aim to shed more light on these issues by analysing efforts to restore seagrass in the Dutch Wadden Sea during the period 1989-2017. Globally, there is a long history of efforts to restore seagrass fields in response to a plant disease in the 1930s and declines caused by fishing and dredging (Cunha et al. 2012; Van Katwijk et al. 2016). Moreover, the global importance of seagrass fields is well recognised as they provide several functions, ranging from fish breeding grounds to carbon sequestration (Duarte et al. 2013). Currently, there are large-scale restoration projects underway in the US, Australia, China and Europe (Van Katwijk et al. 2016). As we will demonstrate, the case of seagrass in the Dutch Wadden Sea is particularly interesting because it entails a relatively long-term and

continuing effort that is directed at a specific type of vegetation in a political and ecological environment characterised by change and uncertainty. Adding to these dynamics is the fact that the restoration is situated in a marine environment where many vital processes are hidden from view. Another noteworthy feature of this case is that the restoration efforts have not, so far, been successful in establishing long-term seagrass fields.

This article is structured as follows. First, we elaborate on our conceptual framework, present conceptually refined research questions, and specify our methods. Then, we describe and analyse the Dutch case of seagrass restoration. Finally, we discuss noteworthy outcomes and draw conclusions.

5.2 Storylines and dealing with uncertainties

Decisions concerning nature restoration are based on why certain actions are required and to what extent there is sufficient and accurate knowledge to support taking these actions. Two key concepts we use to analyse the case of sea grass restoration and to address these issues are storylines and uncertainties. Storylines are used to characterize how the restoration of seagrass is framed by the actors involved. In our use of storylines, we build on Wesselink et al. (2013, p.4), who state that "the multiple, dynamic interactions between processes of knowledge production and decision-making result in stories where both elements are intimately interwoven". These storylines are narratives that give meaning to specific phenomena, in our case seagrass restoration. Through such storylines, "ideas of 'blame' and 'responsibility' and 'urgency' and 'responsible behavior' are attributed" (Hajer 1995, p.65). In storylines, actors frame problems and their preferred solutions in a convincing way, using facts, interests and metaphors to persuade others (Stone 2012; Wesselink et al. 2013). For example, a storyline that is frequently found in restoration efforts runs as follows: historically, there existed a rich and well-functioning ecosystem, but vital components were lost and should be reintroduced to restore the full, authentic ecosystem (Baker and Eckerberg 2013). As we will show, this storyline is found in our seagrass case.

To deepen our understanding of the science-policy debates, we analyse how actors address uncertainties. In doing so, we take a relational perspective on uncertainties, seeing them as constructed in particular settings (Shackley and Wynne 1996; Van den Hoek 2014). As Brugnach et al. (2008, p. 5) observe: "the definition of a problem and what is uncertain about it depends not only on scientific or expert understanding, but on the knowledge, views, and preferences of the decision-maker in relation to those of other actors with whom the decision-maker interacts to make sense of the situation" (Brugnach et al. 2008, p.5). In this study, we examine perceptions of uncertainty among the actors involved in making decisions about nature restoration. Among all potential uncertainties, which ones are acknowledged and addressed as meaningful in the decision-making process?

Building on (Dewulf et al. 2009; Floor et al. 2016; Van den Hoek et al. 2014), we distinguish three types of perceptions of uncertainty: incomplete knowledge, unpredict-

ability and ambiguity; see also Figure 5.1. Uncertainty can be characterised as incomplete knowledge when actors expect that certainty can be obtained by additional research. When uncertainty is perceived as unpredictability, the issue at stake is deemed to be unknowable because it is beyond the grasp of research given the present state of science and the complexity of the issue. We characterize uncertainty as ambiguity when actors present diverging knowledge claims rather than thinking that they do not know enough. Thus, ambiguity can be defined as "the existence of two or more equally plausible interpretation possibilities" (Dewulf et al. 2005, p.116).

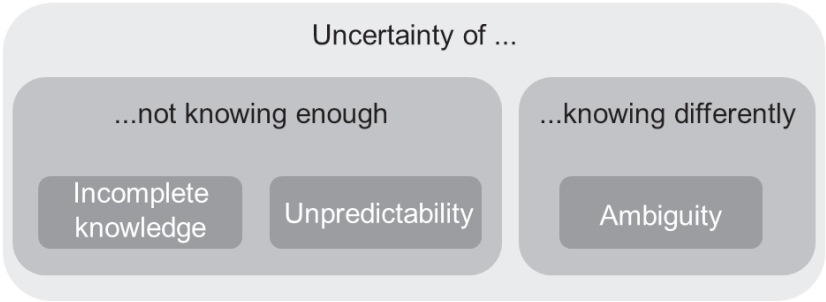

Figure 5.1. Schematisation of types of uncertainties based on Van den Hoek (2014).

Related to these different perceptions of uncertainty, there are different strategies of dealing with uncertainties in decision-making processes. When uncertainty is posited as incomplete knowledge, a strategy to address this uncertainty could be investing in more research, for example through additional data collection, either alongside or before making a decision. It is worth noting that such a strategy is not, per se, effective: more research may also result in the acknowledgement of more uncertainties, as observed by Turnhout et al. (2008). When uncertainty is perceived as resulting from unpredictability, more research makes no sense, and the strategies of decision-makers instead revolve around accepting the unpredictability and acknowledging the risks implied. At the same time, risks can be reduced by anticipating several possible scenarios, diversifying the measures taken, and increasing society's capacity to respond to different potential outcomes, for instance through adaptive management (Brugnach et al. 2008). The perception of uncertainty as ambiguity implies that there are multiple, conflicting interpretations of a situation, each with its own plausible knowledge base. In a cold conflict, actors distance themselves from each other and avoid confrontation; in a hot conflict, the issue is politicised and actors explicitly criticise the opposite camp (Brugnach et al. 2008; Floor et al. 2016). Decision-makers' strategies to address this uncertainty can range from supporting one of the camps against the other to pushing for consensus by stimulating the exchange of views and mutual learning. As we will demonstrate in our case study, these perceptions of uncertainty play a central role in disputes on research and intervention.

Building on these key concepts, we can organize the aims of our study into the following research questions.

1. Which storylines about seagrass restoration emerge in the Wadden Sea case?
2. Which perceptions prevail regarding knowledge uncertainties?
3. What is the impact of storylines and uncertainties, together with socio-political contextual factors, on decisions concerning restoration action and research?

5.3 Methodological approach

We used an interpretative research approach (Yanow and Schwartz-Shea 2006) because it is particularly suitable for our conceptual framework. As Wesselink et al. (2013, p.4) note, "a core tenet of interpretative approaches is the likelihood of multiple meanings, or interpretations, of problem definitions and policy texts, and also of the expertise relating to the policy issues". Following this interpretative tradition, we analysed the different understandings that were expressed in our case study.

First, we analysed the reasons for active restoration efforts. Second, we analysed the perceived role of research in the restoration efforts. Third, we analysed how uncertainties were interpreted by the actors involved, both in the legitimation for restoration projects and in the interpretation of research and project results. Based on these three types of understanding in the restoration efforts, we distinguished the three episodes that structure our description of the case study: 1989-2005, 2006-2013, and 2014-2017. The starting point of 1989 is based on the governmental decision for active restoration of seagrass plants, even though it was decided that research was required first. A new episode started in 2006 when a non-governmental actor initiated restoration efforts, accompanied by a new storyline to support active restoration and a reduced role for scientific research. We distinguished a new episode that begins in 2014, when both the role of scientific research and the storyline to support the restoration efforts changed. The analysis ends in 2017, corresponding to the end of our data collection.

We draw on data collected during the period 2014-2017. Data were gathered from research reports, governmental documents, project plans, organisations' websites, blogs and newspaper articles (using the LexisNexis database). Additionally, nine semi-structured interviews were conducted with key informants from scientific institutes, nature organisations and the government, with the purpose of reconstructing the restoration efforts and perceptions of the actors involved. In autumn 2015, participatory observations were conducted during the restoration efforts at Uithuizen and Schiermonnikoog. In addition, we used insights on the role of science-policy interactions in the protection of the Dutch Wadden Sea, obtained from a larger research project of which this study is part[11].

[11] In the period 2011-2017, observations, informal interactions during symposia and workshops, and twenty-eight semi-structured interviews with key actors in the Dutch Wadden Sea were conducted as part of a PhD project. For the full list of interviews, see Appendix I.

5.4 Seagrass restoration in the Dutch Wadden Sea

5.4.1 Background to the case

The Wadden Sea is a shallow estuarine sea, stretching from the Netherlands to Denmark. It is recognized as a World Heritage site and is protected under the European Bird and Habitat Directive and the European Water Framework Directive. Seagrass restoration efforts in the Dutch Wadden Sea have been targeted at eelgrass (*Zostera marina*)[12]. Before the 1930s, two plant types of eelgrass grew in the Wadden Sea: sublittoral and littoral eelgrass. The sublittoral eelgrass plant type is always submerged and lives for multiple years; the littoral type grows in intertidal zones and is usually an annual plant that grows from seeds every year. In the 1930s, most sublittoral eelgrass fields in the Dutch Wadden Sea, covering an area of 65-150 km^2, disappeared. Probable causes were the building of a dam (the 'Afsluitdijk') that increased turbidity and water dynamics and the 'wasting' disease that diminished seagrass fields all around the Atlantic area (De Jonge et al. 1997). The littoral eelgrass growing on the edges of the waterline also declined in the 1930s but partly recovered. In the early 1970s, however, these fields were again declining, probably because of eutrophication and toxins (De Jonge et al. 1997; Den Hartog and Polderman 1975). Similar processes took place in the German Wadden Sea, but most littoral eelgrass fields in that area recovered after improved water quality measures, whereas in the Dutch Wadden Sea, only a few small fields remained (Folmer 2015). The extent to which intense fishing has played a role in reducing habitat suitability for eelgrass in the Netherlands is disputed.

A first restoration effort took place in the 1950s, when scientists made some unsuccessful attempts to restore eelgrass (Den Hartog and Polderman 1975). Initially, most attention came from ecological scientists. For a long time, the main policy goals for the Wadden Sea were economic. Indeed, until the 1960s, the option of embanking the Wadden Sea was seriously debated. The 1970s saw a radical shift in attitude, as the Wadden Sea became a major target of Dutch conservation efforts. The *Wadden Society* was established as an NGO that lobbied and campaigned to protect the natural environment of the Wadden Sea. In a trilateral agreement among the Netherlands, Germany and Denmark, the Wadden Sea's main function was declared to be ecological. Within this trilateral cooperation, targets were formulated for the protection of nature. One such target was to improve the state of seagrass fields (Wanink and Van der Graaf 2008). *Rijkswaterstaat* (the Dutch implementation agency of the Ministry of Transport and Waterways) was responsible for the implementation of these targets and thus became interested in seagrass restoration.

[12] In the Dutch Wadden Sea, there are two seagrass species: eelgrass (*Zostera marina*) and dwarf eelgrass (*Zostera noltii*). The main target species in restoration efforts is eelgrass (*Zostera marina*). In most policy procedures, the more commonly used term is seagrass.

5.4.2 Episode 1: "Research first" (1989-2005)

In 1989, the Dutch national government decided that active re-introduction of seagrass was required. In a policy document of the Ministry of Transport and Waterways, the government stated "Reestablishment of seagrass fields is possible by a combination of emission- and management measurements. Active planting of seagrass on a small scale will enhance this process" (V&W 1989, p.205). Although the governmental decision proposed active planting, this measurement was postponed because experts thought it was better to first research the possibilities and limitations of seagrass transplantation before starting a large-scale restoration project (Philippart et al. 1992; De Jonge & De Jong 2002). Over the following 10 years, several research projects investigated why seagrass fields had disappeared and not recovered, whether the water quality had sufficiently improved, whether there were suitable donor locations, and which aspects influenced the survival of plants in field experiments. These projects involved desk studies, the modelling of a habitat suitability map, and both lab and field experiments, including re-planting seagrass to analyse the conditions of its survival (for an overview of this research, see De Jonge et al. (1997) and Van Katwijk et al. (2002)). The research was commissioned by Rijkswaterstaat, which was responsible for the implementation of the national policy goals. Based on the findings, Rijkswaterstaat concluded in its policy vision of 1997 that changed hydrodynamic conditions made the restoration of sublittoral seagrass impossible. Active restoration of littoral seagrass, however, had potential even when it was expected to be difficult (De Jonge et al. 1996; De Jonge et al. 1997). In 1998, after a workshop in which managers, fishery organisations and nature organisations were consulted, Rijkwaterstaat concluded that it was time for a restoration project focusing on littoral eelgrass (Van Katwijk et al. 2002).

The restoration project of 2002-2005: Rijkswaterstaat commissioned two research institutes – RIKZ and Alterra – as well as the University of Nijmegen to execute the restoration project, which had an experimental set-up. In this project, seagrass was conceptualised as an 'ecosystem engineer' (in Dutch: 'bio-bouwer', literally bio-builder). Plants from the seagrass field in the Eems-Dollard area (Eastern Dutch Wadden Sea) were replanted at two locations, and plant growth was also promoted with seed depositions; see Figure 5.2. The plants were placed in two different densities, and several techniques were applied to increase the stability and protection of the plants (Van Katwijk et al. 2002). Artificial mussel banks were also constructed but disappeared after several months. The project received very little public attention, except from the Wadden Society, who criticised the interventions and artefacts of the project as 'gardening' and maintained that human impact on the ecosystem should be minimal. Their critique did not affect the restoration project. As a restoration effort, the project largely failed: after a few years there were hardly any eelgrass plants. However, the project did improve scientific understanding of the factors playing a role in seagrass survival (Bos et al. 2007; Van Katwijk et al. 2009).

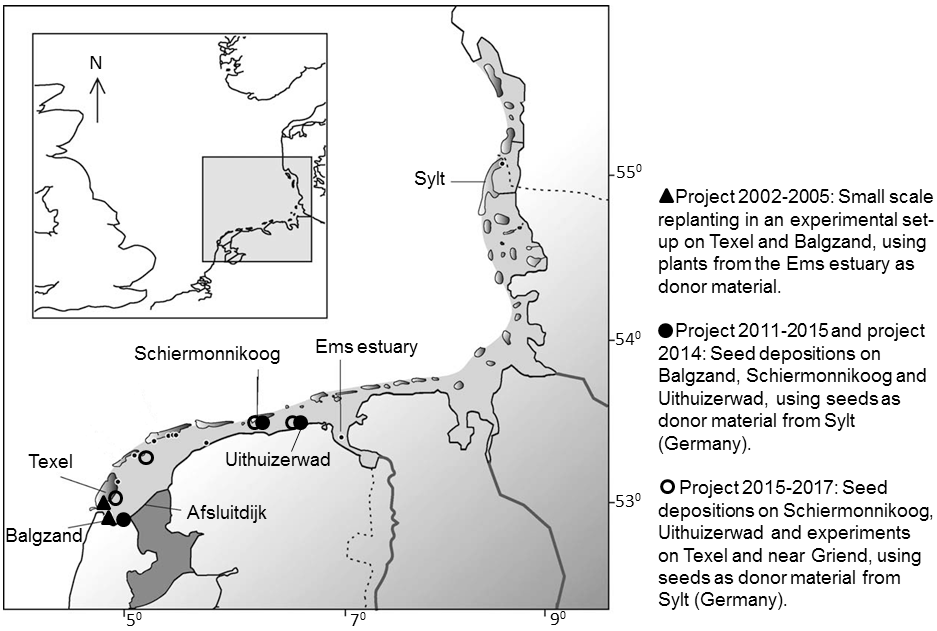

Figure 5.2. Restoration effort locations (based on Van Katwijk et al. 2009).

After the project, Rijkswaterstaat organised an expert meeting to discuss seagrass restoration possibilities on the basis of the results of the restoration project of 2002-2005 and a new habitat suitability map. The potential for more re-planting of eelgrass was perceived to be low: "More [restoration] activities are not perceived as very productive and have to be carefully assessed" (Doeglas et al. 2006, p.6). While Rijkwaterstaat took a negative stance towards further restoration efforts, some scientists showed more optimism. As one of them stated, "Still, it should be possible, because it has been there in the past". Other scientists, however, interpreted the changed water quality and sediment dynamics of the Dutch Wadden Sea as unsuitable for new seagrass fields.

Even though the actual restoration of seagrass was perceived as difficult, and no concrete decision to continue was made in 2006, the claim that seagrass should be restored began to gain momentum. One factor bolstering this claim was the advocacy of nature organisations who framed seagrass as 'the missing pillar' of the Wadden Sea ecosystem and suggested that the replanting of seagrass could be combined with reductions in fishing to minimalize disturbances (Leeuwarder Courant 2005; Van der Eijk 2005). Another influential factor was the qualification of the Wadden Sea as a natural water body under the European Water Framework Directive, with seagrass fields as a quality status indicator. Combined, these two factors kept seagrass on the agenda, even though there remained much scepticism among science-based experts regarding the potential of restoration.

In this episode, there were two dominant *storylines*. One was that seagrass should be restored because it is a valuable and historically authentic component of the ecosystem. The other was that seagrass is important as a functional component of the ecosystem and that it positively interacts with other components. The latter was summarized in the concept of 'ecosystem engineer'. Both storylines were combined in the idea of seagrass as a missing pillar, addressing both its authenticity and its ecological function, see Table 5.1. These storylines remained powerful in societal debates, even though the restoration outcomes from the experiments were disappointing in the sense of establishing long-term seagrass fields.

At the beginning of this episode, the uncertainties of seagrass restoration were prevailingly interpreted as *incomplete knowledge* that should be addressed with scientific research. This interpretation clearly coincided with the initiation of research projects. During the restoration experiments, some *ambiguity* emerged when the Wadden Sea Society criticised the extent of human intervention, but this hardly influenced the course of events. At the end of the period, however, a more powerful type of *ambiguity* arose when the findings from the research projects were interpreted in different ways: some scientists remained optimistic about the potential of restoration, but many became highly sceptical.

The balance between *scientific research* and *restoration action* in this period clearly tilted towards research, as shown in Table 5.1. The aim was to restore seagrass fields, and re-planting activities were undertaken, but only in a setting of scientific experimentation. This fits in well with the storylines on the importance of seagrass and with the prevailing interpretation of incomplete knowledge. However, the experiments did not result in stable seagrass fields. This was perceived as disappointing by those expecting restored seagrass fields, but from a scientific experiment perspective it was successful in the sense that knowledge was produced. Still, scientific experts were divided on the feasibility of seagrass restoration.

5.4.3 Episode 2: "Let's try" (2006-2013)

This episode entailed a new role for the Wadden Society in initiating restoration efforts. To increase their understanding of the Wadden system, staff members of the NGO were in contact with researchers. One NGO staff member became part of a working group on ecosystem engineers in the Wadden Sea. And at the aforementioned expert workshop of Rijkswaterstaat in 2006, she became inspired by a seagrass expert that presented a successful US example of seagrass restoration– the so-called Buoy-method – where seeds were introduced in small bags (Pickerell et al. 2005). As this was regarded as a more 'natural' approach to restoration, it better matched the Wadden Society's view that the Wadden Sea should not become a 'testing ground' for scientists. To secure adequate funding for a restoration initiative, the Wadden Society articulated a link with climate change and positioned seagrass restoration as a 'Climate Buffer' project. 'Climate Buffer' was a government-funded climate change adaptation program in which several environmental

Table 5.1. Storylines in favour of active seagrass restoration in the Dutch Wadden Sea.

	TWO BASIC STORIES		RESHAPED STORYLINES		
	Seagrass as historically missing	**Seagrass as ecosystem engineer**	**Seagrass as missing pillar of the Wadden Sea ecosystem**	**Seagrass as obligation**	**Seagrass as Climate Buffer**
Expressed by	Government, nature organisations and scientists	Scientists, nature organisations and the government	Nature organisations, scientists and the government	Rijkswaterstaat (also expressed by nature organisations and scientists on the role of Rijkswaterstaat)	Wadden Society
In the period	Started in the 1950s, dominant from 1989-2005	Started approximately 1999	Started in the early 2000s	Dominant since 2008	Dominant in 2011-2013
Storyline	Seagrass fields should be restored because there were large fields of seagrass before 1930 in the Dutch Wadden Sea. Articulating the element of authenticity.	Restoration of seagrass fields is necessary because of the ecological function seagrass fields can have as ecosystem engineer; seagrass plants influence sedimentation and are a habitat for other species.	Restoration of seagrass fields is required because of the ecological function seagrass fields have as ecosystem engineer, which has been missing since the decline of seagrass fields. Articulating a combination of authenticity and the function of seagrass fields.	Restoration actions are necessary because of juridical obligations of the European Water Framework Directive, based on the reference situation before 1930. Articulating mostly the authenticity of seagrass in the Dutch Wadden Sea.	Seagrass restoration will help counteract the effects of sea level rise caused by climate change, based on the sedimentation effect of seagrass fields. The restoration project can contribute to the awareness of the general public on climate change and adaptation strategies using natural dynamics. This is mostly connected to the functional properties of seagrass.
Exemplary quote	"If you change something, it should be based on a type of authenticity"[1]	"[seagrass fields] form a structure or habitat for a large number of other species"[2]	"The [seagrass] plant is one of the pillars of the Wadden Sea ecosystem"[3]	"..implementing the obligations of the Water Framework Directive"[4]	"The seagrass forms a natural climate buffer, it prevents that the mudflats will drown"[5]

[1,2,4] Interviewees, [3] Leeuwarder Courant (2003), [5] Trouw (2011)

NGOs took part. In line with the conceptualisation of seagrass fields as ecosystem engineers, seagrass was presented as a climate buffer that would help increase sedimentation and stabilise sediments as an adaptation to sea level rise. A seagrass restoration project was also perceived as a good educational opportunity regarding climate change and as a contribution to providing positive experiences in nature through the involvement of volunteers (Wadden Society 2010). This positioning of seagrass as a climate buffer resulted in funding for a new restoration project. However, the Wadden Society needed co-funding, which Rijkswaterstaat could provide.

After the restoration project of 2002-2005, Rijkswaterstaat had serious doubts about new restoration efforts. They also doubted the merits of seagrass as a climate buffer. However, they had another motive for restoration: the European Water Framework Directive obliged them to improve the status of seagrass in the Wadden Sea (Wanink and Van der Graaf 2008). This put pressure on Rijkswaterstaat to take action. Thus, even though the perception of seagrass as a climate buffer was irrelevant for them, Rijkswaterstaat worked together with the Wadden Society. While the two organisations had different reasons for participating in the restoration project, they shared the perception that seagrass fields should be restored based on both ecological and historical arguments and that the role of research should be limited. They agreed that the emphasis should be on the execution of the restoration effort. In the words of a respondent from the Wadden Society, "As the Wadden Society we made a clear choice: we want to try this. We choose to spend the money we have as much as possible on the actual execution, not too much on research".

The restoration project of 2011-2015: Rijkswaterstaat was the project leader, the Wadden Society was responsible for communication and volunteers, the research institute Deltares lead the execution of the project, and the Fieldwork Company executed the practical work, supported by Wadden Society volunteers. The project was based on scientific advise that proposed to restore on a large scale and to spread risks in time and space to address fluctuations in growth conditions (Erftemeijer and Van Katwijk 2010). This project was perceived as a pilot, with the aim of demonstrating that restoration was feasible. It included concrete restoration activities and monitoring. At the end of the summers of 2011 and 2012, volunteers collected seagrass seeds at Sylt (German Wadden Sea) and released them at three locations in the Dutch Wadden Sea using an adapted version of the US seed-bag method; see Figure 5.2. The actual restoration activities were not intensively measured, as the standard monitoring that was already in place was thought to suffice. In public media, the project was positioned as very successful. In 2011 and 2012, it was reported that seagrass plants were growing and that seagrass restoration was possible. As one newspaper article put it, "Seagrass is back!" (Trouw 2013). At the same time, however, experts involved in the project reported their concerns about the low density of the seagrass fields (Van Duren and Van

Katwijk 2013). In our interviews, experts also voiced these concerns and criticised the poor learning outcomes of the project, particularly because of the limited monitoring.

In 2013, even before the monitoring period of the restoration project was finished, the Wadden Society decided they wanted to continue with the restoration efforts. This decision was motivated by a positive interpretation of the results until that point and also by the fact that in 2013, no new seeding could be conducted because of limited funding, while the original expert advice had been that seeds should be introduced for 3 years. Thus, the Wadden Society began to pursue new project plans.

In this episode, the two *storylines* of the previous period were extended and adapted. The storyline of seagrass as an ecosystem engineer laid the foundation for the new storyline of seagrass as a climate buffer. The storyline of seagrass as an essential component of the authentic system was legally reinforced by the European Water Framework Directive. While the storylines were different, they both implied a need for restoration, and in this way they could be combined within the restoration project. Also helpful was that the Wadden Society, which had criticised intervention in the Wadden Sea, became interested in ecosystem engineering and found a more 'natural' method of intervention in the use of seed bags.

These different storylines also fed into debates about uncertainties. There was *ambiguity* among scientists, with some being optimistic about restoration but many being sceptical. This ambiguity, however, did not result in controversy but rather remained a 'cold conflict'. It was downplayed by a restoration project that emphasized action rather than acquisition of knowledge. In this way, the uncertainty of habitat suitability was *de facto* perceived as *unpredictable* by research, thus ignoring the general expert advice that more research was necessary and neglecting those scientists who contended that establishing seagrass fields in the Netherlands was not possible at that time. Furthermore, *unpredictability* was addressed in the project set-up by spreading risks in the selection of restoration locations.

This development was strongly influenced by contextual factors. There was the legal pressure on Rijkswaterstaat from the European Water Framework Directive, and for the Wadden Society, there was the opportunity for government funding and volunteer engagement. Last but not least, there was a modest degree of temporary success, which the NGO could use for publicity. It is plausible that the two latter factors contributed significantly to the NGO's decision to continue even before the results were fully clear.

5.4.4 Episode 3: "Better understanding is necessary" (2014-2017)

In making its new plans, the Wadden Society asked the Dutch Society for the Preservation of Nature, (commonly called 'Natuurmonumenten' in Dutch) to become project leader. For Rijkswaterstaat, a new seagrass restoration project did not fit within the planning of the European Water Framework Directive. Moreover, the Wadden

Society thought that Natuurmonumenten would be more suitable for supporting a long-term nature management project. To obtain funding, the Wadden Society and Natuurmonumenten submitted a project plan for 2014 to the Wadden Fund (a fund established from gas mining revenues and aimed at improving the Wadden area).

With Natuurmonumenten as the new project leader, the character of the restoration project changed. Although Natuurmonumenten was also involved in the national Climate Buffer project, they perceived seagrass primarily as a missing pillar of the ecosystem. In another restoration project, Natuurmonumenten had worked together with scientists, and this collaboration was continued in the seagrass project[13]. This also changed the focus of the project. Rather than demonstrating that restoration was possible, the project aimed at understanding the potential of restoration, not only for littoral seagrass but also for sublittoral seagrass (Natuurmonumenten 2013). As an involved researcher stated in an interview, "I am surprised all the attention goes to littoral seagrass ... from an ecological perspective the former sublittoral seagrass fields were much more important". Now that scientists were more prominently involved, research became more central. For example, the monitoring of the plants was intensified to obtain more detailed data, and new experiments were introduced to learn which factors influenced the survival rate of seeds. Additionally, after the fungus Phytophtera was discovered in 2013 on seeds from Sylt, Germany, extra funding was obtained for research to study the influence of marine Phytophtera[14] on the germinating power of seagrass seeds (Govers et al. 2016; Govers et al. 2017).

The restoration projects of 2014 and 2015-2017: two new restoration projects, financially supported by the Wadden Fund. The restoration project of 2014 was a collaboration among Natuurmonumenten, the Wadden Society and the University of Nijmegen. This project sought to reinforce the seagrass fields that were established in 2011 and to start experimenting with sublittoral seagrass restoration (Natuurmonumenten 2013). However, before the execution of the new project, the perspective on the performance of the seagrass plants changed. Although there were substantial seagrass fields in 2013, expectations for 2014 were low. This triggered a discussion about whether the new project should introduce seeds at the same location as the previous project or at a slightly different spot. With the first option, the restoration effort would be strengthened; with the second option, it would be possible to measure the initial effect of the 2011-2015 project with higher scientific validity. The clear decline in seagrass field area in the spring of 2014 supported the decision to strengthen previous efforts. In September 2014, new seeds were collected in Sylt (Germany) and placed at the same locations as in previous years, as well as at an

[13] Natuurmonumenten was the project leader of Waddensleutels, a research project on mussel bank restoration.

[14] The species *Phytophthora gemini* and *Halophytophthora sp. Zostera* (Govers et al. 2016).

additional experimental location on Texel under sublittoral conditions; see Figure 5.2. The restoration project of 2015-2017 was a project of Natuurmonumenten supported by the University of Nijmegen. It aimed to continue seagrass restoration efforts, but with more emphasis on scientific learning (Natuurmonumenten 2015). In 2015, seeds were again collected from Sylt by volunteers and introduced at the same locations; however, a slightly different method was used, with the aim of increasing plant density. At the Texel location, an experimental set-up was used to determine which factors influence seagrass growth and survival. In spring 2016, a new method was used, experimentally, to introduce seeds near the uninhabited island of Griend. Furthermore, seeds were stored in winter 2016 to improve seed efficiency in spring. In 2017, again a new seed deposition method was used. Seegrass seeds were directly injected into the seafloor at the location of Griend and Uithuizen (Govers 2017; Natuurmonumenten 2017).

Although the restoration project overseen by Natuurmonumenten was scheduled to continue until 2017, the question of whether and how restoration efforts should continue was already being intensively discussed in 2015. This discussion was facilitated by PRW[15], the nature restoration 'Program towards a Rich Wadden Sea' (in Dutch 'Programma naar een Rijke Waddenzee'). Rijkswaterstaat, nature organisations and the funding organisation Waddenfonds shared the aim of restoring seagrass in the Wadden Sea, based on the perception of seagrass as a missing pillar of the ecosystem. The established seagrass fields, however, were small and vulnerable, and experts remained divided on the issue of habitat suitability. In 2015, PRW contributed with a new habitat suitability map (Folmer 2015) and organised expert meetings with the aim of a long-term vision of seagrass in the Wadden Sea. The main conclusion of the expert meeting was that "new restoration efforts are only meaningful if they are accompanied by research on the failure and success factors" (Oterdoom 2015, p.3). This perception – that more research was required – also dominated the advice that Rijkswaterstaat should uphold the EU Water Framework Directive goals and continue restoration efforts (Van Duren and Van Katwijk 2015).

In 2015, there were also some unexpected seagrass discoveries, reflecting the uncertainties and lack of knowledge with regard to the growth of seagrass in the Dutch Wadden Sea. In March 2015, researchers claimed the observation of a sublittoral seagrass plant that was thought to be completely extinct (Trouw 2015). And in October 2015, a 21 ha eelgrass field was discovered (Leeuwarder Courant 2015; Van Duren and Van Katwijk 2015). This spontaneous growth supported the viability of seagrass in the Dutch Wadden Sea, but the extent to which human actions could increase the area of seagrass fields remained unclear. The perception that more research was first required before deciding whether – and at how large a scale – seagrass restoration was obtainable was expressed in

[15] The nature restoration program PRW is a collaboration between nature organisations and the government to enhance nature restoration of the Wadden Sea.

PRW's vision of collective effort for seagrass restoration in the Wadden Sea (Korporaal et al. 2016). The seagrass restoration project (2015-2017) contributed to new insights on restoration methods. First of all, a treatment with copper sulphur was developed to treat Phytophthora contamination. Secondly, a new method to store seagrass seeds in winter. Thirdly, new methods were developed to directly inject seagrass seeds in the seafloor as alternative for the inefficient seed-bag method. These insights are used in the new research project on Griend (Natuurmonumenten 2017).
In this episode, the dominant *storyline* shifted back to seagrass as a 'missing pillar,' but with a stronger emphasis on authenticity. This focus on authenticity was also expressed in the renewed attention to sublittoral seagrass, emphasizing the historical dominance of this type and the perception that this plant type would have a larger ecosystem engineering effect.

The *ambiguity* regarding habitat suitability and the feasibility of seagrass restoration continued in this period but did not lead to conflicts. Instead, the uncertainty of the habitat suitability for seagrass - including sublittoral seagrass - was again defined as *incomplete knowledge* that needed to be addressed with experiments. New and unforeseen discoveries added to the perception that there might be undiscovered factors that influenced the success of littoral and sublittoral seagrass. In a sense, these discoveries could also be interpreted as evidencing the *unpredictability* of seagrass restoration, but this would go against the aims of both the NGOs and the scientists involved in the projects.

Contextual factors at play in this period were the shift to Natuurmonumenten as the main director and the termination of Climate Buffer funding. Both contributed to a revitalization of the missing pillar storyline. The increased involvement of scientists in the restoration projects reinvigorated the perception of uncertainties as incomplete knowledge.

5.5 Discussion

The description and analysis of the three episodes is summarized in Table 5.1, which presents the most important storylines, and in Table 5.2, which maps the debates on uncertainty. In this section, we will discuss some remarkable outcomes of our analysis.

5.5.1 Overcoming conflicts between storylines and research-action dilemmas

A salient feature across all three episodes is that despite divergent storylines and research-action dilemmas, collaboration has prevailed among science-based experts, NGOs and governmental organizations. In bringing together the different storylines, the conceptualization of seagrass as an ecosystem engineer has been very influential. Furthermore, the framing of the 2011-2015 restoration project as a pilot project helped to overcome differences. Both concepts – seagrass as ecosystem engineer and the pilot project – can be interpreted as boundary objects. A boundary object is "plastic enough

Table 5.2. Summary of expressions and approaches to uncertainty in the three episodes.

	Episode 1: 'Research first' (1989-2005)	**Episode 2: 'Let's try' (2006-2013)**	**Episode 3: 'Better understanding is necessary' (2014-2017)**
View on science	There is insufficient knowledge to start with active restoration of seagrass fields; more research is required first.	More research will not contribute to restoration; there is a need to act and to try a restoration method on a large scale.	The results of the seed introductions in 2011 and 2012 show that the method used is insufficient to restore seagrass fields; better understanding is necessary to improve the restoration effort.
Exemplary quote	"... before you start with large-scale replanting you should first start with intensive research on the possibilities and limitations on a few locations. "[1]	"As the Wadden Society, we made a clear choice, we want to try this. And with the money we have, we want to use the money as much as possible for the execution, and not too much for research."[2]	"More insights are necessary for seagrass restoration in the Wadden Sea."[3]
Main uncertainty perception	*Incomplete knowledge* on seagrass plant, addressed with research projects.	*Unpredictability* of restoration success, addressed with taking the risk of a pilot project.	*Incomplete knowledge* on what the best method is for seagrass restoration, addressed with experiments as part of the restoration efforts.
Other uncertainty issues	*Ambiguity* regarding the appropriate extent of human involvement was not addressed but rather ignored.	*Ambiguity* regarding habitat suitability for seagrass fields was ignored because other factors influenced the perceptions on restoration.	Continuation of *ambiguity* on habitat suitability; however, this was not addressed. Instead, a dominant perception of *incomplete knowledge* on habitat suitability triggered the requirement for more research.

[1]Philippart et al. (1992), [2]Interviewee nature organisation, [3]PRW (2015)

to adapt the local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites" (Star and Griesemer 1989, p.393). The interpretative flexibility of a boundary objects makes it possible for people from different social worlds, with different understandings of the world, to work together (Floor et al. 2016; Star 2010; Star and Griesemer 1989). In our case study, it is plausible that the concept of an ecosystem engineer and the concept of a pilot project have performed in this way.

The scientific concept of ecosystem engineer defines the seagrass plant by its ecosystem function: "physical ecosystem engineers are organisms that directly or indirectly control the availability of resources to other organisms by causing physical state changes in biotic or abiotic materials" (Jones et al. 1997, p.1947). Nature restoration within the Wadden Sea has been focused on restoring ecosystem engineers, especially seagrass fields and mussel banks, based on the assumption that this will support other species as well (Van Duren et al. 2009). This is the basis for the storyline of seagrass as a missing pillar that is bringing together scientists, nature organizations and the government. Moreover, the storyline of seagrass as climate buffer was based on the conceptualization of seagrass as ecosystem engineer, inspired by the involvement of the Wadden Society in the workgroup on ecosystem engineers in the Wadden Sea. Although not everybody agreed with this interpretation, the different parties could work together through the shared concept of an ecosystem engineer. The shared perception of seagrass as an ecosystem engineer was so strong that even a sceptical expert hoped restoration efforts would succeed, saying "I would like to be proven wrong".

Another concept that helped to overcome dilemmas was the concept of the pilot project, thanks to this concept's interpretative flexibility. A pilot can be seen not only as a practical measure but also as a scientific experiment, and thus it can mitigate research dilemmas. The framing of the 2011-2015 project as a pilot project facilitated cooperation. The Wadden Society could see the pilot project of seagrass restoration as a concrete measure to support climate adaptation, and Rijkswaterstaat could see it as a measure to fulfil their obligations under the European Water Framework Directive. However, for scientists, this project was perceived as an experiment. As one respondent said about the activities in retrospect: "they are experiments rather than restoration measures, because if you look at them frankly, you simply cannot see them like that - but they provide essential knowledge about ecosystem management". By defining the project as a pilot, both societal and scientific actors could see their views expressed in the restoration efforts. The latter could regard the pilot as a first step in an experiment that required follow-up with more detailed monitoring.

The co-operation facilitated by the concepts of ecosystem engineer and pilot projects supported the suppression of knowledge ambiguity regarding the feasibility of restoration. All actors could perceive seagrass as a necessary ecosystem engineer in the Wadden Sea and could perceive restoration projects as pilots. These overlapping percep-

tions reduced the need to oppose restoration projects based on a sceptical view of the feasibility of seagrass restoration.

5.5.2 Scientification of nature restoration

Our case study showed a strong dominance of the scientific perception of nature restoration, with a focus on increasing ecological understanding. This fits within the trend of the scientification of nature restoration, in which scientists and scientific knowledge dominate restoration efforts. However, the differences between the three episodes described have also showed that this scientific hegemony can be challenged based on the constellation of actors initiating restoration.

In contrast to the science-driven, depoliticised view of nature restoration, nature restoration can also be perceived as driven by political decisions, which may be based on public debates about why and how active nature restoration should take place (Pellizzoni 2011). Non-scientific actors can be substantially involved in restoration efforts, as described by Higgs when he writes about the "community-engaged" road of restoration (Higgs, 2005, p.161). The trend of scientification is enhanced by the discipline of restoration ecology, which has grown considerably in the past decades, contributing to a better understanding of ecological processes (Choi 2007). However, also within restoration ecology, the appropriate role of scientists in nature restoration choices is disputed in view of the value-laden aspects of nature restoration and the authority of scientists (Davis and Slobodkin 2004; Higgs 2005; Winterhalder et al. 2004). The practice of experimental setups with scientific rigor has been criticised as potentially overshadowing the multiplicity of restoration practices (Higgs 2005).

Our case study showed that the scientification of nature restoration is an active process shaped by the science and policy actors involved. Scientists have a dominant and powerful position, but to act with authority, they need to be acknowledged by the other actors involved. In the first episode, the emphasis was on research, with the goal of reducing incomplete knowledge. This perspective was supported by the participating civil servants of Rijkswaterstaat, who, at that moment, were predominantly ecological experts. An important change took place with regard to the increased role of nature organisations in the restoration projects. In the second episode, the Wadden Society reduced the emphasis on research and increased the emphasis on public communication and the involvement of volunteers, leading to a pilot project with only limited monitoring. In the third episode, Natuurmonumenten reinforced the scientific perception that incomplete knowledge must be addressed with research. These differences show that an increased role of nature organisations does not necessarily lead to de-scientification and more community-engagement, as the reinforcement of research by Natuurmonumenten has shown.

This scientification of nature restoration limits expressions of uncertainty to focus on the incomplete state of knowledge and the need to do more research. Nonetheless,

political choices are still made. To reveal these political aspects, the analytical concept of ambiguity has been very useful, even when – in practice – ambiguity can be ignored and normative conflicts can remain 'cold'. Increased scientification will not eliminate the political questions of "why, whether and how" with regard to nature restoration. Consistent with the view that "politics is not an unfortunate obstacle that complicates or distorts clear-headed, rational decision-making but a valuable and creative process" (Wesselink et al. 2013, p.3), we recommend explicitly acknowledging these political aspects of nature restoration.

5.6 Conclusions

In presenting our conclusions, we respond to our research questions regarding storylines, perceptions of knowledge uncertainty, and the influence of both on decisions concerning restoration actions and research.

5.6.1 Storylines supporting seagrass restoration

Two basic storylines have guided the argumentation for active seagrass restoration in the Dutch Wadden Sea: seagrass as historically missing and seagrass as ecosystem engineer (Table 5.1). These storylines resonate with the concepts of historical fidelity and ecological functions (Baker and Eckerberg 2013). These basic storylines were reshaped to support seagrass restoration projects in the Dutch Wadden Sea. In the first episode (1989-2006), the basic storylines were combined into the storyline of seagrass as a missing pillar. This notion expressed both the historical connotation and the ecological function of seagrass plants in terms of creating a habitat for other species. In the second episode (2006-2013), the new storyline of seagrass as Climate Buffer supported the restoration project, based on the impact seagrass – as an ecosystem engineer – can have on sedimentation. In parallel, the storyline of seagrass as obligation emerged, which reflected the requirement of the European Water Framework Directive to establish a good status of seagrass fields based on the Wadden Sea's historical reference situation. This storyline was essential to Rijkswaterstaat's support for restoration. In the third episode (2014-2017), the storyline of seagrass as a missing pillar was again dominant in argumentation for the restoration projects; it served as a common denominator for nature organisations, government and researchers.

5.6.2 Perceptions of knowledge uncertainty

The main uncertainty perception in decisions about seagrass restoration and research in the Dutch Wadden Sea has been that of incomplete knowledge, consistent with the dominant role of scientific expertise (Table 5.2). This perception of incomplete knowledge has triggered several research projects, experiments and models. In addition, the perception of unpredictability played a role in the episode of 2006-2013, which was characterised as "Let's try". This perception was reflected in the decision to take the risk of allocating most of the money to the execution of restoration rather than to additional research. Further-

more, ambiguity regarding the current habitat suitability of littoral and sublittoral seagrass fields triggered debates on whether to continue active seagrass restoration efforts. When efforts to establish long-term seagrass recovery failed again and again, some of the actors involved adhered to the position that restoration was possible but knowledge about the vital growth factors was still insufficient, while other actors concluded that, apparently, the current Dutch Wadden Sea situation had changed too much to support seagrass fields. While this ambiguity was confirmed in the interviews, it did not lead to open disputes and was not perceived as a salient problem. In this sense, the ambiguity is an analytical observation rather than an actual debate. The differences in views could be ignored because there were limited incentives for a hot conflict: the projects were seen as relatively small, with no impact on current economic activities, and both the NGOs and the scientists involved had no interest in halting the restoration efforts.

5.6.3 Restoration action-research dilemma

During the period 1989-2017, several decisions were made concerning seagrass restoration action and research. First, there was the decision in 1989 to conduct research before implementing active restoration; this was followed by an experimental research project in 2002, a pilot project in 2011 with limited monitoring, and new restoration projects in 2014 and 2015 with a more experimental set-up and additional research. The perception of incomplete knowledge and the involvement of science-based experts led to the decisions to pursue more research. Only in the second episode (2006-2013) were there challenges to the dominant perception of incomplete knowledge and the need for research. Instead, restoration was perceived as a risk worth taking in a largely unpredictable situation. The Wadden Society and Rijkswaterstaat decided that most effort should go into the actual restoration activities. The return, in 2014, to a stronger research focus can be explained by the involvement of the new actor Natuurmonumenten, which had a good working experience with scientists on nature restoration. Furthermore, the decision to pursue more research was also influenced by the observation that restoration activities had not resulted in new stable seagrass fields. The lack of success in creating stable seagrass fields was interpreted differently, from arguments that knowledge of growth factors was incomplete to knowledge claims that questioned the feasibility of seagrass restoration in the Wadden Sea. This ambiguity, however, did not prevent restoration actions from continuing. The storylines in favour of active seagrass restoration were very persuasive, and the need to continue restoration efforts outweighed the potential failure of these efforts. Furthermore, the boundary objects (seagrass as ecosystem engineer, as well as pilot projects) helped to overcome these differences. In this way, actors with different storylines regarding seagrass restoration – and different perceptions of the feasibility of restoration – could support the continued efforts of seagrass restoration.

In sum, our analysis of restoration action and research in the Wadden Sea demonstrates the relational nature of perceptions and debates on uncertainties, as well

as the interplay of different factors in decisions on restoration. Our analysis makes clear that knowledge uncertainties are not just connected to scientific expertise about a set of objects. Uncertainty perceptions are a result of interactions among different actors, in this case nature organisations, government and scientists. These interactions influence which uncertainty perceptions – incomplete knowledge, unpredictability or ambiguity – prevail. How these uncertainties play out in decisions on action and research is also influenced by dominant restoration storylines and socio-political context factors, such as legal regulations and funding opportunities.

Chapter 6

Conclusions and reflections

6.1 Brief recapitulation

This thesis examined knowledge uncertainties in decision-making processes about the use and restoration of the Dutch Wadden Sea. Knowledge uncertainties are an important challenge for coastal nature conservation governance. To date, knowledge plays a key role in the legitimisation of decisions that impact nature protection. However, the decision-making process is complicated when the certainty of the knowledge base is questioned and knowledge claims are contested. Still, the dominant role of scientific expertise in coastal nature conservation governance is not challenged. This situation is described as the paradox of the simultaneous scientification of politics and the politicisation of science. Scientification of politics indicates the increased role of science-based expertise in decision-making processes, whereas politicisation of science indicates the contestation of scientific knowledge in public debates. Although knowledge claims are questioned in decision-making processes, the claim that decisions should be based on scientific knowledge is not. To explain this paradox and understand the role of knowledge uncertainties in decision-making, an in-depth analysis of decision-making processes regarding the use and restoration of the Dutch Wadden Sea is presented in this PhD thesis. The Dutch Wadden Sea is a very dynamic ecosystem; it is used by a diverse group of stakeholders and analysed by different research fields. These elements have contributed to the prominent role of knowledge uncertainties in the governance processes of the Dutch Wadden Sea. To understand the role of uncertainties, an analytical distinction is made among three types of knowledge uncertainties: incomplete knowledge, unpredictability and ambiguity. Incomplete knowledge refers to expressions of knowledge imperfections; unpredictability refers to what is seen as unknowable; and ambiguity refers to situations of diverging knowledge claims. This PhD thesis aims to explain the role of knowledge uncertainties in Dutch Wadden Sea governance and to contribute to more general theoretical insights on knowledge uncertainties in decision-making processes.

Accordingly, three research questions were formulated:

1. *How to understand science-policy interactions in the governance of Dutch Wadden Sea nature?*
2. *How do knowledge uncertainties play a role in decision-making about the use and the restoration of Dutch Wadden Sea nature?*
3. *What does this analysis of knowledge uncertainties in decision-making processes in the Dutch Wadden Sea reveal that can explain the role of science-based expertise in nature conservation governance?*

In chapter 2, a review of science-policy interactions in the Dutch Wadden Sea provided initial insight into the diverse understandings of science-policy interactions. The empirical case studies in chapters 3-5 provided insights into science-policy interactions in different settings and insights into the role of knowledge uncertainties in decision-making processes. In this final chapter, those insights on knowledge uncertainties are combined to explain the dominance of science-based expertise in nature conservation governance. This chapter is structured as follows. First, I synthesize the findings of my empirical case studies and answer my research questions. Then, I reflect on the politics of knowledge uncertainties and the contribution of this PhD thesis.

6.2 Knowledge uncertainties in three empirical case studies

In this section, I synthesize my findings on knowledge uncertainties in the cases of a planned powerboat race (chapter 3), mussel fishery (chapter 3 and 4) and seagrass restoration (chapter 5) in the Dutch Wadden Sea. In Table 6.1, the characteristics of these cases are summarized.

6.2.1 The powerboat race controversy (2010-2011)

The governance process on the powerboat race started in 2010, when a controversial plan was presented for hosting the World Championship powerboat race in August 2011 near the Wadden Sea harbour of Den Helder. In the powerboat race controversy, the main role of knowledge uncertainties was to question whether the decision of 'no significant effect' could be made. As described in more detail in chapter 3, in the case of the planned powerboat race, there were two decision-making processes: the permit process and the juridical process. In both processes, the validity of the assessment of no significant effect was questioned by expressing knowledge uncertainties. In the permit process, the province of Noord-Holland stressed that the first version of the appropriate assessment

Table 6.1. Characteristics of the three case studies.

	Powerboat case	**Mussel fishery case**	**Seagrass restoration case**
Activity	A planned World Championship powerboat race in August 2011 at Den Helder.	Mussel seed fishery and mussel cultivation in the Dutch Wadden Sea (1990-2016).	Research and restoration efforts to restore seagrass fields in the Dutch Wadden Sea (1989-2017).
Main knowledge uncertainty issue	Disturbance and noise from the powerboat race that could affect the nature of the Wadden Sea.	Fishery effects on the Wadden Sea's nature, predominantly the food availability of birds.	Feasibility of seagrass restoration in relation to continuation of restoration activities.

contained too much *incomplete knowledge,* more data was required to support its conclusion. Also, the province expressed the *ambiguity* of assessing very small effects. Based on a precautionary approach, the decision on the permit was postponed until an improved assessment was made. The second version of the appropriate assessment report included more data and was judged by the province as sufficient to grant the permit in July 2011. A monitoring obligation was included in the permit to address the remaining knowledge uncertainties in an adaptive way. In response to this permit, nature organisations protested at the Council of State ('Raad van State' in Dutch). In this juridical process, the nature organisations claimed there was too much uncertainty to make the decision of no significant effect. Their main concern was the *incomplete knowledge* on the effects of underwater noise. Furthermore, they expressed *ambiguity* through their different interpretations of the role of very small negative effects and in their judgement that the reference situation of 45,000 ship movements per year showed the risk of cumulative effects instead of indicating a negligible extra effect. The juridical process narrowed valid expressions of knowledge uncertainty to expressions of incomplete knowledge. The points addressed by the nature organisations were insufficient to make the Council of State see scientific doubt in the assessment of no significant effect. Instead, the Council of State judge concluded that the permit was valid. However, for practical reasons, the race was cancelled.

In the powerboat race controversy, knowledge uncertainties were used by actors to support their position regarding the significant effect assessment. The province expressed its initial critical position towards the assessment through knowledge uncertainties, which led to more data gathering supporting the assessment. The nature organisations expressed knowledge uncertainties as a strategic move to oppose the permit for the powerboat race. These expressions of knowledge uncertainty by the province and nature organisations did not directly change the decisions, but they certainly prolonged the decision-making process.

6.2.2 The mussel fishery controversy (1990-2016)

The controversy on mussel fishery started in 1990 as a reaction to high bird mortalities. The influence of mussel seed fishery and mussel cultivation on bird food availability also became a topic of debate among science-based experts. In the mussel fishery controversy, expressions of knowledge uncertainties triggered knowledge debates around the questions of whether there was sufficient and correct knowledge to support mussel fishery regulations. Four different periods can be distinguished in which knowledge uncertainties on effect claims played different roles. In the first period (1990-1993), the main knowledge uncertainty was *ambiguity* about the cause of the high bird mortality of eider ducks. In the debate, nature organisations blamed harmful fishery, whereas fishermen emphasized natural fluctuations. The *incomplete knowledge* on the effects of fishery contributed to the set-up of evaluation research alongside the decision to partly close areas to fishery.

In the second period (1993-2004), the research projects EVA I and II did not reduce uncertainty. Instead, the different interpretations of research results amplified the *ambiguity* about fishery effects. The fishery coalition emphasized the positive effects of mussel cultivation on the average food available for birds, whereas the nature coalition emphasized the potential harmful contribution of fishery in years with low numbers of juvenile mussels. Furthermore, a new gap in the knowledge on effects was acknowledged: *incomplete knowledge* on sublittoral effects. Not only effects on birds but also effects on other natural values needed to be addressed in the new PRODUS research project.

In the third period (2004-2008), knowledge uncertainties played a crucial role in the juridical processes at the Court of State. From 2005 onward, an appropriate assessment of significant effect was required to obtain mussel seed fishery permits under the nature legislation law. Furthermore, the European litigation on cockle fishery had emphasized that there should be 'no reasonable scientific doubt'. This created a legal opportunity for nature organisations to claim, based on the precautionary principle, that there was too much *incomplete knowledge* to make the assessment of no significant effect. However, the Dutch ministry stated there was sufficient knowledge to make such an assessment. The government acknowledged there was incomplete knowledge on sublittoral effects; however, this was addressed through an adaptive management approach with the PRODUS research project. In this way, the *ambiguity* about fishery effects was transformed into a legal debate on the assessment of significant effect. This conflict was resolved with the court ruling in 2008 stating that the permit was invalid based on the judgement that there was too much scientific uncertainty. The initial expectation of the government that the PRODUS research project could resolve the issue of incomplete knowledge appeared untenable. Instead, efforts were directed towards a political solution, resulting in a covenant.

In the last analysed period (2008-2016), the Mussel transition covenant depoliticised the conflict, and the contested knowledge claims on fishery effects lost their relevance. Instead, an adaptive management approach was adopted by the covenant partners to address *incomplete knowledge* and *unpredictability* in the transition process. This resulted, for example, in shared fact finding on the issue of invasive species.

In the mussel fishery case, there were high expectations that research results could be used for regulation decisions. At the same time, the expectation was that the EVA II process would bring stakeholders closer together. However, the differences were persistent, and ambiguity about research results limited the role of research in making legitimate decisions. In the legal process, knowledge uncertainties were used strategically by nature organisations to stop the permit. As the scientific doubt was convincing for the Court of State, knowledge uncertainty played a crucial role in the decision-making process. After the resulting mussel crisis was resolved with the agreement of a covenant, incomplete knowledge triggered research that informed decisions within that covenant.

6.2.3 Seagrass restoration (1989-2017)

Seagrass restoration as a governance process started in 1989 with the governmental decision that there should be active restoration of seagrass plants. In the seagrass restoration process, expressions of knowledge uncertainties mainly correlated with the role that research should play in restoration projects. Furthermore, knowledge uncertainties played a role in the debates over the continuation of restoration efforts. In the governance process of seagrass restoration, three episodes can be distinguished in which different knowledge uncertainties played a role. In the first episode (1989-2005), *incomplete knowledge* regarding seagrass plant growth conditions was addressed with several research projects, and the restoration project also included experiments on plant growth conditions. However, the results of this restoration project were interpreted differently by science-based experts, leading to *ambiguity* between optimistic and sceptical views about the possibility of restoration. This ambiguity about the habitat feasibility of the Wadden Sea for new seagrass fields was, however, ignored in the second episode (2006-2013). Instead, restoration impacts were perceived as *unpredictable,* and a pilot project of seagrass restoration was initiated. To address some of the unpredictable factors, risk reduction measures were taken within the restoration project in terms of the spread of restoration locations. In the last episode (2014-2017), *incomplete knowledge* again became the dominant perception of uncertainty, to be addressed with research. Both habitat suitability and the method of restoration were perceived as knowledge challenges that should be addressed with experimental set-ups that could enable learning processes.

In the seagrass case, incomplete knowledge expressions led to several research projects. The shared knowledge uncertainty perceptions of unpredictable restoration success enabled the Wadden Society and Rijkswaterstaat to work together even though they had different reasons to support restoration activities. Strategically ignoring the ambiguity of habitat suitability excluded critical scientists from the restoration projects.

6.3 Science-policy interactions in the Dutch Wadden Sea

In this section, I will answer my first research question: *How to understand science-policy interactions in the Dutch Wadden Sea?*

As indicated in the introduction, in this PhD thesis, science-policy interactions are perceived as interactions between knowledge producers and knowledge users in the context of policy-making. The study of science-policy interactions indicates a focus on the relation between knowledge processes and decision-making processes, including knowledge production, exchange, transformation and use. To understand the science-policy interactions in the Dutch Wadden Sea, the starting point for this PhD thesis was a review of studies on science-policy interactions within the cockle fishery and gas exploitation controversies (chapter 2). This review revealed that there are many analytical tools used to study science-policy interactions, ranging from scientific information as a resource for stake-

holders to science-policy typologies based on the policy problem. Furthermore, different ontological positions on science correlate to different science-policy understandings. The reviewed studies on the Dutch Wadden Sea showed that the policy setting of who is involved – and the types of responsibilities they have – structure science-policy interactions. For example, when scientific knowledge is an established condition for legitimate policy argumentation, scientific knowledge itself can become the topic of debate. Furthermore, scientists can willingly and unwillingly become part of coalitions in a controversy.

In my empirical studies of science-policy interactions (chapter 3-5), I started from a critical constructivist position within an interpretative approach, and I used the analytical tools of discourse coalitions, storylines and boundary objects to study science-policy interactions. The interactions on the planned powerboat race (chapter 3) showed a clear demarcation between the science-based experts and the other actors. The ecological expert from IMARES and the contra-experts from the ecological company were involved through contract research. In this way, their role as science-based experts was formalised, and a demarcation was made between knowledge producers and knowledge users. In contrast, the interactions around the regulations of mussel fishery (chapters 3 and 4) did not show such a clear demarcation. During the long time period of the conflict, mussel fishermen, governmental civil servants, and some science-based experts moved closer together within the fishery coalition. Also, a trusted relationship between nature organisations and other science-based experts developed within the nature coalition. Here, the crucial demarcation was within the science domain, between science-based experts from different research institutes and universities. Even after the mussel covenant was signed and the knowledge debate on effects lost its relevance for the regulation of mussel fishery, the more than 15 years of contested expertise did not suddenly disappear. Experts and their research institutes that had been involved as counter-experts were still seen as connected to either the fishery or nature position. Even young scientists were positioned based on their work affiliation, described by a young researcher as "being marked on the forehead before you say anything". Still, although there were important differences between the perspectives of the two discourse coalitions, interactions took place in meetings, in symposia and through the permit procedures. Another aspect of science-policy interactions was articulated in the seagrass restoration process (chapter 5). This case highlighted the dynamic of changing roles for science-based experts over time. The science-policy interactions started as close connections between the governmental actor Rijkswaterstaat and researchers, but then transformed into a more distant relation with science-based experts as only advisors for the restoration project, and finally returned to a close working relation between researchers and the nature organisation Natuurmonumenten in the recent restoration projects. Coalitions between scientists and other actors were not stable, and new collaborations were based on shared storylines regarding seagrass restoration.

When contrasting the findings with the conceptual models of science-policy interactions that were presented in the introduction, I conclude that all three models

are relevant for understanding the science-policy interactions in the Dutch Wadden Sea. These three science-policy models are summarized in Figure 6.1. The model of *Two-Communities* emphasizes the differences between the science and policy worlds. The model of *Intertwinement* emphasizes the interconnection between knowledge production and knowledge use and the socially constructed division between the science and policy domains. The model of *Knowledge Coalitions* emphasizes that people see the world in different ways and that coalitions consisting of both knowledge producers and users can be distinguished as having their own way of knowing.

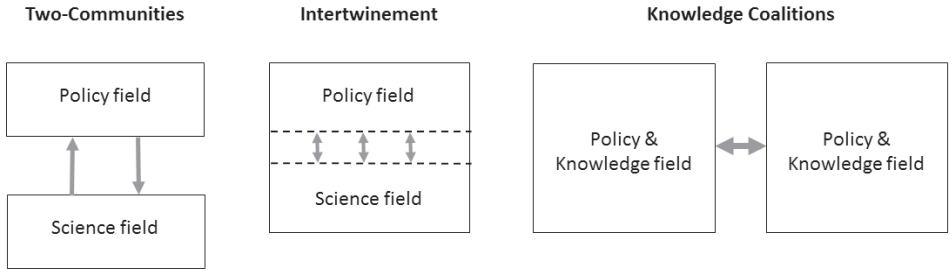

Figure 6.1. Visualisation of three conceptual models of science-policy interactions, based on Janssen (2015).

These three conceptual models support the understanding of science-policy interactions in the Dutch Wadden Sea. First of all, an important aspect of decisions about the Wadden Sea is the high expectation that scientific knowledge is required for decision-making. Particularly, the study of the mussel fishery controversy (chapter 4) showed a linear expectation that scientific knowledge would solve regulation conflicts. This perception is based on the Two-Communities model of science-policy interactions. Also, the current nature legislation for the Dutch Wadden Sea, which emphasizes there should be no scientific doubt on the assessment of significant effect, is based on a separation between knowledge production and use in decision-making. Furthermore, the Two-Communities model can help explain the role of contracted experts in the powerboat controversy. Although the province of Noord-Holland and the nature organisation also had ecological expertise, there was the perception that external organisations were required to grant the authority of expertise.

Secondly, I want to highlight the intertwined character of the science-policy domains within the main actor groups of nature organisations, economic entrepreneurs, the government, and researchers that I observed in my three case studies. First of all, many employees of nature organisations have an ecological science background. Moreover, there are important personal relations between people from nature organisations and science-based experts connected to research institutes. Secondly, economic entrepreneurs can also have close connections with research. For example, the mussel production organisation was not only an important funder of research on production

efficiency and effect studies, but mussel fishermen have also facilitated measurements with their ships and contributed to the advice boards of research projects. Thirdly, Ministries used to have their own internal science-based expert units. For example, in the 1990s, the 'water unit' of the implementation agency Rijkswaterstaat consisted of ecological science-based experts. Although, through privatisation processes, these experts have largely become employees of research institutions, based on this historical relation, there are still close links between these science-based experts and the government. Lastly, researchers have not only been knowledge producers but also stakeholders in the way they have promoted their own research. Furthermore, scientists participated as advisors in policy-making settings. These scientists were asked to participate based on their scientific expertise, although the advice they gave went well beyond their specific knowledge expertise. Moreover, some scientists expressed their views in public debates. For example, in newspaper articles, scientists made clear how they perceived that the cockle and mussel fishery should be regulated. These scientists were criticised for crossing the boundary between science and policy and labelled 'political biologists'. However, it was only a minority of experts that actively spoke out in public. Most science-based experts emphasized the objectivity and validity of their knowledge and saw their role as that of knowledge providers, articulating aspects of the Two-Communities model. According to their perception, their knowledge claims were used by interest groups; they did not initiate the protest. This shows the dynamic of establishing a clear boundary between science and policy, even though aspects of the Intertwinement model are at the same time visible.

Thirdly, within the studied controversies, two groups with different ways of knowing can clearly be recognised. This observation is in line with the Knowledge Coalition model of science-policy interactions. Especially within the mussel fishery and powerboat controversies, clearly opposing coalitions – consisting of both knowledge producers and knowledge users – could be distinguished. However, also in the seagrass restoration case, different ways of knowing were observed regarding the habitat suitability of seagrass in the Dutch Wadden Sea. Nevertheless, as this ambiguity was ignored, it did not lead to knowledge controversies between opposing coalitions.

To conclude, the Two-communities model of science-policy interactions supports the understanding of the expectations of scientific knowledge with regard to decision-making in the Dutch Wadden Sea. The model of Intertwinement on science-policy interactions supports the understanding of the role of scientific knowledge in decision-making processes in the Dutch Wadden Sea for the main actor groups of nature organisations, economic entrepreneurs, the government, and researchers. The model of Knowledge Coalitions supports the understanding of the knowledge controversies in the Dutch Wadden Sea. Hence, science-policy interactions in the Dutch Wadden Sea should be understood in different ways. An important distinction here is between the understanding of science-policy by actors and institutions in the Dutch Wadden Sea themselves and the

analytical understanding of the science-policy interactions in a research study. Expectations and interpretations of science-policy interactions were implicitly and explicitly expressed by actors and institutions in the Dutch Wadden Sea. These expressions were predominantly in line with the Two-communities model, although there were also some reflexive expressions consistent with the Intertwinement model. This combination of both models is explained by Kunseler (2017) as an encapsulation process, in which a reflexive logic is incorporated within the dominant modernist logic. In contrast, the analytical starting point of this study is a constructivist perspective that is more in line with the models of Intertwinement and Knowledge Coalitions. As this study follows an interpretative approach, science-policy interactions are understood from the perspectives of both the interpretations of the people under study and my interpretation as researcher.

6.4 Different roles of knowledge uncertainties

In this section, I will answer my second research question: *How do knowledge uncertainties play a role in decision-making about the use and the restoration of Dutch Wadden Sea nature?*

In this PhD thesis, I analysed the decision-making processes concerning the use of the Dutch Wadden Sea by a planned powerboat race and mussel fishery (chapters 3 and 4) and the decision-making process concerning the restoration of seagrass fields (chapter 5). Although the activities of a powerboat race, mussel fishery and seagrass restoration are very different, within my analysis, I also observed similar contexts that shaped the role of knowledge uncertainties. Based on my three case studies, I distinguish four contexts with different roles for knowledge uncertainties: debates on policy change, legal procedures, research projects and policy implementation. These different contexts provided both limitations and opportunities for incomplete knowledge, unpredictability and ambiguity to play a role in the decision-making processes, see Table 6.2. Here, incomplete knowledge refers to expressions of knowledge imperfections, unpredictability to what is seen as unknowable, and ambiguity to situations of diverging knowledge claims.

First of all, the powerboat and mussel fishery cases showed that knowledge uncertainties played a role in the debates about changing the policy that regulates a human activity. In both cases, economic entrepreneurs and nature organisations tried to influence the governmental authority on the regulation of these activities. A clear example is the first period in the mussel fishery controversy, in which nature organisations made an appeal to the Dutch ministry to develop a new policy framework. Several arguments were used to influence this new policy, including knowledge uncertainties. Specifically, the perception of incomplete knowledge and ambiguity about fishery's effects resulted in the requirement within the Sea and Coastal Fishery Policy that sufficient food must be left for birds. The interpretations of knowledge uncertainties that were used by the fishermen and the nature organisations in the debate were based on the information provided by science-based experts from research institutes with which they already had good rela-

tions. An important context factor for the Dutch Wadden Sea debates was that all actors involved acknowledged the starting condition that scientific knowledge was required as a basis for policies to regulate human activity. In this way, knowledge uncertainty could become an important argument in the debate about changing the human activity policy. Incomplete knowledge could be used to stress that research was required to guide further decisions. Depending on the position regarding the activity, incomplete knowledge could be seen as a reason to stop the activity or as a reason not to change the activity before research could support this decision. Ambiguity about knowledge claims led to discrediting the knowledge arguments of the opponents in the debate. In contrast, unpredictability did not play a role in these debates, probably because not knowing did not fit into the assumption that the regulation policy should be based on scientific knowledge.

Secondly, the powerboat and mussel fishery cases showed that knowledge uncertainties played a key role in the legal procedures that were initiated as part of the controversies. Here, an important context factor was the change in the legal setting, which took place due to the implementation of the European Bird and Habitat Directive in Dutch nature protection legislation. Before 2005, nature organisations that protested against the fishery permits at the Council of State had to show that the activity was harmful. However, with the new legislation, the permit authority had to show in court that there was no significant effect of the activity on the protected nature area. With the inclusion of the requirement of 'no scientific doubt' about the significant effect assessment, science-based experts acquired a crucial role within this legal setting. This also meant that non-scientific arguments were excluded from the legal dispute. As the differences in responsibility in the powerboat race and mussel fishery cases indicated, the exact role of science-based experts was case-specific. The cases show that a more formalized role of experts is part of the legal setting, with contracted expert reports and arguments between expertise and contra-expertise. These opposing positions of expertise can be explained using the concept of ambiguity about knowledge interpretations. However, the legal setting assumes the judge has to decide which interpretation is relevant instead of accepting a plurality of knowledge claims. For example, the debate on mussel seed fishery was based on value differences and ambiguity about different research interpretations, whereas the juridical dispute concentrated around incomplete knowledge. The government claimed that an adaptive management approach was sufficient to address any incomplete knowledge and unpredictability, whereas nature organisations highlighted incomplete knowledge to question the permit based on the precautionary principle. This shows that within the legal setting, expressions of knowledge uncertainties became limited to incomplete knowledge, even though ambiguity can explain the debate.

Thirdly, the seagrass restoration and the mussel fishery cases showed that research projects can be seen as a different setting in which knowledge uncertainties play a role. Within these research projects, there could be a clear division between the science-based experts and the government, nature organisation or economic entrepreneur that com-

Table 6.2. Roles of knowledge uncertainties in different contexts

		Incomplete knowledge	Unpredictability	Ambiguity
Debates on policy change	• Mussel fishery (1990-2008) • Powerboat race (2010-2011)	Trigger for research projects that were expected to guide decisions	Not relevant	Trigger for debate and provider of discrediting arguments
Legal procedures	• Mussel fishery (2004-2008) • Powerboat race (2011)	Trigger for debate on how much uncertainty is accepted	Part of argument for monitoring and an adaptive management approach	Explanation for debate on effects
Research projects	• Seagrass restoration (1989-2005) • Seagrass restoration (2014-2017) • Mussel Fishery (1993-2008)	Trigger for research projects but also a research result	Not relevant	As a result of a research project
Policy implementation	• Seagrass restoration (2006-2013) • Mussel fishery (2008-2016)	Justification to ask for expert advice	Justification for taking a risk	Not relevant

missioned the research. However, I also observed more active roles of these actors in the knowledge production process. For example, in the EVA II evaluation process, representatives of fishermen and nature organisations were involved in the research project. Moreover, in the seagrass restoration case in the 1990s, science-based experts from governmental agencies initiated research projects based on the perception that research was first required before restoration activities could start. In this setting, perceptions of incomplete knowledge are an important start for research projects and are used as justification for the focus of the research project. The expectation is that research will provide more certainty about the knowledge base. Based on this assumption, unpredictability, which by definition cannot be reduced by more research, is not relevant. However, as the case studies demonstrated, research results can indicate new knowledge uncertainties. Furthermore, new research results can cause ambiguity when they are interpreted in different ways.

Lastly, the seagrass restoration and mussel fishery cases showed that knowledge uncertainties also play a role in policy implementation. In this setting, actors do not debate the decision that should be made but rather how to implement a decision that has

already been made. This type of decisions took place within the Mussel fishery covenant and within the restoration project initiated by the Wadden Society in 2011. In this setting, knowledge uncertainties can play a role as justification for specific actions. Incomplete knowledge perceptions can justify the request for advice from science-based experts. The perception of unpredictability can justify both risk taking and actions to distribute the expected risk. For example, in the pilot project of seagrass restoration with seagrass seeds from Germany, the risks of specific location impacts were spread through the selection of three different restoration sites. As the policy framework in this setting is not debated, ambiguity is not relevant in this context. Instead, ambiguity can trigger the policy setting to change into a new debate on policy change in which knowledge uncertainties play a different role.

To conclude, all three types of knowledge uncertainties that were distinguished in the introduction as incomplete knowledge, unpredictability and ambiguity can play a role in decision-making processes regarding the use and the restoration of the Dutch Wadden Sea. Incomplete knowledge can play a role as the trigger of research and as justification for research projects. In setting the debate on policy change, incomplete knowledge can be used not only as an argument to delay a decision but also as an argument that policy change is required based on the precautionary principle. Within the legal procedures of the nature protection law, incomplete knowledge can be used to trigger a debate on how much uncertainty is accepted to make the assessment of no significant effect. Furthermore, incomplete knowledge can be a reason to ask for expert advice about policy implementation. This means that incomplete knowledge can play a role in all decision-making contexts. In contrast, unpredictability is often not relevant in a decision-making process. However, unpredictability can play a role in legal disputes through the argument that uncertainty is inevitable and should be addressed with monitoring and an adaptive management approach. Furthermore, the perception of unpredictability can play a role in the perception that risk reduction measures should be taken within policy implementation. Although ambiguity is often not acknowledged and is more of an analytical concept than an empirical observation, it has played a key role in decision-making processes in the Dutch Wadden Sea. Ambiguity can trigger a debate and provide discrediting arguments for both opponents and advocates of an activity when there are multiple interpretations of research results. Furthermore, ambiguity can be seen as an important explanation for the knowledge debates in the Dutch Wadden Sea.

6.5 Knowledge uncertainties: stimulating and reducing the scientification of nature conservation

In this section, I will answer my research question: *What does this analysis of knowledge uncertainties in decision-making processes in the Dutch Wadden Sea reveal that can explain the role of science-based expertise in nature conservation governance?*

As indicated in the introduction, the decision to focus this PhD thesis on knowledge uncertainties was triggered by the challenge of the simultaneous scientification of politics and the politicisation of science. Here, the scientification of politics refers to the increased role of science-based expertise in decision-making processes, whereas the politicisation of science refers to the contestation of science-based expertise in public debates (Pellizzoni 2011; Weingart 1999). My expectation was that the dominant roles of scientific knowledge and science-based experts in decision-making processes would be challenged by knowledge uncertainties. Knowledge uncertainties can reduce the legitimacy of science-based decisions and enhance the politicisation of science. However, my empirical case studies showed more complex relations between knowledge uncertainties and the role of science-based knowledge in decision-making processes. The powerboat case showed the domination of science-based expertise in the decision-making process (chapter 3). The legal setting of the nature protection legislation showed that the dominant role of scientific knowledge was institutionalised. In this legal context, nature organisations tried to discredit the assessment of no significant effect using arguments of incomplete knowledge. However, the positions of the science-based experts were not publicly questioned. This contrasts with the mussel fishery case, where science-based experts became politicised and were perceived as connected to a specific position within the debate on mussel fishery regulation (chapter 3 and 4). However, this politicisation of science-based experts did not reduce the dominance of science-based experts and research projects in the decision-making process. Instead, the conflicting knowledge perceptions led to stakeholders supporting more research and debating knowledge claims about mussel fishery effects. Furthermore, another dynamic can be observed in the seagrass restoration case (chapter 5). This case study illustrates the contingency of the dominance of science-based experts in the decision-making process. After the initial dominance of science-based experts, a new constellation of restoration initiators led to a reduced role of science-based experts. The perception of restoration feasibility as unpredictable reduced the role of scientists. Whereas, at a later moment, the perception of restoration feasibility as incomplete knowledge re-established the dominant role of scientists. These observations of the scientification of decision-making and the politicisation of science within my case studies in the Dutch Wadden Sea have led to the formulation of factors that stimulate scientification and factors that reduce scientification in nature conservation, which I clarify in the following sections. The combination of these factors that stimulate and reduce scientification help to explain the role of science-based expertise in nature conservation governance.

6.5.1 Factors that stimulate scientification

Based on my research, I identify three factors that stimulate scientification: the dominant perception of knowledge uncertainty as incomplete knowledge, the linear expectation

that scientific expertise can support decisions, and the actual use of scientific knowledge in decision-making procedures. First of all, incomplete knowledge implies that research is the solution when seeking to reduce uncertainty. The prominent role of science-based expertise is enforced in the decision-making process when research is perceived as a requirement to make decisions or to guide future decisions. Crucial in this respect is that uncertainty is predominantly perceived as incomplete knowledge, whereas analytically, the uncertainty can be characterised as ambiguity. For example, in the mussel fishery case, uncertainties about fishery effects were perceived as incomplete knowledge, although the different knowledge interpretations indicate that ambiguity is the main source of uncertainty. In this way, high expectations are placed on research results for decision-making, even though more knowledge cannot resolve the different perspectives that shape ambiguity. Ignoring ambiguity by treating it as incomplete knowledge maintains the dominance of science-based experts in policy-making processes. However, instead of the role of problem-solver, science-based experts can better be described as playing an advocacy role (Turnhout et al. 2008) or as partisan expertise (Pellizzoni 2011).

Secondly, scientification is stimulated by the linear model of expertise, which implies that objective knowledge is used to support rational decisions (Beck 2011). As indicated in chapter 4, this model is based on the perception of incomplete knowledge that can be resolved by research. Moreover, the linear model of expertise is institutionalised in nature legislation. A clear example is the European Habitat Directive. This legislation emphasizes that permit decisions should be based on appropriate assessments, indicating a high level of technocratic decision-making (Turnhout et al. 2015).

A third factor I would like to add is that scientification is stimulated by the actual use of scientific knowledge in decision-making processes. The use of scientific information and the advice of science-based experts support the role of science-based expertise in decision-making processes. Even in the mussel fishery case, in which scientific knowledge became contested, not all fields of scientific expertise were contested. Specifically, at the level of data and concepts, science-based expertise supported decision-making processes. For example, the data on the numbers of birds and mussels guided the decisions about how much mussel seed could be fished. Furthermore, the conceptualisation of mussel banks as ecosystem engineers and biodiversity hotspots influenced the paradigm shift of the government from mussels as purely a fishery commodity to mussels as an important element of nature. This role of science-based experts was supported by activities that de-politicised science, for example scientists who emphasized the objectivity of their data. The accommodating role of science-based experts in the decision-making process also supported the expectations that science-based experts could pacify the conflict (Hanssen et al. 2009). However, my case studies showed that the controversies were more complicated and research projects did not pacify the conflicts. Still, there was a continuation of high expectations that science-based expertise would resolve the controversies.

6.5.2 Factors that reduce scientification

Based on my research, I identify three factors that reduce scientification: the perception of unpredictability; the politicisation of scientific expertise as a result of ambiguity; and most importantly, the aspect that decision-making is largely not shaped by knowledge. First of all, the perception of unpredictability implies that the current state of research cannot reduce uncertainty. This perception reduces the role of science-based experts, as the seagrass restoration case has indicated. Still, science-based experts can play a role as advisors on risk reduction measures.

Secondly, ambiguity as a knowledge problem for decision-making was, in my case studies, not acknowledged as the result of value differences that needed to be addressed in a political way. Instead, it became a technical problem because opposing coalitions discredited each other's knowledge claims. However, this did not reduce the role of science-based experts but rather amplified it. Still, the role of science-based experts changed into one of advocacy, as they became contra-experts in the debate. Furthermore, the politicisation of expertise did complicate the expectations of science-based expertise in the context of decision-making. Here, the impact on personal relations should not be underestimated. The politicisation of science is, to a certain extent, a recursive process of both politicisation and de-politicisation of science, the authority of experts can be re-established through actions that emphasize the objectivity and independence of science. Still, the politicisation of expertise has an impact on the relations between people. As the mussel fishery case showed, the divide between researchers regarding fishery effects has not disappeared with the mussel fishery transition covenant. Research institutes are still coloured politically by their role in the controversy, influencing the selection of the science-based experts who played a role in the decisions within the covenant. As indicated by Pellizzoni (2011), there are different roles for experts depending on the phase of the conflict. However, I would add that these experts sometimes have to be replaced by other persons, as a result of trust relations being disturbed by the controversy. In the mussel case, I observed a shift towards the use of more consultants who were trusted by all actors involved. This means that the politicisation of expertise has an impact on which science-based experts can play a role in decision-making processes.

Last but not least, scientific knowledge is just one of the aspects that play a role in decision-making. Often, economic interests and power relations are more influential on decision-making processes. Furthermore, within the Netherlands, the democratic decision-making setting prescribes that governmental authorities are responsible for making regulation decisions. This reduces scientification in the sense that it limits radical technocratic decision-making wherein politicians are replaced by scientists (Hoppe 2005). Still, there are different gradations of responsibility that science-based experts can have in decision-making processes. For example, the powerboat and mussel fishery cases showed that the exact division of responsibilities for making decisions on significant effect were context-dependent. Although the Dutch Wadden Sea contexts showed a high level of

scientification, decisions continue to be justified by governmental authority. These decisions of governmental authorities can be influenced by science-based expertise, but they are not made by scientists. In most nature conservation governance processes, governmental authorities have formal decision-making responsibility.

6.5.3 Conclusion on the role of science-based expertise in nature conservation governance

Instead of a general trend of scientification of politics as described by Weingart (1999), I conclude that science-based experts have a context-dependent role in nature conservation governance based on factors that stimulate and reduce scientification. First of all, the role of science-based experts in nature conservation should not be overstated; decisions continue to be based on governmental authority and stakeholder agreements that are not directly prescribed by scientists. However, I also conclude that science-based expertise plays a dominant role in decision-making processes and that knowledge uncertainties do not reduce this role. A key factor that can explain why knowledge uncertainties have not reduced the dominance of science-based expertise in nature conservation governance is the dominant perception of uncertainty as incomplete knowledge. Controversies with contested expertise do not reduce the role of science-based experts when ambiguity is not recognised but rather perceived as incomplete knowledge. This dominant role of science-based experts and the perception of incomplete knowledge are also institutionalised in the nature legislation framework based on the European Habitat Directive. Still, the roles that science-based experts play and the selection of experts involved in the decision-making process on nature conservation are both affected by knowledge uncertainty perceptions and the politicisation of expertise.

6.6 The politics of knowledge uncertainties

In this section, I discuss the politics of knowledge uncertainties, indicating the political choices that are made and the power that is performed through expressions and disregards of knowledge uncertainties. Here, the political is perceived as "contestation and decision making in and through power" (Behagel 2012, p.16). My empirical case studies showed that choices were made about which uncertainties were expressed, on how much uncertainty was accepted, and on how and by whom these uncertainties were addressed in decision-making. In this way, power was performed: certain aspects and people were included, whereas others were excluded from the decision-making process. To articulate the implications of the political aspect of knowledge uncertainties for the study and management of nature conservation, I distinguish three challenges: the challenge of different ways of knowing, the challenge of accepting risk and the challenge of action or research. I observed these challenges in relation to the interpretations of incomplete knowledge, unpredictability and ambiguity in my empirical chapters. In chapter 3, the challenge of ambiguity and discrediting knowledge claims indicated whose knowledge was perceived

as relevant and how diversity of knowledge was addressed in the permit and juridical processes. In chapter 4, the challenge of deciding how much risk is acceptable within a context of knowledge uncertainty regarding the effects of mussel fishery indicated the power relations between the actors. In chapter 5, the challenge of deciding between action or research on seagrass restoration and the positions on this dilemma indicated the power relations of researchers and restoration initiators. The different responses to these challenges indicate the political choices that are made, which are discussed in the following sections. See Table 6.3 for a summary.

Table 6.3. Summarizing the three challenges that indicate the politics of knowledge uncertainties.

The politics of knowledge uncertainties			
	Challenge of different ways of knowing	**Challenge of accepting risk**	**Challenge of action or research**
Responses:	• Ignoring ambiguity • Discrediting the other way of knowing • Facilitating interactions	• Not accepting risk (precautionary principle) • Risk perceived as inevitable (adaptive management)	• First research • Action instead of research • Action and research combined

6.6.1 The challenge of different ways of knowing

The challenge of different ways of knowing articulates the choice of how the knowledge uncertainty of ambiguity is addressed. I distinguish three different responses to conflicting knowledge interpretations: ignoring ambiguity, discrediting the other way of knowing, and facilitating interactions. First of all, when ambiguity is ignored, different knowledge interpretations do not play a role in the decision-making process. This can take place when actors with different perspectives are excluded from the governance process. For example, experts that were sceptical of the feasibility of seagrass restoration were excluded from the seagrass restoration projects. Another instance of ignoring ambiguity takes place when different knowledge interpretations are perceived as not relevant to the decision-making process. For example, this behaviour is seen in the choice of the covenant partners to ignore the PRODUS research results on mussel fishery effects. Here, different interpretations were strategically ignored in order to facilitate cooperation. In both instances, political choices were made about which knowledge claims were perceived as relevant and which claims were excluded from the decision-making process. Asymmetrical power relations prescribe who can decide which knowledge claims are relevant.

With the second response – discrediting the other way of knowing – a specific knowledge claim is challenged. Resistance against a specific way of knowing can result in a knowledge debate involving contra-expertise. In this debate, uncertainties

are strategically used to emphasize the limitations of the knowledge claims that are questioned. Although incomplete knowledge is predominantly expressed as uncertainty, the conflict is triggered by ambiguity. However, the social element of ambiguity based on different world views is not acknowledged; instead, the political debate about what is normatively allowed transforms into a debate about what is factually right. In this way, a social problem is transformed into a technical problem of knowledge, in which value disputes are hidden away even though they are the drivers of conflict. Legitimate arguments are limited to scientific claims, excluding normative arguments.

With the third response of facilitating interactions, the social element of ambiguity is acknowledged. Interactions can be organised based on the assumption that through interactions, the differences will disappear or a constructive conflict can be facilitated, with the aim of learning by making different perspectives explicit (Cuppen 2012). Most often, merely facilitating interactions to reduce differences is insufficient and can result in camps that discredit the other way of knowing. Still, boundary objects can facilitate interactions between actors with different ways of knowing. The seagrass case showed that the boundary objects of pilot projects and the concept of ecosystem engineer facilitated collaboration between actors who expressed different knowledge views. Whereas the boundary object of significant effect in the powerboat and mussel fishery cases showed that boundary objects can also facilitate and structure conflicts. However, in both situations of collaboration and conflict, choices are made regarding who is involved in the interactions and on which topics interactions take place. In this way, inclusion and exclusion of people and perceptions takes place. Hence, politics takes place in the decisions about who can interact within the sphere of knowledge interpretations.

The politics of these responses to ambiguity has different implications. First of all, I would like to stress that different ways of knowing should be seen as a social problem. Secondly, conflict can also be seen as positive. The response of discrediting a knowledge claim is part of a power struggle over who decides and on which grounds. Furthermore, there is a learning opportunity in moving towards a more complex understanding of the situation. However, when ambiguity is not acknowledged and is instead perceived as incomplete knowledge, this knowledge conflict can trigger piles of reports that do not contribute to a solution of the problem. It is not the debate about knowledge that is a problem but rather the expectation that more knowledge can resolve the conflict. Furthermore, it should be recognised that research is also a delay tactic to postpone difficult political decisions. For this reason, I suggest that reflection is required on both the knowledge debate and on the potential contribution of research to prevent the frustration that results from unrealistic expectations.

6.6.2 The challenge of accepting risks

The challenge of accepting risks describes the decision about how much uncertainty is acceptable. Here, two different responses can be distinguished within a knowledge-based policy-making setting: uncertainty is not accepted based on the precautionary principle, and uncertainty is perceived as inevitable within an adaptive management approach. First of all, the precautionary principle implies that there is a responsibility to prevent harm when there is scientific uncertainty; when there is sound evidence of no harm, this precaution can be lifted. In this way, the precautionary principle response is directly linked to the perception of incomplete knowledge, as it implies the expectation that scientific research can reduce the uncertainty. The European Habitat Directive legislation is based on the precautionary principle, in the sense that there should be no scientific doubt about the assessment of no significant effect. This approach opened up the possibility for nature organisations to protest against permits with the argument that there was too much incomplete knowledge (Beunen & Duineveld 2013; Opdam et al. 2009). This protest was justified by the precautionary principle, restricting the debate to knowledge arguments instead of value differences. The change in 2005 to the new nature legislation framework for mussel fishery regulation clearly changed the power relations among nature organisations, fishermen and the government in the mussel fishery case. With this legislation, the fishermen, as initiators of the activity, had to show their activity was not harmful, whereas previously, nature organisations needed to show that fishery was harmful. Power relations changed even further with the court decision in 2008 that the fishery permit was invalid based on the perception of unacceptable uncertainty.

Secondly, a different response to accepting risks is seen in the adaptive management approach, which starts from the perception that there will always be uncertainties. The adaptive management approach is based on learning to adapt to changes in the socio-ecological system. Acknowledging incomplete knowledge and the unpredictability of the socio-ecological system is inherent to adaptive management (Holling 2001; Voß 2011). There are different theoretical and practical applications of the adaptive management concept, for example adaptive governance that stresses the inclusion of stakeholder perceptions and, in this way, also acknowledges potential ambiguity (Folke et al. 2005). However, I want to stress how adaptive management is used as a justification for accepting uncertainty through the risk reduction measure of monitoring. In this way, an activity can be allowed based on the condition that it will be stopped or changed when harmful effects are observed. This implies the assumption that the effect is reversible and observable within a short time period (Opdam et al. 2009). The justification of adaptive management was successfully used to allow gas exploitation in the Dutch Wadden Sea, and it was used in a similar way as an argument for the permits for the planned powerboat and mussel fishery. Although the adaptive management approach is presented as a neutral knowledge-oriented strategy, it does reproduce given power relations (Voß 2011). For example, the decisions about which data need to be collected and when an observed effect is perceived as harmful are both political.

The politics of accepting risk highlight that the precautionary principle and adaptive management approach are not politically neutral concepts but are rather used in power struggles over the regulation of human activities. The court case on mussel fishery in 2008 showed that both responses were used in conflict with each other. I would suggest that current proponents of adaptive management approaches in theoretical literature and management practices acknowledge the political use of the concept as an argument to allow human activities. Moreover, how monitoring results are interpreted and acted upon when there is ambiguity on the recursive nature of the effect is highly political. Therefore, I would suggest that a decision for monitoring in itself is insufficient to address uncertainties. Additionally, it should be clear which type of observation indicates that action is required and who is responsible for deciding to alter or stop the activity.

6.6.3 The challenge of action or research

The challenge of action or research describes the choice as to whether or not to start a research project in response to expressions of knowledge uncertainties. I distinguish between three different responses to this dilemma: first research, no research but action, and simultaneously action and research. In the first response, knowledge uncertainty is perceived as incomplete knowledge, and there is a high expectation that research will reduce uncertainty. Furthermore, the expectation is that the research results will support better decision-making. However, when research results are portrayed as a precondition to legitimize decisions, this also provides a strategic way to delay policy change. The power position of those who oppose action is enforced when this response is accepted. Moreover, this perception enforces the dominant role of science-based experts in the decision-making process. In addition, within the choice of a research project, there are again specific choices to be made in the set-up of the research.

In the second response of action instead of research, knowledge uncertainty is ignored or accepted, and a decision for action is made. This choice can be strategically supported by the knowledge uncertainty perception of unpredictability, reducing the expectation that research results can improve decisions about the action in question. Furthermore, this response can be supported by arguments about the financial and time costs of research and about the urgency of taking action. With this approach, the role of science-based experts is reduced to the potential role of advisor. The power position of advocates for action is enforced when this response is accepted.

A third response option is the combination of action with simultaneous research or monitoring, as in an adaptive management approach. In this response, the need for both action and knowledge production are acknowledged. Still, decisions are made about how much and which data are to be collected. Furthermore, the expectation is that the collected data can inform further decisions about taking new actions. The role of science-based experts in the decision-making process is also enforced with this response. Important implications of this dilemma between action and research are the role of sci-

ence-based experts in the decision-making processes and the timing of decision-making. Furthermore, there are important implications for the decision about which research is to be conducted. Here, the decision-making context plays a crucial role. Especially the mussel fishery case has shown that when there is a controversy about effect assessments, more research is conducted on fishery effects. However, from a decision-making perspective that acknowledges this uncertainty as an ambiguity, research on fishery effects is not necessarily the type of knowledge that will contribute to innovative solutions that can reduce the controversy. I would recommend more reflection on what type of research is required. In this way, piles of reports that are only used to support the positions of advocates or opponents on a human activity can be avoided. Although I recognise that effect studies are an established requirement under the current nature legislation, there is room in the permit procedure to include conditions for studying alternative options alongside the requirement of monitoring effects.

6.7 The contributions of this PhD research

In this last section, I reflect on the contributions of my PhD research to nature conservation governance processes and to future science-policy research. I start with the reflection that the context of my research matters. I studied specific decision-making processes in the Dutch Wadden Sea that were shaped by historical and contingent factors, such as the domination of high expectations of expert knowledge for decisions on the Dutch Wadden Sea and crucial court rulings based on uncertainty interpretations of cockle and mussel fishery effects. Furthermore, my research took place in a specific social setting that has shaped the focus of my analysis. For example, easy access to ecological researchers was facilitated by one of my PhD supervisors, my interpretative approach was guided by discussions with colleagues, and the use of the term 'science-based experts' was triggered by debates in literature on scientific and practical knowledge. My specific theoretical interest and social surroundings have contributed to this PhD research that highlights the role of knowledge uncertainties in decision-making processes about the Dutch Wadden Sea. In this way, I have contributed to the growing and complementary understanding of science-policy interactions in the Dutch Wadden Sea, including research on interactive knowledge development (Seijger 2014) and governance arrangements (Van der Molen 2017).

With my research, I aim to contribute to decision-making processes in the Dutch Wadden Sea. One of my contributions has been a booklet with action strategies for a better fit between knowledge and policy. This booklet was developed in collaboration with the NWO-ZKO working group and presented to Wadden Sea professionals (Van der Molen et al. 2015). Furthermore, with this PhD thesis, I aim to open up new insights that are relevant for economic actors, nature organisations, governments and science-based experts in decision-making processes on the Dutch Wadden Sea. I would like to specifically stress my insight that ambiguity as knowledge uncertainty should be acknowledged and addressed as a social problem and not just as a techni-

cal problem. This can help prevent frustrations about the non-use of scientific knowledge in decision-making and reshape expectations on research to resolve controversies. Furthermore, I would like to highlight that the policy setting structures science-policy interactions. From this perspective, it is interesting to see how the current plans to establish one responsible agent for the Dutch Wadden Sea will change the role of science-based experts and knowledge uncertainties in decision-making processes.

Furthermore, my conclusions on knowledge uncertainties are relevant not only for the Dutch Wadden Sea but also for other nature conservation processes. Although my conclusions on the role of knowledge uncertainties for nature conservation decisions are based on empirical insights from Dutch Wadden Sea governance processes, the general patterns that I have observed are also relevant for other nature conservation processes. It is very likely that the dynamics of knowledge debates found in this study also occur in policy controversies on other nature areas. Particularly my conclusions on ambiguity, on the political use of adaptive management as justification for decisions, and on the political choices that are made about which research is conducted are relevant for all nature conservation processes.

Lastly, this research has contributed to new theoretical insights on knowledge uncertainties, and these insights can support further research. This research showed that knowledge uncertainties do not reduce the role of science-based experts in decision-making processes; however, they do shape the roles that science-based experts are able to play. The dominant perception of knowledge uncertainties as incomplete knowledge increased the role of science-based experts in the context of knowledge uncertainties. Furthermore, there is a recursive process of both the politicisation and de-politicisation of science. For example, appeals to objectivity by scientists have reduced the impact of knowledge uncertainties on the scientification of nature conservation governance. Still, the contestation of experts can have a long-lasting impact on relations with and between science-based experts, indicating that a historical understanding is crucial. Last but not least, I emphasize the political aspect of knowledge uncertainties. This not only has practical implications but also implies that research on knowledge uncertainties should recognise the choices and power relations that are performed through expressions and disregards of knowledge uncertainties.

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Appendix I: List of interviewees

Date	Name	Affiliation	Topic
2011-01-24	Pavel Kabat	Wadden Academy	Scoping exercise
2011-01-24	Martin Pastoors, David Goldsborough and Francois Perrot	Center for Marine Policy (Van Hall Larenstein)	Scoping exercise
2011-01-24	Elze Klinkhammer and Liesbeth Meijer	Regiecollege Waddengebied	Scoping exercise
2011-02-01	Han Lindeboom, Norbert Dankers and Kees Dijkema	IMARES	Scoping exercise
2011-02-01	Cor Smit	IMARES	Scoping exercise
2011-02-01	Norbert Dankers	IMARES	Scoping exercise, including Mussel fishery case
2011-02-01	Han Lindeboom	IMARES	Scoping exercise
2011-06-09	Hendrik Oosterveld	LNV-Noord	Scoping exercise
2011-06-09	Herman Verheij	Wadden Society	Scoping exercise
2011-06-10	Martijn de Jong	Programma Rijke Waddenzee, St. Wad	Scoping exercise, including Mussel fishery case
2011-06-16	Aante Nicolai	Rijkswaterstaat	Scoping exercise
2011-06-17	Paddy Walker and David Goldsborough	Van Hall/Larenstein	Scoping exercise, including Mussel fishery case
2012-06-06	Paddy Walker	Programma Rijke Waddenzee, Waddenvereniging	Mussel fishery case
2013-11-28	Martin Baptist	IMARES	Powerboat case
2014-02-17	Mariska Veldhoen°	Provincie Noord-Holland	Powerboat case
2014-03-17	Ellen Kuipers	Wadden Society	Powerboat case
2014-04-28	Nic Grandiek*	Provincie Noord-Holland	Powerboat case
2014-11-13	Josje Fens	Wadden Society	Seagrass restoration case
2014-11-20	Marieke van Katwijk	Radboud University	Seagrass restoration case
2014-12-08	Floris van Bentum	Rijkswaterstaat	Seagrass restoration case
2014-12-09	Anky Woudstra	Wadden Society	Seagrass restoration case
2015-02-23	Frans Maas	Rijkswaterstaat	Seagrass restoration case
2015-02-24	Dick de Jong **	Rijkswaterstaat	Seagrass restoration case

Date	Name	Affiliation	Topic
2015-03-02	Quirin Smeele	Natuurmonumenten	Seagrass restoration case
2015-03-03	Tjisse van der Heije	Radboud University	Seagrass restoration case
2015-04-13	Luca van Duren	Deltares	Seagrass restoration case
2016-07-13	Hans van Geesbergen	PO Mossels	Mussel fishery case
2016-07-14	Aad Smaal	IMARES	Mussel fishery case

° Short interview by e-mail
* Interview by phone
**Short informal interview, not recorded but detailed notes were taken

Appendix II: List of meetings, workshops, presentations and conferences

Date	Wadden Sea related meetings attended as participant observer
2010-11-04	Deltaconference, Den Haag
2010-11-25	Symposium Mosselwad, Leeuwarden
2010-12-09/10	Towards a trilateral research agenda, 5th Wadden Academy symposium
2011-02-02	Workshop Adaptive Management at Van Hall Larenstein, Leeuwarden
2011-03-17	Sandy solutions, symposia van de Wadden Society, Leeuwarden
2011-03-22	Meet & Greet Wadden professionals, Leeuwarden
2011-10-10/14	International Symposium on the Ecology of the Wadden Sea, Texel
2011-12-08	7th Wadden Academy symposium on Wadden governance, Leeuwarden
2011-12-09	Audit meeting on gas mining effects, Ameland
2012-11-19/20	International workshop on mussel-related research in the Wadden Sea, Leeuwarden
2013-05-30	Tijwisselaar, Programma naar een Rijke Waddenzee, Marrum
2014-06-11/12	Sense of place, 12th symposium of the Waddenacademy in cooperation with Oerol, Terschelling
2015-02-24	Workshop on the future of the nature restoration organisation PRW 'Program towards a Rich Sea', session "Werkwijze herijking Programma Rijke Waddenzee", Leeuwarden
2015-04-16	Symposium of MosselWad en Waddensleutels on mussel restoration and research: 'Over leven in de Waddenzee', Leeuwarden
2016-06-08/09	Bird Senses of Places, Oerol seminar in cooperation with MetaWad, Terschelling
2016-06-30/07-1	'Cumulative Effects in Marine Ecosystems', 16th Waddenacademy symposium in cooperation with the NIOZ

Date	Oral presentations during Wadden Sea related meetings
2011-10-14	*Science-policy interactions in the management of the Dutch Wadden Sea*, at the International Symposium on the Ecology of the Wadden Sea, Texel
2011-10-14	*Governance and adaptive management in the Wadden Sea*, 14 October 2011, together with Diana Giebels, at the International Symposium on the Ecology of the Wadden Sea, Texel
2014-12-11	'*How to deal with science-policy problems in the Wadden Sea? Prospects for action'* together with Franke van der Molen, at the 13th Waddenacademy symposium, in cooperation with NWO, Leeuwarden
2016-07-01	*Which cumulative effects? – Effect assessments at science-policy boundaries,* at the 16th Waddenacademy symposium in cooperation with the NIOZ

Date	Presentations of the PhD research *(at conferences not Wadden Sea related)*
2011-11-01	*Science-policy interactions in the management of the Dutch Wadden Sea*, at the WASS Research symposium, Wageningen
2011-11-25	*Science-policy interactions in the management of the Dutch Wadden Sea*, at the IMARES PhD Day, Texel
2012-07-06	*The use of knowledge as evidence in determining 'significant effect' on the Dutch Natura 2000 Wadden Sea site*, at the IPA Conference, Tilburg
2014-07-05	*Contested meanings in the assessment of 'significant effect'- The cases of mussel seed fishery and powerboat racing in the Dutch Natura 2000 Wadden Sea site*, at the IPA Conference, Wageningen
2015-03-24/26	*Protecting nature: Dealing with uncertainty*, poster presentation at the Student Conference on Conservation Science, Cambridge, UK
2015-06-26	*Uncertain seagrass restoration in the Dutch Wadden Sea*, at the MARE conference, Amsterdam
2015-08-26	*Dealing with uncertainty: seagrass restoration in the Wadden Sea*, ESA conference, Prague, Czech
2017-07-06	*(De)politicisation of mussel fishery - Dealing with knowledge uncertainties*, at the MARE Conference, Amsterdam

Date	Presentations of the PhD research in educational settings
2012-09/10, 2013-09/10, 2014-09/10, 2015-09/10	Supervision of group work on Wadden Sea case studies of master students for the course 'Principles of Environmental Science', Wageningen University
2014-09-12/15, 2016-09-11/15	Boat excursion on the Dutch Wadden Sea, indicating the tensions between human use and nature conservation at master students of the course 'Marine Structures', Wageningen University
2016-11-07, 2017-11-09	Guest lecture on the mussel fishery controversy, at the bachelor course 'Science and expertise in nature and environment', Wageningen University
2016-11-29, 2017-11-22	Guest lecture on significant effect, at the master course 'Environmental Policy: Analysis and Evaluation', Wageningen University
2017-04-21/05-23	Guest lecture and group supervision on mussel fishery negotiations, the stakeholder dialogue of the bachelor course 'Kwaliteit van Leven', University of Amsterdam
2017-05-20	Guest lecture on Wadden Sea governance and a workshop on significant effect assessment, at the theme day 'Science' for students of the Open University

Summary

Knowledge uncertainties are an important challenge for coastal nature conservation governance. To date, knowledge plays a key role in the legitimisation of decisions that impact nature protection. Although the legitimacy of science-based decisions is questioned by knowledge uncertainties, the frequent occurrence of such uncertainties has not reduced the dominance of scientific expertise in nature conservation. To explain this paradox and understand the role of knowledge uncertainties in decision-making processes, controversies in the coastal area of the Dutch Wadden Sea were selected as case studies. This PhD thesis aims to explain the role of knowledge uncertainties in the Dutch Wadden Sea governance, and to contribute to theoretical understanding of knowledge uncertainties in decision-making processes more generally. Accordingly, this thesis answers three research questions:

1. *How to understand science-policy interactions in the governance of Dutch Wadden Sea nature?*
2. *How do knowledge uncertainties play a role in decision-making about the use and the restoration of Dutch Wadden Sea nature?*
3. *What does this analysis of knowledge uncertainties in decision-making processes in the Dutch Wadden Sea reveal that can explain the role of science-based expertise in nature conservation governance?*

This study takes a critical constructivist perspective on knowledge uncertainties, and uses an interpretative approach. The research consists of a literature review and three case studies: a planned power boat race, mussel fishery, and seagrass restoration in the Dutch Wadden Sea. To gather empirical data, I analysed documents, conducted interviews and made participatory observations. Discourse coalitions and storylines were used to structure the analysis of different meanings and interpretations of knowledge uncertainties. This approach enabled me to identify changes within the decision-making processes.

The analytical focus of this thesis is on science-policy interactions and knowledge processes in the context of decision-making processes and court rulings. Although there are different conceptual models to understand science-policy interactions, they all recognise knowledge uncertainties as a challenge for decision-making processes. To identify and study how science-policy interactions take place, the concept of boundary objects is introduced as a tool to accommodate interactions between people. To understand the role of uncertainties, an analytical distinction is made between three types of knowledge uncertainties: incomplete knowledge, unpredictability and ambiguity. Incomplete knowledge refers to expressions of knowledge imperfections, unpredictability refers to what is seen as unknowable, and ambiguity refers to situations of diverging knowledge claims.

This thesis has been compiled in a publication-based format, which means that the chapters 2 to 5 are written as articles for peer-reviewed journals. **Chapter 2** presents a review of the social science literature on science-policy interactions in the Dutch Wadden Sea. The review is based on articles and PhD publications between 1995 and 2011 that focused on the cockle fishery and gas exploitation controversies. This review shows that there are different analytical perspectives and tools used to study science-policy interactions. Three main perspectives were distinguished, emphasizing the social and economic dynamics of resource management, the role of nature views and discourses in controversies, and the influence of science dynamics in policy and management debates. The review demonstrates that ecological knowledge and ecological scientists have played important roles in the controversies on cockle fisheries and gas exploitation. However, scientific knowledge was not always the most important factor in the decision-making process, and scientific insights were not always used as expected by the scientists. How scientific knowledge was used and interpreted by stakeholders was dependent on their interests, their nature views and on the dominant policy discourses. Scientists became willingly and unwillingly part of conflicting coalitions in the cockle fishery and gas exploitation controversies.

Chapter 3 contains an analysis of the permit and legal procedures of the mussel seed fishery and powerboat race controversies in the Dutch Wadden Sea. To acquire a permit under the Dutch Nature act, an appropriate assessment of significant effects must be conducted based on the best available scientific knowledge. In both cases nature organisations started a court process against the government-granted permits in protest to the "no significant effect" claim, stating that there was insufficient certainty for this conclusion. The assessment of significant effect became a focal point in the controversies, limiting the debate to ecological arguments and science-based expertise, but also creating options for parties to advance their protest by articulating uncertainties. Only the uncertainty of incomplete knowledge was explicitly addressed, excluding ambiguity of values and unpredictability of the actual ecosystem. This chapter recommends that acknowledging the value aspect in disputes on significant effect would leave more space for effective solutions of the problems under debate.

Chapter 4 presents an examination of the mussel fishery case for the period between 1990 and 2016. The controversy starts with a debate on restricting mussel fishery areas (1990-1993). A new fishery policy in 1993 did not stop the controversy; instead, the debate about sufficient bird protection continued (1993-2004). In 2004, the new legal requirement to make an assessment of negative effects in order to acquire a permit transformed the controversy into a debate about mussel seed fishery permits (2004-2008). This legal requirement amplified the knowledge debate about fishery effects. A court ruling in 2008 on the fishery permit did not resolve the conflict; instead it triggered a

mussel crisis. This mussel crisis increased political pressure on the issue, resulting in a mussel transition covenant. This political agreement pacified the debate and enabled cooperation (2008-2016). Until 2008, there were high expectations that research projects would resolve the knowledge debate on fishery effects. However, the analysis shows that mussel fishery regulation decisions were primarily based on government authority, not on scientific knowledge. Expectations of policy-makers and scientists on conflict resolution by more research were not met, because the knowledge debate was politicised over ambiguous knowledge claims. The persistent belief that more knowledge would resolve the controversy –the linear model of expertise – is explained by the dominant perception of uncertainty as incomplete knowledge. The case study confirms that science-based knowledge fails to guide policy-making as expected in the linear model, but also demonstrates how science plays important strategic, procedural and instrumental roles in structuring interactions between stakeholders in nature protection conflicts.

Chapter 5 presents an in-depth study of seagrass restoration in the Dutch Wadden Sea (1989-2017). This chapter shows the impact of storylines and knowledge uncertainties on decisions concerning restoration action and research. Two basic storylines – authenticity and the ecological function of seagrass as an 'ecosystem engineer' – supported the restoration efforts. In 1989 several research projects on seagrass restoration were initiated based on the perception that incomplete knowledge had to be reduced before starting restoration actions. The results of the restoration project (2002-2005) were interpreted differently by science-based experts, leading to ambiguity between optimistic and sceptical views about the possibility of restoration. However, based on the perception that the success of restoration was unpredictable a pilot project of seagrass restoration was initiated (2011-2015) that did not focus on research. The recent restoration projects (2014 and 2015-2017) emphasized that better understanding was necessary, as no long-term restoration of seagrass fields were established. The dominant perception of uncertainty as incomplete knowledge resulted in new research projects. However, the unpredictability of the success of restoration efforts and the ambiguity regarding the feasibility of restoration complicated the decisions on continuation of restoration efforts. Two concepts – ecosystem engineer and pilot project – facilitated collaboration among science-based experts, NGOs and governmental organizations.

The final chapter, **chapter 6**, synthesises the findings of the three empirical case studies, answers the research questions, and reflects on the politics of knowledge uncertainties. First, I conclude that science-policy interactions in the Dutch Wadden Sea should be understood in different ways. The understanding of science-policy interactions as Two Communities, with a division between the science and policy worlds help to explain the expectations of scientific knowledge for decision-making processes, as they often are found with both science-based experts and decision-makers. The understanding of

science-policy interactions as Intertwinement between knowledge and policy provides insight into the interaction of science-based experts with nature conservationists, economic entrepreneurs and policy-makers. Finally, the understanding of Knowledge Coalitions as opposing groups of knowledge users and knowledge producers sheds light on the conflict dynamics of the knowledge controversies in the Dutch Wadden Sea.

Second, I conclude that knowledge uncertainties were predominantly perceived as incomplete knowledge in decision-making processes about the Dutch Wadden Sea. Incomplete knowledge played an important role as trigger for research projects, as trigger for debates on how much uncertainty is accepted, and as justification to ask for expert advice. The role of unpredictability was relatively small, yet relevant for decision-making processes as argument for monitoring in legal procedures and justification to take risks. Although ambiguity was often not acknowledged and is more of an analytical concept than an empirical observation, it has played a key role in decision-making processes in the Dutch Wadden Sea as trigger for debates.

Based on the analyses of knowledge uncertainties, my third conclusion is that the role of science-based experts in nature conservation governance depends as much on socio-political perceptions as on their actual knowledge input. The knowledge input of science-based experts in nature conservation should not be overstated; decisions continue to be based on governmental authority and stakeholder agreements that are not directly prescribed by scientists. Still, science-based experts play a dominant role in decision-making processes and knowledge uncertainties do not reduce this role. A key factor that explains why knowledge uncertainties have not reduced the dominance of science-based expertise in nature conservation governance is the dominant perception of uncertainty as incomplete knowledge among scientists as well as decision-makers.

Furthermore, I reflect on the politics of knowledge uncertainties, indicating the political choices that are made and the power that is performed though expressions and disregards of knowledge uncertainties. These observations bring me to the recommendation that different ways of knowing should be taken into account when tackling nature conservation problems. The political use of nature conservation terms, such as adaptive management, should be acknowledged. In addition, it is not productive to only concentrate research on the ecological assessment of the effects of economic activities. Studies that support innovation and alternative options should also be encouraged.

Samenvatting

Kennis onzekerheden zijn een belangrijke uitdaging voor natuurbescherming. Momenteel spelen kennisargumenten een grote rol in de onderbouwing van besluiten die effect kunnen hebben op beschermde natuur. Kennis onzekerheden kunnen de legitimiteit van besluiten ondermijnen. Toch heeft de toenemende aandacht voor kennis onzekerheden niet geleid tot een afname van wetenschappelijke expertise in natuurbescherming. Dit proefschrift heeft als doel om deze paradox te ontrafelen en de rol van kennis onzekerheden in besluitvormingsprocessen te begrijpen. Hiervoor is de Waddenzee als case studie geselecteerd.
Met dit proefschrift beantwoord ik de volgende drie onderzoeksvragen:

1. *Hoe zijn kennis-beleid interacties te begrijpen in het bestuur en beheer van de Waddenzee?*
2. *Hoe spelen kennis onzekerheden een rol in de besluitvorming rond het gebruik en herstel van de Waddenzee?*
3. *Welk inzicht geeft deze analyse van kennis onzekerheden in de besluitvorming rond het gebruik en herstel van de Waddenzee over de rol van experts in natuurbeschermingsbeleid?*

In het beantwoorden van deze vragen gebruik ik een constructivistisch perspectief op kennis onzekerheden, waarmee ik de nadruk leg op de sociale constructie waarbinnen kennis onzekerheden betekenis krijgen. Mijn onderzoek bestaat uit een literatuuroverzicht van kennis-beleid interactie rondom het Waddengebied en drie case studies: een geplande powerboot race, mosselvisserij en zeegrasherstel in het Waddengebied. De case studies zijn gebaseerd op empirische data bestaande uit documenten, interviews en participatieve observaties. Discours coalities en verhaallijnen zijn gebruikt als methodes om mijn analyse van verschillende interpretaties van kennis onzekerheden te structureren. Hierdoor kon ik veranderingen in de besluitvormingsprocessen identificeren. Mijn methodologie valt in de categorie van interpretatieve benaderingen.

De analytische focus van deze studie ligt op kennis-beleid interacties en kennis in besluitvormingsprocessen en rechtszaken. Hierbij gebruik ik het concept 'boundary object', een grensobject dat interacties tussen mensen kan faciliteren, als gereedschap om kennis-beleid interacties te lokaliseren en bestuderen. In mijn analyse van kennis onzekerheden maak ik het analytische onderscheid tussen drie soorten onzekerheden: incomplete kennis, onvoorspelbaarheid en ambiguïteit. Bij incomplete kennis ligt de nadruk op kennis imperfectie waarbij de verwachting is dat de kennis via onderzoek aangevuld kan worden. Bij onvoorspelbaarheid wordt de ontbrekende kennis, binnen de huidige grenzen van de wetenschap, als onbereikbaar beschouwd. Bij ambiguïteit gaat het niet om het gebrek aan kennis maar om verschillende manieren van weten, waarbij er meerdere plausibele kennis claims zijn.

Dit proefschrift is gebaseerd op vier artikelen (hoofdstuk 2-5) die geschreven zijn voor wetenschappelijke tijdschriften. In **hoofdstuk 2** presenteer ik een literatuuroverzicht van kennis-beleid interactie studies tussen 1995 en 2011 die gericht zijn op de controverses rondom kokkelvisserij en gaswinning in het Waddengebied. Deze studies geven een variëteit weer aan analytische perspectieven en concepten om kennis-beleid interacties te bestuderen. Hierbij maak ik een onderscheid tussen drie hoofdperspectieven: de sociaal en economische dynamiek van grondstoffenbeheer, de rol van natuurvisies en discoursen in conflicten en de rol van wetenschappers en kennis in beleidsdebatten. In dit hoofdstuk laat ik zien dat ecologische kennis en onderzoekers een grote rol hebben gespeeld in de controverses rondom kokkelvisserij en gaswinning in het Waddengebied. Echter, wetenschappelijke kennis was meestal niet de doorslaggevende factor in de besluitvormingsprocessen. Ook werd wetenschappelijke kennis vaak niet op de manier gebruikt zoals onderzoekers dat verwachtten. De manier waarop betrokkenen in de besluitvorming kennis gebruikten en interpreteerden was afhankelijk van hun belangen en natuurvisies en het dominante politieke discours. Wetenschappers werden gewild en ongewild betrokken bij de coalities in de conflicten rondom kokkelvisserij en gaswinning in het Waddengebied.

In **hoofdstuk 3** presenteer ik een analyse van de vergunnings- en juridische procedure van de mosselzaadvisserij in 2006 en een geplande powerboot race in 2011. Het Waddengebied is een Natura 2000 gebied, beschermd volgens de Europese Vogel- en Habitatrichtlijn. Om een vergunning te verkrijgen onder de Nederlandse Natuurbeschermingswet is daarom een Passende Beoordeling van eventuele 'significante effecten' op het Natura 2000 gebied noodzakelijk. In mijn analyse benader ik de term 'significant effect' als een grensobject waarin zowel wetenschappelijke als beleidselementen zijn verweven. De term 'significant effect' slaat in de wettelijke context op een inschatting van de impact van een activiteit op de bestuurlijk vastgelegde natuurbeschermingsdoelstellingen. Hierbij moeten de beoordelingen plaatsvinden op basis van de best beschikbare kennis. In beide case studies begonnen natuurorganisaties een juridische procedure tegen de vergunning die was gebaseerd op de conclusie dat er geen 'significante effecten' waren op het beschermde Waddengebied. Volgens de natuurorganisaties was er te veel onzekerheid om tot de conclusie van geen 'significante effecten' te komen. In beide controverses werd het debat beperkt tot ecologische argumenten. Hierbij werd vooral de nadruk gelegd op incomplete kennis, terwijl de ambiguïteit van verschillende waarden perspectieven en de onvoorspelbaarheid van het ecosysteem werden genegeerd. Op basis van mijn bevindingen beveel ik aan om in het debat rond significant effect het verschil in waarden meer te erkennen, waardoor er effectievere oplossingen bedacht kunnen worden voor conflicten over menselijke activiteiten in een beschermd natuurgebied.

In **hoofdstuk 4** ga ik dieper in op de mosselvisserij controverse, waarbij ik het debat analiseer tussen 1990 en 2016. In dit debat focus ik op de verwachting dat wetenschappelijke kennis de oplossing kan geven voor de controverse rond mosselvisserij. Als beginpunt van mijn analyse neem ik 1990, toen door massale eidereendsterfte de mosselvisserij in opspraak kwam. Als reactie hierop is er een nieuw visserijbeleid met restricties voor mosselvisserij in 1993 ingesteld. Gekoppeld aan dit beleid vond er een wetenschappelijke evaluatie plaats. In de periode 1993-2004 zorgde het wetenschappelijke onderzoek niet voor een afname van het debat, maar werden wetenschappelijke studies en onderzoekers juist onderdeel van het debat. Met de inwerkingstelling van de nieuwe wetgeving gebaseerd op de Europese Vogel- en Habitatrichtlijn in 2004 kwam de nadruk te liggen op het beoordelen van de effecten van mosselvisserij op de natuur. De uitspraak van de rechter in 2008 over een mosselvisserijvergunning verhevigde het politieke debat. Onder politieke druk kwam er eind 2008 een Mossel transitie convenant tot stand tussen de mosselvissers, natuurorganisaties en de overheid. Deze politieke overeenkomst depolitiseerde het debat en maakte samenwerking mogelijk. Mijn analyse laat zien dat de besluitvorming over de regulering van mosselvisserij met name was gebaseerd op de autoriteit van de overheid, niet op wetenschappelijke kennis. Door de ambiguïteit over kennis claims rond de effecten van mosselvisserij zorgde de toename van kennis niet voor vermindering van het debat. De dominante interpretatie van kennis onzekerheden als incomplete kennis zorgde voor het in stand blijven van het geloof dat kennis tot de oplossing zal leiden. Met andere woorden: het lineaire expertise model bleef dominant. Deze studie laat zien dat meer kennis niet de oplossing vormde voor het mosselvisserij conflict. Kennis speelde echter wel een belangrijke strategische, procedurele en instrumentele rol in de interacties tussen belanghebbenden in een natuurbeschermingsconflict.

In **hoofdstuk 5** presenteer ik mijn analyse van het zeegrasherstelproces in de Nederlandse Waddenzee tussen 1989 en 2017. De focus ligt hier op de rol van verhaallijnen en kennis onzekerheden op besluiten rond zeegrasherstelactiviteiten en zeegrasonderzoek. Twee perspectieven op zeegras ondersteunde de natuurherstelactiviteiten: de historische aanwezigheid van zeegras in het gebied en de ecologische functie als biobouwer voor het ecosysteem. In 1989 werden meerdere onderzoeken gestart vanuit de redenatie dat eerst incomplete kennis verminderd moest worden voordat herstelactiviteiten konden starten. Deze nieuwe inzichten werden gebruikt in het herstelproject (2002-2005). De uitkomsten van dit zeegrasherstelproject werden verschillend geïnterpreteerd door wetenschappelijke experts, met als resultaat ambiguïteit tussen optimistische en pessimistische visies op zeegrasherstelmogelijkheden. In een nieuw herstelproject (2011-2015) was het uitgangspunt dat het herstel onvoorspelbaar is en deze activiteit werd gepresenteerd als pilotproject. In de recente natuurherstelprojecten (2014 en 2015-2017) ligt de nadruk weer op incomplete kennis en meer onderzoek. Deze studie laat zien dat de rol van onderzoek dynamisch is en afhankelijk van de visies van de betrokken actoren.

In **hoofdstuk 6** presenteer ik een synthese van mijn drie empirische case studies, beantwoord ik mijn onderzoeksvragen en reflecteer ik op het politieke van kennis onzekerheden. Ten eerste concludeer ik dat kennis-beleid interacties in het Waddengebied op verschillende manieren kan worden begrepen. Om de verwachtingen van kennis in de besluitvorming beter te begrijpen is het model van 'Twee Gemeenschappen' van nut, waarin een onderscheid wordt gemaakt tussen een kenniswereld en een beleidswereld. Het model van 'Verstrengeling' helpt in de analyse van interacties tussen wetenschappelijke experts en natuurbeschermingsorganisaties, ondernemers en beleidsmakers. Om de dynamiek van kennisdebatten beter te begrijpen is het model van 'Kennis Coalities' het meest van nut.

Ten tweede concludeer ik dat kennisonzekerheden voornamelijk als incomplete kennis werden beschouwd in besluitvormingsprocessen in het Waddengebied. De perceptie van incomplete kennis vormde het begin van onderzoeksprojecten. Incomplete kennis was echter ook het begin van debatten over de mate van onzekerheid die acceptabel is. Incomplete kennis werd daarnaast ook gebruikt als argument om experts advies te vragen. De rol van onvoorspelbaarheid was zeer gering in besluitvormingsprocessen; deze werd enkel ingezet als argument voor monitoring en als onderbouwing om bepaalde risico's te nemen. Ambiguïteit als kennisonzekerheid werd meestal niet erkend in de besluitvorming. Ambiguïteit kan dus beter benaderd worden als analytisch concept dan als een empirische observatie. Echter, de rol van ambiguïteit is niet gering, aangezien het gezien kan worden als drijvende kracht achter de vele kennisdebatten in besluitvormingsprocessen over de Waddenzee.

Mijn laatste conclusie, gebaseerd op de analyse van kennisonzekerheden, is dat de rol van wetenschappelijke expertise in natuurbeschermingsbeleid net zoveel afhangt van sociaal-politieke perspectieven als van de daadwerkelijke kennisbijdrage. De kennisbijdrage aan besluitvormingsprocessen moet niet worden overschat; besluitvorming is met name gebaseerd op de politieke autoriteit van de overheid en de argumenten van belanghebbenden. Echter, wetenschappelijke experts spelen een grote rol in besluitvormingsprocessen rond natuurbescherming. Kennisonzekerheden zorgen niet voor een vermindering van deze rol. Een doorslaggevende factor voor de dominantie van experts in natuurbeschermingsprocessen is het heersende idee onder zowel wetenschappers als beleidsmakers dat onzekerheden opgelost kunnen worden door meer kennis te vergaren.

Als laatste reflecteer ik op het politieke van kennisonzekerheden. Ik stel dat politieke keuzes worden gemaakt en machtsverhoudingen tot uiting komen door het expliciet maken en negeren van kennisonzekerheden. Dit leidt tot de aanbeveling dat verschillende manieren van kennis interpretaties erkend moeten worden in natuurbeschermingsvraagstukken. Verder geef ik aan dat concepten niet neutraal zijn. Zo wordt bijvoorbeeld adaptief management strategisch gebruikt. Daarnaast zou niet alle aandacht

naar de effectanalyses van economische activiteiten moeten gaan. Ook al is effectbeoordeling momenteel een wettelijke verantwoordelijkheid, er is ook ondersteuning nodig voor het innovatief en alternatief gebruik van natuurgebieden.

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Completed Training and Supervision Plan

Name of the learning activity	Department/Institute	Year	ECTS*
A) Project related competences			
Political Theory, ENP 35306	Wageningen University	2010	6
Social Theory and the Environment	WASS & SENSE	2011	6
Masterclass Interpretative Analysis	WASS	2011	1.5
The practical course on the methodology of fieldwork	CERES	2011	2
Fokuz Marine Masters Course	NIOZ, Texel	2011	4
Seminar Story Telling	WASS	2011	0.5
IMARES PhD Day	IMARES, Texel	2011	1
MUST PhD workshop "Knowledge production for sustainable development"	SENSE & Maastricht University	2012	1.3
Pre-conference IPA methodology workshop "Varieties of discourse analysis"	IPA conference, Tilburg University	2012	0.5
ECPR summer school "Interpretative and Qualitative Research Design"	ECPR, Ljubjana, Slovenia	2012	2
Visiting scholar at the Cambridge University	Cambridge University, UK	2016	6
B) General research related competences			
Co-organiser discussion groups on Interpretative analysis & Social theory	Wageningen University	2011-2016	1
"Science-policy interactions in the management of the Dutch Wadden Sea"	International Symposium on the Ecology of the Wadden Sea, Texel	2011	1
"The use of knowledge as evidence in determining 'significant effect' on the Dutch Natura 2000 Wadden Sea site"	Interpretative Policy Analysis Conference, Tilburg	2012	1
"Contested meanings in the assessment of 'significant effect'- The cases of mussel seed fishery and powerboat racing in the Dutch Natura 2000 Wadden Sea site"	Interpretative Policy Analysis Conference, Wageningen	2014	1

"How to deal with science-policy problems in the Wadden Sea? Prospects for action"	13th Waddenacademy symposium, Leeuwarden	2014	1
"Protecting nature: Dealing with uncertainty" and "Uncertain seagrass restoration in the Dutch Wadden Sea"	Student Conference on Conservation Science, Cambridge, UK	2015	1
"Dealing with uncertainty: seagrass restoration in the Wadden Sea"	ESA conference, Prague, Czech	2015	1
"Which cumulative effects? – Effect assessments at science-policy boundaries"	16th Waddenacademy symposium, Texel	2016	1
"(De)politicisation of mussel fishery - Dealing with knowledge uncertainties´	MARE Conference, Amsterdam	2017	1
C) Career related competences/personal development			
Facilitating Interactive Processes, CPT 60306	Wageningen University	2012	6
Teaching assistant of the MSc course 'Principles of Environmental Science'	Wageningen University	2012-2015	1
Guest Lecturer on Wadden Sea topics in various MSc and BSc courses	Wageningen University	2014-2017	1
Scientific writing	Wageningen in'to Languages	2014	1.8
Mobilising your Scientific Network	Wageningen Graduate Schools	2014	1
Career Orientation	Wageningen Graduate Schools	2016	1.5
Total			**52.1**

*One credit according to ECTS is on average equivalent to 28 hours of study load

List of publications

Floor J.R., Van Koppen C.S.A. and Lindeboom H.J. (2013). Review of science-policy interactions in the Dutch Wadden Sea – The cockle fishery and gas exploitation controversies *Journal of the Sea Research*, 82, 165-175.

Floor, J.R., Van Koppen C.S.A and Van Tatenhove J.P.M. (2016) Uncertainties in the assessment of "significant effect" on the Dutch Natura 2000 Wadden Sea site - The mussel seed fishery and powerboat race controversies *Environmental Science and Policy, 55, 380-392.*

Floor, J.R., Van Koppen C.S.A and Van Tatenhove J.P.M. (2018) Science, uncertainty and changing storylines in nature restoration – the case of seagrass restoration in the Dutch Wadden Sea, *Ocean and Coastal Management.*

Floor, J.R., Van Koppen C.S.A and Van Tatenhove J.P.M. Knowledge uncertainties in environmental conflicts: how the mussel fishery controversy in the Dutch Wadden Sea became depoliticised, *re-submitted to Environmental Politics.*

Van der Molen, F., **Floor, J**., Van Enst, W., Seijger, C, Giebels, D., Puente Rodríguez, D., Van Tatenhove, J., Runhaar, H., Van der Windt, H. (2015) 'From frustration to integration: Action strategies for a better fit between knowledge and policy on the Wadden Sea', Deltares (booklet in Dutch and English).

Floor, J. and Van der Molen, F. (2016) 'Benut alle kennis die je hebt voor het wad', *Friesch Dagblad,* 26 januari 2016 (Newspaper article).

About the author

Judith Floor was born on 23 January 1984 in Nijmegen, The Netherlands. In 2002, she started her scientific career with the BSc program 'Natuurwetenschappen', nowadays called 'Science' at the Radboud University Nijmegen. She finished this multi-disciplinary study with a BSc thesis on the potential effect of dust particles on climate change, with the department of Biophysics. In the same period she completed the Interdisciplinary Honours Programme of the Radboud University Nijmegen. In 2006, she switched to the MSc Environmental Sciences at the Wageningen University. She became inspired by the social sciences and completed her MSc with a thesis on the influence of local actors and legitimacy issues in the policy process around nature development of the Westerschelde area. Directly after her MSc, she obtained a grant from the Thomas More foundation to study Ethics and Political Philosophy at the Radboud University Nijmegen for one year. At the end of 2010 she returned to Wageningen University to start her PhD at the Environmental Policy Group. During her PhD she spent three months as visiting scholar with the Geography Department at Cambridge University UK. Furthermore, she has been involved in several teaching activities, using the Wadden Sea case study to explain decision-making dynamics and science-policy interactions.

Currently, Judith works as lecturer at the Open University in Heerlen. So far, she contributed to the online course 'Marine Litter' and has developed the online course 'Governing Climate Change: Polycentricity in Action?' as part of the EU project INOGOV. In the coming year, Judith will be involved in the development of environmental and governance courses and the supervision of MSc theses.

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Acknowledgement & Dankwoord

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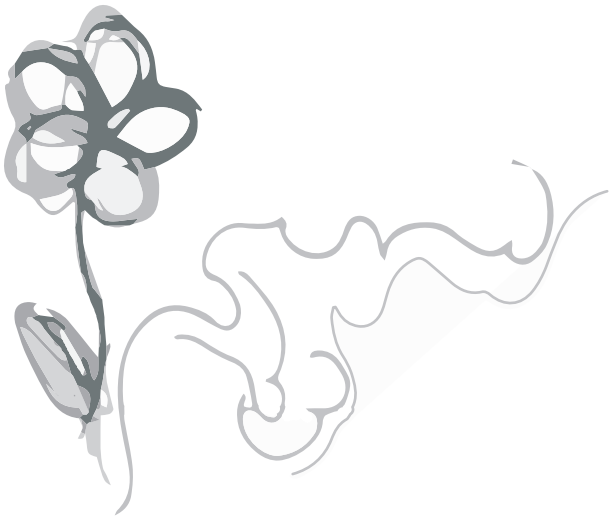
Judith Floor, Wageningen, 3 maart 2018



Colophon

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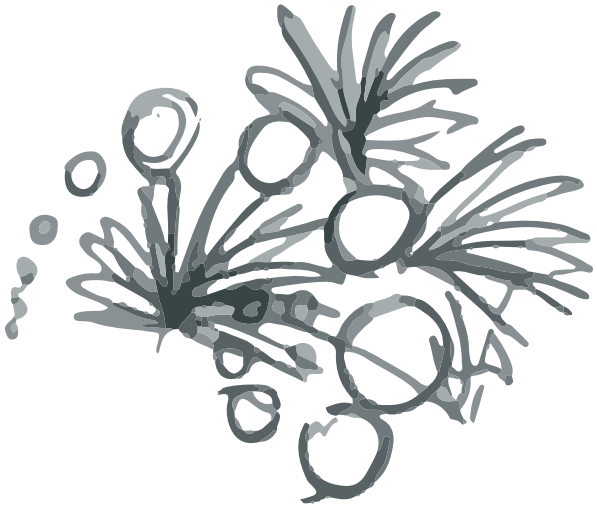

About the cover: The powerboats, mussels and seagrass on the cover illustrate my three case studies of a planned powerboat race, mussel fishery and seagrass restoration. The theoretical framework of three types of knowledge uncertainties are illustrated with the binoculars views. The vision of a blurred image of a mussel illustrates incomplete knowledge, indicating information is available, but not everything is clear. The lack of vision illustrates unpredictability, indicating that information is not obtainable. The two different visions of a mussel fishery ship and flying eider ducks illustrate ambiguity, indicating that there are different perspectives that shape how knowledge is interpreted.

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