Master's Thesis for Earth System Governance Track - Sustainable Development Masters

Collaborative Governance for Adaptation to Multi-Risk in the Dutch North Sea

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Abbreviation	Full name
BZ	Ministry of Foreign Affairs
DAPP	Dynamic Adaptive Policy Pathways
DAPP-MR	Dynamic Adaptive Policy Pathways for Multi Risk
EU	European Union
EZK	Ministry of Economic Affairs and Climate Policy
I&W	Ministry of Infrastructure and Water Management
IDON	Interdepartmental Directors North Sea Consultation Body
IPCC	International Panel on Climate Change
LNV	Ministry of Agriculture, Nature and Food Quality
MSFD	EU Marine Strategy Framework Directive
MYRIAD-EU	Multi-hazard and sYstemic framework for enhancing Risk-Informed mAnagement and Decision-making in the E.U.
NGO	Non-Governmental Organisation
NVWA	Dutch Food and Consumer Product Safety Authority
NZO	North Sea Consultation
OFL	Consultative Body for the Physical Environment
RVO	Netherlands Enterprise Agency
SDG's	Sustainable Development Goals
UN	United Nations
UNCLOS	United Nations Convention on the Law of the Sea

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Abstract

The Dutch North Sea is a space of tremendous economic potential in which efficient organisation of space is key for enduring climate adaptation. Climate change exacerbates natural hazards that pose dangers to the infrastructure set out to be installed at sea. The Dutch Government elaborated a medium-term plan that steers the system towards key transitions in energy production, food systems and ecosystem conservation. The user groups are currently participating in the governance efforts but there are still trade-offs to be made. Dynamic Adaptive Policy Pathways for Multi Risk (DAPP-MR) represents a methodology in development that MYRIAD-EU aims to tailor for use in transboundary sea settings. This research analyses the collaborative governance regime of the Dutch North Sea to understand where potential lock-ins might occur when attempting to implement DAPP-MR in this system. Taking advantage of being part of the MYRIAD-EU project and the collaboration with Deltares, this research uses primary data from the first North Sea pilot stakeholder workshop and internal sessions. Concurrently, interviews with experts in the field were conducted and an extensive literature review and document analysis were also used. The results showed a governance system that has already started to implement collaborative processes, but the system also has a preference for some activities over others. The user groups that fell within the spectrum of the research have displayed siloed thinking when it comes to climate adaptation. Both compatibilities and incompatibilities between activities would impact how multi-use of space can occur. There are knowledge gaps regarding systems impacts, and those are being taken into decision-making due to the urgency with which the government treats climate action. Furthermore, there were also gaps in single hazards to multi-hazard to multi-risk thinking in this system. DAPP-MR could be used to navigate the uncertainties of this system in theory, but more research and potential changes to the method are required. The conceptualisation of space as the resource of a socio-ecological system represents a starting point in both developing collaborative governance and DAPP-MR for use in maritime areas. Further research is required in both fields, as well as in multi-hazard and multi-risk thinking that should develop in this area.

Key words: North Sea, adaptation pathways, multi-risk, collaborative governance

1. Introduction

We are at the point in history when humanity has reached the boundaries of the Earth's systems (Steffen et al., 2015). To continue to operate on this planet without causing irreversible climate change, certain steps need to be taken to navigate these uncertain times. With so many human activities having been placed at sea, it is equally important to make sure that these are optimised for extreme events. The North Sea has one of the highest economic potentials, considering its waters wash the shores of Western Europe. Moreover, there are plenty of plans to replace the old oil and gas industry with renewables and the greening of other practices at sea (The Economist, 2023). With great opportunities comes competition between developers and, each country has its own agenda for organising its territorial waters to enhance what was developed on land. This occurs in a limited space and strategic planning should help navigate the future. The latest IPCC report projects changes in extreme events and wind patterns in North-western Europe which could have unforeseen impacts on the spatial plans we make today for the future decades (IPCC, 2022).

1.1. Societal context

Julietta D, a Maltese bulk carrier, came adrift during storm Corrie in 2022 (figure 1), its collision with a transformer platform endangered both human life and electricity generating infrastructure at sea (Buitendijk, 2022). This is an incident that raises the awareness of potential incidents that may occur due to competition of space between different industries. Climate change would increase likelihood of natural hazards affecting the North Sea system, through events such as storms or heatwaves that would be increasingly more powerful and irregular (IPCC, 2022). With increase in assets at sea, comes vulnerability to multiple hazards, thus, introducing multi-risk as a pressing concern for an efficient collaborative regime for the adaptation of the Dutch North Sea. Agenda 2030 affirms the need for urgent action dedicated to reduction and mitigation for risk to disasters (UNDRR, 2015a). One completing piece of the puzzle that would ensure that the most is extracted out of the Sustainable Development Goals (SDGs) is the Sendai framework for Disaster Risk Reduction. Several goals established through Agenda 2030 have their attainment directly linked to development of risk: affordable and clean energy (7), decent work and economic growth (8), life below water (14), and climate action (13) (UNDRR, 2015a). Furthermore, the Sendai Framework iterates on the importance of stakeholders from diverse backgrounds, as public institutions bring a structured approach to the table. In contrast academia brings the knowhow of the events that can affect the system, whereas the public sector sees the adoption of disaster resilient practices in industries (UNDRR, 2015b). Recently, the Climate Action Summit of 2021 has yielded an action agenda that aims to complement the SDGs towards adaptation and resilience (IISD, 2021).

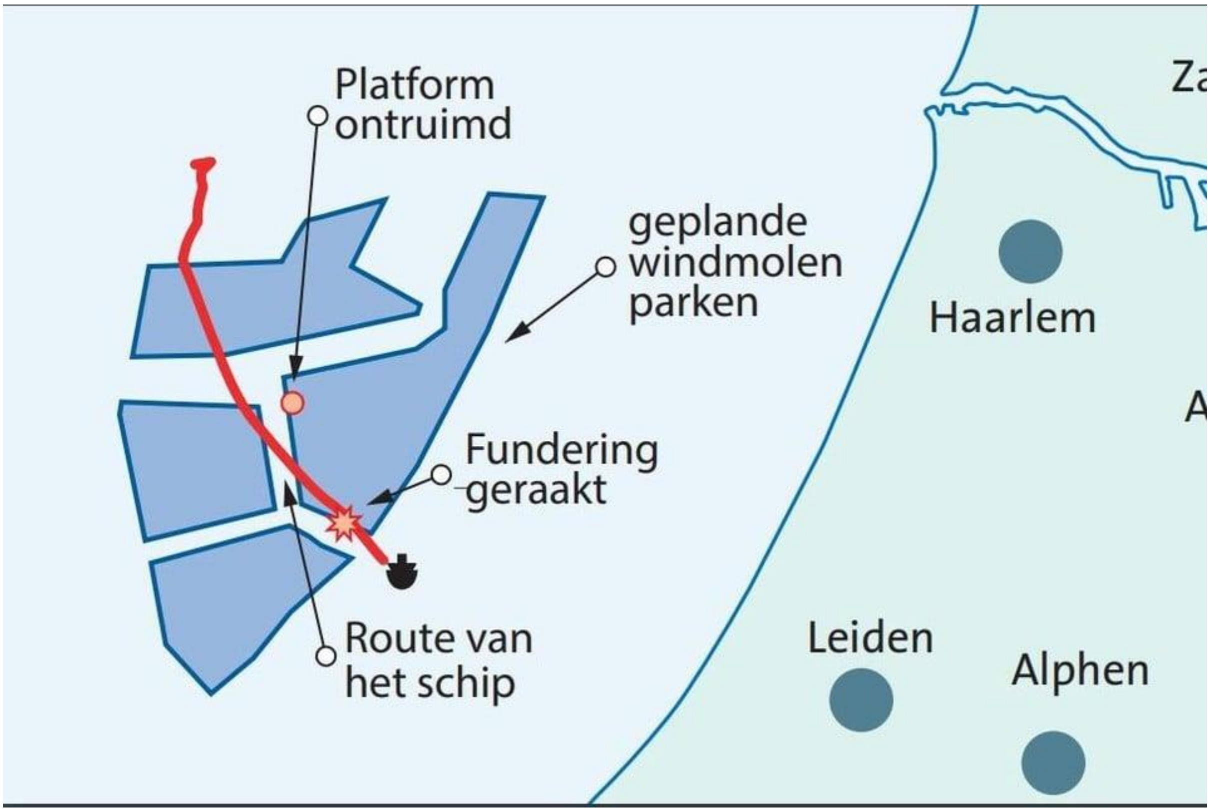

Figure 1: Trajectory of Julietta D incident (van Aarsen, 2022)

1.2. Looking at the literature

There is a need for collaborative processes that are suited to the rapid changes that are faced by maritime systems. One can investigate concepts evolved in academia to tackle uncertainties, eloquently exemplified by adaptation pathways. These have been increasingly researched as a method for decision-making under deep uncertainty and during the past decade, the literature has evolved to suit the challenges of collaborative processes and the prospects of multi-risk (Haasnoot et al., 2013; Hermans et al., 2017; Schlumberger et al., 2022). One initiative that set out to provide solutions to the nuances of disaster risk management is MYRIAD-EU (n.d.) – Multi-hazard and sYstemic framework for enhancing Risk-Informed mAnagement and Decision-making in the EU. One of the benefits of this project is that it brings together stakeholders from multiple sectors to be directly involved in the development of tools that eventually would provide a path towards navigating better solutions for the mitigation of future risks. It also harbours a knowledge production system that bridges conceptual and empirical research.

The North Sea system is explored as one of the areas that would increasingly experience more complex challenges in the decades to come and is potentially heading for lock-ins that can affect sectors either individually or concurrently (van der Werff et al., n.d.). Single hazards or specific sectors have already taken steps towards alleviating disaster risk. Despite that, collaboration across economic, governance and spatial systems would be the key to unlocking the potential that can be developed in the North Sea (MYRIAD-EU, n.d.-b). The Dutch North Sea could be conceptualised as a collaborative governance regime. Emerson & Gerlak (2014b) explain that these regimes "*refer to public policy or service oriented, cross-organizational systems involving a range of autonomous organizations representing different interests and/or jurisdictions (as opposed to like-minded coalitions)"* (p.769). As these could be used to tackle a specific goal, in this case multi-risk adaptation, by including in the process an array of organisations and stakeholders.

The wicked problem of the North Sea involves a level of transboundary maritime spatial planning that is yet to be explored widely in both literature and practice. As collaborative aspects are key for the development of policies within the European Union seas, there are steps yet to be taken into facilitating the cohesion of North Sea planning (Moodie et al., 2021; Moodie & Sielker, 2021). The degree of fragmentation apparent within the North Sea governance regime, makes it difficult for a comprehensive analysis that would yield solutions beyond the establishment of a strong overarching institution as there are still ambiguities regarding regional governance endeavours (van Tatenhove & van Leeuwen, 2016; Woolley, 2013).

1.3. Research aims and questions

The identified gaps are both conceptual and empirical. On the one side, there is a limited number of sources beyond Emerson and Gerlak (2014b), and the authors' body of research, that aim to further the integration of collaborative governance with adaptation governance. The majority of the literature is comprised of case studies of the local governance scale (Barton et al., 2015; Brink & Wamsler, 2018; Sharifi et al., 2022). The scale of collaborative governance for planning is an aspect that has been explored by Hamilton and Lubell (2018), as the level of collaboration seems to weaken with the spatial level increase. On the other, MYRIAD-EU represents an opportunity to comprehend the interactions between multiple sectors within a multi-risk environment. The cross-sectoral dimensions of collaborative decision-making are also a field that should be further explored, as mentioned by Fischer and Sciarini (2016). Planning is just one of the aspects that would need to be further explored in the North Sea, as problems are forthcoming there are certain adaptation thinking that needs to involve all sectors. Recommending the design of a new institution or platform is not always the solution (Kallis et al., 2009). Adaptation pathways are a means of guiding decision-making under deep uncertainty conditions. This theoretical approach involves a great deal of intricate issues and parties whose interests need to be captured not only for the design phase but also for implementation (Hermans et al., 2017).

The use of the term "sector" implies a branch of an economy, activity of industry. **This research aims to investigate the lock-ins that can occur due to specific uses of the sea surface, thus looking at actors, albeit state or non-state, that are directly linked to the use of the sea surface as a resource, which will be grouped in user groups. Therefore, the focus of this research would be on six user groups: offshore wind production, shipping, food production (fisheries and mariculture), cables and pipelines, ecosystems and conservation, and sand extraction.** The choice was motivated by the priority placed by the 2022-2027 North Sea Programme on three dimensions of transition, i.e. sustainable energy, food production and nature conservation (I&W et al., 2022). Another motivating factor was the relevance of the research for the North Sea Pilot of MYRIAD-EU, and the sea activities that it focuses on (MYRIAD-EU, n.d.-b). It is important to note that some prevalent uses were excluded, with the most economically and environmentally significant of them being oil and gas. This was justified by the emphasis placed on decommissioning the infrastructure corresponding to this use, as part of the future promoted by the Dutch Government (I&W et al., 2022).

Despite the greater challenges of the North Sea region, this research aims to focus on the territorial waters and economic exclusive zone of the Dutch sectors of the sea. Overarchingly, this research aims to use joint adaptation and collaborative governance principles to understand lock-ins that may arise within the Dutch North Sea cross-sectoral collaboration regime and reflect on how these could potentially be overcome. To do so a second approach to adaptation must be introduced to structure the use of information gathered into furthering adaptation endeavours. The MIRIAD-EU project has been developing concepts and methodology in order to advance adaptation thinking from single-hazard to multi-risk. The proposal of Dynamic Adaptive Policy Pathways for multi risk by Schlumberger et al. (2022) represents an opportunity to use collaborative governance principles to navigate adaptation issues. Specifically, this research aims to further the conceptual advancement of collaborative governance for adaptation, by advancing collaborative understanding of adaptation lock-ins, and integrate collaborative governance through processes into the development of DAPP-MR methodology, by using the Dutch North Sea as a case study.

Raising this question:

What are the potential lock-ins of the collaborative governance regime in developing adaptation pathways in the Dutch North Sea?

Drawing from the principles of Emerson and Gerlak (2014) and Siebenhüner et al. (2021), a set of sub-questions arise that would help identify characteristics of the governance regime and the basis of the theory that sustains them:

1. *What are the current governance structures and how can these cause decision-making lock-ins?*

Governance structure refers to rules and norms that are constantly developed for including new constituents, which reflect the receptivity and sensitivity of actors to commit to shared goals. In terms of leadership, that occurs at multiple levels, which strengthens the legitimacy and capacity of advocacy, which would create opportunities for mobilisation and support for adaptive action (Emerson & Gerlak, 2014a). These reflect on the institutions that are set in place as their path dependencies could affect the adaptation capacity of the system.

2. *How do different user groups interact and what are potential conflicts that might occur in future collaboration?*

The **collaborative leaders** are those who influence the dynamic of the regime, as it is essential for trust building, knowledge generation, uptaking of social and ecological information, communicating perspectives of change and mobilising support for it (Emerson & Gerlak, 2014a). Siebenhüner et al. (2021) mention that actors in charge are a topic that is not empathised well enough by the research and may reflect in decision-making for maritime planning.

3. *What are the knowledge gaps present within the system? How can collaborative systems analysis bridge these gaps? What methods can be used to transition from single hazard to multi-risk thinking?*

The diversity of **knowledge** pools brought together enables the participants to develop and challenge existing information. The shared learning not only reflects the limits and prospects of the knowledge present within the system but also explains the level of cognitive flexibility required for adaptation (Emerson & Gerlak, 2014a). The different knowledge generators may have concurrent or opposing discourses on what they believe the best outcome for adaptation strategies should be. This could also reflect on the transition from hazard to risk.

4. *How can adaptation pathways be used to tackle spatial claims related lock-ins?*

Resource sharing is required to achieve common goals. Within a specified area there may be overlap between entities that claim the multiple resources, as well as unbalanced dynamics created by leverage one might have over another (Emerson & Gerlak, 2014). This would reflect in the 'physical infrastructure' of Siebenhüner et al. (2021), as decisions are set to impact on attribution of sea surface for certain developments.

2. Theories and concepts

Head and Alford (2013) frame wicked problems as challenges that are faced by contemporary governments, such as disaster risk, as these require non-traditional thinking. The literature on wicked problems suggests that these centre around the pluralism of values, institutional complexity, and scientific uncertainty (Head & Alford, 2013). One might argue that the North Sea is facing a wicked problem. On the one hand, the change in climate brings an increase in mean wind density and maximum speed, which in turn provides both challenges and opportunities for offshore wind, the forthcoming dominant industry of this maritime sector (Dieterich et al., 2019; Rusu, 2022). On the other hand, there are asymmetries in terms of both power dynamics and the impact of climate change on various sea surface uses. The already mentioned challenge for space is exacerbated by the increased likelihood of events like the one that caused the Julietta D incident, as well as the diversification of economic activity through the development of sectors such as aquaculture that also have a role in strengthening resilience (Soma et al., 2019; Weisse et al., 2012). The fragmented approach towards planning is perceived as outdated, as the Netherlands move towards broader time horizons.

2.1. Governance theories

A straightforward definition offered by O'Leary et al. 2006 refers to governance as a "*means to steer the process that influences decisions and actions within the private, public and civic sectors*" (p.7). Ansell and Gash (2008) analysed the use of collaborative governance and identified elements that influence the degree of success of collaborative governance. Those variables are pre-existing collaboration patterns, institutional arrangements, incentives for stakeholder participation, resource and power asymmetries and leadership structures. Building on this work, **collaborative governance** is defined by Emerson et al. (2012) as "*the processes and structures of public policy decision making and management that engage people constructively across the boundaries of public agencies, levels of government, and/or the public, private and civic spheres in order to carry out a public purpose that could not otherwise be accomplished"* (p.2). These theoretical concepts have been further developed by Emerson and other scholars in the field, and experiments with combining governance modes have been emerging.

Adaptation had been elaborated on by Nelson et al. (2007) who synthesized the literature to define it as "an adjustment in ecological, social, or economic systems in response to observed or expected changes in environmental stimuli and their effects and impacts in order to alleviate adverse impacts of change" (p.398). The need for adaptation has become apparent in the past decade, with scholars attempting to introduce it in decision-making. The most eloquent example is represented by **adaptation pathways**, an analytical approach that can be used to integrate external conditions changing over time into action taking. These could also integrate a greater timeframe and a multitude of factors and evolve into dynamic adaptation policy pathways (Haasnoot et al., 2013).

This merger of **adaptation and collaborative governance** has been explored by Emerson and Gerlak (2014), scholars who are at the centre of developing understandings for collaborative governance solutions. The four dimensions that Emerson and Gerlak (2014) have found that "*collaboration dynamics foster specific collaborative capacities that in turn generate associated adaptive capacities, and further, that together these capacities shape the collaboration dynamics of collaborative governance regimes in an iterative fashion thus assisting institutional adaptation*" (p.777). They presented four dimensions in which collaborative dynamics evolve, which were previously presented as they correspond to the research sub-questions.

The North Sea is a complex system, that is expected to face multiple challenges regarding spatial planning of shared resources, in an international area without a strong institutional structure at the centre of its governance regime. The literature recommends the creation of such a strong institution is not necessarily ideal, as it is a lengthy, costly endeavour that would prolong the exposure of assets to risk during the political process of design and subsequent implementation. Fischer and Sciarini (2016) explored factors that facilitate intersectoral collaboration, that have been previously overlooked when addressing single sector collaboration dynamics. Their approach borrowed elements from network theory to address the interlinkages between multiple stakeholders, which is one of the ways of rewarding the knowledge of adaptation thinking (Werners et al. 2021). Thus, looking at the cross-sectoral synergies is a dimension of complexity that has been missing from developing the potential of the existing collaborative regime of the North Sea to develop resilient adaptation strategies.

2.2. Hazards and risks

Hazards are processes, phenomena or human activity that could cause loss or damage of life or property, social or economic interruptions and can have lasting impacts on the environment (UNDRR, n.d.-b). These can occur in single episodes, they can increase/ decrease the probability of occurrence or trigger other hazards. Multiple hazards can also affect a system through a relationship of coincidence (Gill & Malamud, 2014). Each hazard can be seen through properties such as the location it affects, frequency, intensity and probability. Transition to **multi-hazard** occurs when looking at either a selection of major hazards experienced by one geographical area or when the individual events arise at the same time, in a cascading succession or amount over a time period. These also entail interrelated impacts that jointly affect the system (UNDRR, n.d.-b).

The North Sea is categorised as being relatively inert in terms of geohazards compared to other sea basins, with low probabilities of earthquakes, underwater landslides, and tsunamis affecting the installed infrastructure (Kopp et al., 2021). Although there is a possibility of such events occurring and should be accounted for, they are not amounting to represent a primary threat. Thus, when looking at the potential natural hazards that may occur within this geographical area, we should focus on those with atmospheric origins (see figure below). This was the case for the hazards identified during the first North Sea Pilot stakeholder workshop. Events such as powerful storms may create winds and surges that could damage the infrastructure. Extreme amounts of rain may bring excessive river discharge and sediments that could be detrimental to both the manmade and natural environment (Stakeholder Workshop, 2022). Similarly, periods of extreme and no wind would have an impact on human activities at sea (Stakeholder Workshop, 2022). Periods of extremely hot and cold weather likewise can for example impact algae blooms that would then impact other systems (Stakeholder Workshop, 2022). Fog, for example, could amount to unsafe conditions for shipping (Stakeholder Workshop, 2022). The occurrence of these single hazards could cause damage to the ecosystems of the North Sea, but from a certain viewpoint they become problematic when human activity is involved. Furthermore, hazards can trigger or cooccur with anthropogenic hazards, for example oil spills, or other pollution events.

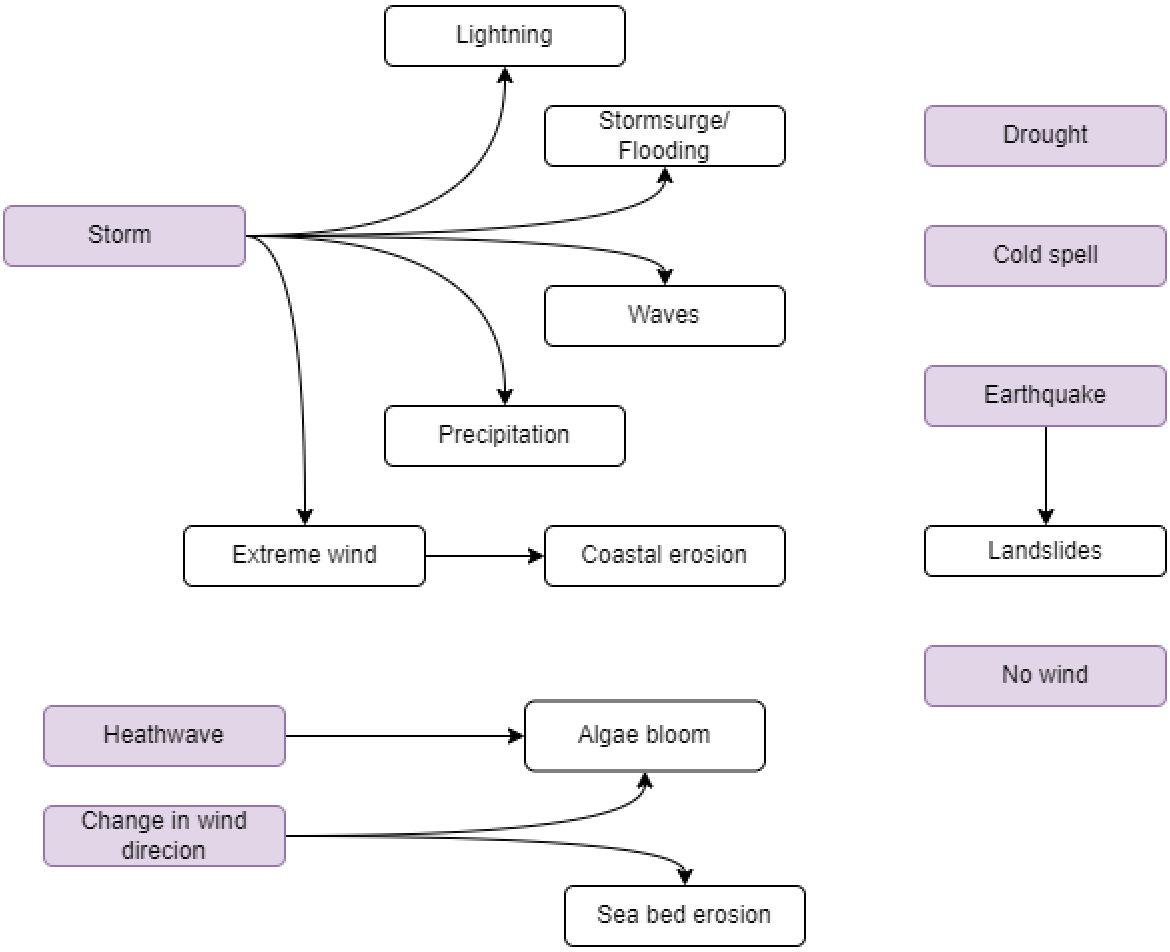

Figure 2: Hazards identified by participants of the first North Sea Pilot stakeholder workshop - purple represents primary hazards and white represents cascading hazards/effects (Stakeholder Workshop, 2022)

Perceptions of impacts could be experienced differently depending on the socio-economic background of those affected (UNDRR, n.d.-a). Governance entails either a process, structure or action through which actors from both public and private backgrounds join to address a specific goal. This involves institutions, that can either belong to the state structure or be informal, and those manage, implement and monitor roles and norms that guide the behaviour of a system within a geographical boundary (IPCC, 2022). Scolobig et al. (2017) argues for the development of strategies of multi-risk governance so that they reflect the innovative requirements for decision-making to match these nuanced issues. Some of the barriers that are highlighted by the author are centred around collaboration, as interagency communication and partnership with private actors and misalignment of priorities based on single hazard. Thus, although there are mechanisms in place for decision-making in risk settings, coordination can make a beneficial difference.

The dynamics of **risk** are dictated by the relationship between hazards, exposure and vulnerability, and these can evolve through time (MYRIAD-EU, n.d.-a). The correlation between risk variables that determine how it could be experienced on multiple scales, from communities to systems, and the possible resulting losses of life and assets reflect through the susceptibility of the spatial unit to disaster risk (UNDRR, n.d.-a). Interrelationships established between multiple hazards and vulnerability factors generate **multi-risks** (DRMKC, 2017). The relation between hazards and risk has also been explored during the stakeholder workshop and was covered in chapter 3.3.

2.3. Dynamic adaptive policy pathways

The latest IPCC report defines adaptation pathways as "*A series of adaptation choices involving trade-offs between short-term and long-term goals and values. These are processes of deliberation to identify solutions that are meaningful to people in the context of their daily lives and to avoid potential maladaptation*" (IPCC, 2022, p.2917). This approach could help sequence action-taking based on external developments. The Dynamic Adaptive Policy Pathway (DAPP) put forward by Haasnoot et al. (2013) represents a stepped approach that acknowledges scenarios that represent a considerable amount of uncertainties over a time period, with possible actions to be taken around adaptation and opportunity tipping points. Establishment of a monitoring mechanism is also important to ensure that preferred pathways are taken (Haasnoot et al., 2013). DAPP for Multi Risk is an adaptation of the framework for multi-risk settings, by progressively applying the pathway formation steps of DAPP to single-sector single-hazard, single-sector multi-hazard to multi-sector multi-hazard (Schlumberger et al., 2022). These concepts and their suitability for this case study are further analysed in chapter 3.3.

2.4. Analytical framework

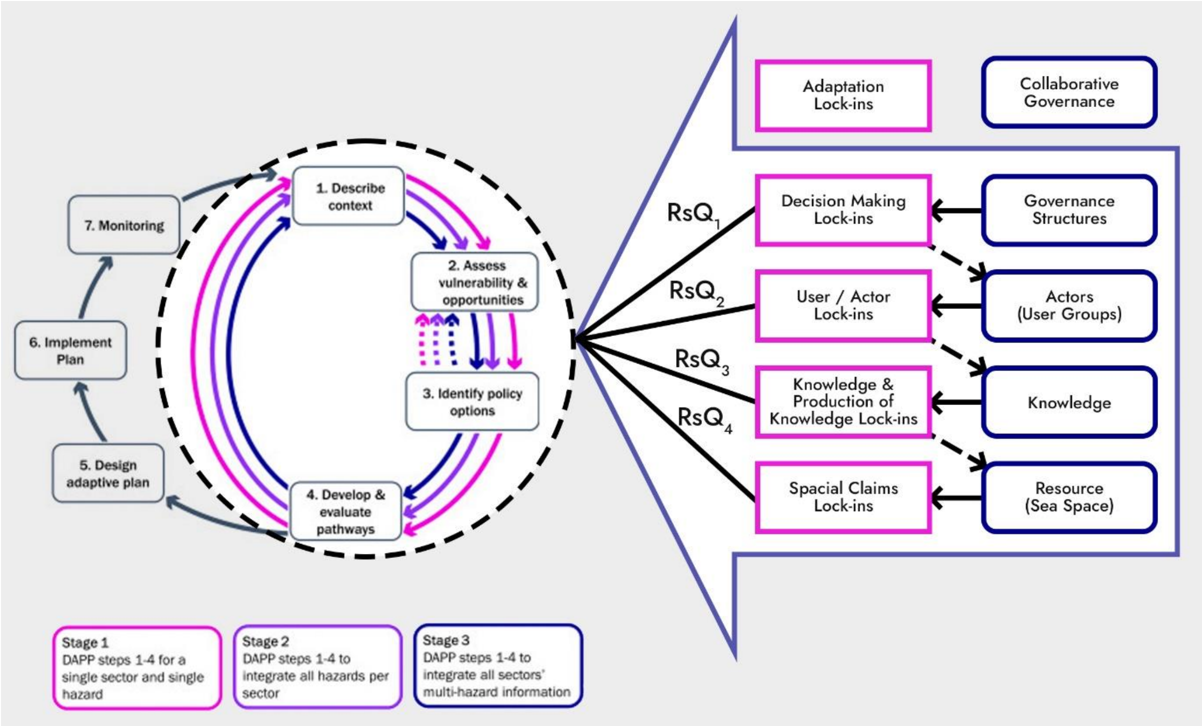

Figure 3: Conceptual and analytical framework depicting the contribution of collaborative governance principles and adaptation lock-ins to the conceptual application of DAPP-MR in this case study

Governance concepts are used in describing the 'who', 'what' and 'how' of decision-making and within a regime one can distinguish the rules of distribution of one resource. The Dutch North Sea represents a finite space with a governance regime that presents traits of both bureaucracy-based and co-management systems. The literature on collaborative governance for adaptation developed by Emerson and Gerlak (2014) could be used to explore adaptation lock-ins as seen by Siebenhüner et al. (2021). The North Sea is plagued by the forthcoming problem of increased vulnerability to multi-risk caused by already mentioned factors. Therefore, the development of the proposed DAPP-MR methodology represents a means to further adaptation pathway formation for sharing sea space by multiple user groups. The aims of this research are to use collaborative governance concepts to highlight the potential lock-ins of this system, that could arise in adaptation pathways formation and could be overcome using DAPP.

When addressing an adaptation standpoint, Siebenhüner et al. (2021) proposed four dimensions of conceptualising lock-ins: knowledge, discourse and expertise; physical infrastructure, institutions and past policy tools; and actors. To investigate potential lock-ins for the adaptation of the Dutch North Sea, one must investigate the multiple dimensions of the governance regime. Collaborative governance processes are crucial for the development of maritime spatial planning (Ehler, 2018; Moodie et al., 2021; Moodie & Sielker, 2021). This concept refers to the process of harvesting knowledge and resources from a plethora of stakeholders to address complex challenges. From an academic standpoint, Emerson & Gerlak, (2014) found a significant overlap between adaptation and collaborative governance with four common denominator dimensions between them**: structural arrangements, leadership, knowledge and learning, and resources**. This structured framework could be used to understand the distinct types of lock-ins that can appear within this system.

The research sub-questions can also be seen as a sequence of steps that need to be taken to understand adaptation lock-ins from a collaborative governance standpoint. Thus, the first sub-question aims to map the governance structure responsible for resource allocation within the identified geographical area, identify the overarching institutions that influence actor behaviour, and establish what potential lock-ins might occur. Subsequently, the second sub-question is focused on constructing the image of user groups and their relations, especially considering the proposed multi-use of space there could be conflicts that may occur. Following on the information gathered, another question rises in regard to methods and efficiency of practices used in knowledge exchange and coproduction. This also implies an investigation into transitioning single-hazard methodology to multi-risk environments. Lastly, the information gathered would be used and corroborated with spatial claims of the different user groups to narratively hypothesise on the evolution of adaptation pathways using the stages proposed by DAPP-MR (further information in the theory chapter 2.3.).

The visual representation of the merge between collaborative governance concepts and the steps of DAPP can be observed in figure 3. Each dimension of collaborative governance can be understood for this research as follows:

1. The governance structure scoping would frame the system and its boundaries, as well as overall objectives on the agenda of the region. These would serve to understand the dynamics between the resource management regime of the Dutch North Sea, which would in turn have an impact on how actors work. By regime one can understand "*set of implicit or explicit principles, rules, norms, and decision-making procedures around which actors' expectations converge in a given area*" (Krasner, 1982, p.186). Regimes are long-lasting but are susceptible to change if rules and decision-making procedures are changed (Krasner, 1982). Since sea space represents the resources around which choices are made, the window of opportunity that is soon to open within the regime of the Dutch North Sea could be attributed to changes in sea space function allocation.
2. Multiple actors, state or non-sate, represent groups of users that seek to share the same space. There are considerable power dynamics that shape their interaction, as each user group is affiliated with an institution that influences the interaction between the organisations that use the sea and the prioritisation of those needs on the agenda of the region. Similarly, any conflict that might occur may influence the options for space use, as the current trends focus on increased multi-use of areas, hence the need for better collaboration. Multi-use of space is proposed. Thus, collaboration between actors will play a key role in the future.
3. The knowledge required to navigate the future of the Dutch North Sea is yet to be developed. It is crucial to map out the gaps in order to ensure efficiency in the use of current knowledge and focus future research. Simultaneously, an introspection in use of collaborative sources is required to ensure that the best means are used when stakeholders are engaged. DAPP and DAPP-MR are means of facilitating the navigation of future uncertainties, but one must also reflect on the suitability of this methodology for this case study.
4. Building upon previous dimensions, the spatial claims of the users represent the shared use of a common resource. Developing potential pathways and exploring opportunity tipping points in a narrative way through the three stages proposed by DAPP-MR, with the information gathered would help reflect on the methodology.

2.5. Research strategy and methodology

RQ: What are the potential lock-ins of the collaborative governance regime in developing adaptation pathways in the Dutch North Sea?

As previously stated, the aim of this research is to identify the lock-ins present within the system from a collaborative governance standpoint, when attempting to apply DAPP to this geographical area. Four sub questions have been raised to tackle the four collaborative governance dimensions and sequentially add systems information that would answer the main research question (figure 4). The research solely focuses on use of qualitative sources. This reflects the iterative nature of the process for which multiple methods were deployed. A breakdown of methods used per sub question is provided in table 1.

Table 1: Methods used per sub-question

Sub-question	Literature review	Stakeholder workshop	Interviews	Documents from internal session
1.What are the current governance structures and how can these cause decision-making lock-ins?	X	X	X	
2. How do different user groups interact and what are potential conflicts that might occur in future collaboration?	X	X	X	
3.What are the knowledge gaps present within the system? How can collaborative systems analysis bridge these gaps? What methods can be used to transition from single hazard to multi-risk thinking?	X	X	X	
4.How can adaptation pathways be used to tackle spatial claims related lock-ins?	X	X	X	X

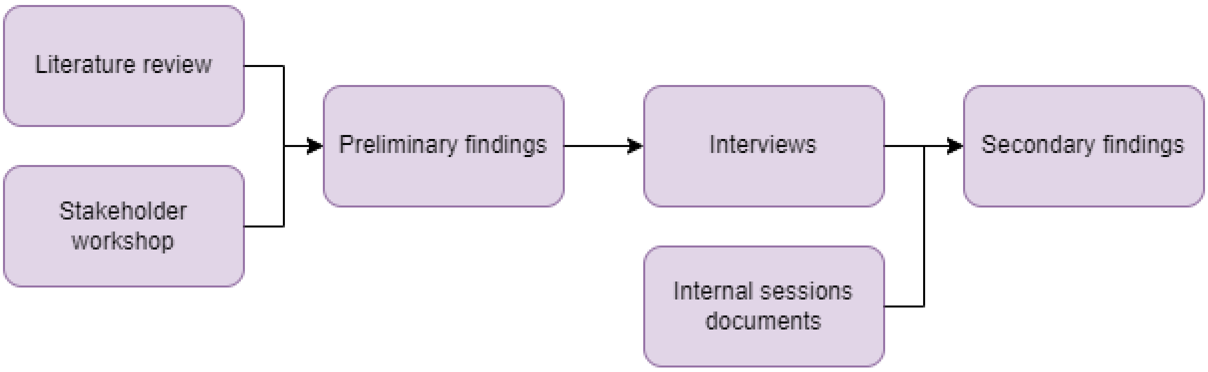

Figure 4: Research Strategy

In an atypical manner, the researcher took part in the first stakeholder workshop of the North Sea Pilot of the MYRIAD-EU project, as the first activity of this research. This kickstarted the research design process with notes and figures gathered during the sessions used as primary data. All information from the stakeholder workshop has been gathered and digitalised directly by the researcher. The ethics of processing the data from the stakeholders were covered by the board responsible for the MYRIAD pilot. The participants were offered an information sheet prior to being asked for their express consent (Appendix 1 & 2).

This initial overview of the system has been corroborated with literature and document analysis. On the one side, reports on related topics from Deltares were given access to the researcher, on which the snowballing technique was used to gather the most relevant literature references. These were grouped based on their abstracts according to the four dimensions of the research. On the other, supplementary literature was gathered from Google Scholar and Scopus searches, using the key terms "collaborative governance", "adaptive governance", "multi hazard", "multi-use", "adaptation pathways" combined with "sea space", "sea surface", "North Sea", "Dutch North Sea". Consequently, information regarding spatial planning processes, agendas and strategies for the investigated area were sought on the government's website. More information regarding each ministry's or agency's activities have also been extracted from documents widely available on their website. This information was collected and compiled in the initial findings which were used to organise the interview process. The interviewees' names will not be disclosed, and they have been assigned numbers that would be referenced throughout the research (table 2).

A second primary data source emerged from expert interviews conducted by the researcher throughout May of 2023. Prior ethical approval was sought and obtained from the board responsible for the MYRIAD project. Participants came from three domains: governance, academia, and user group representatives. All but one of them were identified and contacted based on their willingness to collaborate in previous projects on related topics with Deltares, with the latter being contacted via LinkedIn. This reflected the decision of the researcher using networking opportunities available within Deltares to use time efficiently and have a higher response rate. Out of 17 people contacted, 7 interviews were successfully scheduled and completed. The interviews were semi-structured, and guidance was provided to the researcher when compiling the list of questions. The interviews were conducted either online or in person and were recorded. Summaries were made by the researcher and coded directly into text. A breakdown of the field of expertise of the participants is provided in table 2.

Table 2: Breakdown of stakeholder interviews as these will be referenced in text

Participant number	Field of expertise
1	North Sea knowledge uptake
2	Adaptation pathways/ climate adaptation
3	Offshore wind
4	Maritime spatial planning
5	Offshore wind
6	Climate adaptation
7	Dutch government

Lastly, internal sessions were held at Deltares with the North Sea pilot team to build on the feedback gathered on DAPP approaches presented to the stakeholder. Throughout these sessions, climate and spatial scenarios have been tailored for the system, based on widely available research and the systems knowledge of the research team. The scope of that exercise comprised the wider North Sea. Subsequently, lists of measures for three sectors were created and compiled into scenarios for achieving preestablished sectoral goals. This was a theoretical exercise to which the researcher directly partook. Developing on these documents, and information gathered during the research, a climate and spatial scenario was created, lists of measures adapted with subsequent narrative pathways formed by the researcher for the theoretical application of DAPP to the geographical scope of this study.

3. Findings

3.1. Governance structures

RsQ: What are the current governance structures and how can these cause decision-making lock-ins?

Emerson et al. (2012) propose an extended framework for assessing a collaborative governance regime, that implies understanding the drivers that have led to an increase in collaboration, the dynamics at play between different actors, stakeholder or institutions that can be placed into three categories – principled engagement, shared motivation, and capacity for joint action – these resulting in actions that have impacts and reflect in subsequent adaptation of the regime. At the same time, if one considers the system present in the Dutch North Sea, as a socio-ecological system focused on resource allocation and use, then typologies of actors can be seen as either holding authority to distribute right to space exploitation or actors grouped around a specific activity (Dutra et al., 2019). **These theoretical concepts would guide the following section by firstly looking at drivers of change and collaboration, then identify the actors at play, followed by a look at collaboration dynamics and finalising with the actions and their impacts on sea surface use and future collaboration on the subject.** During this process potential lock-ins in collaboration will be identified. Furthermore, throughput this process, information regarding, the boundaries of the collaborative regime would be gathered.

3.1.1.Drivers of change

In the case of the Dutch North Sea, the conditions that have led to change in collaboration practices originate from both international and national circumstances. Emerson et al. (2012) explain that in the extended assessment framework, they propose there are differences between the general context that facilitates the collaboration and the drivers that can be identified as being a crystallised version of the conditions that have a direct influence on the collaboration chain that occurs within the regime.

The North Sea Region is composed of multiple high performing economies like France, Belgium, Netherlands, Germany, Denmark, and Sweden, which are part of the EU, Norway, part of the European Economic Area, and the UK, no longer an EU member (European Commission, n.d.). Although a centralised platform and EU directives for relevant conservation efforts are set in place, the approach towards organising the sea space within each country's jurisdiction stays relatively independent. The North Sea Commission is part of the EU's arenas aimed to offer space for political collaboration and foster collaboration on maritime strategy design (European Commission, n.d.; North Sea Commission, n.d.). Another player that brings all relevant countries and the EU together to reflect on the conservation of the North Sea is the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention) (OSPAR, n.d.-a). As, it sets agenda points and makes recommendations that are relevant for the entire region (OSPAR, n.d.-b). Even though there are mechanisms to make national maritime planning strategies more coherent, the way in which space is organised for its economic and conservation uses remains to be decided in accordance with each country's priorities.

The context of climate change led to plenty of calls for substantial steps to be taken, especially towards the transition to renewable energy, economic development brings increased shipping activities within the North Sea, conservation efforts are also required. Thus, a series of national and international agreements and directives are cumulating to influence the changes in policies and institutional arrangements at national and local level. The Sustainable Development Goals that emerged from the Paris Agreement represent an umbrella under which many directives and targets have been set at the European level. The North Sea Programme for 2022-2027 and the North Sea Agreement list the Water Framework Directive, Common Fisheries Policy, Birds Directive, Habitats Directive and Sustainable Energy Policy as some of the EU level that have had an influence of the way in which the Dutch government organises itself to set and adhere to targets (I&W et al., 2022; OFL, 2020). Subsequently, the UNCLOS also represents a key piece of international legislature that influences the governance of the Dutch sector of the North Sea, thus many actions can be perceived as deriving from it (OFL, 2020). At a regional level, the European Maritime Spatial Planning Directive and the Marine Strategy Framework Directive are influencing the approach Dutch take towards developing the sea space (I&W et al., 2022). Similarly, nowadays there are quotas of space that have to be set aside for conservation, further constricting the available space for other user groups (de Vrees, 2021; European Commission, 2022).

Leadership is a key component in understanding how collaboration occurs within a regime, as institutions and organisations must commit to collective problem solving, without advocating for a particular solution, and present a willingness to sustain possibly high transaction costs (Emerson et al., 2012). The system that is to be analysed in this paper can be classified as a bureaucracy-based regime with co-management elements, as the resource at play, i.e. sea surface, is owned by the Dutch Government and is managed on behalf of the people (Dutra et al., 2019; RVO & BZ, 2021). Thus, the multiple agencies, ministries and branches of the Dutch government represent actors of the decision-making landscape that facilitate allocation of sea space, and they pave the way the way sectors conduct their activities, set and attain their targets.

The latest IPCC report represents an extensive scientific basis for arguing for decision-making that can reflect increased vulnerabilities and takes into consideration possible scenarios that affect not only characteristics of regional climate, but also the likelihood of extreme wheatear events and sea level rise (IPCC, 2022). Thus, the transition from the Water Act to the more integrated Environment and Planning Act (coming into effect in 2024) can be perceived as a window of opportunity for a change in policy thinking from a siloed sectoral approach to an integrated coordinated effort (DutchGovernment, n.d.). Similarly, there is a turnover of roadmaps for energy transitions between the previous strategy that was in effect until 2023 and the one that succeeds it and covers tender arrangements up to 2030 (RVO & BZ, 2021). There are changes in fishing quotas as a result of Brexit, and in stocks of fish which are influenced by climate change (Hatenboer et al., 2023; Miller et al., 2010). These can represent some of the consequential incentives that have a positive influence on collaboration patterns (Emerson et al., 2012).

Current plans follow the decommissioning of oil and gas, in favour of renewable energy sources, as well as acknowledge the need to combine functions to make use of space efficiently (I&W et al., 2022). Thus, multi-use became one of the key strategies that are to be developed in the coming decades (I&W et al., 2022; OFL, 2020; Rijkswaterstaat, 2014). The wicked problem of the North Sea represents conditions for uncertainty that have not been accounted for previously. Considering the transition from single user group thinking to collaboration on agenda setting and action taking, one must understand the importance of joining resources and knowledge to create robust pathways. The Dutch government has already opened the debate around bringing user groups together. The Polder model of consensus-based policy making was cited by one of the interviewees as a precedence that facilitates collaborative processes through the transfer of practices from one setting to another (Expert interview 5, May 2023).

The Dutch government anticipates the interdependence between the user groups, and the policies it is creating, heavily encourage future collaboration. From that emerged the Consultative Body for the Physical Environment (OFL) an independent consolation forum for government bodies and function stakeholders to have equal representation, from which emerged the North Sea Agreement (OFL, n.d.-a). The ministries part of OFL are the Ministry of Infrastructure and Water Management (I&W), Ministry of Interior Affairs (BZK), Ministry of Economic Affairs and Climate (EZK), Ministry of Agriculture, Nature and Food Quality (LNV), and the Ministry of Housing and Spatial Planning (VRO) (OFL, n.d.-a). It is important to note that OFL's North Sea Consultation (NZO) was the interinstitutional space that facilitate the agreement being reached. To this, only I&W, LNV and EZK represented the government, and to the dialogue user group representatives were included (NZO, n.d.).

3.1.2.Institutions

The Interdepartmental Directors North Sea Consultative Body (IDON) represents an instrumental body that coordinates policy and management of the Norths Sea, by bringing together all the ministries and government agencies that have responsibilities over activities conducted at sea (Casimiro & Guerreiro, 2019; Noordzeeloket, n.d.-e). According to their website, the parties involved are "Ministries of Infrastructure and Water Management, the Environment (chairman), Economic Affairs and Climate Policy, Agriculture, Nature and Food Quality, the Interior and Kingdom Relations, Defence, Finance, Justice and Security, Education, Culture and Science", with Rijkswaterstaat and Coast Guard as implementation agencies (Noordzeeloket, n.d.-e). This collaborative approach to decision-making has been at the centre of developing the marine spatial plans that are currently in implementation. This cross-departmental organisation represents an opportunity for principled engagement, as agendas are developed and set by people responsible for user function decision-making in a collaborative setting, creating mutual trust between participants. Among the ministries that participate in this effort, the Ministry for Infrastructure and Water Management emerges as the lead coordinator of activities and decision-making, and it is seconded in connections by the Ministry of Economics and Climate policy, and possibly by the Ministry of Agriculture, Nature and Food quality (Geurts, 2019). As it is implicated directly in the process of spatial allocation for each function and could be considered the leading actor of the network. Its subagency, Rijkswaterstaat, and the Coastguard are the implementors and monitors of joint decisions, facilitating the resources required for acting on joint goals.

The Ministry of Infrastructure and Water Management (I&W), as previously mentioned, is the coordinating body for North Sea policy and management, this is the case not only for national level but also for representation at regional and European level (I&W, 2021). When analysing the actions on the implementation programme of the 2022-2027 North Sea programme, I&W is proposed as a leader in all policy and conflict resolution points that concern general planning, serving as a co-lead along LNV for actions regarding marine ecosystems, and as sole leaving actor on matters regarding maritime shipping (I&W et al., 2022). Thus, I&W is not only a coordinator but also responsible for the shipping function through its organisational structure. Rijkswaterstaat is the oldest and largest executive body of I&W, and oversees infrastructure work both onshore and offshore, its resources are critical for implementation and monitoring, and it is reaching the capacity in terms of staff and funding represents a vulnerability for the plans set in motion (I&W, 2021). The relationship between the Coastguard and I&W differs from the previous one, as the ministry is involved in establishing the action agenda of the Coastguard, as it also collaborates with other ministries that are relevant for different actions at sea.

I&W is the ministry responsible tough Rijkswaterstaat for the oversight of sand extraction activities within the Dutch North Sea. This chain of decision-making is a consequence of Rijkswaterstaat's responsibilities over regulating flood risk management and water quality, thus Rijkswaterstaat issues permit for sand exploitation and naturally oversees the coordinating and monitoring aspects of this activity (I&W et al., 2022). Despite sand extraction being an activity that has strong links with maintaining the Dutch coastline and contributing towards land reclamation, there were no representatives of this group involved in the establishment of the North Sea Agreement (OFL, 2020; Wageningen University & Research, 2022).

The dedication for a transition towards a more sustainable economy is expressed by the government through having a joint Ministry for Economic Affairs and Climate (Rijksoverheid, n.d.). This ministry is responsible for attaining the international goals, regarding climate action, that the Netherlands has endorsed. It coordinates the responsibility and coherence of the Climate Agreement (EZK, 2022). This also implies taking the forefront towards realizing an energy transition, for the scope of this research the most apparent being the deployment of offshore wind energy in the North Sea. For this, EZK takes responsibility for the tenders offered for future offshore windfarms based on the Offshore Wind Energy Act and assessment focused on space, environmental and monetary efficiency (I&W et al., 2022; RVO & BZ, 2021). The Dutch Enterprise Agency (RVO) is a subagency of the ministry that also undertakes assignments from LNV and I&W, it aims to be an organization that bridges between state and private actors (EZK, 2022; RVO, 2021). The State Supervision of Mines also falls under the ministerial umbrella of EZK and is responsible for sea floor related activities, such as cables and pipelines and sand extraction (Noordzeeloket, n.d.-c).

The Ministry of Agriculture, Nature and Food Quality is the governmental body responsible of both the fishing, aquaculture, mariculture, or other activities that concern the food production of the Dutch EEZ, as well as the conservation efforts of maritime ecosystems (LNV, 2022). These are also the actions that are led by LNV in the North Sea Programme (I&W et al., 2022). The Dutch Food and Consumer Product Safety Authority (NVWA) is a subagency of the ministry that, in the context of the North Sea, ensures the control of fisheries and enforcement of regulations, although the permits for exploitation are issued by Rijkswaterstaat (I&W et al., 2022; LNV, 2022).

Following the approach forwarded by Dutra et al. (2019) and taking into consideration the uses of the North Sea that fall within the scope of this research allocators, would be placed into two categories, authority holders and users. Based on the work of Geurts (2019) and de Klerk et al. (2021) who have completed extensive research on North Sea stakeholder scoping some organisations can already be identified as being relevant for the specific user function of the sea space that is investigated in this research. Subsequently, these have been placed into two categories according to their position as authority holders, responsible for allocating sea space, implementing, and monitoring of planning policies, and users, either individual or group representatives (Dutra et al., 2019). Despite IDON representing an overarching body where the collaboration is nested, the joint action undertaken by ministries and their subagencies is a legacy of structures that predates the establishment of the institution. A schematical representation of the link between user groups and government agencies that manage them is presented in figure 5.

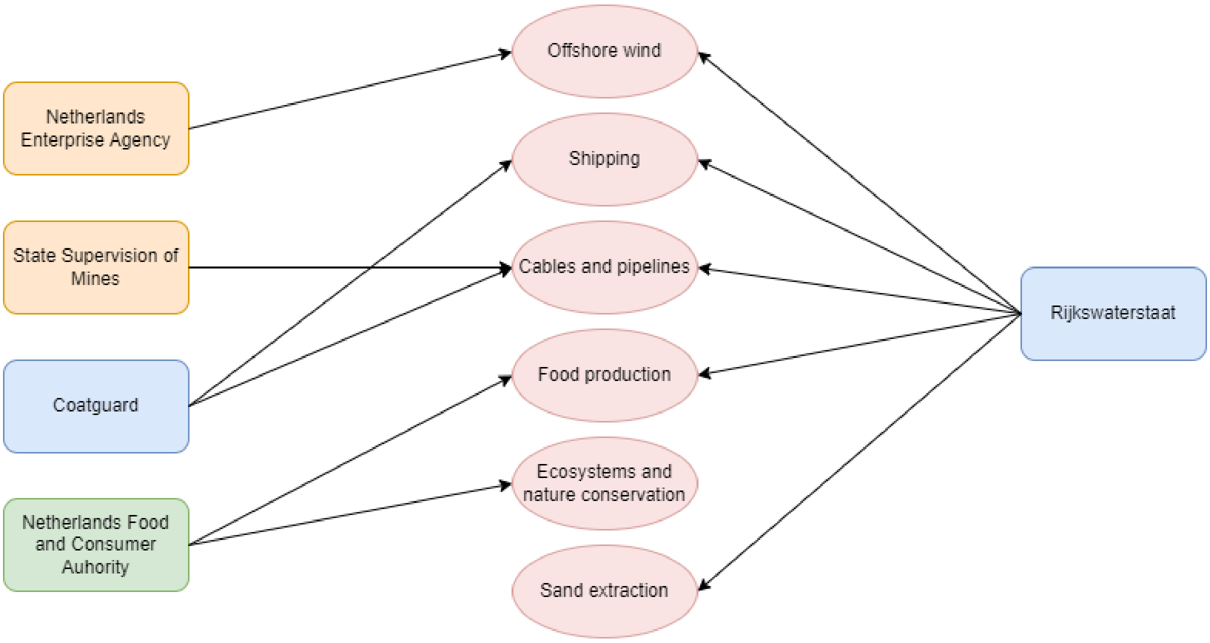

Figure 5:Connection between executive state agencies (rounded rectangles) and user groups (circles)

3.1.3. Governance Dynamics

Emerson et al. (2012) implies that there is a linear relationship between the events, policies and knowledge that amount to being drivers of collaboration and the dynamic relationships that occur between parties. Thus, between the actors one can observe participant engagement, shared motivation, and capacity for joint action. These can be observed if the general governance map is divided into functions and understanding the collaborative process among the different actors. The governance map is visually presented in figure 6.

The process that links the actors of the offshore wind energy function is presented step by step in the Dutch Offshore Wind Guide. Through the National Water Plan, EZK and I&W allocate exclusive areas for the development of windfarms (RVO & BZ, 2021). The process is guided by the roadmaps created in consultation with user group representatives. This action reflects the position of the governmental agencies as allocators, but consultation in policymaking with the private sector represents an opportunity to build trust for developers ((RVO & BZ, 2021). The environmental impact assessment is commissioned by RVO on behalf of EZK and I&W, with the costs being covered by the state (RVO & BZ, 2021). Tender allocation and process are coordinated by RVO, with the winner of the bidding process being appointed by the minister (RVO & BZ, 2021). There are certain requirements that the bidders must fulfil, despite that there are characteristics of the wind warm itself that are discretionary to the developer, also there are procedures set in place for developers to gain subsidies from the state (RVO & BZ, 2021). It can be apparent despite the bureaucratic nature of the process there is space left for the users to tailor their projects. The grid connection is commissioned by the state owned TenneT, as the Transmission System Operators (TSO), which decreases costs and potential issues that may arise due to decentralisation (RVO & BZ, 2021). The construction and operation are overseen by Rijkswaterstaat (RVO & BZ, 2021).

As previously mentioned, there are quotas of conservation space that must be left outside of economic use, as well as untouched by human action (European Commission, 2022). There are knowledge gaps further investigated in chapter 3.3. Some of which are also acknowledged in the ecosystems chapter of the spatial planning programme reflecting the relationship between the distinct functions. The path dependent route encourages us to believe that offshore wind takes precedence over the other uses, at least for the areas further away from the coast. The nature conservation sites are overseen by LNV, and the enforcement and monitoring of fishing within Natura 2000 and MSFD sites is the objective of NVWA (I&W et al., 2022). For the entirety of the North Sea the fishing and aquaculture permits are issued by Rijkswaterstaat on behalf of I&W. Compliance with regulations on vessels and monitoring of fisheries falls under the jurisdiction of NVWA (I&W et al., 2022).

When looking at cables and pipelines there are certain restrictions of proximity that must be respected when installing a new cable, the clearance is 500 meters for electricity and rises to 750 for telecommunication use (I&W et al., 2022). There are desired routes that are mentioned in the energy roadmaps that already give the direction of zones for installing such cables, these are set through the energy roadmap, issued by EZK (I&W et al., 2022; RVO & BZ, 2021). After installation, the cables and pipelines become the responsibility of the operators, and their damage or malfunction must be reported to the supervision body (Noordzeeloket, n.d.-b).

The maritime transportation within the Dutch jurisdiction is overseen by I&W, through Rijkswaterstaat and planning Coastguard activities (I&W et al., 2022). According to the North Sea Agreement, the Dutch Government would have responsibility over establishing shipping routes beyond the 12-mile zone, in accordance with the wind farm developments (OFL, 2020). This guidance would fall onto the Coastguard, which would be funded accordingly (I&W et al., 2022).

As in many of the previous mentioned areas of interest, sand extraction is directly overseen by Rijkswaterstaat, further consolidating its central position within the governance structure (I&W et al., 2022). There are two aspects of the extraction of sand that are encompassed in the Earth Removal Act (to be incorporated in the Environmental and Planning Act); these are extraction for coastal preservation and for construction use(I&W et al., 2022). All policies, procedures, coordinating and enforcement activities fall under Rijkswaterstaat according to the North Sea Programme 2022-2027 (I&W et al., 2022).

The North Sea Programme represents an opportunity for multiple ministries to collaborate on spatial planning, with I&W, LNV, EZK and BZK being the authors. Following the processes established during the previous programme cycle, for 2022-2027 the emphasis of multi-use is (I&W et al., 2022) placed on the opening wind farm areas to nature, passive fishing and aquaculture, and hydrogen production (I&W et al., 2022). This was supported by the requirements set for the bidding process overseen by EZK. These represent a novel approach, as it integrates multi-use in the design of wind farms, developing the knowledge that was cited as lacking for previous projects (Spijkerboer et al., 2020).

The Dutch government is taking steps towards integrating formal and informal knowledge from the various user groups within the scope of this study. It has taken steps towards affirming its commitments towards international treaties and agreements set on alleviating climate change effects, and this also entails institutional adaptation. The gap between the Dutch government and the user groups it is bridged by the OFL and the North Sea Consultation (NZO), with the former facilitating the latter. These are focused on the three main themes of transition that are planned for the North Sea: energy, nature and food (Noordzeeloket, n.d.-f). This coincides with the general trend present across the Dutch government to seek external knowledge and advice, which van den Berg (2016) attributes to the desire of legitimising policies through the eyes of the stakeholders. Thus, the stakeholders brought to the table of NZO are representatives of government branches (I&W, LNV, EZK) and industry representative associations, NGOs focused on conservation and TenneT (Noordzeeloket, n.d.-f). NZO has an independently appointed chair. OFL is the wider consultation forum, that covers all physical infrastructure, and its members are appointed by I&W according to current legislation (OFL, n.d.-b). NZO was established as a means to promote participatory maritime planning after differences between state and private parties have been found (OFL, 2018). This organisational cluster ensures that the societal and industry momentum that led to the North Sea Agreement is translated into policies and implemented in planning strategies. It also reduces the likelihood of expected resistance to implementing policies, as a consequence of participatory trust. This trust-based process also ensures that the common denominator between conflicting parties could be open to negotiations in an equal environment. Despite that, fisheries representatives, for example, have expressed grievances over their interests being taken into consideration in this process. Hatenboer et al., (2023) found that there are tensions between nature conservation organisations and the fishing industry that are predating the establishment of this organisational cluster. These originate from the advancement of termination of bottom-disturbing fishing methods that have extreme economic importance for the Dutch fishing fleet. The authors also found that future uncertainties are also the reason why this user group is reluctant to agree to designate a space for conservation with the fear that these are decisions that cannot be undone. There are also uncertainties regarding the exact breakdown of the transition fund, and its impact on the fleet, that create financial distrust between parties involved in the North Sea Agreement (Hatenboer et al., 2023). Similarly, there can be questions if the forums established are inclusive enough, as sand exploitation is a topic that has failed to be tackled by the North Sea Agreement.

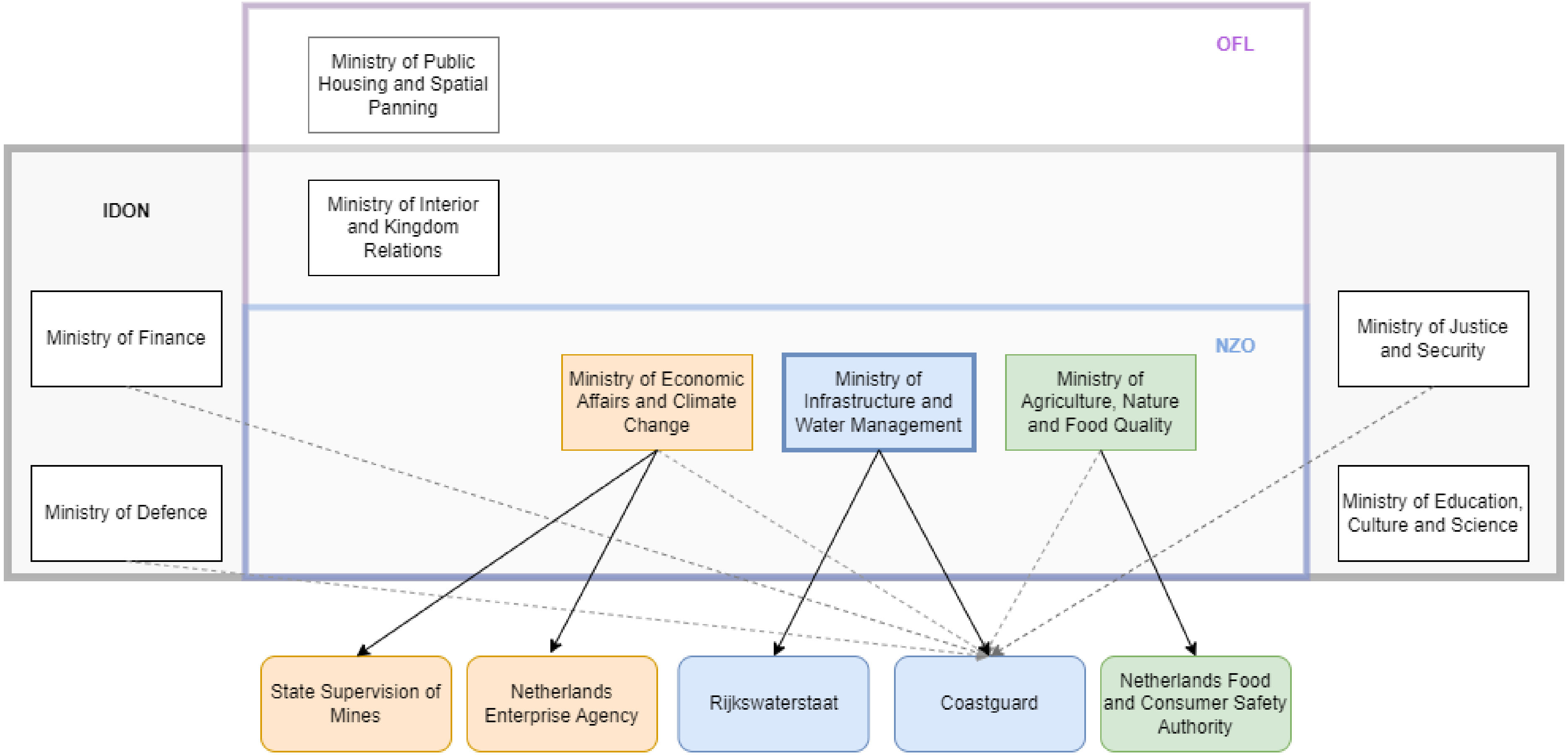

Figure 6: Governance map of the North Sea, with representative ministries (rectangles) represented based on their participation in IDON, OFL and NZO respectively, and their affiliated governmental agencies (rounded rectangles); the Ministry of Infrastructure and Water Management is highlighted as it is the chair of IDON; straight arrows represent direct appointment of agenda of issues regarding the North Sea, dotted arrows represent commissioning of certain activities on behalf of ministries

3.1.4. Lock-ins

There are multiple dimensions of trust that affect the dynamic of this system, on the one hand, there is the trust in the democratic process and relationship with the authoritative bodies, and the trust in representation of all stakeholders involved in the system. Trust in planning strategies facilitated the evolution of offshore wind and lowered the costs (Expert interview 3, May 2023). This was facilitated by the emphasis placed by I&W on offshore wind. The opposite is currently happening for the transition towards sustainable food systems, through the decommissioning of more traditional fishing methods. This transition is facilitated through a fund established by the government (Koning et al., 2021). There are uncertainties that are yet to be addressed, which led to the fishing representative organisations withdrawing from OFL. Their protest represents a precedent that can create further distrust within the collaboration dynamics. The fact that the fishing industry already is concerned with assigning uses of space as becoming constrictive raises the question if this is the case for other stakeholders.

There are systems uncertainties and knowledge gaps yet to be fully investigated. In order to overcome those in policy making, decision-makers are elected to balance the unknowns and prospects of the systems. This can be influenced by the amount of time spent in office and could limit adaptation efforts, a typical long-term process, to shorter timeline (Expert interview 6, May 2023; Stakeholder Workshop, 2022). Another concern could arise from the preference for offshore wind due to its economic prospects. Targets are set regarding the capacity to expend this use of the sea. This creates a policy bias in favour of this use, that can affect long-term policy-making. One example that could already be observed is emphasis placed on multi-use combinations that occur within wind farms (more information in the following chapter). The tools and mechanisms used by the state to monitor the evolution of this system rely on a limited number of agencies. These may become a constricting factor due to the amount of activities planned for the coming decades. Any issues that may arise in terms of personnel and resources may lead to near misses, accidents or delays that can have impacts on the day-to-day functioning of the system.

The pressures of the current geopolitical context were topics that emerged after conducting the interviews that pose governance challenges. In that regard, experts in the field expressed their concern over oil and gas having its decommissioning delayed due to the Russo-Ukrainian War (Expert interviews 1 & 3, May 2023). This may impact the attainment of carbon emission targets and possibly delay the conversion of infrastructure.

3.2. User groups

RsQ: How do different user groups interact and what are potential conflicts that might occur in future collaboration?

Building on the information gathered in the previous section, it is clear that all the decision-making structures and forums that influence the policies and planning for the North Sea are set in motion by a small number of governmental agencies which have direct contact with the user groups. The most prevalent of which is Rijkswaterstaat, as it is central for the efficient management of the entire Dutch EEZ (figure 8). This could also represent a point of vulnerability, especially due to staffing, resources and capacity of supervision, as well as an opportunity to efficiently manage all the uses through one institutional entity.

This section will start with a **brief description of each user group that aims to present the status of the function, future targets, possible grievances and collaboration opportunities. Using this information, an overview of the interactions between functions will be conducted. Subsequently, three interactions that are found to be most relevant will be analysed in depth**. The following table summarises the scope of each user group that is analysed in this research, the formal institutions that manage the evolution of the user groups with respect to the resource, and organisations that have been found relevant for the group based on previous research.

Table 3: User group description with activities that are encompassed in the scope of this research, breakdown of actors as either governance resource allocators or relevant sectoral collaborators, compiled from Klerk et al., 2021 and Geurts, 2019

Use	Scope	Allocator	Users
Offshore wind energy	Entails the installed offshore wind capacity and the planned developments within the Dutch EEZ, it also entails other hybrid means of harvesting renewables at sea where wind power is a dominant component	I&W EZK Rijkswaterstaat National Enterprise Agency	Netherlands Wind Energy Association, Top consortium for Knowledge and Innovation Offshore Wind, Growth through Research, development & demonstration in Offshore Wind Consortium, Confederation of Netherlands Industry and Employers, WindEurope
Cables and pipelines	Entails to all cables used for electricity transportation; focus on the role of pipelines for the sustainable energy transition, within Dutch EEZ	I&W VRO (unsure) Rijkswaterstaat Coastguard State Supervision of Mines	TenneT
Shipping	Entails transportation at sea for commercial purposes, maintenance or infrastructure development, excludes leisure activities, within Dutch EEZ	I&W Rijkswaterstaat Coastguard	Port of Rotterdam, Association of Rotterdam Shipbrokers and Agents, Royal Association of Netherlands Shipowners, Netherlands Shipmasters' Associations, Dutch Pilots, Rotterdam Terminal Operators‵ Association, Shipping Advisory Group North Sea
Food production	Refers to commercial shipping and mariculture (sea farming and shellfish production), within Dutch EEZ	I&W Rijkswaterstaat NVWA	North Sea Farm Foundation, Dutch Flat Oyster Consortium, Unity Makes Strength Foundation, VisNed, Netherlands Fishing Alliance (Vissersbond), Topsector Agri & Food
Ecosystems and nature conservation	Refers to nature conservation and implementation of nature-based solutions in order to protect species above	LNV NVWA	North Sea Foundation, World Wildlife Fund, Greenpeace, Nature and Environment Foundation, Netherlands Bird Protection, Society for the Preservation of Nature

	and below the sea surface, within Dutch EEZ		
Sand exploitation	Refers to the exploitation of mineral material for commercial or conservation use, within Dutch EE	I&W Rijkswaterstaat	EcoShape Waterbouwers

3.2.1.Current state

Offshore wind

The offshore wind is currently at the centre of agendas and plans made for the North Sea, with the continued development of new farms seen as indispensable in the transition to sustainable energy (I&W et al., 2022; OFL, 2020). This resulted in policies that are lenient towards integrating uses in wind farm areas. Thus, adjustments were made to the tendering process that resulted in an increase in collaboration mandating the allocation of space (RVO & BZ, 2021). This is apparent in the diversification of entities that are involved with the user function representatives. NWEA is the dominating organisation that links the private, knowledge generation, NGOs and policy-making parts of the offshore wind landscape of the North Sea. The organisation aims to use its influence and representational power with regard to the user group to promote its goal of 70% energy from renewable sources until 2030 (NWEA, n.d.). This target matches the ones set by the government in the National Energy and Climate Plan, albeit it mentions possible limitations in terms of the alignment of grid capacity with offshore production (EZK, 2021). This concern is somewhat mirrored by the focal points proposed by NWEA, although there seems to be a confident message of sustained increased demand for the coming decades (NWEA, n.d.). Naturally, these ambitions match the current promoted in favour of all wind energy in Europe, and the key advocator for that is Wind Europe, which coordinates NWEA with other national counterparts (WindEurope, n.d.). Knowledge seems to be a topic central to the development of the user group, as the acceleration of technology innovation and knowledge for decreasing production costs are themes that have brought together multiple consortiums. These environments are also fostering the development of information regarding the increase in demand for multi-use. Top consortium for Knowledge and Innovation Offshore Wind and Growth Offshore Wind Consortium are two organisations aiming to facilitate research, development and innovation, through exchange of information across institutes and with the private sector (Geurts, 2019; Grow, n.d.; Topsector Energie, n.d.).

The North Sea Programme 2022-2027 reflects the direction towards including other uses in areas designated for offshore wind. The other uses that are furthest in development to be combined with offshore wind are the ones linked to food production (I&W et al., 2022). Nature inclusive designs and less invasive installation and operation procedures are also sought to be developed to dampen the impact the growing industry will have on the environment and on potential ecosystems services. This can become a topic of contention for representatives of businesses and entrepreneurs, as the emphasis for one activity and the decrease of another in the same geographical area (Ebbers, 2019).

Cables and pipelines

The diversification of means of harvesting renewable resources from the North Sea is dependent on the connection to the national power grids and the capacity and demand of onshore systems (Stakeholder Workshop, 2022). TenneT is the sole stakeholder identified as part of the cables and pipelines subsystem both by de Klerk et al. (2021) and Geurts (2019). This does not translate into a less relevant user group, as there are two components to this group and both are highly relevant for achieving the sustainable energy transition proposed for the Dutch North Sea (I&W et al., 2022).

(I&W et al., 2022). TenneT has a unique position within the decision-making landscape as it is owned by the Dutch Government and has been designated as the sole grid operator for the Netherlands, connecting any new developments with the existing grid (RVO & BZ, 2021). This procedural standardisation is aimed to decrease transaction costs and takes advantage of economies of scale (RVO & BZ, 2021).

The logistics of cables supporting the transition towards cleaner energy implies not only new routes to be determined for electricity but also coordinated landings points. These landfalls must follow the demand on land and serve industrial clusters, for example, with shorter distances being most desirable. Furthermore, it is important to note the international aspect of grid connection between North Sea countries, as some of the windfarms are also used for energy export (I&W et al., 2022). The creation of corresponding energy hubs will also have an effect on the trajectories of underwater cables (TNO, n.d.).

The emphasis on renewable energy comes with the decommissioning of traditional energy stemming from oil and gas. As is aimed to satisfy the enormous amount of energy required from industry, agriculture and the built environment. It is certain that to promote the transition of entire economic sectors there are other types of energy from the North Sea that could suit the task better (I&W et al., 2022). For instance, hydrogen is perceived as an important part of the energy transition. Research is being conducted that aims to repurpose gas infrastructure with hydrogen (Peters et al., 2020a). Another use for existing pipelines would be for carbon capture storage, this would further reinforce the transformation of oil and gas infrastructure to support climate goals (I&W et al., 2022). These activities are also requiring further research. The interviews with experts from the energy field and researchers have highlighted the importance of the geopolitical climate in the conversion of infrastructure, with possible delays affecting climate targets (Expert interviews 3-5, May 2023). Another threat that has become apparent due to the current geopolitical environment is related to cybersecurity. It was mentioned during the interviews that these are threats that are not currently accounted for and could pose an energy security threat (Expert interviews 1 &3, May 2023).

Shipping

Transportation across the North Sea reflects the other activities that occur as ships transport goods and are required for the construction of all infrastructure and its subsequent maintenance. With the North Sea already being intensely used for maritime transportation, it is important to plan for a projected increase in this use. This would originate from a range of factors varying from general trends of economic development on land, as well as greater exploitation of resources at sea, with climate change opening new navigation routes that would also impact the region (de Vrees, 2021).

The potential growth of the North Sea transportation system is highly reliant on the capacity of ports to process ships through (Stakeholder Workshop, 2022). The Port of Rotterdam is a node of communication between transportation at sea and on land. With the largest seaport in Europe expanding, comes the reconsideration for the space for ecosystems, as a Natura 2000 site has been altered to make space for this function (Informatiehuis Marien, n.d.). The enlargement of the port correlates with the expansion of offshore wind, as space is needed for developers and their ships, the port itself is tested for wind energy suitability, and is to be connected directly with one of the offshore wind farms (Port of Rotterdam, n.d.). This is just one aspect of the symbiosis occurring between shipping and offshore wind, as smaller vessels are proposed to be allowed to cross through wind farms compared to past policy of no access. Due to the high traffic, separation schemes had to be set in place as well as anchorage zones established to avoid vessel collision. Safety is a concern that is most often raised by representatives of ship owners and pilot associations. This would also entail the joint collaboration of operators across the region, as approaches towards shipping lanes and safety zones vary between countries (Nilsson et al., 2018).

Food production

The transition towards a sustainable food supply originating from the North Sea is heavily reliant on the carrying capacity of the ecosystem, and it has deep implication on Dutch society and culture. With many communities having their identity and development tied to fishing, it is natural that any decisions taken towards transforming this user group would be met with scepticism. Two branches of the Dutch sea food supply are observed closely in this study: cutter fisheries, of which demersal species, such as sole, plaice and mullet, and oyster fishing (I&W et al., 2022; van Hoof et al., 2020; Wageningen University & Research, n.d.). Pressing issues according to Hatenboer et al. (2023) originate in the expansion of marine protected areas, uncertainties regarding the fleet transition fund, and reduction of quotas following Brexit. These are creating divides between the fishing group and other user group representatives, as well as differences of opinions within the community on how to best proceed facing the food system transition (Hatenboer et al., 2023). The North Sea Agreement aims to harmonise the fishing fleet to both challenges faced by the industry and with any subsequent EU legislation that might affect which practices are deemed sustainable (OFL, 2020). Understanding the transition towards sustainable food in North Sea implies being aware of its two most important subsystems, fishing and mariculture.

Fishing is conducted through quotas rather than designated areas. Spatial planners have resorted to ban the activity in specific areas instead of allocating space specifically for it, due to the dynamic characteristic of the resource (van Hoof et al., 2020). According to van Hoof et al. (2020) the demersal fishing industry is mostly comprised of family-owned businesses, which have been passed through generations, with fishing as a trade that is essential to communities beyond direct employment. The type of fishing conducted by this industry implies methods that are to be phased out completely in protected areas, and to be adapted outside of these (EU Business, 2023). Considering the change in regime for the fishing industry, the advocacy groups that are representing entrepreneurs in the field have been stating their concern over the justness of the transition. VisNed and Visserond are the two organisations that are relevant for the North Sea fishing. These are involved in informing decision-makers of the perspective of the fishing industry.

In counterbalance, mariculture has become a developing industry in the North Sea. Mariculture is a branch of aquaculture that focuses on cultivation, harvesting and management of various marine organisms, either in their natural environment or in enclosed spaces (Laird, 2001). Since, mariculture is quite a novel term, for the purpose of this research it will be used to reflect the research also found under aquaculture, sea cultivation and literature on shellfish. The North Sea Agreement placed the emphasis for the need for developing this field, which is also translated through action proposed for integrating mariculture with other uses at sea during the 2022-2027 programme (I&W et al., 2022; OFL, 2020) The North Sea Farm Foundation is the representative organisation for seaweed farming, it brings together both the private sector, comprised mainly of small companies seeking to innovate in the field, research institutes and LNV (North Sea Farmers, n.d.). Similarly, the Dutch Flat Oyster Consortium is a representative for the industry, seeking to restore the native oyster species of the area, following the decrease of bottom disturbing practices (POC, n.d.).

Ecosystems conservation

It is generally believed that nature would benefit from being kept out of economic activities in specific areas, or that existing activities should diminish to make space for sea life (Stakeholder Workshop, 2022). Ecosystems conservation policies will be affected by trends in increased space for nature and the development of nature-based solutions for other industries at sea. These solutions are being campaigned for by associations and NGOs. The North Sea Foundation is one of the longest lasting organisations that has its work focused on mitigating the ecosystem of the sea. The foundation lobbies and generates policy recommendations, as well as research on opportunities and risks raised by the proposed expansion of offshore wind (Stichting De Noordzee, n.d.). The Nature and Environment Foundation has a similar role, in campaigning for policymakers to adjust legislation and to take steps towards the conservation goals that the organisation promotes (Natuur & Milieu, n.d.). The already mentioned organisations are mitigating different aspects of the ecosystems, but mostly focus on life below water. The Society for Nature Preservation has part of its focus on the preservation of the sea and coastal landscape. This civic organisation connects society through representation for policy design. Furthermore, there are branches of international organisations such as WWF and Greenpeace that are mitigating largely for the same goals. There are also advocating groups that are more specialised, some could focus on above sea or below sea fauna specifically (Boeschoten, 2022). During the stakeholder workshop questions were raised by the participants regarding advocation for specific species (Stakeholder Workshop, 2022). Similarly, concerns were expressed over the conservation of benthic fauna, as there are limitations to the benefits MPA can have on such dynamic ecosystems (Stakeholder Workshop, 2022; Weinert et al., 2021). All NGOs identified in this section have actively collaborated in the discussion and the following establishment of the North Sea Agreement. They are also taking on collaboration with other stakeholders and companies that are developing in accordance with their respective goals. Another means of enhancing consciousness over offshore activities and their impact on the ecosystem is through nature-based solutions.

Sand Extraction

Sand extraction is crucial for Dutch coastal defence strategies and considering sea level rise, it will continue to play a role in the coming decades (I&W et al., 2022; Noordzeeloket, n.d.-h). Despite that, it is not a user group that was fully included in the discussion preceding the establishment of the North Sea Agreement. Sand extraction is not only important for reinforcing the coastline but also for various processes of land reclamation, the most important of which is the expansion of the Port of Rotterdam (Noordzeeloket, n.d.-h). Beyond sand, there are other minerals that are also extracted from the seabed such as gravel and shell grit (Noordzeeloket, n.d.-h). The material can be extracted from deep and shallow pits (I&W et al., 2022). The invasive nature of the procedures makes it difficult for coordinating multi-use of space, thus only specific areas have been set aside (I&W et al., 2022). Areas for surface mineral extraction are typically chosen based on cost efficiency, as most suitable areas tend to compete with other uses such as fisheries, oil and gas or shipping (I&W et al., 2022). Following extraction, questions arise regarding the landscape left behind by dredging activities (De Jong et al., 2014).

3.2.2.Multi-use

Considering the scope of the research and limited uses of the sea, one can draw some preliminary conclusions on opportunities and conflicts for shared use of space. An example is one the government gave for the future of wind farms in a collaborative future. This translates in the observed systems through the North Sea spatial agenda for 2050 in which multifunctional use of space was proposed and with the aim of being iterated in future policy design (Rijkswaterstaat, 2014). Some of the possibilities mentioned were the combination of offshore wind with activities that have a limited impact on the seabed, such as fishing and mariculture; combining aquaculture with mariculture; or using space beneath sea farms for anchorage (Rijkswaterstaat, 2014). This approach is more apparent in the maritime planning programmes that have been issued recently, and more knowledge must be gathered to successfully implement these ideas (I&W et al., 2022; Rijkswaterstaat & EZK, 2015)

An example of this development direction is the Borssele wind farm opening to passage of ships meeting specific requirements, through pre-determined corridors. A mussel farm is also being developed with tendering plans for fixed point fishing being overseen by LNV (Noordzeeloket, n.d.-a). This represents a working example that more than two uses could be implemented in one constrained geographical area. Multiple compatibilities between two uses can be identified in the table 4 below. Despite compatibilities between more than two user groups being theoretically possible, the Borssele and Hollandese Kusk seem to be the only projects to have an advanced level of planning and execution for the coming decade. There are also some limitations to this approach, as co-use activities start only after the completion of the wind farm, and the area is entirely closed in that period for safety (Noordzeeloket, n.d.-d). Although this vision perpetuates the idea that offshore wind remains at the centre of such developments, there are significant changes from the previous approach of restricted access in wind farms. The 2022-2027 programme does not seem to offer similar guidelines on how multi-use should occur in areas without offshore wind. As it derives its core from the North Sea Agreement, in which conservation, fisheries and wind are the main foci (OFL, 2020). This narrow focus of multi-use can represent a vulnerable point, as coordinated efforts in one geographical area require time and knowledge to develop. Hazards and risk assessment also occur on a project by project basis which makes it difficult to coordinate and transfer system awareness.

Considering the development trends there are also some incompatibilities between uses of the sea, as well as disagreements between the stakeholders of the same group. Geukes et al. (2020) interviewed representatives of multiple organisations that took part in the negotiations preceding the establishment of the North Sea Agreement. They highlighted conflicting views between the representatives of the fishing industry and those of NGOs. The advocators for conservation efforts believed that the fishing industry has a narrow approach towards what aspects of the sea can be considered healthy and can sustain exploitation. Whereas, the NGO's representatives believe that the traditionally used practices are at the origin of why such intense conservation efforts are needed.

The technological evolution of ships may result in means that connect shipping activities directly with the power sources at sea, either as electricity or hydrogen. They raise their own manoeuvrability and safety issues and are not fully developed in the 2022-2027 programme, although it is an interaction sought in the 2050 agenda (I&W et al., 2022; Rijkswaterstaat, 2014). A larger scale version of this concept are hubs that would connect the different wind farms, that would ensure the conversion between energy forms and countries, through fewer connections carrying larger amounts of energy. This project is envisioned to take the form of an island (TenneT, n.d.). There are certain combinations of functions that are not compatible and are expected to remain so in the future. One example would be shipping anchorage areas and cables and pipelines. These zones are important, especially with the projected increase in shipping frequency and the likelihood of storm events. Another example would be between cables and pipelines and conservation. As the process of installing such infrastructure is disruptive to the sea floor it contradicts the conservationist ideas of protecting ecosystems both below and above water. However, there are means of integrating nature-based solutions such as porous rock armour that would protect the cables or pipelines as well as create artificial reefs.

A schematic summary of the interactions between sectors that are within the scope of the research is presented in table 4. The traffic light system was used to highlight the degree of compatibility between every combination of two at a time. Green refers to a wide degree of compatibility of use within the same maritime area, yellow implies that there are technical restrictions that make only some of the activities available for co-occurring, while red means that the two identified activities cannot occur within close vicinity. The interactions that were further analysed in the following section have been highlighted in the table.

Table 4: Dual compatibility between user groups

	Offshore wind	Shipping	Cables and pipelines	Food production	Ecosystems conservation	Sand extraction
Offshore wind		Due to necessity of safety and freedom of shipping, crossing through offshore wind infrastructure is restricted. Some ships can pass through established corridors	Required for establishment of wind farms	Restricted previously, soon to open for some activities through pilots in existing areas and already included in tender process allocation for future development	With expansion of offshore wind there will be more nature-based solutions for mixed use of space	Incompatible
Shipping	Projected increase in traffic corresponding to increase in infrastructure (maintenance and installation)		Co-use possible along shipping routes	Compatible with fishing, less compatible with mariculture	Restricted	Co-use possible
Cables and pipelines	Wind farm developments determine routes for new cables and power stations	Co-use possible, with certain exceptions, such as anchorage		Incompatible with bottom disturbing fishing techniques. Compatible with offshore farming	Some cables and pipelines may not be decommissioned after transforming into artificial reefs during their life span	Incompatible
Food production	Passive fishing and mariculture	Fishing and shipping present possibility of co-use. Stationary equipment may be disturbed by traffic	Co-use possible with fixed structures		Restricted	Incompatible

Ecosystems conservation	Currently, areas designated for Natura 2000 are restricted for windfarms, but open to integration on larger areas	Reduced traffic	Disturbing practices, restricted	Areas closed for fishing		Incompatible
Sand extraction	Incompatible	Co-use possible	Incompatible	Incompatible	Incompatible	

Offshore wind + food production

Following the current spatial plans, the two sides of food production systems influence the bivalence of the interaction between this use and offshore wind. Considering the constraints placed on the fishing industry following the transition towards sustainable food production, different methods of harvesting food resources from the sea seem to be favoured. The North Sea agreement promotes mariculture and fixed-point fishing as the pillars of integrating these two user groups' interests in one geographical area (OFL, 2020). This highlights the dual nature of opportunities and conflicts arising within the food production group. For example, Geukes et al., (2020) mentioned how fishing representatives may be reluctant to the placement of mariculture within farms due to competition for nutrients. One representative interviewed by Geukes et al., (2020) expressed concerns over the potential rivalry for nutrients between seaweed and mussels farms. The authors further call into question the ability of the North Sea Consultation (NZO) to represent an inclusive debate in which all stakeholders can successfully express their views. Despite the concerns discovered by the literature, throughout the interviews conducted for this study, only positive remarks were made regarding the capacity of NZO to bring stakeholders together and facilitate users reaching trade-offs.

On the one hand, the interaction between offshore wind and fisheries can only occur within certain parameters. The use of traditional fishing methods is restricted within wind farms. When discussing with experts of offshore wind, decommissioning of bottom trawling fleets will occur with or without the support of the industry during the NZO agreements (Expert interviews 3 & 5, May 2023). One expert cited the differences in economical importance between the two user groups and ecosystems impacts these have as reasons that reinforce the decommissioning (Expert interview 3, May 2023). The practitioner also mentioned that throughout this process, the knowledge of the fishing communities should not be lost, and the people should be integrated in different branches of the economy (Expert interview 3, May 2023)

On the other hand, there is increased interest in the farming potential of the Dutch North Sea. The carrying capacity of the system and hydrodynamic effects must be investigated before the tendering of multi-use areas occurs (Paulson, 2022). Circling back to the example of Borssele farm, there are entrepreneurs that are ready to build a large-scale seaweed farm and engage with the windfarm operator. For these clear procedures have to be set in place as, it became apparent, the technical requirements of offshore farm take precedence in these areas. Regardless, these joint operations are most viable in wind farms located relatively close to the coast, due to nutrient availability and ease of transportation (Rijkswaterstaat, 2014). Seaweed cultivation is vulnerable to anthropogenic hazards, as chemical and physical pollutants can be accidentally discharged or brought in the vicinity of farms by ships or leeched by the materials used for wind infrastructure (Banach et al., 2020). These pose threats to the suitability of the product to meet the safety standards that were set for with the original end consumer in mind (Banach et al., 2020). This could point to a new dimension required for the risk assessment that must be conducted before establishing co-uses of space. The demand for this product should also match the capacity of installing sea farms in the North Sea.

With the increase of assets that results from multi-use of space comes the increase of vulnerability of a geographical area to be affected by a hazard, thus resulting in multi-risk. One aspect proposed during the tendering process was to have developers of wind farms also be operators of mariculture and fixed-point fishing to reduce transaction costs (RVO & BZ, 2021). This not only raises the economic prospects resulting from attaining sea space for development by investors, but it also rises the damages one party can withstand in case of a hazard. The knowledge developed for integrating uses must also match the risk raised, and one practitioner cannot hold the knowhow for all sea uses (Expert interview 1, May 2023). A discussion with an expert in offshore wind highlighted the value of placing the economic importance of each use when addressing spatial planning for developing sustainable business models for developing a blue economy (Expert interview 3, May 2023).

Offshore wind + ecosystems conservation

Considering the general direction of European decision making that is reflected at the national level, we have observed the prevalence of increased space dedicated to ecosystems conservation.

Considering that 30% of the sea space would be set aside for this purpose with 30% of this quota representing zones of no human activity, there are consequences on maritime planning (European Commission, 2022). This approach favours giving nature time for recovery over intervention for biodiversity recovery. This was a topic also debated during the MYRIAD stakeholder workshop as this seems to have a direct impact over the availability of space for all other uses. Another function of the sea that is also following a general trend, is offshore wind (Stakeholder Workshop, 2022). The determination of the Dutch government to meet climate targets is reliant on offshore wind to play a key role, as wind power is the most technologically advanced renewable currently.

Until recently these two functions were considered mutually exclusive. Currently, Natura 2000 sites could be opened for wind developments, pending biodiversity goals are met and appropriate impact assessments are drawn (European Commission, 2020). Similarly, environmental impact assessments are a mandatory part of the tendering process for future wind farms (RVO & BZ, 2021). The establishment of marine protected areas and the increase in installed capacity are representative of two transitions that are planned for this decade, nature and energy respectively (I&W et al., 2022). The addition of nature inclusive designs to wind farms such as Borssele and Hollandse Kust represent one step towards integrating both uses (I&W et al., 2022). Less invasive installation procedures and further considerations of the use of the infrastructure beyond its productive lifespan could also contribute to co-use (Dähne et al., 2017). However, Geukes et al. (2020) present the duality in conservationist discourse, as one might argue that the overlap between nature and wind developments is beneficial since it tackles aspects related to the climate crisis, another might argue that it exacerbates problems regarding biodiversity loss. This lack of cohesive discourse within groups represents a potential for conflict to arise during future NZO debates. Beyond the original disruption of the ecosystem occurring during the installation of offshore wind, there is research that argues in favour of its beneficial impacts as a refuge for benthic species (Hammar et al., 2015). Although it is important to note that wind turbines are found to be disturbing for birds (Hammar et al., 2015).

A traditional spatial planning approach can be observed through the mandate for conservation area quotas. All practitioners interviewed were asked about the relationship between ecosystems conservation and spatial planning. Another approach, for which input was sought, would be to use ecosystems conservation as boundary conditions for the development of other uses. This mix of methods was proposed and explored in discussions with all interviewees. Within this specific interaction, the tendering process for wind farms could be used to favour projects that facilitate more biodiversity enrichment or are less invasive in the installation process (Expert interview 3, May 2023).

Offshore wind + sand extraction

Looking at the status of the investigated uses in the Dutch North Sea, it is apparent that there is a status quo of incompatibility between offshore wind and sand extraction. These two uses are on their own highly relevant for the Netherland's climate resilience. On the one hand, offshore wind represents the most developed technology to advance in mass the transition towards green energy (I&W et al., 2022). On the other, there is the problem of sea level rise, for which the science has restated its importance, and the use of marine extracted minerals to reinforce defences against this threat (IPCC, 2022; I&W et al., 2022). Currently these two uses are mutually excluding each other, as dredging activities would be damaging to the energy infrastructure placed in the sea floor. The most recent cycle of spatial planning has restated the emphasis placed on offshore wind to the detriment of other uses. The overlap between the Borssele and Hollande Kust wind farms and space for sand extraction has resulted in the withdrawal of exploitation permits, and direct decrease of area allocated for that use (van de Bilt et al., 2018). This is a challenge that is particularly relevant for the Netherlands out of all countries within the North Sea Region due to the subsidence trends that are prevailing along the entirely of the coast, beyond the already mentioned sea level rise. The areas designated for the sand extraction strategy rest largely within the 12 nautical miles of the Dutch territorial waters (figure 7). This area has been set aside for recreation, shipping and sand extraction and is not considered for development of offshore wind farms (Expert interview 6, May 2023).

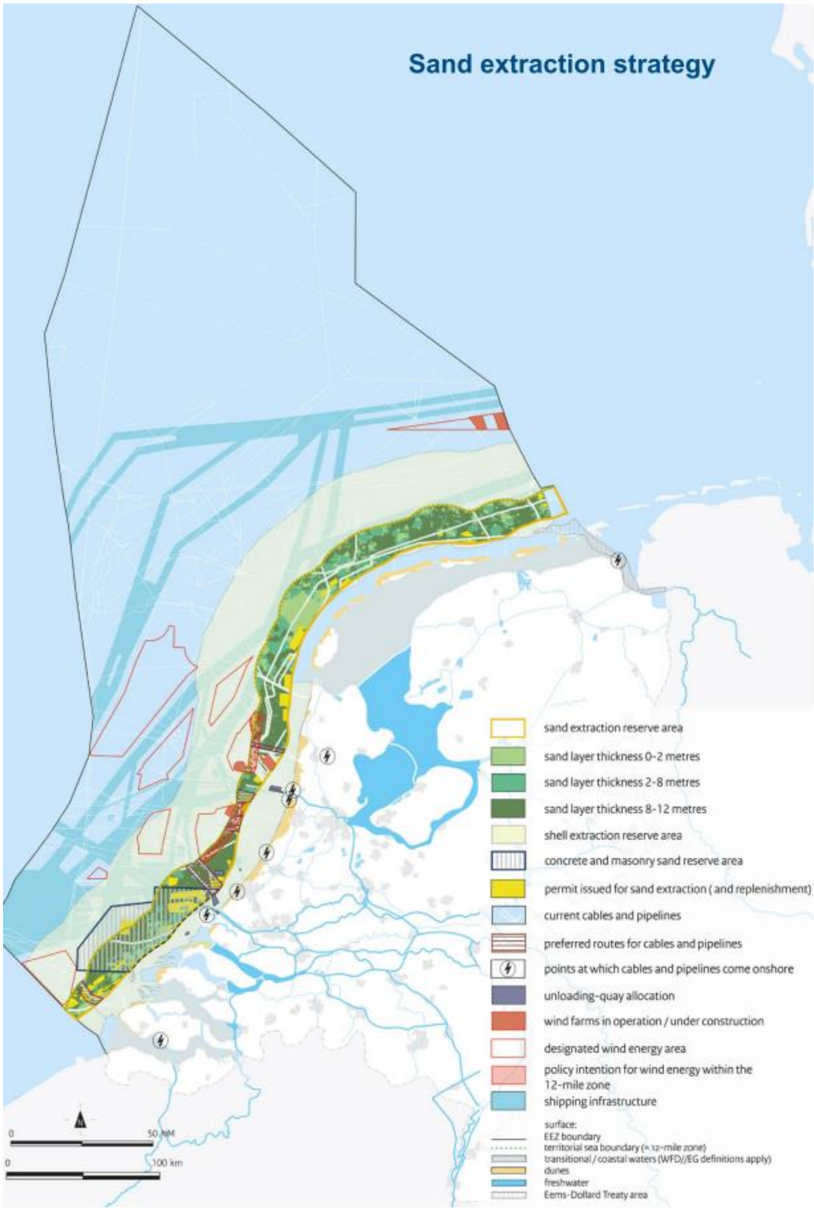

Figure 7: Surface mineral extraction planning of the Dutch North Sea (Noordzeeloket, n.d.-h)

Throughout the interviews, more information was sought regarding the future interaction between the two user groups. Some hypothetical solutions that may decrease clashes in spatial claims would come from the move of offshore wind farms further out sea, leaving navigation routes and sand dredging areas closer to the shore (Expert interviews 5 & 6, May 2023). Another approach could be sequential use, by firstly using suitable areas for sand dredging, then placing offshore wind to also act as artificial reefs and support biodiversity and sea floor repopulation (Expert interview 3, May 2023). Furthermore, it was speculated that the costs of concurrently using sand dredging technology and offshore wind may be too high for the current market setting, as it would require technological innovations to overcome incompatibility (Expert interview 5, May 2023). A more practical remark was raised by a governance practitioner regarding the emissions created by the sand dredging and beach nourishment fleet. As there is no international standard that mandates these vessels to have zero emissions, they are contributing to the problem that they are used towards solving (Expert interview 6, May 2023).

Overall, the importance of both uses cannot be denied for the climate resilience of the Netherlands. When acknowledging that both uses cannot take place in the same area, no conflict can be perceived in the short to medium term. Although, there may be future trade-offs that are required based on the evolution of availability of space in long term.

3.2.3.Lock-ins

The constraints that rise from restricted availability of space already influence the evolution of different uses within the Dutch North Sea. Currently, the reliance on only one renewable resource technology narrows the opportunities for other suitable technologies and may raise problems in the future. This creates a path dependency for the system. Although diversity is a key component of the sustainable blue economy, exploring horizontally only one space intensive resource will place constraints on the areas available for other economic uses. Similarly, ecosystems conservation also represents another factor that influences, not only through space, but also through dictating what practices and technologies could be used. This is apparent in the conflict between fishing communities and conservationists. The willingness to make trade-offs between the different users will impact the evolution of their relationship in a limited space. Although the decommissioning of the bottom trawler fleet comes as a foregone conclusion, it may still pose societal pressure. This is extremely sensitive in a country already affected by disagreement between other parts of the food sector, the farmers, and central government. The reaction of the fishing communities represents a sign of entrenched psychological conservatism, as traditional livelihoods for communities could be perceived as less important for the transition towards a sustainable blue economy. The withdrawal from the North Sea Agreement creates precedence and may make stakeholders feel less valued in joint discussions.

Siloed thinking is still present in this system, and although the spatial planning agendas propose joint assessment, it will continue to occur on a case-by-case basis. Throughout discussions, both during interviews and the stakeholder workshop, it became apparent that there is knowledge regarding both mitigation and adaptation to individual hazards across the system. Even so, it is not centralised or coordinated into one strategy, thus representing another vulnerability of the system.

Sequential use of space for multiple sectors at different times is not a topic that is being explored. Some evidence can be seen in the transition of oil and gas towards carbon capture storage or hydrogen. Another example would be the transition of monopiles into artificial reefs during and beyond their productive lifespan. Also, it is unclear if intended multi-use plans are aimed to be permanent or have any mobility. Currently, it is assumed that increasingly more space will be dedicated to offshore wind and conservation, but not if these quotas of space needed are stationary or could be flexible. This stems from traditional planning approaches that are transferred from land to the sea. A danger to the system comes from failing to be flexible, not only through space but also time.

3.3. Knowledge

RsQ: What are the knowledge gaps present within the system? How can collaborative systems analysis bridge these gaps? What methods can be used to transition from single hazard to multi-risk thinking?

To foster adaptive learning, one must be able to develop on socio-ecological findings to further the understanding of the behaviour of the system as well as how various actions can be taken and what the systems response might be (Emerson & Gerlak, 2014a). The lack of ability to acknowledge the multiple perspectives of the different users, governance and knowledge generators of the system can cause issues when trying to develop comprehensive adaptation pathways. Lock-ins may also originate from competing discourses, and it is inherently linked to power dynamics. There are multiple knowledge generator entities within the Dutch North Sea, the problem that must be overcome revolves around collaborating to develop and use said knowledge instead of a traditional siloed approach. This section aims to investigate the knowledge generating system of the Dutch North Sea that is within the scope boundaries of this research. To achieve that the knowledge gaps of the system emerging from the literature will be investigated. Further, means to alleviate those gaps will be sought with information from MYRIAD outputs will used. Transition from single hazard thinking to multi-hazard thinking is important for DAPP-MR, thus suitability of means identified will be assessed. Throughout this process knowledge and discursive lock-ins will be identified.

3.3.1. Knowledge gaps present within this system

The knowledge required to develop adaptation thinking for a specific area requires an understanding of the system's characteristics as well an interaction between various issues. This research focused on six user functions of the Dutch North Sea, and when iterating on the current state and development trends of co-use some knowledge gaps became apparent. These knowledge gaps refer to the ones that are apparent for the specific user group or co-use. Simultaneously, there are knowledge gaps that affect the entire system. And there are systemic impacts that originate from the management of the region, with each country having its own complex system of granting permits, that facilitated the user functions in in the specific EEZ to evolved in a siloed manner (Schütz & Slater, 2019). These made it harder for systematic awareness at the scale of the North Sea to be feasibly investigated. Even so, studies are emerging regarding the possible cumulative systems impacts corresponding to the current plans of multi-use revolving around wind, there are still aspects that require further knowledge (Gușatu et al., 2021). Considering the co-uses identified previously, gaps emerged from the literature that could be placed in three categories: social, technical and environmental.

Social

The conflicting views between the fishing industry and those who argue for ecosystems conservation has already been mentioned. These represents a type of discursive gaps that are detrimental to the development of future collaborative approaches. The Dutch fishing industry has been constantly changing, but one constant seems to be the reliance of the group on the knowledge developed by fisherman and their adaptation to changes in policies, technology and fish stocks (van Hoof et al., 2020). Fish stocks available within the Dutch EEZ are relevant for both the fishing industry and environmental NGOs (Verweij et al., 2010). Both groups monitor fisheries and have developed measuring units that reflect their key interests (Verweij et al., 2010). The fishing community quantifies the productivity proportional to the material investment, whilst environmentalists look at the reproductivity potential of the fishery. Verweij et al. (2010) also observed that people within the fishing industry experience a shifting baseline view towards productivity of fisheries, as most of them operate with the assumption that the catch rates they experienced at the beginning of their career are the point of refence for how the system is behaving. In contrast, the environmentalists and scientist tend to look at historical data (Verweij et al., 2010). Furthermore, interviews with experts raised the question of placement of fishermen's knowledge in the future of the system. These group harbours knowledge of the sea that could potentially be lost in the transition (Expert interview 1&3).

Another branch of the food systems, mussels farmers have also displayed contradicting views compared to ecosystems conservation representatives (Causon et al., 2022). Research in collaborative decision-making practices has to be tailored to mediate the conflicts between the transition for sustainable food systems and nature to co-occur (Causon et al., 2022). Even more concerning is that Verweij et al. (2010) found even when addressing the same issue, i.e. fish stocks, the interpretations of the findings different between people with a background in economics or administration, policy makers and those with a background in science or operation for environmental NGOs.

Analysing the plans drawn by the Dutch government one can observe the prevalence of co-use that involves as a key player offshore wind (I&W et al., 2022). To ensure a harmonious development of other uses, the government and its agencies have displayed the capacity to evolve and adapt to emergence of the new sector (Schütz & Slater, 2019). The uptake of knowledge in the policy may encompass some of the uncertainties that have not yet been thoroughly researched. One researcher expressed concern over the differences between the timeline of production of systemic knowledge and the pace at which information is needed for policymaking (Expert interview 1, May 2023).

Technical

In order to test the feasibility of certain technologies, as well as their impacts pilot testing needs to occur first. This is prevalent in uses of the sea that are relatively new, such as hydrogen generation and storage or mariculture. The emergence of such niches implies the increase of demand for the final product. There are still uncertainties regarding actions that need to be taken to develop these industries, not only on the public side, but also through regulatory aspects (Jansen et al., 2016). The development of hydrogen technology in the North Sea is aimed to be linked with the decommissioning of existing oil and gas infrastructure (I&W et al., 2022). There are also multiple possibilities regarding the conversion from hydrogen to power and most efficient means of transportation of this new resource (Peters et al., 2020b). These debases are also similar to the ones that arise when discussing the future of CCS (Peters et al., 2020b). These uncertainties are highly relevant for the evolution of the cables and pipelines user function, as routes have to be coordinated with landing zones of connection with onshore infrastructures, as well as are strictly incompatible with other uses such as fishing or sand dredging. Within these uncertainties there are smaller questions regarding the optimisation of nature inclusive designs for certain uses (Expert interview 3, May 2023).

A point that was raised by the experts participating in the stakeholder workshop has been the capacity of the grid to intake all the energy planned to be deployed currently (Stakeholder Workshop, 2022). The participants hypothesised that this dyssynchronisation may occur due to internationally signed agreements by the states and may be exacerbated by lack of timely decision-making action (Stakeholder Workshop, 2022). Gaps between political ambitions and the rate of deployment according to spatial plans may also cause issues.

It can also be a limitation of maritime spatial planning with onshore activities, as siloed thinking may lead to the overdevelopment of one use compared to the demand and the other uses. The current licensing for other uses within existing wind farm infrastructure represents a point of limitation for the power generating systems already installed. Thus, knowledge has to be generated on how the existing power installations can support for example the load of mariculture installations. Simultaneously, there can be changes in the placement of industries at sea or close to the shore to account for the availability of energy. Both cables and pipelines are susceptible to seabed changes. These may affect the initial costs of the project but are alleviated when taking into consideration the lifespan of this infrastructure (Deltares, n.d.).One method of reorganising the activities would be through energy hubs or artificial islands at sea (Expert interview 3&4, May 2023).

Experts have expressed that it is only a matter of time before the Arctic shipping routes will open and will intensify the maritime transportation in the North Sea(Stakeholder Workshop, 2022). There are still technical aspects regarding the reliability of the route and systems that could be set in place for the Northern Sea Route (Kuznetsov et al., 2019). Despite that, the prospects are acknowledged by the government and preparations are part of future spatial planning (Noordzeeloket, n.d.-g). Developing on that, there are synergies between sectors that should be acknowledged when planning for establishing routes at sea. However, there may be uncertainties regarding the transition of shipping vessels through nature reserves areas, and the timeline of expanding both uses.

Environmental

After multiple discussions with researchers in the field mentioned that gaps in the most pressing knowledge gaps are the ones concerning the environmental impacts of industrial scale deployments of economic activities at sea and their cumulative effects on the marine ecosystems (Expert interview 1 & 4, May 2023). Consequently, there are questions regarding the dynamic of wind and possible shadow effects from one wind farm to the other. Similarly concerns have been raised regarding the turbidity and salinity of water layers with possible biophysical changes impacting both the biodiversity and potential fisheries (Bergström et al., 2013; Expert interview 1, May 2023).

With the focus on development of offshore wind being at the forefront of the energy transitions, there are aspects that require further research and are associated with the impacts of built infrastructure at sea. WWF's 2014 literature review on impacts of offshore wind farms captures that there is still a need for a reliable scientific baseline of the status of the environment prior to the infrastructure being built. The same report mentions the suitability of turbines as artificial reefs, and their potential to alter dynamic between invasive and native species. The same topic emerged from discussions with researchers and practitioners (Expert interview 1 & 3-5, May 2023). There can also be opportunities brough by the vertical exploitation of the water column. Although not all implications, such as those on the evolution of species or availability of nutrient in the water column are currently known (Jansen et al., 2016; Schütz & Slater, 2019).

Gaps in single hazard to multi hazard to multi risk thinking

The new area passports introduced by the 2022-227 programme, include risk assessments (I&W et al., 2022). This case-by-case approach prevents planning for mitigating complex risks. The interviewees generally accepted that across the system, more extreme events will occur (Expert interview 1-7, May 2023). Notably, the transition from hazard to risk implies and anthropocentric perspective, in which assets are out at sea, and there are significant economic losses that could occur. Early 2022, three storms occurred within the same period, and were treated as separate events, as mentioned by a climate scientist (Expert interview 7, 2023). This reflects that there is still a gap to be bridged transitioning the approach and knowledge of hazard events and practitioners.

"Multi-risk aims to address the linearity of interdependencies in a system" (Expert interview 2, May 2023). Discussing with a climate scientist is important to note that multi-risk is not only related to the hazard events, but also to the multiple uses that occur within a space (Expert interview 7, May 2023). This has been confirmed through other interviews, and it is apparent that when attempting to apply theoretical frameworks to navigate the complexity of the North Sea, the sectoral interdependencies bring non-linear responses to the linear hazards that can impact the system (Expert interview 2, 2023) Consistently across the sectors there appears to be a siloed thinking to hazard mitigation approaches. Talking to experts from offshore wind it is apparent that technical solutions are perceived as the answer for any storm events, and their intensity and frequency, if predicted can be addressed through the planning process (Expert 3 & 5, May 2023). Cables can be buried deeper to account for high enough waves that can dramatically change sand patterns (Expert interview 5, May 2023). In terms of shipping, as a highly mobile group of users, monitoring and warning systems should become increasingly more complex to match changes in the system (Stakeholder Workshop, 2022). The exercises conducted with the stakeholders during the workshop show that there is knowledge available on across the participating groups but could only be developed in similar sessions currently (see figure below). Furthermore, a table 5 has displays the relevant hazards identified by the stakeholders and the user groups these would affect.

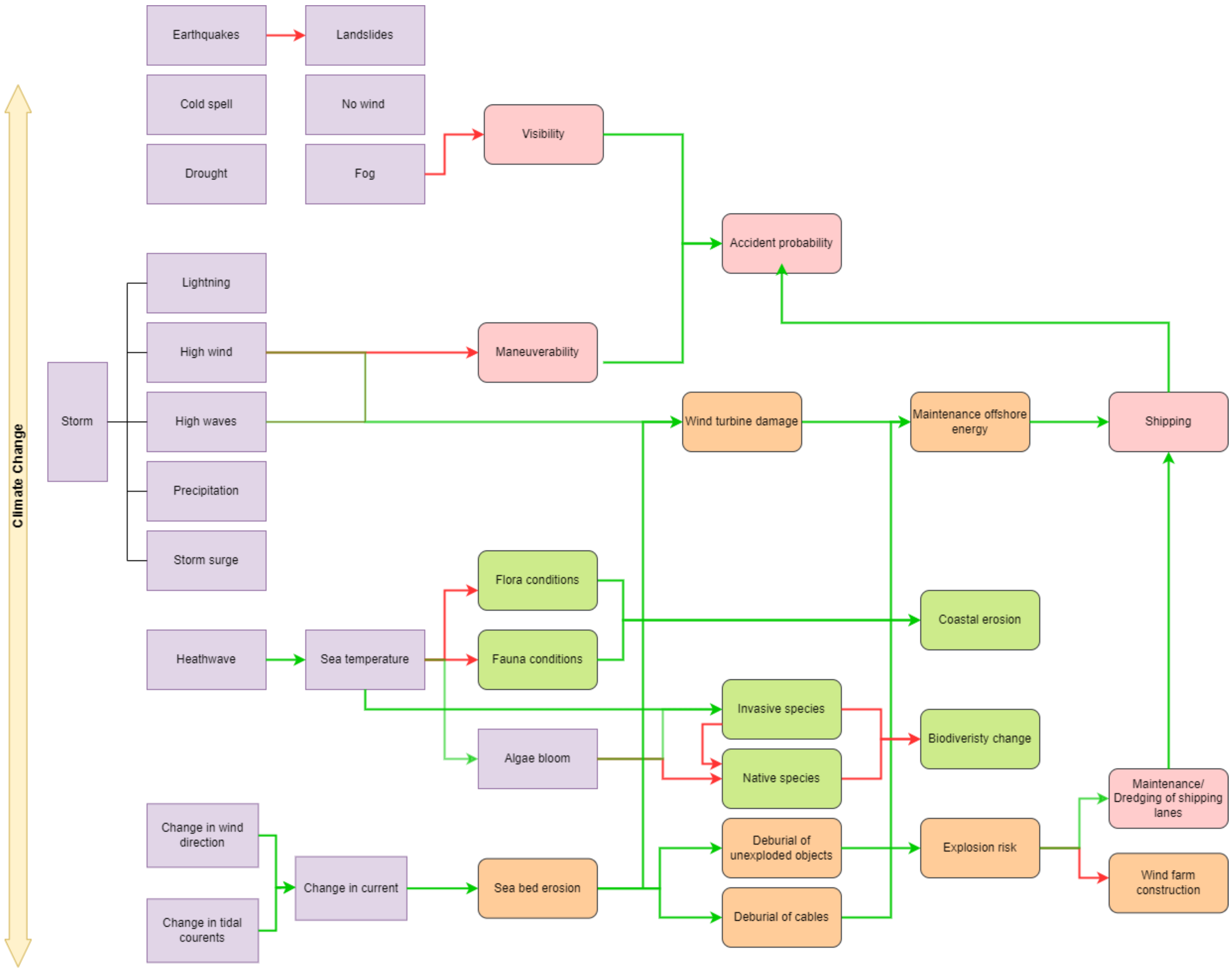
Climate Change
Earthquakes
Landslides
Cold spell
No wind
Drought
Fog
Visibility
Accident probability
Storm
Lightning
High wind
High waves
Precipitation
Storm surge
Maneuverability
Wind turbine damage
Maintenance offshore energy
Shipping
Flora conditions
Fauna conditions
Coastal erosion
Heathwave
Sea temperature
Invasive species
Native species
Biodiveristy change
Algae bloom
Change in wind direction
Change in tidal courents
Change in current
Sea bed erosion
Deburial of unexploded objects
Deburial of cables
Explosion risk
Maintenance/ Dredging of shipping lanes
Wind farm construction

Figure 8: Combined causal chin of hazards exacerbated by climate change and their effects developed during the Stakeholder Workshop, (2022) *. Purple sharp rectangles represent the hazards. Rounded rectangles represent effects perceived from different sectoral standpoints - green for ecosystems, red for shipping and orange for energy.*

Table 5: Hazards that are relevant for user groups observed in this reserach6: Hazards that may influence each user group

User group	Possible hazards
Offshore wind	Storm events, with high winds and high waves
Shipping	Storm events, with high winds and high waves, fog
Cables and Pipelines	Earthquakes, underwater land slides
Food production	Algae bloom, Heath waves
Ecosystems conservation	Heath waves
Sand extraction	Storm events, with high winds and high waves

There are also limitations of the MYRIAD-EU project that have transferred onto this research when addressing hazards. The project and this research focus on natural occurring hazards, largely of atmospheric origin, in this geographical area, as displayed in 5. A climate scientist might argue that since all hazards considered within this area are aggravated by climate change, there are no true natural hazards (Expert interview 7, May 2023). Industry representatives have also mentioned that socio-technical hazards (i.e. a cascading evet such as a ship becoming adrift due to a storm) are of more direct concern when making plans for a user group (Stakeholder Workshop, 2022; Expert interview 3&5, May 2023).

3.3.2. Collaborative systems approaches

Collaborative systems analysis is meant to capture the complexities of effective decision-making (Warren et al., 2022). This should entail a level of comprehension of how the systems functions that captures biophysical socioeconomical or institutional aspects of the system at hand. It should also entail the multiple economic sectors that are evolving within the boundaries of the system (Warren et al., 2022). The aim is to overcome both the problems that occur within each individual sector as well as at a systems level. It should also highlight constraints or interdependencies that emerge from the interactions between actors. Collaborative systems approaches represent multiple tools that facilitate the development of mitigation strategies or adaptation pathways (Warren et al., 2022). After analysing the literature and the benefits of multiple methods regarding the best ways to approach this in the MYRIAD context a strategy was devised for the individual stakeholder workshops. There imply defining system boundaries, undertaking sectoral analysis then transitioning to the systems level an integrating the knowledge developed at individual level (Warren et al., 2022).

Trust and discourse are also topics that influence the ability of stakeholders, scientist and policymakers to address issues in joint settings. This also became apparent during the interviews. On the one side, scientists expressed concern over the ability of the knowledge they produce to be easily accessible to policymakers and sectoral representatives, in terms of wording and content (Expert interview 1, May 2023). On the other, there also needs to be trust in the process of up taking the knowledge, and that people involved aim to address the same problem, and establishing timelines that fit both research and decision taking was mentioned by interviewers to be an issue (Expert interview 2, May 2023)

The opportunity offered by working under the North Sea pilot of the MYRIAD-EU project reflected in the access to the first stakeholder workshop organised by the consortium. During the organisation stages of this workshop, it became apparent that there are certain barriers in the involvement of stakeholders for adaptation knowledge coproduction, which resulted in a limited number of participants present that were representing sectors only from two countries of the system (Geurts, 2022). Furthermore, there are constricting factors that stem from the nature of MYRID as a project. For instance, the project aims are not directly linked with any maritime planning or decision-making entities responsible for the system. Also, the project involves partners across the North Sea Region, with little to no representation for some of the countries that are bordering the sea. Despite that the partners that took part in the session mentioned that they found useful participating to the discussion and that will take some of the themes to discuss within their organisation. However, it is important to note that this exercise required a great deal of imagination from the participants, as impacts of hazards in this area are limited currently but are expected to increase (Ciurean et al., 2022). Although in a limited manner, the first workshop contributed to the development of multi-risk thinking of people and organisations involved.

Concurrently, the other pilots of the project organised stakeholder workshops in which they also aimed to familiarise the stakeholders to working in a multi-risk cross sectoral setting. All workshops involved a series of collaborative tools relevant for the setting of the workshop, either online or in person (Ciurean et al., 2022). It became apparent that the complexity of the system may become overwhelming for stakeholders and visual tools are also needed to give context to exercises (Ciurean et al., 2022). Notably the workshops that already prepared scenarios for their stakeholders used them to facilitate plenary and breakout discussions (Ciurean et al., 2022). The most prevalent tools used were causal chains that were developed by the participants during the workshop. These were facilitated by the use of physical and digital whiteboards. The development of scenarios was eased by the availability of data regarding hazards occurring within the respective system. Two of the workshops took time addressing hazard terminology, assuring that all of the participants are familiar with these concepts, whilst another helped familiarise the stakeholders with disaster risk management practices (Ciurean et al., 2022). Noting that having the stakeholder on the same page is also applicable for disaster risk management endeavours outside of MYRIAD (Ciurean et al., 2022). The geographical scale of the exercise is also a notable variable, as pilots covering an area withing the boundaries of a country managed to get input from a higher number of people compared to the ones covering and a system that crossed country borders.

All workshops tested the suitability of DAPP approaches to address such problems that are being experiences withing their system. The concluding remarks of the workshop organisers was that this completing a DAPP exercise is a lengthy process that involves a considerable number of variables that may make some stakeholders become overwhelmed by the complexity of sectoral synergies (Ciurean et al., 2022). Despite that there was plenty of positive feedback regarding the applicability of DAPP in multi-risk multi- sector setting. This must be completed under multiple sessions and is facilitated by the identification of relevant hazards and scenarios involving them as well as hypothesizing over sectoral impacts. The implementation of these methodology within one system is also reliant on the culture of collaboration not just within sectors but also with the relevant governance levels. It is also important to note that the workshops focused experimented with the first three steps of DAPP that imply systems definitions, identification of risks and opportunities and scenario development.

The Dutch Nort Sea is just one segment of the system explored by the pilot. When looking at the greater picture of collaboration one can observe that systems thinking approaches have been progressively implemented in maritime spatial planning over the past decades (Ehler, 2021). Furthermore, one can say that the establishment of OFL and NZO are signs of the government acknowledging the benefits of collaborative processes and the need for cross sectoral thinking. For disaster management of multi-risk to become a more common practice, one pilot discussion concluded that there needs to be a national strategy developed on the subject (Ciurean et al., 2022). This can occur easier on a regional or national scale compared to a strategy covering a cross boundary system.

3.3.3.DAPP and DAPP-MR

Dynamic Adaptation Policy Pathways (DAPP) represents and method for dealing with uncertainties for long-term policy planning, through exploring sequences of actions that can influence the development of a system overtime (Haasnoot et al., 2013). This method for developing planning strategies under deep uncertainties can be summarised through a set of steps which the researchers propose to be followed. The steps of DAPP are as follows (Haasnoot et al., 2013):

1. Identify objective and constraints present within the system, as well as transient scenarios
2. Vulnerabilities and opportunities are identified, those being used to conceptualise the thresholds, as adaptation tipping points, those influencing subsequent measures, and opportunity tipping points, those pointing towards leveraging changes in the system for specific actions.
3. Developing on the scenarios identified previously, a timeline of reaching identified tipping points is established.
4. Pathways are designed based on the adaptation and opportunity tipping points to map alternative routes, those would be evaluated based on the objectives established previously, as well as feasibility and flexibility in implementation.

5. Preferred pathways are identified, and an adaptive strategy is reflecting both flexibility as well as keeping in mind the initial actions. Also, at this stage, means of monitoring are established.
6. Implementation
7. Monitoring

DAPP has been used in MYRIAD-EU as starting point to explore pathway for the different contexts corresponding with the pilots of the project. Although, there are some limitations in the use of DAPP, and one is that in its current form it is not equipped to address multi-hazard and multi-sectoral settings, as it has been mainly used to address single-hazard context. Schlumberger et al. (2022) contributed to the development of the original analytical framework for multi-risk – DAPP-MR. After assessing the literature identified three main aspects that are relevant when addressing multi-risk systems, these being the effects of multiple interacting hazards, the interdependencies and dynamics between sectors, and trade-off and synergies between disaster risk management policy that may differ between sectors and might refer to different spatial and temporal horizons.

The integration of sectoral contribution represents one of the challenges of implementing this approach aims to solve, by taking advantage of networks developed within each sector and possible uses of sectoral scenarios. Subsequently, this would help develop the multi-risk understanding of stakeholder taking part in the DAPP-MR process. To this stepped approach three stages are added to account for the already mentioned complexities of multi-risk and multi-sectors (Schlumberger et al., 2022). The research team considered the most suitable point of increasing complexity the sectoral level, where connections can be taken advantage of, and multi-hazard scenarios can be explored (Schlumberger et al., 2022). According to Schlumberger et al. (2022) the there additional stages of DAPP-MR are as follows (visualised in figure 9):

1. Single-sector, single-hazard perspective
2. All hazards are accounted for in each sector transitioning to a single-sector, multi-hazard perspective
3. All information is subsequently integrated in a multi-sector, multi-hazard perspective

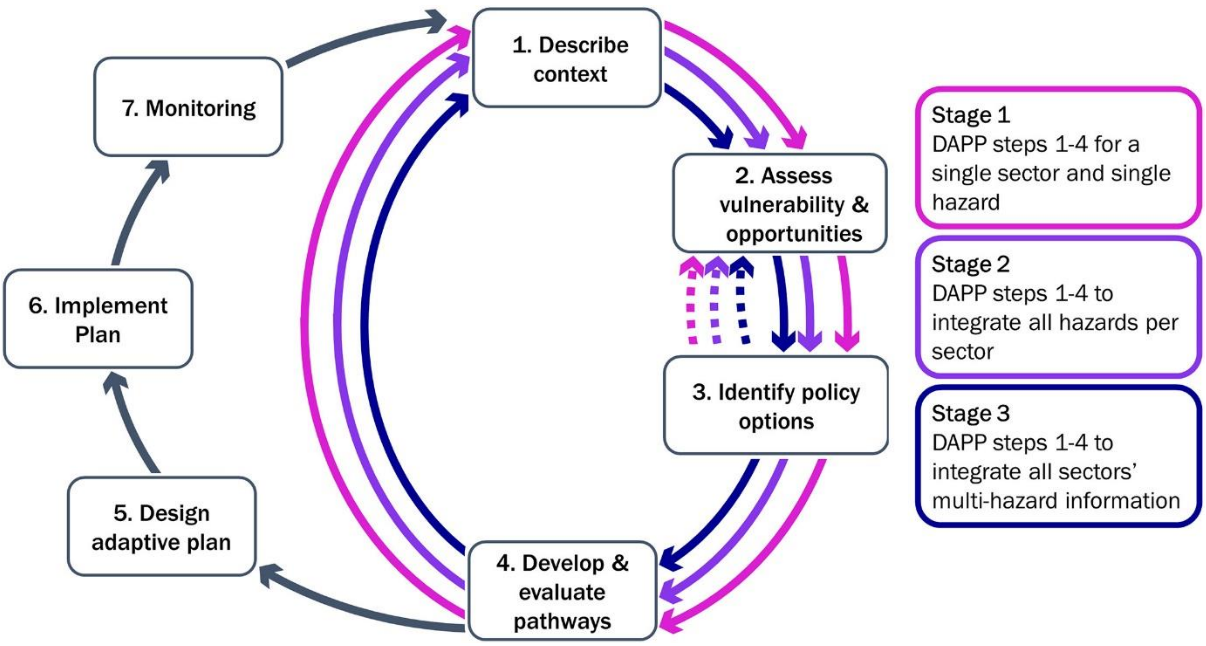

Figure 9: DAPP-MR analytical framework (Schlumberger et al., 2022)

Already integrating a level of complexity, it may be easier to make the information accessible to the various stakeholders. Although this process would require additional time and resources, it aims to bring together the different perspectives in a manner that alleviates possible power dynamics between sectors (Schlumberger et al., 2022). Currently this approach towards developing adaptation pathways for decision-making has only been tested on a stylised case. It was also presented to the stakeholders present at the first North Sea Pilot Workshop. The concept of multi risk was introduced to the stakeholders but not much detail was covered during the workshop as they did not have the information regarding trends in future hazards and risks (Stakeholder Workshop, 2022). Despite that, the feedback was mostly positive from the stakeholders regarding the usefulness of this tool, especially to construct pathways ready for knowledge assisted decision-making (Stakeholder Workshop, 2022). One point that emerged out of the discussion was how people within one sector are indeed aware of this type of integrated thinking but find it hard to understand the synergies and trade-offs that are required for multi-sectoral thinking (Stakeholder Workshop, 2022).

DAPP represents a structured approach and presents structure for evaluation of decisions, with end goals in mind. Thus, it provides guidance for the energy and resources that are put into organising a system over time, through the improved understanding of the system over time. This provides opportunities within a system that is already being explored through research and organised through spatial strategies (Expert interview 2 & 7, May 2023). There is also a level of flexibility that can be explored through the evaluation criteria, what and how one wants to measure in a system (Expert interview 2, May 2023).

There are other operationalisation challenges for adapting DAPP-MR to the North Sea that were explored through the expert interviews. The setting of the case brings challenges on its own, through its offshore nature, the level of financial investments, and climate and systems uncertainties, also it is a system with multiple boundaries, and complex sectoral systems that are nested within them (Expert interview 2 & 7, May 2023). DAPP has been applied in climate change or resource contexts, making the transfer of methodology offshore and in a spatially intricate setting a challenge (Expert interview 7, May 2023). Thus, exploring pathways for the North Sea in a spatial scarcity mindset would be more difficult than the traditional areas in which DAPP has been used.

When testing the methodology with multiple stakeholders it became apparent that both multi-risk thinking, and adaptation pathways are not yet used to their potential by the user group. Despite that, progress was made when exploring the sectoral stage of DAPP-MR, as building gradually the pathways could avoid overwhelming the stakeholders (Expert interview 2, May 2023).

3.3.4. Lock-ins

The absence of cumulative systems impacts knowledge would cause lock-ins as these bring uncertainties into policy. Within this, there are smaller gaps regarding operationalisation, or environmental or social impacts that are nested. This results in a discrepancy between the timeline of designing and conducting research to generate knowledge and the timeline of decision-making. This may also affect the willingness to address question marks regarding systems' impacts within the spectrum of a political term. These gaps are taken into spatial planning policies and could lead to the placement of infrastructure or the use of practices that could be damaging the ecosystem beyond the lifetime of the infrastructure. This also reflects the trust between decision-makers and researchers and their ability to collaborate for timely climate action. One must not overlook the social dimension of the transition of knowledge from the fishing industry, which could add to or ease the friction between representatives of North Sea groups in agreement talks. This could be applicable to all current industries that would transform with the sustainable blue economy in the future.

These conditions potentially have a spill-over effect in implementing collaborative systems approaches within the boundaries of the observed system. Going beyond collaborative approaches and using, in addition, adaptation pathways through DAPP-MR could represent the flexibility required for integrating knowledge and tailoring policymaking through time. Despite that, there are still questions raised by the applicability and operationalisation of DAPP-MR for this case study, and even for the wider North Sea, as per the discussions had with researchers. These stem from the complexity of the system and the particularities of maritime spatial planning that make it harder to frame the issue in a manner that would result in stakeholder collaboration for developing pathways.

3.4. Spatial Claims

RsQ: How can adaptation pathways be used to tackle spatial claims related lock-ins?

3.4.1.Problem framing

The potential for the development of lock-ins regarding the spatial use for sectoral development stems from the impacts of infrastructure being built and its lifespan on the environment and how one use of the space can directly negate another, like how current policies section sea area solely for wind energy. The main approach to managing marine resources has been disjointed and treated separately under specific ministries, which hinders the practical implementation of notions such as the ones promoted by the SDGs (Stead, 2018). In the case of the North Sea, maritime spatial planning can be conceptualised as a form of multi-sectoral governance (Kidd & Shaw, 2013). This was also reflected in the literature, although cumulative environmental impacts are not necessarily a criterion traditionally used in spatial planning. Kidd et al. (2020) express that maritime spatial planning is grounded in territorial planning and this raises the question of conceptualising ecosystem boundaries. On the one hand, space for ecosystems can be seen as a standalone user function, like offshore wind or shipping, that requires a designated space (Kidd et al., 2020). On the other, one can perceive the need for conservation as a boundary condition for the impact different uses can have on the ecosystem (Kidd et al., 2020; van der Molen et al., 2015). The diversification of avenues considered in territorial planning opens new pathways that must be considered (Kidd & Shaw, 2013). At the centre of the collaborative governance regime of the Dutch North Sea sector lies the increased competition for space. Making, in this case, access to the sea surface vital for developing activities and exploiting resources. The surface of the Dutch territorial sea is a finite resource, and its exploitation is zoned by the government for specific uses which are subsequently developed or exploited by corresponding sectors (figure 10). The shared use of sea surface is a future that is increasingly explored by policymakers and will most likely be implemented within the coming decade across the Dutch North Sea.

Moodie and Sielker (2021) conducted an analysis along the broad lines of the cross-national dimension of collaborative governance for transboundary maritime planning. They found a general lack of integration between the overarching institutions present in the North Sea, such as OPSAR and the North Sea Commission. They also found that maritime spatial planning within the sector remained mostly country specific. This might have been the result of the legislative environment, that although encouraged collaboration, focused on integrated planning action that was to be undertaken by each country (Directive 2014/89/EU 2014; Moodie et al., 2021). The Dutch opted for an approach that offered a degree of freedom to the economic activities that were meant to be developed in the area, with the policies offering a framework for location-based usage (de Vrees, 2021). The maritime strategy for the Netherlands has been developed in mid-term stages, with the North Sea Policy 2016-2021 being part of the National Water Plan and that shapes the use of space nowadays (figure 4). This is subsequently followed by an agenda for 2030, with plans being made for a new time horizon of 2050.

The Dutch North Sea covers 57,000 km^2, which is larger than the surface of the land area of the country (de Vrees, 2021). There are many developments planned to be built in the North Sea in the coming years, from the pressingly needed carbon storage, to more fixed and even floating windfarms to satisfy the need for greener energy in the surrounding countries. Researchers at TU Delft and Rijkswaterstaat modelled the uses of the space in the territorial Dutch waters (Buitendijk, 2021). De Vrees (2021) identified the uses of the North Sea that are relevant for adaptive planning, these all need to be taken into consideration, as consensus has to be reached and decisions taken have to suit a myriad of parties involved. These areas of development are growing alongside the increase in planned offshore wind power. Questions started arising as the forthcoming overlap between sectors became apparent, one example mentioned by both literature and stakeholders is the safe distance between shipping routes and wind farms (de Vrees, 2021; Stakeholder Workshop, 2022). The conflicting relationships between the uses have been iterated on in Chapter 3.2.2.

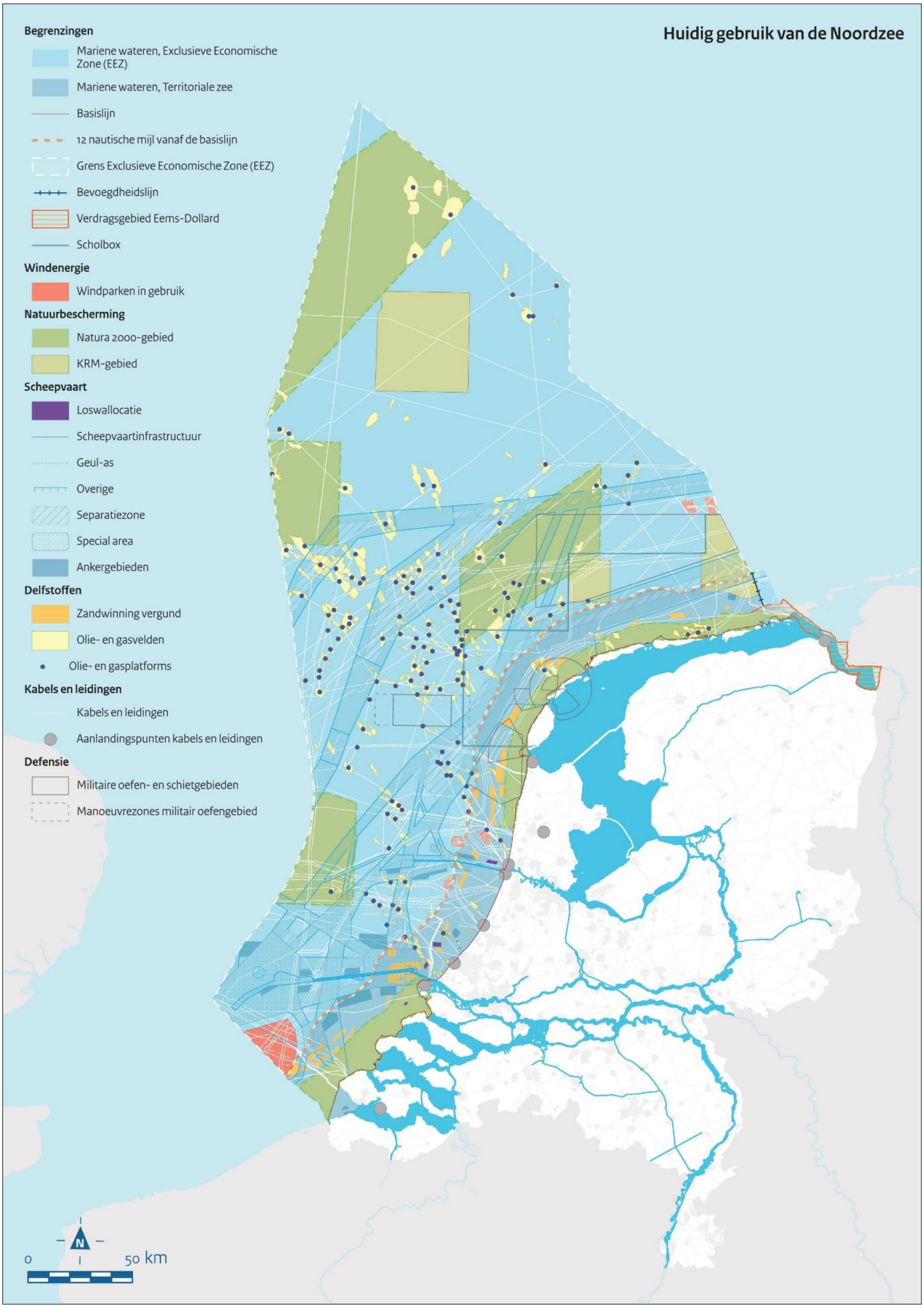

Figure 10: Map of marine spatial plan 2022-2027 (I&W et al., 2022)

The issues of the Dutch North Sea have been explored in depth in the previous chapters. The key to overcoming all the constraints should come from developing pathways to navigate spatial scarcity most efficiently and organising an environment where collaboration between users could make for reaching trade-offs that are flexible in time. One means to overcome the issues mentioned in framing the problem of the North Sea for DAPP-MR is to conceptualise the sea surface as a finite resource. In socioecological systems, sustainable resource management implies means of managing common goods (Ostrom, 1990). Using Ostrom's principles one can conceptualise sea space as a common resource, representing a system with designated boundaries that are relevant for the uses involved, that is immobile and finite, and nests resource subsystems of the energy potential of the wind above, the nutrients and fish below, and the minerals of the sea floor (Ostrom, 2009). Although the way in which users navigate this system is monitored by a stronger governance presence, there are still spaces for self-organisation where their sharing the knowledge and perspective could facilitate the design of spatial plans. An example could be the bidding process for multi-use tenders. Introducing the conceptualisation of sea space as a common could pave the way for overcoming impediments in talks of developing adaptation pathways. This would facilitate future thinking by increasing the sense of ownership among stakeholders.

3.4.2. Vulnerabilities and tipping points

The North Sea covers a vast area that is highly susceptible to climate change as the region is influenced by the warming of the Arctic (Stendel et al., 2016). When looking from a broader geographical perspective, the North Sea covers the continental shelf of north-western Europe. OPSAR (n.d.) considers 750 000 km^2 that encompasses a great deal of land-sea interface landscapes, such as estuaries, fjords, intertidal mudflats, sandbanks and bays. The temperate latitude with the influence of Atlantic warm water currents makes the sea not only viable for shipping (Rotterdam and Hamburg world's largest ports being located within the North Sea catchment area) but also on the abundance and complexity of fauna (van Tatenhove & van Leeuwen, 2016). The general direction of western air currents builds on the water temperature and creates a low-pressure system that directly impacts the hydrology of the surrounding areas, including the occurrence of extreme events OPSAR (n.d.).

Beyond the changes in sea level, temperature and salinity, there are aspects regarding the atmospheric evolution of the entire region that may have a direct impact on human activities at sea. May et al. (2016) foresee that taking the end of the 20th and beginning of the 21st century as a baseline, we can expect that significant atmospheric changes may occur from the middle of the 21st century onwards. Some of the options explored by the authors imply increased cyclone density, more frequent strong westerly winds, increased mean precipitation during the cold season and decreased in the warm season, increased intensity of heavy rain during one day, especially in winter, and increased hourly extreme precipitation during the summer (May et al., 2016). It is important to note that these are the general trends, and these are subsequently plagued by their own factors of uncertainty. Overall, the likelihood of extreme weather events is increasing, and some important single hazards are storm-surges, extra-tropical cyclones, or convective storms (and their subsequent hazards) (Gaslikova et al., 2013; May et al., 2016; Vemuri et al., 2022).

The vulnerabilities and tipping points of this system were identified during the interviews or observed throughout the stakeholder workshop. The climate related tipping points that could affect this system are related to the general direction of air and sea currents and their economic potential, as well as sea level rise and its impacts on maintaining the Dutch coastline (Stakeholder Workshop, 2022, Expert interview 6, May 2023). In terms of natural hazards, the economic vulnerabilities of the system, stem from the impacts events have on joint economic ventures out at sea, and the mismatch in mitigation opportunities. For instance, throughout discussions with the representatives of offshore wind, it became apparent that technological measures can be taken to reduce the impact extreme events have on wind turbines (Expert interview 3, 5 & 6, May 2023). It is unclear from the data gathered if the same view or economic possibilities to mitigate these events are common among other user groups. One looming concern among planners is the timeline of the availability of space. Throughout the interaction with the governance representative, it became apparent that the urgency of climate action was prioritised over future flexibility of space use (Expert interview 6, May 2023).

3.4.3.Actions and design of pathways

To explore the suitability of adaptation pathways for the Dutch North Sea, this exercise will qualitatively hypothesise relevant context and contingent actions based on internal reports provided by Deltares and systems information gathered throughout the research. When looking at the system problem of the Dutch North Sea, there are two drivers that can be identified, climate change (as an overarching exacerbator or hazard event) and spatial scarcity. One climate scenario will be assumed, three sectoral viewpoints will be analysed, along with available spatial trends.

This exercise will comprise one climate scenario based on the moderate shared socioecological pathway presented by the latest IPCC report (IPCC, 2022). This entails an ice-free Arctic by the end of the century, an increase in temperature of 2ºC on global average, with a sea level rise of approximately 50cm within the next 70 years (IPCC, 2022). For this geographical area, this would result in an estimated increase in the frequency of storms by a third in the midterm, and an increase in both intensity and frequency by half by 2100 explored in table 6 (Schlumberger et al., 2023). Spatial scarcity is more relevant for Dutch maritime planning than any other country in the region. For this exercise, the priority for offshore wind is carried through from the previous findings of this research. The spatial target is assumed to maintain as much space free of infrastructure for as long as possible. The three user groups that would be studied in this exercise are offshore wind, shipping and ecosystems. All of these are relevant for the context of MYRIAD and are most spatially challenging to plan due to the vast requirements of space. Each group has its own objectives to attain, in the context of climate impacts on the sea. Offshore wind aims to produce an increased amount of electricity to match the demand raised by the energy transition through maximising production and minimising unproductive times for the turbines. For shipping, the priority would be to avoid material losses produced by collisions, that occur due to storm events and increased density of activities at sea (insert citation). Ecosystems, as a user group, considers both maritime protected areas, and the boundaries set for the development of other uses of the sea (Schlumberger et al., 2023).

Table 6: Impact of spatial use scenario (Schlumberger et al., 2023)

	Now	2050	2100
Energy	5%	20%	25%
Ecosystems	3%	30%	35%

Sets of relevant measures were developed to explore the possible developments within the user groups. These have been listed with tables 7 through 9 and characterised by the research team base on sensitivity to spatial limitation, contribution to achieving the goal of the group, costs, and the likelihood of a measure to cause regret, through creating changes to the natural environment.

Table 7: Potential measures for the offshore wind user groups w1-12 (Schlumberger et al., 2023)

	Description	Sensitivity to spatial limitations	To achieve maximisation of production		Timelines of availability	Regret	Cost	Explained	Impact on other sectors
			Minimizing downtime	Maximizing production					
1	Bigger wind turbines	0	0	+	Mid term	Low	$$	Bigger turbines with bigger rotors catch more wind	Ecosystem: rotors are more dangerous to birds
2	Increased efficiency of wind turbine design	n/a	0	+	Mid term	Low	$$	Technological advancements lead to more efficiency	
3	Optimization of wind turbine position	0	0	+	Short term	Medium	$	The position of the wind turbine is improved and results in higher	Shipping: maybe more space is needed

								energy generation	because the locations are more optimal, but not as dense
4	Low maintenance offshore wind infrastructure	n/a	+	0	Mid term	Low	$	Leads to lower risks	
5	Deep water technology	-	0	+	Mid term	Low	$$	Allows for the installation of wind turbines in deeper waters	Ecosystem: more potential areas with wind farms
7	Back-up cable	-	+	0	Short term	Low	$$	An additional cable serves as a back-up during outages	
8	Bury cables deeper	0	+	0	Mid term	Low	$$	Cables are buried deeper and less likely to be exposed or damaged	
9	Anti de-burial measures	0	+	0	Short term	Low	$	Measures are taken to prevent cables from getting exposed	
10	Sharing of energy surplus between countries	0	0	+	Mid term	Low	$	If countries produce a surplus of energy, they can share it with a country that needs it. This will also provide more flexibility and make the phasing out of fossil energy easier.	
11	Business as usual	0	0	0	Short term	Low	$	Nothing changes	
12	Windfarm layout optimization	-	0	0	Short term		$	Allowing for other uses and sectors in a windfarm in the most optimal way	

Considering the relatively short lifetime of the infrastructure of this user group, measures for addressing the climate uncertainties will not affect the existing installed capacity, and based on discussions with stakeholders would imply technical solutions (Expert interview 2, 2023). Thus, solutions addressing the size, efficiency or position of turbines and wind parks would be taken into account throughout the future tendering process, through targets set by the government. This progressive turnover of technology would yield increasing amounts of revenue and match the pace of agreements signed by the country but would imply installing infrastructure that causes irreversible damage to the environment (w1-4). Better, monitoring systems would be implemented to account for smaller safety zones and to optimize the downtime of the installations. To economise on the space, the gaps between turbines will be used for other activities, like sea farming, fixed point fishing, shipping or recreation. These coexisting activities have to be designed to withstand the lifetime of the wind farm. Joint decommissioning or replacement becomes a topic of discussion, multi-use farms are being replaced progressively with similar or more efficient multi-use installations (w12). Rotation of uses should occur to tackle the global trends in the depletion of nutrients in the epipelagic zone. Whereas, windfarms developed and installed prior to the shift in philosophy to multi-use, would be decommissioned and the monopiles left in place to continue to act as artificial reefs. Installation of back-up cables and sustained anti-burial measures would protect against many potential losses created by damage and subsequent power outages. Cross border energy collaboration between countries would account for other subsequent losses that may be caused by fluctuations in demand or required downtime caused by extreme events (w10). There are no contingency plans for this type of energy to become obsolete, either through major technological advancements or catastrophic climate change. The current resilience of this sector lies within its financial capabilities to innovate and the governance structure that promotes it as the most efficient use of space.

Table 8: Potential measures for the shipping user groups s1-11 (Schlumberger et al., 2023)

	Description Improve navigation systems	Sensitivity to spatial limitations	Less collisions	Timelines of availability	Regret	Cost	Explained	Impact on other sectors
1	Surveillance (coastguard)	N/A	+	Short term	Low	$$	Coastguard is monitoring the North Sea more closely	Ecosystem: more options for enforcement of rules Energy: risks can be identified in an earlier stage
2	Training of crew	N/A	+ +	Short term	Low	$	Crew is trained to improve their skills and expertise	
3	Increase towing capacity	N/A	+ +	Short term	Medium	$$	Ships that are adrift can be controlled sooner, because a towing vessel is more likely to be in the area	Energy: less chance that adrift ships end up in wind farms
4	Opening wind farms for shipping, rather than going around – for bigger ships	N/A	-	Short term	Low	$	Trying to see if wind farms can be made accessible for ships. Is beneficial for spatial use, but not necessarily beneficial for one specific sector	Ecosystem: traffic in areas that were previously not accessible Energy: potentially more risks
5	Marine traffic system / control tower	N/A	+ +	Short term	Low	$$	Having all of the marine traffic monitored by one system	Energy: risks can be identified in an earlier stage
6	Increase/designating new clearways	-	+	Mid term	high	$	Ships have more room in case of issues	Energy: less chance that adrift ships end up in wind farms. Less room for wind farms
7	Expand safety zones around built infrastructure	--	+ +	Short term	low	$	There is more room around infrastructure	Energy: less chance that adrift ships end up in wind farms.

								Less room for wind farms
8	Separation zones (areas between opposing shipping lanes – for ships that come adrift)	--	+ +	Mid term	high	$		Energy: less chance that adrift ships end up in wind farms. Less room for wind farms
9	Widening of shipping lanes	--	+	Mid term	high	$	To give ships more room and decrease the chances of a collision	Energy: less chance that adrift ships end up in wind farms. Less room for wind farms
10	More manoeuvrable ships	+ +	+ +	Mid term	low	$$$		Energy: less risks for wind farms. Maybe shipping routes can be made narrower, more room for wind farms. Maybe this leads to ships being allowed in windfarms
11	Smaller ships	+	+	Mid term	high	$$$	More manoeuvrable, but less sensible from economic perspective	Energy: less risks for wind farms. Maybe shipping routes can be made narrower, more room for wind farms

Similarly, the shipping user groups would start with taking measures that would be achieved with measures that would require lower costs (s1-3). These would slightly decrease the number of collisions but as more space will be opened for shipping within the boundaries of existing wind farms (s4-5), more measures need to be taken. By 2050, considering the expected increase in shipping density and with a clearer perspective of the Arctic routes, and at the pressure of the user group, the government would start widening the shipping lanes (s9) and create separation zones (s8), at the same time new routes would be established to navigate the new conditions (s6). This spatial expansion of the sector would clash with the required space for conservation that is enforced by the EU. Ships technologically evolving (s10-11) was only found financially viable by the ship owners. By 2100, the number of collisions would plateau, and they would be dictated by storm events that occur, rather than by sociotechnical measures taken.

Table 9: Potential measures for the ecosystems user groups e1-11 (Schlumberger et al., 2023)

	Description	Sensitivity to spatial limitations	To achieve good ecological status	Timelines of availability	Regret	Cost	Explained	Impact on other sectors
1	Increase MPAs	--	++	Short term	Medium	$	Increase the amount of MPAs in order to provide more area for ecosystem	Energy: maybe less room for windfarms Shipping: maybe less room for shipping
2	Stricter regulations for MPAs	-	++	Short term	Medium	$	Expand and strengthen current	Energy: maybe wind farms are

							regulations in order to protect the ecosystem	excluded from MPAs
3	Enforcement of MPAs	n/a	+	Short term	Low	$	Stricter enforcement of regulations	
4	Ban on bottom trawling fisheries	+	++	Short term	Medium	$		Energy: less risks for cables
5	Decrease runoff from land	n/a	++	Mid term	Low	$$	Decrease the runoff of nutrients and other harmful components from land	
6	Waste management	n/a	+	Mid term	Low	$$	Less plastic in the water	
7	Wastewater management	n/a	+	Short term	Low	$$	Less pollutants in the water	
8	Measures to prevent and mitigate oil spills	n/a	+	Short term	Low	$$		
9	Underwater noise reduction	n/a	+	Short term	Low	$		Energy: maybe stricter regulations for the installation of wind turbines Shipping: maybe stricter regulations for engine and propellor noise
10	Nature restoration	-	+	Mid term	Low	$$		Energy: maybe less room for windfarms Shipping: maybe less room for shipping
11	Invasive species	n/a	+	Short term	Low	$	Install policies to stop invasive species from spreading and existing	

To achieve good ecological status, more in-depth analysis and measuring must occur on predetermined parameters of the system. Sensible measures have been identified. There are two general directions in which ecosystems conservation can evolve: through maritime protected areas and through enforcement of conditions that encroach on the ability of other economic activities to deteriorate the environment. Measures e1 through e3 are the most certain to be implemented by 2050, this would put stress on all sectors observed throughout the study. Storm frequency and intensity may not affect ecosystems directly within the next century. The focus would shift towards the protection of fauna (e11) or mitigating changes in water properties. Thus, measures tackling pollution from both on and off the land (e-5-8, e11) would become progressive throughout decades, in order to avoid conflict with stakeholders. Stricter parameters for noise cancellation would directly affect the offshore wind sectors, and if costs for that are not entailed in the tendering process from the beginning, developers would be reluctant to take action (s10).

3.4.4.Lock-ins

More information is required to address the evolution of each sector individually when assessing spatial claims. From the simplified hypothetical narrative perspective of this exercise, it appears that a great deal of space will be taken by the only three uses analysed. This either emphasises the greater need for coordination in multi-use, or the need to reconsider if these uses are indeed the ones that should receive such vast amounts of sea surface. Spatial planning for multi-hazard scenarios requires thresholds that need to be negotiated amongst stakeholders not necessarily drawn up from a top-down decision-making position (Expert interview 5, May 2023). Thus, a level of flexibility is required that could theoretically be navigated using DAPP. Combining individual pathways from each sector into an adaptive plan would imply a new dimension of complexity that is not yet ready to be considered in a hypothetical qualitative exercise. A point that could be further explored is the possibility to use space for multiple activities in a sequential manner, thus avoiding the mutual exclusion inferred by the incompatibility of practices that were uncovered in chapter 3.2.2. For developing pathways for the Dutch North Sea, a quantitative model should represent an advantage when trying to navigate the suitability of exploring this case study with DAPP. More information is required, and a greater number of stakeholders should be involved, than was available to the researcher.

Considering the particularities of maritime spatial planning that occur within one country's circumscription, standardisation of practices is required for this methodology to be applied in a transboundary case. MSFD aims to harmonise planning in EU water (Expert interview 5, May 2023). But such an overarching policy umbrella may not be as effective for countries that have a higher density of activities due to limited space. User groups in one country face different challenges and opportunities compared to another (Stakeholder Workshop, 2022, Expert interview 5, May 2023). Despite MSFD existing, the misalignments between countries in the North Sea may make it harder to apply DAPP-MR beyond the boundaries of one country at a time. This geographical dimension is not currently accounted for in the development methodology (Expert interview 7, May 2023). Therefore, DAPP-MR's suitability for an individual country's case is greater than an entire region.

4. Further discussion

4.1. Reflecting on the research questions

The potential adaptation lock-ins that may arise in this collaborative governance regime have been classified based on the four dimensions of governance used as lenses for this research. These could be seen as:

From a structural arrangement standpoint, the Netherlands is a country with a tradition of collaborative processes around the governance of water. Looking at the governance system of the studied area, one could observe multiple endeavours evident through interinstitutional spaces like IDON and NZO. From a theoretical standpoint, this interinstitutional space could harbour the development of adaptation pathways for this system. Despite that, the system is not yet suited for the application of these concepts. There is a government that has an agenda set on mass renewable energy at sea, which favours offshore wind, one of six user groups observed.

There are also disagreements between user groups, which hamper the implementation of the current agreements, which have only been studies through the viewpoints of a limited number of groups. As maritime space is a place without a community of people, it may be harder for decision-makers to address spatial planning holistically. The only people that have a deeper community like connection to the sea, are the fisherman. The generational bonds people have to this livelihood and the knowledge they have gathered should be capitalised upon. Although, this is an anthropocentric view, as there are species that have their habitats altered due to developments that cannot advocate for themselves. These are represented by environmental NGOs that have conflicting views with the fishing community. This misalignment represents a challenge for this system from a societal standpoint. This type of conflict can create distrust that plagues stakeholder interactions in settings such as the NZO.

The knowledge required is yet to be completed and its availability should be more cohesive across users. Gaps in the knowledge are currently being taken into policy due to the urgency with which the Dutch government is acting on international agreements regarding energy transitions. Ensuring trust between knowledge generator and users was mentioned by multiple experts the researcher interacted throughout this research. However, this was not a theme of this research and would require a more in-depth analysis.

Conceptualising the Dutch North Sea as a socio-ecological system is a challenging process. Tackling spatial claims using DAPP-MR was limited by the current state of the methodology and the available information. Nevertheless, narrative pathways for individual user groups could be drawn. These could help guide towards identifying where spatial conflicts may occur. Sequential use of space could be planned once these pathways are developed, based on the systems response to the degree of climate change that occurs at different points in time.

This research set out originally to focus on the multi-risk aspects of the adaptation in the light of the collaboration of a wide range of parties. In lieu of evidence of multi hazard thinking the research the emphasis shifted on navigating the multi-sectoral aspects of the system, as these would set the stage for the uptake of hazard knowledge into practice. Thus, multi-use of space for multi-hazard adaptation has to go first through enhancing collaboration across public and private actors so there is a functioning interinstitutional environment where all the lock-ins can be tackled.

4.2. Limitations

There are also some limiting factors in conducting this research. These could be divided into scope and design limitations, that were acknowledged from the planning process and aspects that were found to be constricting throughout the researching and writing phases of the thesis.

On the one side, due to time and scale constraints, the research could not tackle the entirety of the North Sea, tackling only one of the countries that are part of the MYRIAD-EU North Sea pilot. Considering the fluidity and complexity of maritime ecosystems, and international dimensions of spatial planning, this may have a constraining effect on the perspective of the research. Another example, interviews could be affected by selection bias, which may lead to an incomplete picture of the status of the system. Although it is important to note that the researcher attempted to contact and send invitations to stakeholders across all user groups. Furthermore, there could be a level of personal bias within the discussion with the experts that could have affected their answers, which were aimed to be filtered during the data processing. There could also be limitations in the design of the research that stem from the experimental nature of DAPP-MR. The methodology has only been applied to a stylised case, and it is still being developed under MYRIAD-EU, thus some of the constraints in its operationalisation would also have an impact on this research. Furthermore, there are not many studies that conceptualise sea space as a resource from a governance standpoint, and none were available to the researcher that tackle maritime resources. Collaborative governance as a governance theory is not widely applied, which may also affect the design of this research.

On the other, through the discussion with experts' questions were raised regarding the selection of user groups. There are other uses of the sea such as oil and gas, recreation or defence that have not been accounted for in this research. These were originally dismissed due to requiring less space compared to the others and presenting a linearity in their evolution in the coming decades. There was a vast number of policy documents and governmental websites that were analysed by the researcher after these were translated from Dutch, which made the process longer and further clarification had to be sought.

4.3. Reflecting on MYRIAD and Greater North Sea

MYRIAD-EU represented a great opportunity to gather a variety of data and to directly interact with some of the stakeholders. Even so, there are some limitations that stemmed from the project's overarching design.

MYRIAD- EU took into consideration only natural hazards and the risks raised to human capital. This was questioned by some of the experts that were interviewed as it was hard to draw the line between the natural hazards, that were identified as affecting this system, and the anthropogenic hazards or cascading events that these were influencing (Expert interviews 3,5 & 7, May 2023). Also, there are some anthropogenic hazards like oil spills or technical failure of ships that were also mentioned as relevant by interviews but were not in the scope of the research (Expert interviews 3,5 & 7, May 2023). This may be one of the reasons, but not the only, that impedes the involvement of stakeholders in the North Sea pilot. There was a smaller number of participants at this workshop compared to the other held by the project pilots. This might have affected the feedback received on the development of DAPP-MR and its operationalisation for this case study. As previously mentioned from the perspective of this research some of the challenges that are encountered in the implementation of DAPP-MR for the North Sea could be overcome by using collaborative governance lenses. For example, problem framing, mentioned by Expert 2 during the interview, has been addressed in this research by conceptualising sea space as a finite resource, that has multiple dimensions, that could be exploited simultaneously. In this case, the two-dimensional parcellation of the sea surface is enriched by multi use through exploiting the minerals of the sea floor, the nutrients of the water column or the energy potential of the wind. This would help the stakeholders that collaborate on developing pathways to relate to the sea as a socio-ecological system. Another issue that would impede the applicability of DAPP-MR for the North Sea, as it is encompassed in the pilot, is the international boundaries that would have to be accounted for at the sectoral level. Considering the information gathered in the workshop and from the interviews, the researcher hypotheses that a 4th stage should be added (multi-sector multi-hazard multi-country). Currently, there are MSP policy boundaries between the EU and Britain. Thus, addressing the complexity through national integration of multiple national adaptation plans would represent a solution for the current status of collaboration.

The project encompasses not just the Netherlands, the geographical scope of the research, but also the North Sea waters of Germany, Denmark, Belgium and the United Kingdom. This does not align with the North Sea region, as it is defined by OSPAR (n.d.-c). One country that could potentially play a key role in the future of this region is Norway, a country that is part of the Scandinavia pilot focused on forestry, but not in the North Sea. Norway has already reached its renewable energy potential without extensively investing in renewables at sea (Expert interview 5, May 2023). The opening of the Arctic shipping routes would also imply increased shipping through Norway's waters., Thus, its role in the stakeholder collaboration activities of the project would have enriched the outcomes. This limitation has to be accounted for when the findings of the pilot are reflected upon. The North Sea represents a dynamic system, and political boundaries have an impact on the permanent placement of infrastructure at sea, which disrupts water column, nutrient availability and wind dynamics, that in turn affect the habitats of multiple species.

This thesis contributed to the project by bringing insight into lock-ins that might occur while applying the three stages of DAPP-MR in this system, as it is proposed at the time of conducting this research. It also brought insight into the workings of the Dutch North Sea as a collaborative governance regime that could be used for the application of this methodology. It also gave a comprehensive picture of the governance and user group structure that need to be engaged in the process. It used and reflected upon the information already gathered by Deltares in the stakeholder workshop and developed in internal sessions. Furthermore, through networking and interviews, a number of experts in the field have been made aware of the work conducted under the MYRIAD-EU project.

4.4. Contributing to the literature

Considering the conceptual and analytical dimension of this research there are multiple areas of literature from which knowledge was drawn. This research aimed to assess potential lock-ins that may arise in this collaborative governance regime when developing adaptation pathways using DAPP-MR. The suitability of DAPP-MR and reflections upon its tailoring for this case study and the North Sea, in general, have already been addressed in this discussion. Thus, the following section would focus on collaborative governance, maritime spatial planning, knowledge co-production and uptake and adaptation pathways in the context of governance.

Conceptualising the Dutch North Sea as a collaborative governance regime was a successful endeavour. The regime exhibited multiple levels of governance, that span across both private and public spheres. It was also a suitable choice considering the current policy changes that influence the evolution of user groups. The parties involved contribute to constructive engagement, evident in the existence of NZO, and have established rules through the form of the North Sea Agreement, that guide the regime for the short and medium term. Collaborative governance is not necessarily suited to tackle long term evolution. Thus, the four dimensions of collaborative governance for adaptation were introduced by Emerson & Gerlak (2014b). These were tailored into separate sections that completed the picture of a changing regime. It was found that the governance arrangement, in this case, steers towards climate change mitigation, with a strong preference for one user group, i.e. offshore wind. This may occur due to the economic branch having organically transitioned from a niche technology to an established industry. The biggest impasse is how to navigate the programme set out through the North Sea Agreement when one of the groups does not agree with the outcome of the negotiation (i.e. fisherman). Despite the introspection this research got into the trust and leadership and their impact on communication, this research was established with the mindset of highlighting adaptation lock-ins. Thus, it could only offer hypothetical solutions for overcoming identified issues. Emerson & Gerlak (2014b) found that leadership was not a focus of environmental change and adaptation, and it is crucial to be integrated in order to navigate complex situations with conflicting views among groups. Considering there are no 'communities of people' that live in the geographical area of this research, makes the representation and influence the user groups have on the way this system is managed, more nuanced than in a traditional collaborative governance regime. Emerson et al., (2012) offered further guidance on how to analyse in depth each of the four dimensions. Even with more structure available, the researcher would recommend for each dimension to be analysed in depth at a time. The scope of this research was quite broad and also encompassed DAPP and worked with a limited amount of data. Therefore, each part of the system, the governance arrangements, the sectoral structure, knowledge production and resource management in the North Sea are all topics that should be further researched.

Maritime spatial planning is a process that refers to the collaborative development of strategies to manage a sea space (Páez et al., 2020). This process has been indirectly addressed in this research, as spatial plans have been analysed and so was the dynamic between user groups and governance. Maritime spatial planning could be conceptualised as a transdisciplinary tool that syntheses the actions agreed upon by a collaborative governance regime (Páez et al., 2020). To benefit the tailoring of DAPP-MR for sea spaces, more research should be done to understand how to merge the two. Furthermore, transboundary maritime spatial planning would help manage the North Sea considering the spatial constraints and potential systems impacts (J. Moodie et al., 2021; Moodie & Sielker, 2021). There is evidence that the system is heading into that direction, through the development of MSFD or the discussions regarding joint power hubs that would link the energy development. Nevertheless, these should optimise the use of the sea space in a manner that would avoid, for example, wind shadow between developments of different countries or the placement of marine protected areas. Before tackling cohesive transboundary maritime spatial planning, a step back must be taken to ensure collaborative planning works at a national level. A key topic that must be included in all future maritime policymaking is adaptation to climate change at the risks it raises over the system. Another topic that should further be reflected upon is the lifetime of infrastructure that is planned to be developed, and its impacts on the ecosystem.

Which brings the discussion to the topic of knowledge. This research has looked into understanding what gaps are plaguing the system at the moment that could foster future uncertainties. There are multiple means of examining learning and knowledge in maritime protected areas that are not part of the collaborative governance perspective (Keijser et al., 2020). One must acknowledge that maritime spatial planning implies a multi-phased process of iterative integration of knowledge, which would facilitate the eventual implementation of an adaptive plan. This study attempted to understand the multi-hazard thinking present in the system; it became apparent that it was absent. To facilitate the development of this thinking a wider range of people should be included in the discussion, and a goal to prioritise multi-hazard and multi-risk in the system must be set. From the perspective of this research multi-risk thinking is deemed as essential for establishing collaborative governance for adaptation. This is not an aspect that is captured in the literature, thus justifies the merger of multiple conceptual elements with analytical steps is justified to tailor collaborative governance to both multi-risk and maritime areas.

There is no right way to tackle the wicked problem of the North Sea. Collaborative governance is not a type of governance that has been widely explored for sea spaces, and neither has DAPP or DAPP-MR. Although collaborative governance theory could be used in transboundary settings, DAPP-MR is not. Thus, looking into developing these concepts for this type of system would benefit not only the North Sea but would have an impact on developing maritime spatial plans in terms of uncertainty with minimal conflicts.

5. Conclusion

What are the potential lock-ins of the collaborative governance regime in developing adaptation pathways in the Dutch North Sea?

The analysis of the collaborative governance regime of the Dutch North Sea has been conducted with the mindset of tackling the forthcoming problems of the system. The theoretical basis of this governance theory has been merged with adaptation pathways concepts in order to highlight lock-ins that may occur in the system based on spatial development trends.

Looking at the governance structures, lock-ins may arise due to issues of trust in both the democratic process of collaboration and from mistrust in the ability to include and work with all relevant stakeholders. The government presents a strong preference for offshore wind as a technology that is ready to sustain, in mass, the energy transition of the sea away from conventional sources. There is a reliance on decision-makers to balance the uncertainties regarding systems knowledge, which can be limited by the term-to-term political system. Furthermore, the timeline of decommissioning of oil and gas could be detrimentally influenced by the current geopolitical context, with spillover effects on the urgency to meet internationally agreed green energy targets.

The users of the sea present conflicting perspectives that negatively impact the implementation of agreed agendas. The groups analysed present siloed thinking when it comes to adaptations and largely develop their targets individually. All current developments occur within a mindset of being allocated space permanently. Sequential optimisation of space is not considered.

There are unknowns regarding the cumulative systems impacts due to the mass deployment of infrastructure at sea. Social, technical and environmental knowledge gaps are nested within them. The transfer of knowledge from industries that are slowing down to ones that are developing represents a key to overcoming unrest. Evidence from single to multi hazard thinking was sought and it only occurs within academia or specific project developments, and is not a wide practice. DAPP-MR represents an opportunity for taking collaborating systems analysis a step further but requires further development as a concept.

Spatial claims could raise lock-ins as each user group requires certain areas to develop economically. Multi-use is a proposed solution and can be sequentially explored using DAPP-MR. The data gathered for this research was sufficient to understand the origins of potential lock-ins within this system. Although, a model-based quantitative approach could help to navigate the options of the system.

The wicked spatial problem of the Dutch North Sea cannot be addressed by one user or one governance institution alone but rather through collaboration. The system is ripe for policy change towards adaptation to climate change. The efforts currently made need to be sustained and enhanced by setting goals that include multi-risk on the agenda of future thinking.

References

Ansell, C., & Gash, A. (2008). Collaborative Governance in Theory and Practice. *Journal of Public Administration Research and Theory*, *18*(4), 543–571. https://doi.org/10.1093/JOPART/MUM032

Banach, J. L., van den Burg, S. W. K., & van der Fels-Klerx, H. J. (2020). Food safety during seaweed cultivation at offshore wind farms: An exploratory study in the North Sea. *Marine Policy*, *120*, 104082. https://doi.org/10.1016/J.MARPOL.2020.104082

Barton, J. R., Krellenberg, K., & Harris, J. M. (2015). Collaborative governance and the challenges of participatory climate change adaptation planning in Santiago de Chile. *Climate and Development*, *7*(2), 175–184. https://doi.org/10.1080/17565529.2014.934773

Bergström, L., Sundqvist, F., & Bergström, U. (2013). Effects of an offshore wind farm on temporal and spatial patterns in the demersal fish community. *Marine Ecology Progress Series*, *485*, 199–210. https://doi.org/10.3354/MEPS10344

Boeschoten, A. (2022). *Meer bescherming voor belangrijke vogelgebieden op de Noordzee | Vogelbescherming*. Vogelbescherming Nederland. https://www.vogelbescherming.nl/actueel/bericht/meer-bescherming-voor-belangrijke-vogelgebieden-op-de-noordzee?ss360SearchTerm=noordzee

Brink, E., & Wamsler, C. (2018). Collaborative Governance for Climate Change Adaptation: Mapping citizen–municipality interactions. *Environmental Policy and Governance*, *28*(2), 82–97. https://doi.org/10.1002/EET.1795

Buitendijk, M. (2021). *New chart shows how busy the North Sea really is | SWZ|Maritime*. SWZ|Maritime. https://swzmaritime.nl/news/2021/11/16/new-chart-shows-how-busy-the-north-sea-really-is/

Buitendijk, M. (2022). *Dutch Safety Board investigates increasingly crowded North Sea waters | SWZ|Maritime*. SWZ|Maritime. https://swzmaritime.nl/news/2022/09/22/dutch-safety-board-investigates-increasingly-crowded-north-sea-waters/

Casimiro, D., & Guerreiro, J. (2019). Trends in Maritime Spatial Planning in Europe: An Approach to Governance Models. *Journal of Environmental Protection*, *10*(12), 1677–1698. https://doi.org/10.4236/JEP.2019.1012100

Causon, P. D., Jude, S., Gill, A. B., & Leinster, P. (2022). Critical evaluation of ecosystem changes from an offshore wind farm: producing natural capital asset and risk registers. *Environmental Science and Policy*, *136*, 772–785. https://doi.org/10.1016/j.envsci.2022.07.003

Ciurean, R., Gottardo Silvia Torresan, S., Harris, R., Ferrario, D., Giannini, V., Tosarin, E., Sophie Daloz, A., Ma, L., Sakic Trogrlic, R., Reiter, K., Hochrainer-Stigler, S., Petrescu, E.-C., Tatman, S., Geurts, D., Padrón-Fumero, N., Díaz-Pacheco, J., García González, S., García Vaquero, M., & Febles Arévalo, T. (2022). *MS11/Pilot Workshop 1 completed and feedback to WP2, 4-6 Lead by BGS*.

Dähne, M., Tougaard, J., Carstensen, J., Rose, A., & Nabe-Nielsen, J. (2017). Bubble curtains attenuate noise from offshore wind farm construction and reduce temporary habitat loss for harbour porpoises. *Marine Ecology Progress Series*, *580*, 221–237. https://doi.org/10.3354/MEPS12257

De Jong, M. F., Baptist, M. J., van Hal, R., de Boois, I. J., Lindeboom, H. J., & Hoekstra, P. (2014). Impact on demersal fish of a large-scale and deep sand extraction site with ecosystem-based landscaped sandbars. *Estuarine, Coastal and Shelf Science*, *146*, 83–94. https://doi.org/10.1016/J.ECSS.2014.05.029

de Klerk, I., Reimers, N., Wurpel, G., & Jørgensen, A.-M. (2021). *North Sea Energy – Social embedding of North Sea energy system integration – a stakeholder analysis*.

de Vrees, L. (2021). Adaptive marine spatial planning in the Netherlands sector of the North Sea. *Marine Policy*, *132*, 103418. https://doi.org/10.1016/J.MARPOL.2019.01.007

Deltares. (n.d.). *Pipelines & Cables Sector* . Retrieved 15 March 2023, from https://www.deltares.nl/en/issues/offshore-engineering/pipelines-cables-sector/

Dieterich, C., Wang, S., Schimanke, S., Gröger, M., Klein, B., Hordoir, R., Samuelsson, P., Liu, Y., Axell, L., Höglund, A., & Markus Meier, H. E. (2019). Surface Heat Budget over

the North Sea in Climate Change Simulations. *Atmosphere 2019, Vol. 10, Page 272*, *10*(5), 272. https://doi.org/10.3390/ATMOS10050272
DRMKC. (2017). *Science for Disaster Risk Management 2017 European Commission*. https://drmkc.jrc.ec.europa.eu/knowledge/science-for-drm/science-for-disaster-risk-management-2017
Dutch Government. (n.d.). *Introduction of the Environment and Planning Act (Omgevingswet) | Business.gov.nl*. Retrieved 9 February 2023, from https://business.gov.nl/amendment/introduction-environmental-and-planning-act-omgevingswet/
Dutra, L. X. C., Sporne, I., Haward, M., Aswani, S., Cochrane, K. L., Frusher, S., Gasalla, M. A., Gianesella, S. M. F., Grant, T., Hobday, A. J., Jennings, S., Plagányi, É., Pecl, G., Salim, S. S., Sauer, W., Taboada, M. B., & van Putten, I. E. (2019). Governance mapping: A framework for assessing the adaptive capacity of marine resource governance to environmental change. *Marine Policy*, *106*, 103392. https://doi.org/10.1016/J.MARPOL.2018.12.011
Ebbers, R. (2019). *Hoe de Noordzee te vol werd voor de Nederlandse visserij | VNO-NCW*. VNO NCW. https://www.vno-ncw.nl/forum/hoe-de-noordzee-te-vol-werd-voor-de-nederlandse-visserij
Ehler, C. N. (2018). Marine spatial planning - An idea whose time has come3. In A. M. Slater & G. Reid (Eds.), *Offshore Energy and Maritime Spatial Planning* (pp. 6–17). Taylor and Francis. https://doi.org/10.4324/9781315666877-2/MARINE-SPATIAL-PLANNING-CHARLES-EHLER
Ehler, C. N. (2021). Two decades of progress in Marine Spatial Planning. *Marine Policy*, *132*, 104134. https://doi.org/10.1016/J.MARPOL.2020.104134
Emerson, K., & Gerlak, A. K. (2014a). Adaptation in Collaborative Governance Regimes. *Environmental Management*, *54*(4), 768–781. https://doi.org/10.1007/s00267-014-0334-7
Emerson, K., & Gerlak, A. K. (2014b). Adaptation in Collaborative Governance Regimes. *Environmental Management*, *4*(54), 768–781. https://doi.org/10.1007/S00267-014-0334-7
Emerson, K., Nabatchi, T., & Balogh, S. (2012). An Integrative Framework for Collaborative Governance. *Journal of Public Administration Research and Theory*, *22*(1), 1–29. https://doi.org/10.1093/JOPART/MUR011
EU Business. (2023). *EU targets bottom trawling in new sustainable ocean plan — EUbusiness.com | EU news, business and politics*. https://www.eubusiness.com/news-eu/eu-sustainable-ocean-plan.21gl
European Commission. (n.d.). *North Sea | The European Maritime Spatial Planning Platform*. Retrieved 27 March 2023, from https://maritime-spatial-planning.ec.europa.eu/sea-basins/north-sea-0
European Commission. (2020). *Commission notice Guidance document on wind energy developments and EU nature legislation Commission notice Guidance document on wind energy developments and EU nature legislation Guidance document on wind energy developments and EU Nature Legislation*.
European Commission. (2022). *EU Biodiversity Strategy Actions Tracker*. https://dopa.jrc.ec.europa.eu/kcbd/actions-tracker/
Directive 2014/89/EU of the European Parliament and of the Council of 23 July 2014 establishing a framework for maritime spatial planning, Pub. L. No. 2014/89/EU, Official Journal of the European Union 135 (2014). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32014L0089
EZK. (2021). *Ministry of Economic Affairs and Climate Policy Integrated National Energy and Climate Plan*.
EZK. (2022). *Introductiedossier Minsterie van Economische Zaken en Klimaat (EZK)*.
Fischer, M., & Sciarini, P. (2016). Drivers of collaboration in political decision making: A cross-sector perspective. *Journal of Politics*, *78*(1), 63–74. https://doi.org/10.1086/683061/SUPPL_FILE/00192APPENDIX.PDF
Gaslikova, L., Grabemann, I., & Groll, N. (2013). Changes in North Sea storm surge conditions for four transient future climate realizations. *Natural Hazards*, *66*(3), 1501–1518. https://doi.org/10.1007/S11069-012-0279-1/FIGURES/10

Geukes, A. H., Pesch, H. ;, Correljé, U. ;, & Taebi, A. ; (2020). A Healthy Metaphor? The North Sea Consultation and the Power of Words. *Sustainability*, *13*(22), 12905. https://doi.org/10.3390/su132212905
Geurts, D. (2019). *Unravelling the Governance System of the North Sea Master thesis Environment and Resource Management*.
Geurts, D. (2022). *MYRIAD-EU Pilot Workshop 1 North Sea*.
Gill, J. C., & Malamud, B. D. (2014). Reviewing and visualizing the interactions of natural hazards. *Reviews of Geophysics*, *52*(4), 680–722. https://doi.org/10.1002/2013RG000445
Grow. (n.d.). *About Grow*. Retrieved 7 March 2023, from https://grow-offshorewind.nl/about
Gușatu, L. F., Menegon, S., Depellegrin, D., Zuidema, C., Faaij, A., & Yamu, C. (2021). Spatial and temporal analysis of cumulative environmental effects of offshore wind farms in the North Sea basin. *Scientific Reports 2021*, *11*(1), 1–18. https://doi.org/10.1038/s41598-021-89537-1
Haasnoot, M., Kwakkel, J. H., Walker, W. E., & ter Maat, J. (2013). Dynamic adaptive policy pathways: A method for crafting robust decisions for a deeply uncertain world. *Global Environmental Change*, *23*(2), 485–498. https://doi.org/10.1016/J.GLOENVCHA.2012.12.006
Hamilton, M., & Lubell, M. (2018). Collaborative Governance of Climate Change Adaptation Across Spatial and Institutional Scales. *Policy Studies Journal*, *46*(2), 222–247. https://doi.org/10.1111/PSJ.12224
Hammar, L., Perry, D., Gullström, M., Hammar, L., Perry, D., & Gullström, M. (2015). Offshore Wind Power for Marine Conservation. *Open Journal of Marine Science*, *6*(1), 66–78. https://doi.org/10.4236/OJMS.2016.61007
Hatenboer, C., van den Berg, C., & Holzhacker, R. (2023). The Dutch fisheries sector and the North Sea Accord: Unpacking stakeholder participation in multi-levelled marine governance. *Marine Policy*, *147*. https://doi.org/10.1016/j.marpol.2022.105364
Head, B. W., & Alford, J. (2013). Wicked Problems. *Administration & Society*, *47*(6), 711–739. https://doi.org/10.1177/0095399713481601
Hermans, L. M., Haasnoot, M., ter Maat, J., & Kwakkel, J. H. (2017). Designing monitoring arrangements for collaborative learning about adaptation pathways. *Environmental Science & Policy*, *69*, 29–38. https://doi.org/10.1016/J.ENVSCI.2016.12.005
Informatiehuis Marien. (n.d.). *PMR - Natuurcompensatie Voordelta - Informatiehuis Marien*. Retrieved 10 March 2023, from https://www.informatiehuismarien.nl/projecten/pmr-natuurcompensatie-voordelta/
IPCC. (2022). *Climate Change 2022: Impacts, Adaptation and Vulnerability . Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. https://www.ipcc.ch/report/ar6/wg2/
I&W. (2021). *Introductiedossier Ministerie van Infrastructuur en Waterstaat*.
I&W, LNV, EZK, & BZK. (2022). *North Sea Programme 2022-2027*.
Jansen, H. M., Van Den Burg, S., Bolman, B., Jak, R. G., Kamermans, P., Poelman, M., & Stuiver, M. (2016). The feasibility of offshore aquaculture and its potential for multi-use in the North Sea. *Aquaculture International*, *24*(3), 735–756. https://doi.org/10.1007/S10499-016-9987-Y/TABLES/4
Kallis, G., Kiparsky, M., & Norgaard, R. (2009). Collaborative governance and adaptive management: Lessons from California's CALFED Water Program. *Environmental Science & Policy*, *12*(6), 631–643. https://doi.org/10.1016/J.ENVSCI.2009.07.002
Keijser, X., Toonen, H., & van Tatenhove, J. (2020). A "learning paradox" in maritime spatial planning. *Maritime Studies*, *19*(3), 333–346. https://doi.org/10.1007/S40152-020-00169-Z/TABLES/3
Kidd, S., Calado, H., Gee, K., Gilek, M., & Saunders, F. (2020). Marine Spatial Planning and sustainability: Examining the roles of integration - Scale, policies, stakeholders and knowledge. *Ocean and Coastal Management*, *191*. https://doi.org/10.1016/j.ocecoaman.2020.105182
Kidd, S., & Shaw, D. (2013). Reconceptualising territoriality and spatial planning: insights from the sea. *Planning Theory & Practice* , *14*(2), 180–197. https://doi.org/10.1080/14649357.2013.784348

Koning, S. de, Steins, N., & Hoof, L. van. (2021). Balancing Sustainability Transitions through State-Led Participatory Processes: The Case of the Dutch North Sea Agreement. *Sustainability* , *13*(4), 2297. https://doi.org/10.3390/SU13042297
Kopp, H., Chiocci, F. L., Berndt, C., Çağatay, N., Ferreira, T., Fortes, J., Gràcia, E., González Vega, A., Kopf, A., Sørensen, M. B., Sultan, N., & Yeo, I. (2021). *Marine geohazards Safeguarding society and the Blue Economy from a hidden threat*. https://doi.org/10.5281/zenodo.5591938
Krasner, S. D. (1982). Structural Causes and Regime Consequences: Regimes as Intervening Variables. *International Organization*, *36*(2), 185–205. http://www.jstor.org
Kuznetsov, A. L., Kirichenko, A. V, Kiselev, V. S., & Semenov, A. D. (2019). Simulation model for the North Sea Route transit time estimation. *IOP Conference Series: Earth and Environmental Science*. https://doi.org/10.1088/1755-1315/539/1/012019
Laird, L. M. (2001). Mariculture Overview. *Encyclopedia of Ocean Sciences*, 1572–1577. https://doi.org/10.1006/RWOS.2001.0474
LNV. (2022). *Introductiedossier*.
May, W., Ganske, A., Leckebusch, G. C., Rockel, B., Tinz, B., & Ulbrich, U. (2016). Projected Change—Atmosphere. In M. Quante & F. Colijn (Eds.), *North Sea Region Climate Change Assessment* (pp. 149–173). Springer, Cham. https://doi.org/10.1007/978-3-319-39745-0_5
Miller, K., Charles, A., Barange, M., Brander, K., Gallucci, V. F., Gasalla, M. A., Khan, A., Munro, G., Murtugudde, R., Ommer, R. E., & Perry, R. I. (2010). Climate change, uncertainty, and resilient fisheries: Institutional responses through integrative science. *Progress in Oceanography*, *87*(1–4), 338–346. https://doi.org/10.1016/j.pocean.2010.09.014
Moodie, J. R., & Sielker, F. (2021). Transboundary Marine Spatial Planning in European Sea Basins: Experimenting with Collaborative Planning and Governance. *Planning, Practice and Research*, *37*(3), 317–332. https://doi.org/10.1080/02697459.2021.2015855
Moodie, J., Sielker, F., & Goldsborough, D. (2021). Territorial cohesion and the sea: experiences from European maritime spatial planning. In D. Rauhut, F. Sielker, & A. Humer (Eds.), *EU Cohesion Policy and Spatial Governance* (pp. 66–82). Edward Elgar Publishing. https://doi.org/10.4337/9781839103582.00014
MYRIAD-EU. (n.d.-a). *MYRIAD-EU About MYRIAD-EU* . Retrieved 6 December 2022, from https://www.myriadproject.eu/project/
MYRIAD-EU. (n.d.-b). *MYRIAD-EU North Sea*. Retrieved 6 December 2022, from https://www.myriadproject.eu/pilots/north-sea/
Natuur & Milieu. (n.d.). *Over ons | Natuur & Milieu*. Retrieved 3 March 2023, from https://natuurenmilieu.nl/over-ons/
Nelson, D. R., Adger, W. N., & Brown, K. (2007). Adaptation to Environmental Change: Contributions of a Resilience Framework. *Annual Review of Environment and Resources*, *21*(1), 395–419. https://doi.org/10.1146/annurev.energy.32.051807.090348
Nilsson, H., van Overloop, J., Mehdi, R. A., & Palsson, J. (2018). *Transnational Maritime Spatial Planning in the North Sea: The Shipping Context Report on Work-package 4 of the NorthSEE Project*.
Noordzeeloket. (n.d.-a). *Borssele wind farm zone*. Retrieved 13 March 2023, from https://www.noordzeeloket.nl/en/functions-and-use/offshore-wind-energy/free-passage-shared-use/borssele-wind-farm-zone/
Noordzeeloket. (n.d.-b). *Cables and pipelines - Noordzeeloket UK*. Retrieved 17 February 2023, from https://www.noordzeeloket.nl/en/functions-and-use/kabels-leidingen/
Noordzeeloket. (n.d.-c). *Economic Affairs - Noordzeeloket UK*. Retrieved 27 March 2023, from https://www.noordzeeloket.nl/en/management/government/economic-affairs/.
Noordzeeloket. (n.d.-d). *Free passage and shared use* . Retrieved 14 March 2023, from https://www.noordzeeloket.nl/en/functions-and-use/offshore-wind-energy/free-passage-shared-use/ .
Noordzeeloket. (n.d.-e). *Interdepartementaal Directeuren Overleg Noordzee (IDON) - Noordzeeloket*. Retrieved 16 February 2023, from https://www.noordzeeloket.nl/beleid/interdepartementaal-directeuren-overleg-noordzee/
Noordzeeloket. (n.d.-f). *North Sea Consultation - Noordzeeloket UK*. Retrieved 20 February 2023, from https://www.noordzeeloket.nl/en/network/north-sea-consultation-0/

Noordzeeloket. (n.d.-g). *Shipping*. Retrieved 13 April 2023, from https://www.noordzeeloket.nl/en/functions-and-use/scheepvaart/
Noordzeeloket. (n.d.-h). *Surface mineral extraction* . Retrieved 13 March 2023, from https://www.noordzeeloket.nl/en/functions-and-use/artikel-baseline/
North Sea Commission. (n.d.). *Who We Are – CPMR North Sea Commission*. Retrieved 27 March 2023, from https://cpmr-northsea.org/who-we-are/
North Sea Farmers. (n.d.). *About NFSI - North Sea Farmers*. Retrieved 2 March 2023, from https://www.northseafarmers.org/about-nsf1
NWEA. (n.d.). *NWEA Policy Plan 2020-2022* . Retrieved 7 March 2023, from https://www.nwea.nl/nwea-beleidsplan-2020-2022/?lang=en
NZO. (n.d.). *Noordzeeoverleg | Noordzeeoverleg*. Retrieved 22 March 2023, from https://www.noordzeeoverleg.nl/home/default.aspx
OFL. (n.d.-a). *About OFL - Consultation Body Physical Living Environment*. Retrieved 16 February 2023, from https://www.overlegorgaanfysiekeleefomgeving.nl/over+ofl/default.aspx
OFL. (n.d.-b). *Noordzeeoverleg | Overlegorgaan Fysieke Leefomgeving*. Retrieved 20 February 2023, from https://www.overlegorgaanfysiekeleefomgeving.nl/actuele+projecten/actuele+projecten+overzicht/noordzeeoverleg/default.aspx
OFL. (2018). *Adviesrapport Verkenning Noordzeestrategie 2030*.
OFL. (2020). *The North Sea Agreement - Going those extra miles for a healthy North Sea*.
O'Leary, R., Gerard, C., & Bringham, L. B. (2006). Introduction to the Symposium on Collaborative Public Management . *Public Administration Review*, *66*, 6–9. https://www.jstor.org/stable/4096565
OSPAR. (n.d.-a). *About | OSPAR Commission*. Retrieved 27 March 2023, from https://www.ospar.org/about
OSPAR. (n.d.-b). *North-East Atlantic Environment Strategy 2030 | OSPAR Commission*. Retrieved 27 March 2023, from https://www.ospar.org/convention/strategy
OSPAR. (n.d.-c). *Region II: Greater North Sea | OSPAR Commission*. Retrieved 6 December 2022, from https://www.ospar.org/convention/the-north-east-atlantic/ii
Ostrom, E. (1990). Governing the commons: the evolution of institutions for collective action. In *Governing the commons: the evolution of institutions for collective action*. Cambridge University Press; Political Economy of Institutions & Decisions. https://doi.org/10.2307/3146384
Ostrom, E. (2009). A general framework for analyzing sustainability of social-ecological systems. *Science*, *325*(5939), 419–422. https://doi.org/10.1126/SCIENCE.1172133/SUPPL_FILE/OSTROM.SOM.PDF
Páez, D. P., Bojórquez-Tapia, L. A., Delgado Ramos, G. C., & Chavero, E. L. (2020). Understanding translation: Co-production of knowledge in marine spatial planning. *Ocean & Coastal Management*, *190*, 105163. https://doi.org/10.1016/J.OCECOAMAN.2020.105163
Paulson, S. (2022). *Optimizing Shellfish Aquaculture for Multi-Use Spaces Within Offshore Wind Farms in the Dutch North Sea*.
Peters, R., Vaessen, J., & Van Der Meer, R. (2020a). Offshore Hydrogen Production in the North Sea Enables Far Offshore Wind Development. *Annual Offshore Technology Conference*, *2020-May*. https://doi.org/10.4043/30698-MS
Peters, R., Vaessen, J., & Van Der Meer, R. (2020b). Offshore Hydrogen Production in the North Sea Enables Far Offshore Wind Development. *Proceedings of the Annual Offshore Technology Conference*, *2020-May*. https://doi.org/10.4043/30698-MS
POC. (n.d.). *Projecten | Platte Oester*. Retrieved 2 March 2023, from https://www.platteoester.nl/nl/projecten/
Port of Rotterdam. (n.d.). *Rotterdam Offshore Wind Coalition | Port of Rotterdam*. Retrieved 10 March 2023, from https://www.portofrotterdam.com/nl/vestigen/offshore/rotterdam-offshore-wind-coalition
Rijksoverheid. (n.d.). *EZK-verhalen | Ministerie van Economische Zaken en Klimaat | Rijksoverheid.nl*. Retrieved 16 February 2023, from https://www.rijksoverheid.nl/ministeries/ministerie-van-economische-zaken-en-klimaat/het-verhaal-van-ezk
Rijkswaterstaat. (2014). *North Sea 2050 Spatial Agenda*.

Rijkswaterstaat, & EZK. (2015). *Policy Document on the North Sea 2016-2021*.
Rusu, E. (2022). Assessment of the wind power dynamics in the North Sea under climate change conditions. *Renewable Energy*, *195*, 466–475. https://doi.org/10.1016/J.RENENE.2022.06.048
RVO. (2021). *Over ons*. https://www.rvo.nl/onderwerpen/over-ons
RVO, & BZ. (2021). *Dutch Offshore Wind Manual*.
Schlumberger, J., Geurts, D., Sharon Tatman, Warren, A., & Dochiu, C. (2023). *DAPP Application in the North Sea Pilot – MYRIAD (internal document)*.
Schlumberger, J., Haasnoot, M., Aerts, J., & de Ruiter, M. (2022). Proposing DAPP-MR as a disaster risk management pathways framework for complex, dynamic multi-risk. *IScience*, *25*(10), 105219. https://doi.org/10.1016/J.ISCI.2022.105219
Schütz, S. E., & Slater, A. M. (2019). From strategic marine planning to project licences – Striking a balance between predictability and adaptability in the management of aquaculture and offshore wind farms. *Marine Policy*, *110*. https://doi.org/10.1016/j.marpol.2019.103556
Scolobig, A., Komendantova, N., & Mignan, A. (2017). Mainstreaming Multi-Risk Approaches into Policy. *Geosciences 2017, Vol. 7, Page 129*, *7*(4), 129. https://doi.org/10.3390/GEOSCIENCES7040129
Sharifi, A., Feng, C., Yang, J., Mukhlis, M., & Perdana, R. (2022). A Critical Analysis of the Challenges of Collaborative Governance in Climate Change Adaptation Policies in Bandar Lampung City, Indonesia. *Sustainability 2022, Vol. 14, Page 4077*, *14*(7), 4077. https://doi.org/10.3390/SU14074077
Siebenhüner, B., Grothmann, T., Huitema, D., Oels, A., Rayner, T., & Turnpenny, J. (2021). Lock-Ins in Climate Adaptation Governance. In R. Djalante & B. Siebenhüner (Eds.), *Adaptiveness: Changing Earth System Governance* (pp. 127–146). Cambridge University Press. https://doi.org/10.1017/9781108782180.009
Soma, K., van den Burg, S. W. K., Selnes, T., & van der Heide, C. M. (2019). Assessing social innovation across offshore sectors in the Dutch North Sea. *Ocean & Coastal Management*, *167*, 42–51. https://doi.org/10.1016/J.OCECOAMAN.2018.10.003
Spijkerboer, R. C., Zuidema, C., Busscher, T., & Arts, J. (2020). The performance of marine spatial planning in coordinating offshore wind energy with other sea-uses: The case of the Dutch North Sea. *Marine Policy*, *115*, 103860. https://doi.org/10.1016/J.MARPOL.2020.103860
Stakeholder Workshop. (2022). *MYRIAD North Sea Pilot Stakeholder Workshop*.
Stead, S. M. (2018). Rethinking marine resource governance for the United Nations Sustainable Development Goals. *Current Opinion in Environmental Sustainability*, *34*, 54–61. https://doi.org/10.1016/J.COSUST.2018.12.001
Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., Biggs, R., Carpenter, S. R., De Vries, W., De Wit, C. A., Folke, C., Gerten, D., Heinke, J., Mace, G. M., Persson, L. M., Ramanathan, V., Reyers, B., & Sörlin, S. (2015). Planetary boundaries: Guiding human development on a changing planet. *Science*, *347*(6223). https://doi.org/10.1126/SCIENCE.1259855/SUPPL_FILE/STEFFEN-SM.PDF
Stendel, M., Van Den Besselaar, E., Hannachi, A., Kent, E. C., Lefebvre, C., Schenk, F., Van Der Schrier, G., & Woollings, T. (2016). Recent Change—Atmosphere. In M. Quante & F. Colijn (Eds.), *North Sea Region Climate Change Assessment* (pp. 55–84). Springer, Cham. https://doi.org/10.1007/978-3-319-39745-0_2
Stichting De Noordzee. (n.d.). *Onze doelen*. Retrieved 3 March 2023, from https://www.noordzee.nl/onze-doelen/
TenneT. (n.d.). *North Sea Wind Power Hub*. Retrieved 17 March 2023, from https://www.tennet.eu/about-tennet/innovations/north-sea-wind-power-hub
The Economist. (2023). *Can the North Sea become Europe's new economic powerhouse?* https://www-economist-com.proxy.library.uu.nl/business/2023/01/01/can-the-north-sea-become-europes-new-economic-powerhouse
TNO. (n.d.). *Required infrastructure offshore wind | TNO*. Retrieved 8 March 2023, from https://www.tno.nl/en/sustainable/renewable-electricity/system-integration-wind/required-infrastructure-integrate/
Topsector Energie. (n.d.). *TKI Wind op Zee | Topsector Energie*. Retrieved 7 March 2023, from https://www.topsectorenergie.nl/tki-wind-op-zee

UNDRR. (n.d.-a). *Disaster risk | UNDRR*. Retrieved 9 December 2022, from https://www.undrr.org/terminology/disaster-risk
UNDRR. (n.d.-b). *Hazard | UNDRR*. Retrieved 9 December 2022, from https://www.undrr.org/terminology/hazard
van de Bilt, S., Jaspers Faijer, M., & Muller, M. (2018). *MER Kavel V en VI Windenergiegebied Hollandse Kust (noord) |*.
Van Den Berg, C. F. (2016). Dynamics in the Dutch policy advisory system: externalization, politicization and the legacy of pillarization. *Policy Sciences*, *50*, 63–844. https://doi.org/10.1007/s11077-016-9257-x
van der Molen, F., Puente-Rodríguez, D., Swart, J. A. A., & van der Windt, H. J. (2015). The coproduction of knowledge and policy in coastal governance: Integrating mussel fisheries and nature restoration. *Ocean and Coastal Management*, *106*, 49–60. https://doi.org/10.1016/j.ocecoaman.2015.01.012
van der Werff, S., Baart, F., van den Heuvel, J., & Jense, D. (n.d.). *Drukte op de Noordzee*. Retrieved 7 December 2022, from https://ais-scrolly.netlify.app/#
van Hoof, L., Steins, N. A., Smith, S., & Kraan, M. (2020). Change as a permanent condition: A history of transition processes in Dutch North Sea fisheries. *Marine Policy*, *122*. https://doi.org/10.1016/J.MARPOL.2020.104245
van Tatenhove, J. P. M., & van Leeuwen, J. (2016). Marine Governance of the North Sea: Patterns of Regionalization. In M. Gilek & Kristine Kern (Eds.), *Governing Europe's Marine Environment* (pp. 199–218). Routledge. https://doi.org/10.4324/9781315585543-18
Vemuri, A., Munters, W., Buckingham, S., Helsen, J., & Beeck, J. Van. (2022). Modeling extreme weather events for offshore wind in the North Sea: a sensitivity analysis to physics parameterizations in WRF. *Journal of Physics: Conference Series*, *2265*(2). https://doi.org/10.1088/1742-6596/2265/2/022014
Verweij, M. C., van Densen, W. L. T., & Mol, A. J. P. (2010). The tower of Babel: Different perceptions and controversies on change and status of North Sea fish stocks in multi-stakeholder settings. *Marine Policy*, *34*(3), 522–533. https://doi.org/10.1016/j.marpol.2009.10.008
Wageningen University & Research. (n.d.). *Agrarische feiten en cijfers*. Retrieved 28 February 2023, from https://www.agrimatie.nl/?subpubid=2526
Wageningen University & Research. (2022). *Ecologically sustainable sand extraction in the North Sea - WUR*. https://www.wur.nl/en/research-results/research-institutes/marine-research/show-marine/ecologically-sustainable-sand-extraction-in-the-north-sea.htm
Warren, A., Stuparu, D., Schlumberger, J., Tijssen, A., Dochiu, C., & Rimmer, J. (2022). *D6.2/Guidance document for Pilots on collaborative systems analysis approaches*.
Weinert, M., Mathis, M., Kröncke, I., Pohlmann, T., & Reiss, H. (2021). Climate change effects on marine protected areas: Projected decline of benthic species in the North Sea. *Marine Environmental Research*, *163*, 105230. https://doi.org/10.1016/J.MARENVRES.2020.105230
Weisse, R., von Storch, H., Niemeyer, H. D., & Knaack, H. (2012). Changing North Sea storm surge climate: An increasing hazard? *Ocean & Coastal Management*, *68*, 58–68. https://doi.org/10.1016/J.OCECOAMAN.2011.09.005
WindEurope. (n.d.). *About us | WindEurope*. Retrieved 9 March 2023, from https://windeurope.org/about-us/
Woolley, O. (2013). Governing a North Sea Grid Development: The Need for a Regional Framework Treaty. *Competition and Regulation in Network Industries*, *14*(1), 73–97. https://doi.org/10.1177/178359171301400104
WWF. (2014). *Environmental Impacts of Offshore Wind Power Production in the North Sea A Literature Overview*. www.reddesign.no

Appendix 1

PARTICIPANT INFORMATION SHEET

(NTERVIEWS)

Project title: Multi-hazard and sYstemic framework for enhancing Risk-Informed mAnagement and Decision making in the E.U. (MYRIAD-EU): *Work Package 3 North Sea pilot*

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About the project

MYRIAD-EU addresses multi-hazard risk management through the lens of sustainability challenges that cut across sectors, regions, and hazards. Our vision is to catalyse a paradigm shift in risk science, by co-developing the first harmonised framework for multi-hazard, multi-sector, systemic risk management.

By the end of MYRIAD-EU, we hope that diverse decision makers will be able to develop forward-looking disaster risk management pathways that assess trade-offs and synergies of various strategies across sectors, hazards, and scales, recognising interrelated effects and the cascading effects of multi-hazard risk. The project starts with the belief that focusing on single sectors and hazards is no longer an option for effective disaster risk management.

MYRIAD-EU is producing products and services which will offer new ways to assess trade-offs and synergies between multiple hazards and different economic sectors. These solutions are developed in five pilot regions across Europe. Within Work Package 3 each pilot is studying a different combination of interrelated geological, meteorological and economic characteristics. The diversity of the pilots makes it possible to adapt their outcomes to other areas in Europe.

The North Sea system is one of the pilots in the project; it has been chosen because it will experience increasingly more complex challenges in the decades to come and is potentially heading for lock-ins that can affect sectors either individually or concurrently. Single hazard or specific sectors have already taken steps towards alleviating disaster risk. Despite that, collaboration across economic, governance and spatial systems will be key to unlocking the potential that can be developed in the North Sea. Considering the scope and limitations of this research six sectors have been chosen: offshore wind energy, shipping, cables and pipelines, sand extraction, food production and ecosystems conservation.

Involvement in interviews

Through April to May of 2023, we are conducting phone and in-person interviews to gather information and perspectives regarding the collaborative governance regime of the Dutch North Sea. The aims of the interviews are to (i) validate preliminary findings emerging from the literature regarding governance structure, collaboration opportunities and relationships between sectors, (ii) to gather information regarding potential system conflicts in relation to joint use of space at sea, as seen from the perspective of the interviewee and his/her operational practice.

Through a consent form, we invite you to provide an email address, so we can share final reports and outputs directly with you. This is optional, and your contact information will not be published or shared outside of the project team. Email addresses will be stored securely and separately from other contributions. Approval for recording the interview will also be sought through the consent form, if accepted by the interviewee, the session will be recorded, and notes will also be taken. If recording is not accepted, only notes taken during the interview will be used.

All data will be stored in a dedicated, secure online folder on the Deltares system. Personal information will be deleted no later than 6 months after the completion of the project.

What are the risks and benefits of being involved in this study?

We do not believe there to be any risks from your involvement in this study. While there are no personal benefits from involvement in this study, your participation could help the research team to strengthen their understanding of sectoral perspectives on multi-hazard, multi-risk management in the North Sea.

What are your rights as a participant?

Taking part in the study is voluntary. Declining to participate will have no negative consequences for you or your organisation. If you do decide to participate, you can withdraw at any point should you want to or choose not to answer a particular question.

If requested by you, and where we can extract and destroy data solely attributed to you, we are able to remove this from our study up until the point at which research outputs are put into the public domain (e.g., presentation at a conference, publication of a blog, submission of a research article, publication of a report).

Who has reviewed the project?

This proposed research has been tested for compliance with the Code of Ethics for Research involving the Human Participants Faculty of Science, Vrije Universiteit Amsterdam (VUA), using the ethics review self-check provided by the Ethics Review Committee of the Faculty of Science (BETHCIE, VUA).

What if I have concerns about this research?

If you are worried about this research, or if you are concerned about how it is being conducted, you can contact either the Principal Investigator (Philip Ward, philip.ward@vu.nl) and/or the Work package 3 Pilot North Sea lead (Sharon Tatman, Sharon.tatman@deltares.nl).

Appendix 2

CONSENT FORM

Project title: Multi-hazard and sYstemic framework for enhancing Risk-Informed mAnagement and Decision making in the E.U. (MYRIAD-EU): *Work Package 3 North Sea pilot*

Conducting the interviews: Corina Dochiu **Address:** Boussinesqweg 1, 2629 HV Delft **Email:** corina.dochiu@deltares.nl

Work Package 3 North Sea Pilot Lead: Sharon Tatman **Address:** Boussinesqweg 1, 2629 HV Delft **Email:** sharon.tatman@deltares.nl

Principal Investigator: Professor Philip Ward. **Address:** Institute for Environmental Studies (IVM), De Boelelaan 1111, 1081 HV Amsterdam, Netherlands. **Email:** philip.ward@vu.nl

Before taking part in this data gathering workshop, please review the statements below. If you wish to participate, please tick the box to confirm your consent.

In giving my consent to participate in this study, I confirm that:

- I understand that this study is designed to further scientific knowledge, and that all procedures adhere to the MYRIAD-EU ethics framework.
- I have read and understood the participant information sheet.
- I understand that I can ask questions, using the email address above, about this research before participating.
- I understand that I am under no obligation to take part in the study, have the right to stop my participation at any point for any reason, or decide not to answer a particular question, and will not be required to explain my reasons for any of these actions.
- I understand that I can withdraw my consent to participation and request my data is extracted from the study and destroyed, at any point up until the publication of research outputs.

Use of Information

- I agree to any personal information I choose to provide being processed in accordance with the General Data Protection Regulations (further information can be found here: https://ec.europa.eu/info/law/law-topic/data-protection/data-protection-eu_en).
- I understand that my personal information will be stored in a secure location for no more than 6 months after the completion of the project.
- I understand that personal information will only be accessible to the project team, unless (under the statutory obligations of the agencies which the researchers are working with) it is judged that confidentiality will have to be breached for the safety of the participant.
- I understand that anonymised data may be used in research outputs (e.g., publications, reports, web pages).

I agree to take part in this study.	**YES**	**NO**
If Yes, I agree to anonymised quotes being used in research outputs	**YES**	**NO**
I agree to this interview being recorded	**YES**	**NO**

Name:	**Signature:**	**Date:**

If you would like to receive copies of outputs (reports, academic journal articles) resulting from your participation, please provide your email address:

Who has reviewed the project?
This proposed research has been tested for compliance with the Code of Ethics for Research involving the Human Participants Faculty of Science, Vrije Universiteit Amsterdam (VUA), using the ethics review self-check provided by the Ethics Review Committee of the Faculty of Science (BETHCIE, VUA).

What if I have concerns about this research?
If you are worried about this research, or if you are concerned about how it is being conducted, you can contact either the Principal Investigator (Philip Ward, philip.ward@vu.nl) and/or the Work package 3 Pilot North Sea lead (Sharon Tatman, Sharon.tatman@deltares.nl).