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The cod crisis - fisheries management seen through the eyes of key stakeholders

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DECLARATION

I, Griet Nobis, declare that this thesis is a result of my research investigations and findings. Sources of information other than my own have been acknowledged and a reference list has been appended. This work has not been previously submitted to any other university for award of any type of academic degree.

Signature: 

Date: 1st of August 2021

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ABSTRACT

Millions of people rely on the ocean and its resources for food and livelihoods. Many fisheries are however greatly impacted by human action and at risk of overexploitation. The environmental changes and pressure on the ecosystem call for sustainable natural resource management practices. While they should be defined by resource users and based on the best and most holistic knowledge possible, in many cases it is evident that the condition of the natural resource is worsening. The actions taken have not been sufficient or correctly targeted to secure the stocks. Understanding stakeholders' perspectives about the resource and its current management regime can provide information about their limitations and beneficial aspects. In this thesis, qualitative interviews with stakeholders of Atlantic cod (*Gadus morhua*) in the Skagerrak facilitate exploration of the current management system. The application of the Knowledge-Action Framework by Nguyen et al., leads to greater understanding of the dynamics between knowledge production and knowledge action. Involvement of multiple stakeholders facilitates thorough understanding of perspectives regarding the status of the populations and the reasons for their decline. There is general agreement about the poor state of the cod stocks. Overfishing and climate change were identified as the main perceived reasons for the population decline. Further understandings of the reason for declines differed. Stakeholders raised more limitations than advantages within the management system. The main limitations identified were within the 'relational dimension', the 'characteristics and perceptions of actors', and the 'characteristics of knowledge'. Therefore, most participants experienced communication, collaboration, and attitudes and knowledge of other actors as the main factors limiting successful management. The lack of knowledge about the resource was an additional element. Greater stakeholder involvement can help to overcome these limitations, as it can improve relations, lead to increased social justice of resource users, and contribute a variety of knowledge. Most recently, the management of the Skagerrak is more anticipatory and includes more stakeholders, which is a move in the right direction. However, even greater involvement of stakeholders will likely be beneficial. These advantages of greater stakeholder participation point towards knowledge co-production as a suitable strategy for improving this management system.

Key terms: stakeholder participation, Atlantic cod, Knowledge-Action Framework, Skagerrak, knowledge co-production, common pool resource

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EEA	European Environment Agency
EU	European Union
ICES	International Council for the Exploration of the Sea
IMR	Institute of Marine Research
SSB	Spawning Stock Biomass

1 INTRODUCTION

The ocean and its resources are used by millions of people all over the world for food and livelihoods (Gaines et al., 2018). Of all major marine fisheries, 25 % are in danger of severe overfishing and 52 % are fully exploited (FAO, 2021). Marine fisheries are largely common pool resources (Ostrom, 2008; Rickels et al., 2016). Property rights for numerous commercially valuable species in the open ocean are missing, therefore there is no restriction on access and harvest of the resource (Ostrom, 2008). Additional pressures like pollution, alterations to coastal zones, and increasing resource extraction put the health and resilience of the oceans at risk. In 2018, multiple assessed stocks in the EU marine region were not in Good Environmental Status (European Environment Agency, 2021). The European Environment Agency (EEA) described the EU marine regions as being at risk and highlighted that immediate action is needed to avert irreversible changes in the ecosystem (Reker et al., 2019, Degraer et al., 2019). This is especially important for the North Sea, as its ecosystems are ranked as some of the most impacted ecosystems worldwide (Degraer et al., 2019). Effective regulatory mechanisms are needed to protect these resources (Rickels et al., 2016).

Despite fisheries management often being successful in reducing fishing pressure and rebuilding stocks (Hilborn & Ovando, 2014, Vasilakopoulos et al., 2014), cases persist where management did not lead to recovery of the stocks. Atlantic cod (*Gadus morhua*; hereafter, 'cod') is a notable example of both a management success and a management failure. In Canada in 1993, overexploitation led to the collapse of six cod populations (Myers et al., 1997). The inability to reduce fishing mortality at that time resulted in cod stocks that have not recovered since (Sguotti et al., 2019). In contrast, the Northeast Arctic cod in the Barents Sea has, despite similar environmental pressures and harvesting strategies, not seen such a collapse. The drastic reduction in harvesting pressure at early signs of population decline prevented overexploitation of these stocks (Lilly et al., 2013).

The empirical evidence of ecosystems being at risk and fish stocks declining suggests that the actions taken were insufficient or not correctly targeted to protect the ecosystems. A New Institutional Economics perspective would assign such outcomes to the existing institutions governing the access, utilization, and management which do not lead to sustainable management practices (Forsyth & Johnson, 2014). Whenever access to resources is not

regulated (i.e., when everybody can access and make use of resources), overuse and exploitation can occur (Ostrom, 2008; Vatn, 2015). Clear rules and boundaries about the resources are thus essential to avoid overexploitation (Forsyth & Johnson, 2014). While sustainable management practices should be based on the best and most holistic knowledge possible, such application is often lacking (Nguyen et al., 2017). Nguyen et al., (2017) developed the Knowledge-Action Framework aimed at fully identifying the actors and processes influencing the transition of knowledge into action. To comprehend why a current management system has not been successful at protecting certain stocks, it is important to investigate the inherent processes influencing the management action and thus the gap between knowledge and action. In successful management, resource users define the institutions and rules that combine the needs of resource users and the base of the resource (Forsyth & Johnson, 2014). Perspectives of multiple stakeholders involved with the resource thus helps to provide a holistic understanding of the institutions and management system governing a resource. Such knowledge can subsequently be used to create a more integrated management system that is more successful at protecting fish stocks and resource users. The risk of fish stocks collapsing, like the cod in Canada (Myers et al., 1997), can be reduced.

To improve and broaden traditional fisheries management practices, scholars have suggested practices like the 'management strategy evaluation approach' (Holland, 2010) and the incorporation of new scientific technology (Crossin et al., 2017) to try to tackle the uncertainty (Holland, 2010; Crossin et al., 2017). Other approaches like 'Ecosystem-based fisheries management' (Hall & Mainprize, 2004; Trochta et al., 2018) address issues with single species management. The integration of complexity and interaction between different species along with sustainable utilization of the resource are essential topics in this approach (Trochta et al., 2018). Similarly, the importance of stakeholder involvement is a concept that regularly reappears in literature about natural resource governance (Scoones et al., 2007, Lockwood et al., 2010). Knowledge co-production for example is a way to include stakeholders and their knowledge (Cooke et al., 2021). In Norway, a similar approach to ecosystem-based fisheries management is used to govern the coastal zones. Norway's integrated ocean management plans aim at combining the sustainable use of marine resources with the protection of the ecosystems (Ministry of Climate and Environment, 2021). At the centre of this management approach is the understanding that stakeholders are a central part of the ecosystem, interacting and influencing several of its processes and components

(Ministry of Climate and Environment, 2021). Understanding these actors' perspectives is central in understanding the policy process itself (Leach et al, 2010). This reflects Ostrom's (1990) and Nguyen's (2017) approaches, of identifying the resource users and their influences as a central part of successful natural resource management. Understanding stakeholders' perceptions is thus essential for successful resource management.

The cod populations in the Skagerrak and Oslofjord in Norway are an example where immediate management action is needed. High human population density and intensive agriculture in the catchment area greatly impact the ecosystems (Klima- og Forurensnings-Direktoratet, 2012; Havforskningsinstituttet, 2021). The ecosystems have changed over time, strongly influenced by human activities (Miljøstatus, 2021). Cod stocks in the Skagerrak are at an all-time low level (Aglen et al., 2016; Huserbråten et al., 2018) and subsided the critical limit set by the International Council for the Exploration of the Sea (ICES) (Miljøstatus, 2021). Cod in the Skagerrak/Oslofjord is separated into local, genetically distinct populations, some occupying as little as 30 km (Olsen et al., 2004). It can also be divided into genetically different ecotypes, called "Fjord" and "North Sea". Management needs to account for both ecotypes and local populations to guarantee their conservation, as genetic diversity can otherwise be lost irreversibly and the resilience of the stock as a whole be reduced (Knutsen et al., 2018; Jorde et al., 2018).

This study applies the discussed principles to the case of cod in the Skagerrak/Oslofjord. The main research objective of this study is to understand stakeholders' perspectives regarding limitations and advantages of the management system's capacity for sustaining the cod populations. Sub-research questions explored how the status of the cod and the domestic management processes are perceived by stakeholders. Qualitative interviews were conducted, which could then be analysed using the Knowledge-Action Framework of Nguyen et al., (2017). The framework is applied by organizing the perceived limitations and advantages of the management system into the categories of the frameworks Knowledge-Mediation sphere.

This thesis continues with an introduction to the case study and the methods applied. During the analysis chapter, I applied the framework, and stakeholders' perspectives are disclosed. Thereafter, in the discussion I highlight the main findings and connect them to the current management system. I conclude with a review of the main limitations and advantages and an outlook to possible future strategies.

2 METHODS

2.1 THE CASE

This study uses the case of cod in the Skagerrak/Oslofjord, Norway, to exemplify a way to understand current management systems and where their advantages and limitations lie.

The Skagerrak/Oslofjord (Figure 1) is greatly impacted by human activities putting the ecosystems at risk (Klima- og Forurensnings- Direktoratet, 2012; Havforskningsinstituttet, 2021). Environmental changes like increased water temperatures of 1-2 °C since 1988 (Perälä et al., 2020) add to the pressure on the ecosystem.

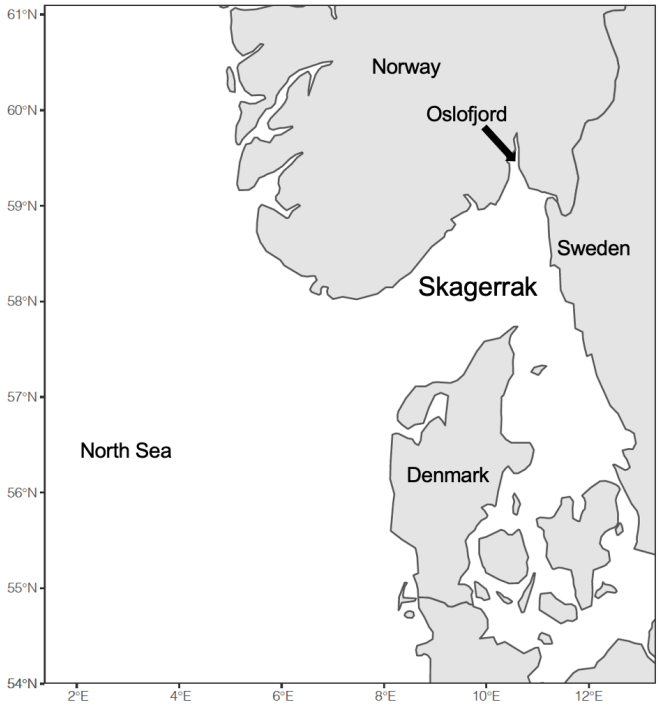

FIGURE 1: MAP OF SKAGERRAK AND OSLOFJORD

Cod is one example species impacted by these pressures. In Norway especially and in the Skagerrak/Oslofjord as well, cod is a commercially and recreationally important species (Bråte et al., 2016; Kleiven et al., 2016). In the Skagerrak, cod abundance is at an all-time low level (Huserbråten et al., 2018). The highest spawning stock biomass (SSB) of cod in the North Sea, English Channel and Skagerrak was observed between the 1960 and 1970. After that, SSB declined over time, while fishing pressure increased. Catches drastically declined

around 2000, followed by gradually declining fishing pressure (ICES, 2021a). The number of fish that survive and enter a fishery, called recruitment (McShane, 1995), also drastically dropped after 2000. In 2021, SSB, catches, and recruitment are at the lowest rates. Fishing pressure is low, but higher than the previous 10 years (ICES, 2021a).

Each year, the EU and Norway set the fisheries regulations in the Skagerrak, informed by advice from the ICES. For 2021, the total allowable catches for cod in the Skagerrak are 1893 metric tons, of which 61 metric tons are allocated to Norway (European Commission, 2021). Additional measures are taken to protect juvenile and adult cod, like the seasonal closure of spawning areas with a prohibition of fishing with all gears (European Commission, 2021). In Norway, the Ministry of Trade and Industry establishes the legal basis fishing regulations (Lovdata, 2020). Next, a proposal for the domestic quota allocation is made by the Directorate of Fisheries (Fiskeridirektoratet). Here, fishermen's associations, fishing industry, trade unions, the Sami Parliament, local authorities, environmental organisations, and other stakeholders are involved through Advisory Meetings. Based on the proposal by the Directorate of Fisheries and the Advisory Meeting, the Ministry of Fisheries and Coastal Affairs decides on quota allocation and technical regulations. The Directorate of Fisheries is the main advisory and executive body concerning fishing and aquaculture. Its management is based on scientific advice from the Institute of Marine Research (IMR) (Norwegian Ministry of Fisheries and Coastal Affairs, 2007).

Recent regulations set by the Directorate of Fisheries prohibit the use of nets and bottom trawls in restricted areas in the Skagerrak (Bakke, 2018). Since June 2019, fishing for cod in the Oslofjord is prohibited all year (Directorate of Fisheries, 2018) and the minimum landing size of cod in the Skagerrak is 40 cm (Directorate of Fisheries, 2019). The effects of the recent measures on population recovery are not yet known.

This study focusses on the domestic management process of the cod in the Skagerrak.

(For more details about study area and study species, see Appendix 1, 2 and 3.)

2.2 SAMPLING

A literature review about the status of cod in the Skagerrak was conducted in November 2020.

For this study, the population of stakeholders was chosen based on relevance for the domestic management system and the biggest influences for the cod in the Skagerrak. Researchers and managers belong to the sample population to gain insight into the basis and effectiveness of science-based management. Next to this, recreational and industrial fishers were included as the literature currently points towards these two groups as resource users with the biggest impact on the cod (Baden et al., 2012; Kleiven et al., 2016). The choice of stakeholders supports the use of the Knowledge-Action Framework (Figure 2). Researchers are relevant actors within the Knowledge Production sphere. Managers and resource users like industrial and recreational fishers are relevant actors within the Knowledge-Action sphere (Nguyen et al., 2017). (For more details about qualitative methods and sampling selection in relation to theory, see Appendix 4 and 5.)

Samples were selected through a non-probability, purposive sampling, choosing participants in a strategic way to ensure their relevance to the research question and to provide a variety of perceptions (Bryman, 2012). The initial sampling population started with scientists from the IMR, as 45 out of 91 articles included in the literature review were published by the institute. A snowball sampling technique relying on further recommendations from the initial participants was used to add to the sampling population. The community around the research and management of the cod was relatively well connected, and it was possible to reach a wide range of participants. Additionally, personal connections and direct contacting of individuals via email were used to contact participants. In total, 14 interviews were conducted in March and April 2021. It was found that 14 interviews were sufficient to ensure theoretical saturation. Theoretical saturation, a concept first introduced by Glaser and Strauss (Low, 2019), means that with new information gathered, further insights of the theory or theoretical categories was no longer obtained (Bryman, 2012). However, this does not mean that “no new information” emerged from the interviews (Low, 2019).

2.3 DATA COLLECTION

Data about perceptions of stakeholders was collected through a mix of semi structured and unstructured individual interviews, whereas unstructured interviews were followed up upon to

complete the main questions from the interview guide. The interview guides for each group of stakeholders differed slightly, as questions about the own group of stakeholders and the other groups had to be adjusted accordingly (see Appendix 6 for interview guides). Overall, the interview guides consisted of 25-29 questions addressing the status of the cod populations in the Skagerrak and perceived reasons for decline, impressions of other stakeholder groups, communication between groups and self-reflection. The questions were kept general and open, to suit each stakeholder group, ensuring comparability between the groups, while this also encouraged the interviewees to accentuate their own perspectives (Bryman, 2012). Interviews were either recorded and transcribed or detailed notes were taken during the interviewing process. All interviewees were informed about the topic of the study, the use of their data and their rights by a consent from (Appendix 7). They have full anonymity, and the methods were approved by the Norwegian centre for research data. Overall, the collected data affirmed the application of the Knowledge-Action Framework. (See Appendix 8 for ethical considerations.)

2.4 DATA ANALYSIS

The transcripts and notes from the interviews were used for the analysis. The response from the interviewees were first grouped according to context and perceived limitations and advantages of the system. The limitations and advantages were then analysed using the conceptual Knowledge-Action Framework by Nguyen et al., (2012) (Figure 2), focussing on the Knowledge Mediation Sphere. Rather than the original application of the framework investigating why new knowledge is not incorporated in decision making (Nguyen et al., 2018; Nguyen et al., 2019), this study aimed at understanding the processes in an already informed management system.

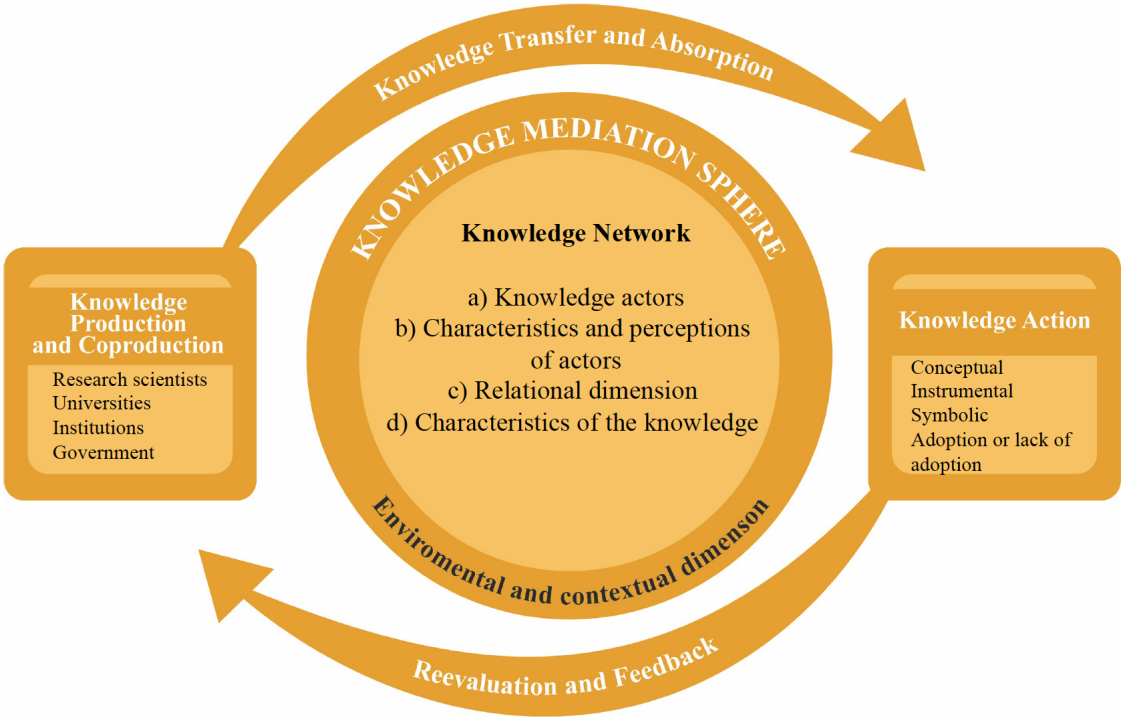

FIGURE 2: KNOWLEDGE-ACTION FRAMEWORK APPLIED FROM NGUYEN ET AL., (2017)

The Knowledge-Mediation sphere describes the gap between knowledge and action. Process and variables that mediate, alter, and facilitate the flow of knowledge between production and action, called the Knowledge Network, are included in this sphere. 'Knowledge actors', 'characteristics and perceptions of actors', the 'relational dimension' and 'characteristics of the knowledge' are elements within the Knowledge Network (Figure 2). The Knowledge Network is placed within the 'environmental and contextual dimension' (Nguyen et al., 2017). A detailed description of the elements of the Knowledge-Mediation sphere is given in Table 1.

TABLE 1: ELEMENTS OF THE KNOWLEDGE MEDIATION SPHERE, SUMMARIZED FROM NGUYEN ET AL., 2017.

Component	Description
Knowledge Actors	Individuals involved in exchange and mobilization of knowledge. I.e., Who, what, how many?
Characteristics and perceptions of actors	Character and perceptions of knowledge actor, including for example personality and skills, background and education, motivation, power and authority, contacts, and attitudes.
Relational Dimension	Relationships and connections between knowledge actors. Also influenced by trust, norms between individuals, respect, collaborations, partnership, and engagement with other actors.
Characteristics of the knowledge	Type and characteristics of knowledge entering the network.
Environmental and contextual dimension	External factors influencing the movement and exchange of knowledge. I.e., culture, institutional norms, economic and political context.

The framework was applied by a first coding of the interviewees' responses deductively according to the variables of the Knowledge Mediation Sphere (Table 1). With a second, inductive coding of the responses, different themes and arguments within the variables of the mediation sphere were identified. This approach to organize the data produced a clear overview of the responses. An application of the framework facilitates a thorough understanding of the dynamics influencing the current management processes and their limitations and advantages.

(For more details on the theory used, see Appendix 9. For details about validity and reliability considerations, see Appendix 10.)

3 ANALYSIS

For this study, 14 interviews were conducted with stakeholders from four different groups, recreational fishers, industrial fishers, researchers, and the managers, respectively. In total five interviews were conducted with researchers in the scientific community and three in every other group. The fishing industry was embodied by representatives and fishers in the Skagerrak, currently mainly trawling for shrimp. Interviewees from the scientific community were researchers from the IMR and university professors. The management group was represented by employees from the Norwegian Directorate of Fisheries and environmental advisors from county governors.

All participants had experienced the cod in the Skagerrak and were knowledgeable within their own field. The interviews in each group were not representative for the whole community, but rather give insights into different perspectives, ideas, and experiences from individuals (Bryman, 2012).

To get an impression of stakeholders' standpoints to better understand their arguments, their perceptions of status of cod, reasons for population change, management and responsibility are described first in the descriptive analysis, chapter 3.1. This is followed by the analysis of perceived limitations and advantages of the current system in chapter 3.2. Here, the Knowledge-Action Framework is applied to explore the dynamics influencing the current management processes.

3.1 DESCRIPTIVE ANALYSIS

3.1.1 STATUS OF THE COD

The overall perception from stakeholders was that cod populations in the Skagerrak are at a very low, critical level. Even when not addressing the status directly, all four groups were aware and concerned about the changes in the ecosystem in the Oslofiord and Skagerrak. It seemed obvious for the interviewees that there are issues with the cod populations. All groups were talking about "problems" and "crisis" in connection to the general situation in the Skagerrak and around the cod.

Recreational fishers mentioned bad fishing conditions for the cod and seemed pessimistic to catch cod bigger than the size limit. Expressions like "Well, good luck catching a bigger one,

I guess." (Recreational fisher #1) and "they [the larger fish] are gone for some reason" (Recreational fisher #10), were common. However, the recreational fishers did report on sightings of small first year cod in recent years, that do not seem to survive to the next year. Similar perceptions were found within the other stakeholder groups:

> *"Now, it's more like crisis. We should really do something about it. In the 1920s and 30s, they landed cod, like, one and a half meters in excess. Now there is none like that left at all." (Researcher #7)*

One other scientist, agreeing to the low population level of the cod, additionally highlighted the differences of the Fjord and North Sea cod and stressed the poor condition of the cod from the Oslofjord:

> *"It's really a crisis when it comes to the fjord cod. But for the migratory cod, it's not such a crisis. It's definitely low levels, from the North Sea bodies definitely at low levels but it's not a crisis as it is for the fjord cod."*
>
> *"(...) We basically can't get cod. And the few ones that we get they look horrible, (...). Extreme starvation and pale, and full of parasites. And they are really striving and very few of them" (Researcher #11).*

Contrary to the general concern about cod, one scientist argued that, while the stocks are at a low level, they are still able to reproduce efficiently:

> *"Even with this low stock the fecundity is high enough to produce strong year classes and as I said, we had two highest numbers [of recruitment], ever recorded" (Researcher #9).*

However, during other interviews very opposing points were raised about this topic. While speaking about the danger of only paying attention to numbers and not individuals, an example of one female cod being able to have enough eggs for the whole Oslofjord was

brought up. The interviewee emphasized the issues regarding low genetic diversity and offsprings poorly adapted to environmental change. The importance of multiple individuals and necessity to keep the populations intact was a main theme during this interview.

Besides the condition of the cod, it stood out that at least one individual from every stakeholder group additionally addressed a changing ecosystem. One recreational fisherman mentioned that not only the cod, but also other larger fish and sprat are gone. Other species like wrasses are much more present, especially in the Oslofjord. Industrial fishermen noticed a higher abundance of crayfish and less gadoid fishes in general, like pollock and saithe. The management is talking of "(…) a considerable higher outbreak of hake" (Manager #6) within the Skagerrak. Likewise, many scientists made a similar observation. While some mention a shift towards more scavengers like crabs, lobster and some wrasses, others are talking about an absolute change in the ecosystem: a regime shift.

> *"After regime shift, we never seen the ecosystem coming back again." (Researcher #9)*

The degree of change mentioned varies within and between the stakeholder groups, but all observe changes.

3.1.2 CAUSE OF POPULATION CHANGE

When asked about the causes for the population change, most participants are not able to identify a single cause, neither are most of them convinced about the causes they describe. Overall do participants express speculations and highlight the variety of causes and complexity of the system. Phrases like "It might be several things." (Recreational fisher #1), "I think it is very complex." (Industrial fisher #3) "I assume" or "I guess" (Manager #6) were commonly used during the interviews by participants from all stakeholder groups. However, the main theories addressed could be grouped into two groups; biotic and abiotic elements affecting the cod.

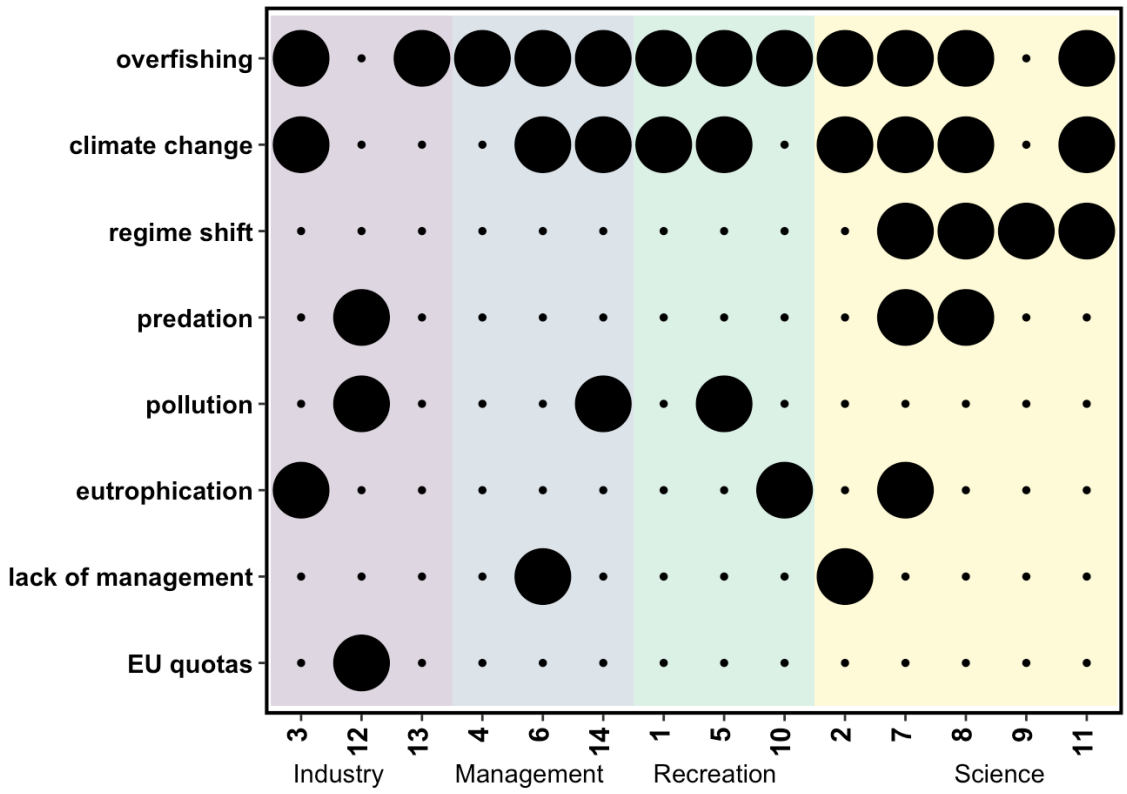

FIGURE 3: DISTRIBUTION OF PERCEIVED CAUSES FOR POPULATION CHANGE. ON THE X-AXIS ARE INDIVIDUAL PARTICIPANTS ORDERED ACCORDING TO STAKEHOLDER GROUPS. Y-AXIS REPRESENTS POSSIBLE CAUSES FOR POPULATION CHANGE. BIG CIRCLES INDICATE A SUPPORT OF THE CAUSE.

3.1.2.1 Biotic factors

Biotic factors describe living or once-living organisms within the ecosystem such as plants and animals that affect, in this case, the cod. Throughout the interviews, the main biotic factors identified were humans through their fishing practices, a shift in the plankton community and predation through seals and cormorants.

3.1.2.1.1 Overfishing

Overfishing by commercial and recreational fishermen was mentioned by 12 of the 14 interviewees (Figure 3). Different fishing practices, like commercial fishing, shrimp trawling, recreational fishing, and wrasse fishing were mentioned in varying degrees. Some stakeholders declared overfishing as one of the main threats to the cod populations.

"We know that the main source of mortality, at least here in the south coast is fishing, and especially recreational fishing. (…). So, we found like for instance for adult cod, like mature cod of those fish that died, 90% of those deaths, was caused by fishing, and then 10% was natural mortality. So, no doubt. Who is the bad guy, who are the bad guys? That is us!" (Researcher #2)

The general opinion however was that overfishing is causing problems for the cod but is not the main reasons why the population is declining. Often, recreational, and industrial fishing is seen to worsen the situation of the cod populations. Industrial fishing seems to be impacting the cod in several ways.

"And I think that [the shrimp trawling] might be, maybe not, THE most important thing, but a very important thing in the outer fjord, which is not as important in the inner part of the fjord because we don't have that much trawling for shrimp in the inner part. But it does exist." (Researcher #11)

"Anglers do kill of lot of fish. So, we are a very important mortality factor when it comes to the fish in that area. And when the stocks are as low as they are now that factor, strengthens. (…) What we mean is that we are not the reason for the decline of the cod." (Recreational fisher #5)

It is argued that through the shrimp trawling cod is caught as by-catch and habitat could be destroyed.

Additionally, one industrial fishermen (Industrial fisher #13) argues that shrimp trawling by large vessels (>35 feet) fishes away the cod's prey. Additionally, the wrasse fisheries, which are unregulated for by-catch of cod is perceived to have a big impact on the cod populations.

The opposition were one scientist (Researcher #9) and one commercial fishermen (Industrial fisher #12), who both stated that overfishing is not the cause of the decline.

"Overfishing? No, simply because whiting is just as affected as the other species, and it is a non-commercial species." (Researcher #9)

The interviewees did, however, have different explanations for the population decline, like a regime shift, predation, and pollution (Figure 3).

3.1.2.1.2 Zooplankton community shift

Increased natural mortality in the early life stage of the cod was a common topic being addressed. The theory of regime shift was presented by one of the scientists (Researcher #9) (Figure 3). According to this theory, there was a shift in the zooplankton community. Another, less energy rich type of zooplankton is now available for the cod and other fish. However, the cod relies on energy rich zooplankton for survival. The change in zooplankton community reduced the survival of the cod in the first summer, where energy rich zooplankton is its main prey. Later in the year, the main prey of the cod changes to shrimp and other fish, which also rely on energy rich zooplankton for survival and are thus also reduced.

> *"They are starving, they don't survive for the first winter because the food is gone." (Researcher #9)*

The same argument was made by another scientist. However, in contrast to interview #9 (Researcher) considering the shift in plankton community as the only reason for decline of cod populations, other reasons like climate change and overfishing were also addressed.

What causes the regime shift is not clear, it can potentially be a change in temperature or eutrophication. It is clear however, that gradual changes in these suddenly led to a drastic regime shift.

Observations from fishermen and recreational fishers fit the theory that most cod juveniles do not survive their first year, as well as their observed changes in the ecosystem.

> *"It [the cod] doesn't live longer than one year at the coast of Norway in Skagerrak. (...) It seems the fishermen have seen very peculiar change of the ecosystem especially in the Oslofjord and also the Skagerrak, where the water is warmer and its more turbid. (...) And I think it [the theory] corresponds very well with what the fishermen*

observe. As particularly now, we see that there is a spawning stock, so they can spawn and reproduce. The fishermen, they, there is no direct fishing of cod in the Skagerrak now. There is only bycatch of shrimp and still there is no fish. The cod still doesn't grow up." (Industrial fisher #3)

The shift in plankton community is also supported by other researchers #7, #8 and #11 (Figure 3). All argue that there has been a change in the zooplankton community which might affect the cod in a negative way.

3.1.2.1.3 Predation

One participant (Industrial fisher #12) presented the impact of seals and cormorants as the single reasons for population change (Figure 3). The increase in cormorant and seal populations in the Skagerrak are seen as the only variable that has changed, compared to the situation before the decline. However, throughout the other interviews, predation is rarely mentioned. When addressed, it was presented as a thought that others might have.

3.1.2.2 Abiotic factors

Abiotic factors are the physical and chemical components of an ecosystem. According to the interviewees, the cod is influenced by several different abiotic changes. Climate change, eutrophication through runoff and sewage release, and pollution were the main factors discussed (Figure 3). The degree of detail and description varied within and between stakeholder groups and depending on the topic.

3.1.2.2.1 Climate change

Most stakeholders mentioned climate change and warmer waters as one reason why the cod populations are declining (Figure 3). Often it is mentioned without clear explanations and more as a factor contributing to the poor situation of the cod:

"You can explain it from a climate point of view. The ocean or at least the coast are warmer, so it is more difficult for the cod to survive. It has to go down to colder water. That is one reason." (Manager #14)

Some scientists gave more detailed explanations to why the cod is negatively impacted. Firstly, the south coast of Norway is "on the borderline of what cod likes" (Researcher #8) in terms of temperature and gets stressed. Secondly, temperature is thought to be one possible reason for the shift in zooplankton community.

3.1.2.2.2 Eutrophication and pollution

Eutrophication was addressed less frequently than climate change (Figure 3). However, it is speculated to be responsible for the shift in zooplankton community. Changes in oxygen concentration and availability are also mentioned in combination with eutrophication:

> *"It is not big news that with increased eutrophication and more browning, you will have a change, or you will have less things that happen at the bottom. Less kelp and so on. And you will get fundamental changes in the food web." (Recreational fisher #10)*

Pollution was mentioned as often as eutrophication (Figure 3). When discussed, it is never mentioned as a main reason, often only expressed as a speculation or an additional variable putting pressure on the cod. Also, no interviewee has specific explanations on how the cod is impacted by the pollution and what the effects are. Pollution is mentioned in combination with the high population density around the Skagerrak.

3.1.3 PERSPECTIVES ABOUT MANAGEMENT

Next perspectives about the domestic management were a focus point throughout the interviews. Understanding the positioning of participants towards the management is crucial to identify the limitation and advantages of the system.

Even though most stakeholders have different dependencies on the cod as well as differing interests, most shared the same attitude towards the management. The degree of agreement and circumstances however, differed. Only one interviewee opposed the fishing ban, claiming that harvesting cod is still possible, only on a much lower level (Researcher #9). Of the other

13 participants, 11 supported a fishing ban and 2 did not position themselves. The supporters of a ban often mentioned to agree to the ban if this is an effective way to save the cod. Additionally, many interviewees mentioned the need for further regulations such as a maximum landing size (Recreational fisher #1, Researcher #2) and bag limits for recreational fishers (Recreational fisher #5) to protect bigger, more reproductive fish and limit the outtake per person. Moreover, the need for actions like a more regional management (Researcher #2, Industrial fisher #3, Manager #4) and improved management of the land surrounding the fjords (Researcher #7, #11) was addressed. Stakeholders saw a problem in only focusing on the cod, and the possible implications for other fish (Recreational fisher #1, #10, Manager #4). Several stakeholders with different backgrounds address the same issue of inequality. Recreational fishers (#5, #10), as well as industrial fishers (#12, #13) and researcher (#11) mention the importance of equality, either same regulations for recreational and commercial fisheries and between small and big fleets in commercial fishing. More enforcement of the regulations (Recreational fisher #10, Researcher #11) and auditors on commercial fishing boats for more transparency (Industrial fisher #13) are requested. Finally, some scientists stressed the need for the management to be more proactive and to act faster (Researcher #2, #7):

> *"We're going to have to work, make decisions based on imperfect knowledge, (...). Sometimes I still hear that argument that we can't give advice on this or we don't know this for sure so it's too early. (...) But it will never be perfect! So, while we talk the fish are disappearing. I think you just have to make decisions based on the knowledge that you have. Then you have to be careful, rather than optimistic." (Researcher #2)*

3.1.4 RESPONSIBILITY

During the interviews, participants were asked about their own role in protecting the cod and who the main responsibility has in their opinion. This can give insight into distribution of roles and perceived power of stakeholders.

The responses could be grouped into three main categories, the responsibility being shared, shared but authorities need to go first, and government/politics have the responsibility. The most common answer was that everyone has responsibility, but that the authorities, i.e., the government or the Directorate of Fisheries, need to act first and provide rules and guidelines

for best practice. In total, 8 out of 14 interviewees, including every stakeholder group shared this opinion (Figure 4).

> *"Everyone. We have to pull together. The farmers have to stop pollution, factories have to be aware of the pollution, and everybody has to take action. But of course, the Directorate of Fisheries they have a main part in making regulations and taking care of that people follow regulations, but everyone has to pull in the right direction." (Manager #14).*

One interviewee (Industrial fisher #12) thought that the responsibility to protect the cod was totally shared and two interviewees (Manager #4, Recreational fisher #5) thought that it was the government that has the responsibility to protect the cod. Three interviewees did not position themselves.

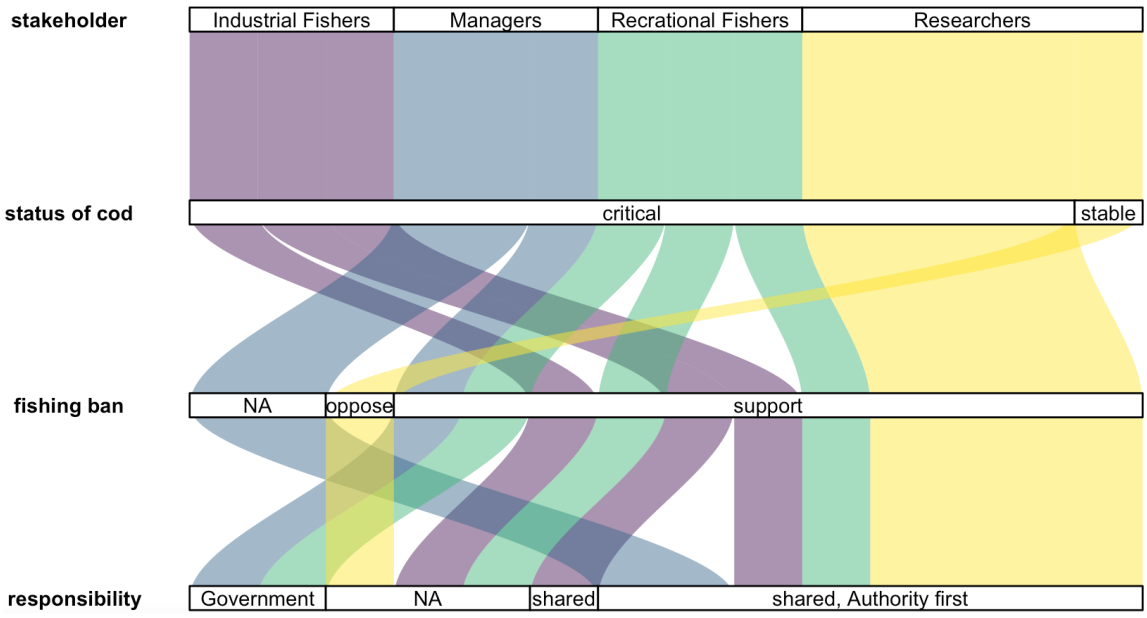

FIGURE 4: PERCEPTIONS OF STAKEHOLDERS OF STATUS OF COD, THE PRESENCE OF A FISHING BAN, AND RESPONSIBILITY TO PROTECT THE COD.

3.2 ANALYSIS USING FRAMEWORK

Applying the Knowledge-Action Framework facilitates the exploration of the main perceived limitations and advantages of the current management system. By organising and structuring

the responses from open-ended interviews according to themes, easy comparison with other and future work is ensured.

Overall, 76 % (88 out of 113) mentions were limitations, and 24 % were advantages (Figure 5). Of the limitations, the majority with 28 % were 'relational dimension', followed by 27 % from the 'characteristics and perceptions of actors' (Table 1). The 'characteristics of knowledge' category held 23 % of the limitations, 13 % were 'environmental and contextual dimensions' and 1 % of the limitations were from the category 'knowledge actors' (Table 1). Additionally, the category 'time' added and 8 % of the limitations were found here (Figure 5). Advantages were only found in three categories, the 'characteristics of knowledge' with 41 %, the 'relational dimension' with 33 % and the 'environmental and contextual dimension' with 26 % of all mentioned benefits (Table 1) (Figure 5). The findings are presented according to the framework, following the order from most to least mentioned limitations, with a more detailed description of the limitations and advantages, including quotations.

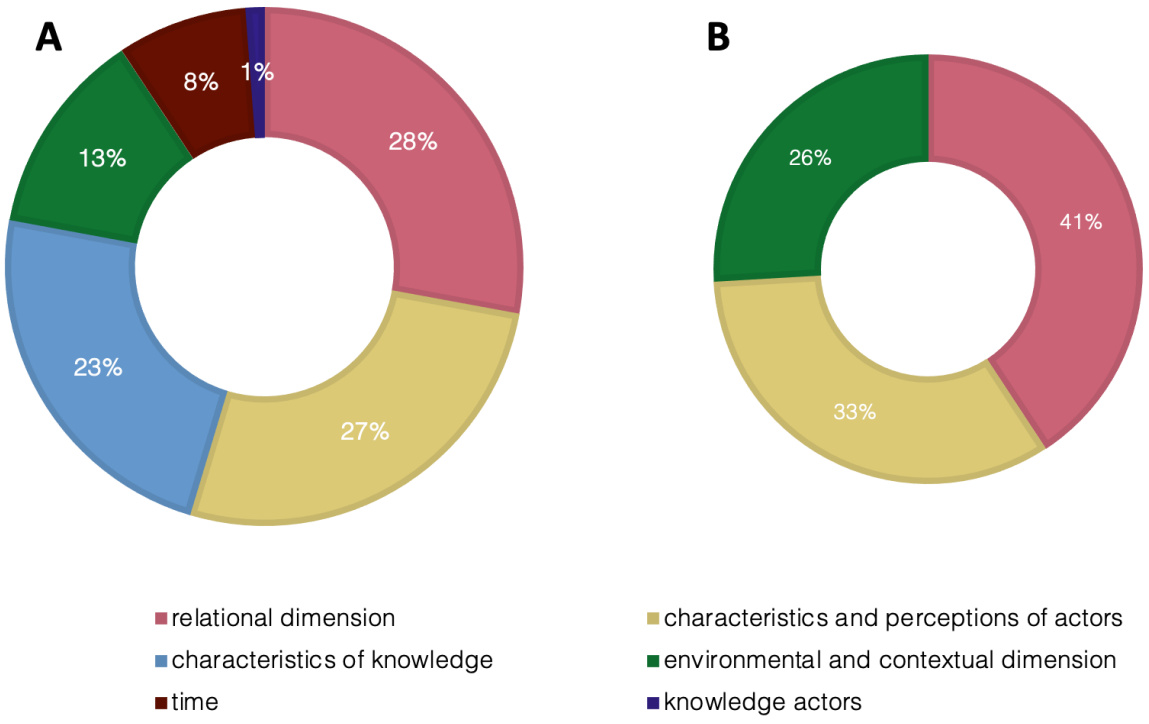

FIGURE 5: PERCEIVED LIMITATIONS (PANEL A), 89 RESPONSES IN TOTAL; AND ADVANTAGES (PANEL B), 29 RESPONSES IN TOTAL, OF THE SYSTEM CATEGORIZED USING THE KNOWLEDGE-ACTION FRAMEWORK.

3.2.1 RELATIONAL DIMENSION

Within the 'relational dimension' (Table 1), i.e., the relationships and links between actors (Nguyen et al., 2017), 4 main limitations were perceived. The most prominent limitation was the communication between the stakeholders, followed by collaboration issues between the stakeholders and issues with communicating scientific knowledge. Simultaneously, the advantages of the system also represented these three points. Additionally, the public communication of the regulations was perceived as problematic.

3.2.1.1 Communication between Stakeholders

Often, the communication between stakeholders is experienced as insufficient by stakeholders from all groups. While some statements are kept very general, pointing towards the possibility for improvement of communication, others are more directed towards individual relations between two stakeholder groups, i.e. the communication between recreational fishers and industrial fishers (Recreational fisher #5), between authorities and end-users (Researcher #11) or industrial fisherman (Industrial fisher #12) and between different authorities (Manager #4). The impact of communication issues is far reaching and, in some cases, lead to heavy frustration.

> *"The communication with the authorities is almost non-existent because they don't listen. They don't listen and of course we see that and there is a limit when is to stop contacting them and informing them because they don't listen anyway. And I think those are really a shame." (Researcher #11)*

However, most advantages also fall into the communication between stakeholders. Especially in the last few years, since the cod started to decline drastically, the communication improved and while still not satisfied, stakeholders approve of this change (Researcher #2, #7, Recreational fisher #5, Industrial fisher #12, Manager #14).

3.2.1.2 Collaboration

The main issue addressed here was that stakeholders do not feel heard, and their perspectives are not included in the decision-making process. This applies particularly to recreational and industrial fishers, who also often feel to be blamed for the decline of the stocks.

> *"Oh, it's super hard for the recreational fishermen to have their thoughts get heard. And none of the... none of the commercial parts when it comes to sports fishing equipment's, have been listened to and even be told about the plans about a fishing ban in the Oslofjord." (Recreational fisher #10).*

However, also scientist feel unrecognized by the management or colleagues. It was reported that scientists outside IMR often do not have the chance of being included in the decision-making process (Researcher #11). Scientists with diverging theories for decline seem to struggle of including their ideas (Researcher #9). Conversely, the management describes the decision-making process as open and points towards heavy involvement of scientists:

> *"Scientists are heavily involved in providing the knowledge base. So, it's a collaboration with them and us as managers to try to find the best knowledge-based decisions. So, we heavily depend on the scientist in many decision makings." (Manager #6).*

3.2.1.3 Communication of scientific knowledge

The publication of scientific knowledge to the end-users, including industrial and recreational fishermen was criticized by scientists, managers and recreational fishermen. Lately, there have been increased efforts to close this gap, however, it seems not sufficient yet.

> *"There's a big gap of course when what's published scientifically, and how that is communicated to the general public. Only a little bit gets across. Yeah, and that's a shame." (Researcher #2)*

3.2.1.4 Communication of regulations

The last grouping of responses addresses the communication of the rules and regulations in place. Interviewees mention the need for publications of regulations in multiple languages, facing the internationality of many recreational fishers in the area (Recreational fisher #5, Researcher #11, Manager #14).

3.2.2 CHARACTERISTICS AND PERCEPTIONS OF ACTORS

Perceived limitations and advantages that fall within the category 'characteristics and perceptions of actors' (Table 1) (Figure 5) relate to actor's standpoints, how they perceive and are perceived by other actors (Nguyen et al., 2017). Overall, were 23 mentions of limitations and 9 mentions of advantages documented. Most of the limitations addressed the managers, followed by researchers. Industrial and recreational fishers were addressed equally.

The main limitations directed towards the characteristics of the managers was their unsatisfactory knowledge on ecological process (Manager #4, Researcher #7, #11). Moreover, the hesitation of managers was criticized and especially scientists expressed the need for them to act more pro-actively (Researcher #2, #7) and based on facts, especially on municipal level (Manager #4):

> *"It's a complex issue with sort of in the end everybody loses if the fish disappear. So yeah, I think sometimes they can be a bit more progressive or be on the safe side, rather than risking it." (Researcher #2).*

It is claimed that the management is not objective enough. It seems as it favours the fisheries and research from the IMR (Researcher #11). However, small scale industrial fishermen feel overlooked, and advantages from their profession not recognized by the management (Industrial fisher #13).

Mainly industrial fishermen perceived researchers approach of being too focused on the fishermen, while other possible reasons for population decline are rarely considered (Industrial fisher #12, #13). For the industrial fishermen, it leads to frustration and feeling of unfairness. Especially compared to the larger vessels (>35 feet), small scale fishermen seem

to lose out, new regulations are favouring large vessels and younger generations struggle to find employment and a future in the fishing industry (Industrial fisher #13).

In addition, it is argued that larger vessels do not have an incentive for keeping the stocks, at least not in the same way smaller, more region bound vessel do (Industrial fisher #12).

Regarding the recreational fishermen, the main characteristics pointed out was the lack of awareness for the decline of the stocks and need to act (Recreational fisher #10). There seems to be a misconception of the public about how much wild nature is left and people seem not aware of the impact humans have on nature (Researcher #2, #7). To bring this message across can be a big challenge.

However, recreational, and industrial fisher's awareness increases. They have a sense of stewardship towards nature (Recreational fisher #1, #10, Researcher #2, Industrial fisher #12, #13). Both reported about different actions taken to protect fish, especially the cod, and to enhance their habitat.

3.2.3 CHARACTERISTICS OF KNOWLEDGE

In the category 'characteristics of knowledge' (Table 1) only limitations were (Figure 5). This category covers attributes and the type of knowledge that is being dealt with (Nguyen et al., 2017). The limitations concerned a lack of knowledge and the research focus.

3.2.3.1 Lack of knowledge

At least one individual from all stakeholder groups saw a lack of knowledge as one of the main limitations within the system. The lack of knowledge was the single most mentioned issue. Some responses were general and addressed the overall lack of knowledge, others were very specific. Areas where knowledge is missing spanned a wide range of topics from location spawning grounds (Industrial fisher #3) and recruitment (Researcher #9), impacts of recreational fishing (Industrial fisher #3, Manager #6, #14) up to the specific reason for the decline of the stocks (Recreational fisher #5, #10, Researcher #11). This is paired with the complexity of the issue, meaning that there is likely not a single reason for the decline (Researcher #2, #8, Industrial fisher #3). Missing knowledge in a very complex system does hinder the formulation of appropriate action and, as in this case, can be a limitation in the system.

3.2.3.2 Research Focus

Mainly researchers among themselves criticize the focus of past and current research and tradition in research. The focus on monitoring populations and numbers and not individuals seen as problematic, as variation and local adaptations are crucial (Researcher #2, #11). Additionally, it is argued that the focus of research should be the whole ecosystem and how it reacts to climate change, rather than on single species:

> *"Temperature and cod is the focus. How can it tolerate the higher temperatures. But that's not the problem. The ecosystem can tolerate the temperature and it appears that increase in temperature can switch the system, long before it is a problem for the cod." (Researcher #9)*

3.2.4 ENVIRONMENTAL AND CONTEXTUAL DIMENSION

Limitations addressed within the 'environmental and contextual dimension' (Table 1), thus external factors like culture, economic and political context (Nguyen et al., 2017), represent only 13 % of all limitations addressed (Figure 5). Limitations could be regarding the political cultural context or the natural context of the resource. Advantages mentioned include the social context and the positive outlook for the future were mentioned. Here again, the limitations outweigh the advantages.

3.2.4.1 Political and cultural context

According to the interviewees the political and cultural context of the cod in the Skagerrak bears some limitations. The relatively small economic importance of cod compared to the stocks in northern Norway led to it not being the prioritized area, which in turn impacted the efficiency of the protection of the cod (Industrial fisher #3, Manager #6):

> *"For example, the shrimp fishery continued without introducing selective gear like we did up in the North. Because we consider shrimp fisheries and pelagic fisheries, as important fisheries in the South, so they have a stronger voice down here in the South (…). So, any regulatory measures that would improve the fishing pattern would be met by scepticism by the fishermen in the South." (Manager #6).*

The internationality possibly puts additional pressure on the system through EU quotas (Industrial fisher #3). During one interview, the planning and managing processes in Norway were questioned, as special planning is currently mostly done at a local scale, however this leads to loss of overview and cooperation between areas. Consequently, the impact of small-scale projects on the fish populations is difficult to determine (Manager #4). Norway's culture is strongly based on the interaction with nature, including hunting and fishing. Such a strong cultural importance can hinder strict fishery regulations (Industrial fisher #14).

However, cod being greatly valued in the social context and its cultural importance can also be seen as a benefit of the system. The importance of the cod in Norwegian culture was mentioned several times throughout the interviews (Researcher #2, Industrial fisher #3, Recreational fisher #5, Manager #6). Cod being a valuable resource means that the management has invested interest in research regarding the stocks (Researcher #2).

3.2.4.2 Natural context

The population structure and the use of different habitats make it difficult to manage the cod. Based on the geographical distribution of different stocks, a more regional management seems to be needed to account for it (Researcher #2, #7, #11, Industrial fisher #3).

> *"So, it's a complicated system with the two main components [North Sea and Fjords] and the fjord component is again divided into several small units, possibly in fjords as well. And if you erased one of those, then, they won't get help from outside to restore themselves." (Researcher #7)*

Nevertheless, researchers agree that it is not too late to act (Researcher #2, #9), however, the degree of restoration differs greatly.

3.2.5 TIME

In addition to the variables from the Knowledge-Action Framework was the variable 'time' added (Figure 5). Two main limitations relating to time were addressed, one being that the

management action came too late, and the other being the time restoring processes take. The underlying reasons for late actions were not always addressed.

Scientists, managers, and industrial fishermen claimed that the action taken by the management came too late (Researcher#2, #7, Industrial fisher #3, Manager#6). Some were pointing towards the history of the Skagerrak (Manager #6) and the prioritization of fisheries (Industrial fisher #3), while others did not clarify it.

> *"So, but it [management action] took a long time we knew all these years before." (Researcher #7).*

The time it takes for actions to make changes in the ecosystem is long (Manager #4, Researcher #7) and time scales and expectations of manager and politicians often do not recognize this (Manager #4). This is especially important when considering regulations tackling problems like environmental pollution on land. This can be much more time consuming and difficult than regulating the fisheries:

> *"So, we have to regulate, or you have to do something about the one thing you can do something about. It takes longer to do something about pollutions from farmers and factories and so on. But you can do something about the fisheries and of course it is very difficult to do something about the climate and the warming of the ocean." (Manager #14)*

4 DISCUSSION

This study investigates stakeholders' perceptions about the management system of a common pool resource using the case study of cod in the Skagerrak/Oslofjord. The aim of the analysis in chapter 3 was to understand stakeholders' perspectives on ecosystem, and their views on limitations and advantages of the current governance system. Analysis using the Knowledge-Action Framework enabled detailed understanding of the actors' perspectives and their capability of participating in informed decision making.

First, the status of the cod populations in the Skagerrak was addressed in this study. A majority of stakeholders shared the perception of the stocks being at a very low level or even critically low. These perceptions reflect the general view in the scientific literature (Huserbråten et al., 2018, Rogers et al., 2017, Svedäng et al., 2019) and reports (Aglen et al., 2016) where stocks are described to be at an all-time low level. Several of the interviewees also observed a change in species composition of the aquatic community in the Skagerrak. Other gadoid fishes declined as well and of scavengers increased. This holds true especially in the Oslofjord. Changes in species composition was not directly addressed in this study, but indications among most stakeholders suggest dramatic changes in recent years.

Next, the reasons for the population change were addressed. Change in cod populations in the Skagerrak is always described as a decrease. Overfishing is the single most mentioned theory for the decline, followed by climate change (Figure 3). The scientific literature also addresses overfishing as a main reason for cod mortality. Commercial and recreational fishing are responsible for more than 50 % of the total deaths of cod (Kleiven et al., 2016). While increased temperature can negatively affect several biophysical processes in the cod at juvenile and/or adult stage (Freitas et al., 2015; Freitas et al., 2021), the current climate in the Skagerrak is found to be suitable for the cod (Núnez-Riboni et al., 2019). It might only affect the cod in the future (Aglen et al., 2016). Predation, pollution, eutrophication, regime shift, lack of management and EU quotas were also mentioned during the interviews as possible impacts on cod stock. These responses had relatively little support from stakeholders compared to overfishing and climate change. However, respondents did present different theories with different convictions. The theory of regime shift for example was brought forward with very strong conviction compared to others. Some of these factors are believed to negatively impact the cod populations in the Skagerrak, e.g., pollution (Ono et al., 2019).

Overall, these theories are less often represented in the literature compared to overfishing and climate change (Aglen et al., 2016).

The perspectives about management and responsibility showed that overall, most stakeholders approve of the current management practices and support a fishing ban if necessary. Many stakeholders attributed the main responsibility to protect the cod populations to a form of authority, mostly the 'management' or the government. Additionally, stakeholders acknowledged that everybody needs to contribute their part, and that responsibility is thus shared. Acknowledging one's responsibility for the actions and decisions taken and demonstrating how this has been internalized is an essential part of natural resource management (Laban, 1994; Lockwood et al., 2010).

Overall, the descriptive analysis shows the diverse perspectives of stakeholders with different interests. Only the most common perspectives are also presented in the scientific literature and marginalized ideas seem to have little influence. Often the narratives from the most powerful actors and institutions are the basis for management action, while narratives from more marginalized groups remain occluded (Leach et al., 2010). However, within a complex socio-ecological system, integrating all perspectives into the policy making and supporting the participation of stakeholders can be very beneficial for natural resource governance (Lockwood et al., 2010). Many different perspectives and types of knowledge constitute better solutions to more complex problems (Lockwood et al., 2010). In the case of common pool resources, which cod in the Skagerrak/Oslofjord can be considered being, greater inclusion of small-scale fishermen and recreational fishermen, and uncommon perspectives of researchers can add greatly to the understanding of the natural resource and how it is affected, contributing to a more complex framing of the system. It is very likely that broader perspectives and more diversity will lead to increased innovation and better tackle complex problems (Leach et al., 2010; Lockwood et al., 2010). Seeing that several stakeholders feel overlooked, awareness and valuation from the management for their perspectives and needs, is important in terms of social justice and the incorporation of goals and needs of marginalized groups (Reed et al., 2009, Leach et al., 2010).

The latter part of the analysis explored limitations and advantages of the current domestic management system using the Knowledge-Action Framework. Overall, the mentioned limitations numerically outweigh the advantages (Figure 6). Most limitations and advantages

were perceived within the ‘relational dimension’ and ‘characteristics of actors’ (Table 1). Communication between stakeholders, collaboration, and communication of scientific knowledge are perceived as problematic. However, it was often stated that communication and relations are improving (Figure 6), which is an indication for further improvement in the future. Limitations about the characteristics of actors were mentioned by stakeholders outside the group, which suggests potential criticism. Especially the fisheries and environmental authorities, and researchers were perceived to have a lack of change of strategy and their behaviour was criticised (Figure 6). The time needed to take actions and the time for the restoration process was perceived as an additional limitation. Nguyen et al., (2018) also found that time can be a limiting factor in incorporating new knowledge into management. Especially in established fisheries management, incorporating new knowledge can be challenging because of existing structures and motivations. Decision makers are often constrained by internal and external factors and are thus hindered to take the optimal decision (Nguyen et al., 2017). Social networks are often the base for gathering information and to evaluate the legitimacy and credibility of knowledge (Young et al. 2016). In a case where different stakeholders interact, social networks are potentially more important than formal structures (Bodin & Crona, 2009) and conservation success can be improved by increased trust between stakeholders (Young et al., 2013). This indicates that the relation between stakeholders is crucial for successful management of natural resources.

Even though stakeholders expressed frustration, the willingness to protect the cod and the sense of stewardship for nature is high (Figure 6). This is especially important for the ecology of the cod, as it facilitates the protection of common pool resources and prevents overharvesting (Bennett et al., 2018; Ostrom, 1990 in Rivera-Hechem et al., 2021)

The limitations within the ‘environmental and contextual dimension’ (Table 1) like area prioritization, internationality of waters and Norwegian culture can be associated with the history. Decisions made in the past, like the general distribution of EU quotas or the prioritization of other fishing areas in Norway, has created a path dependency and influences today’s decision making (Hegland & Raakjær, 2008). Whenever substantial changes in the management are needed, the participation of as many stakeholders as possible is desired (Lockwood et al., 2010). In this process, societal valuation of cod (Figure 6) is influential, as norms and values of the society can have great impact on the management system. Greater

involvement of stakeholders and greater representation of societal norms can lead to a change in the management system (Vatn, 2015).

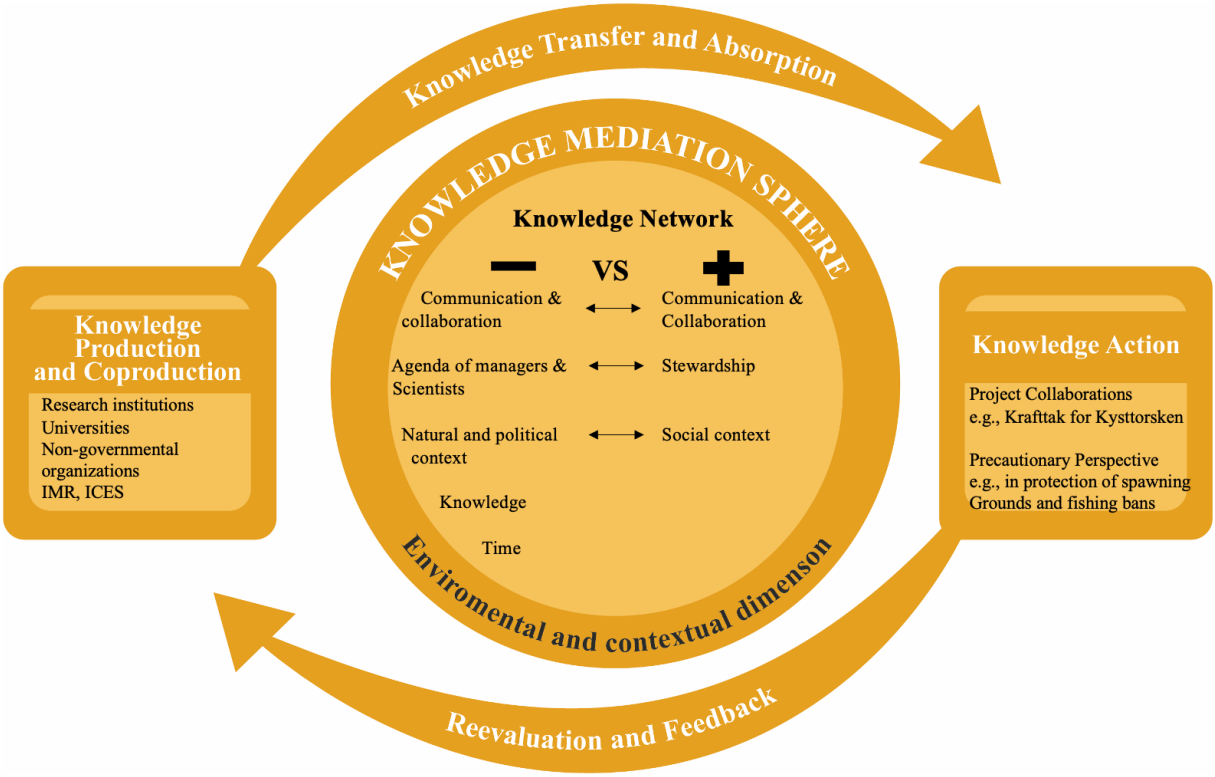

FIGURE 6: KNOWLEDGE-ACTION FRAMEWORK ADAPTED FROM NGUYEN ET AL., (2017). FRAMEWORK SHOWN HERE WAS APPLIED TO THE CASE STUDY COD IN SKAGERRAK/OSLOFJORD.

A lack of knowledge, from the category 'characteristics of knowledge' (Table 1) was the most strongly perceived limitation (Figure 6). Marine ecosystems are very complex. Due to heterogeneous patterns like species interaction, topography, water stratification and movement, marine ecosystems are difficult to predict (Crowder & Norse., 2008). Human interaction and global climate change add additional uncertainty to the system (Lockwood et al., 2010). Anticipation, a long-term focus, and emphasis on sustainability are especially important characteristics for the management (Leach et al., 2010, Lockwood et al., 2010). The absence can ultimately lead to failure in tackling environmental and development problem, while increasing inequality and injustices (Leach et al., 2010). Stakeholder participation can be crucial in extending the framing of the natural resource problem. The more participation of

stakeholders, the more diverse the framing, the more diverse solutions to complex problems (Lockwood et al., 2010) applies here, too.

Scoones et al., (2007) argue that dynamic and bottom-up approaches to governance and policy development should be applied to address the complexity of socio-ecological systems. Key features in a situation characterised by complexity, dynamism and uncertainty are an understanding and awareness of these attributes. Amongst other things is the recognition of different framings of the context, the system and its properties by actors with varying interests crucial, as a failure of understanding the systems functioning quickly leads to failure of development activities (Nederveen Pieterse, 1996 in Scoones et al., 2007). This study shows how the inclusion of diverse actors with differing interests can increase the diversity of framings of the system, which in turn is shown to be beneficial for a holistic approach to policy development. Additional issues between stakeholders and uncertainty about the resource itself can be overcome by greater inclusion of stakeholders in the management processes.

Given that the discussed results in this case regularly come back to greater stakeholder participation, knowledge co-production comes to mind as a strategy to overcome most of the limitations and strengthen the advantages. Knowledge co-production is described as "*Iterative and collaborative processes involving diverse types of expertise, knowledge and actors to produce context-specific knowledge and pathways towards a sustainable future*." (Norström et al., 2020). It is a way to close the knowledge-action gap (Kaiser et al., 2017; Cooke et al., 2021) and can help to increase interpersonal trust and ensure approval from stakeholders (Cooke et al., 2021). Issues within the 'relation dimension' and the 'characteristics of actors' could be addressed this way as relations between stakeholders could be strengthened. As knowledge co-production broadens scientist's perspectives, making science more understanding and creative (Cooke et al., 2021), it has potential to decrease the lack of knowledge.

The importance of stakeholder involvement is recognized in the new project in the outer Oslofjord, 'Krafttak for Kysttorsken', established in 2016 to strengthen the coastal cod populations. The project is a unique collaboration from the National Park Boards, the county municipalities on both sides of the Oslofjord, the IMR, the fishermen's organizations, the Directorate of Fisheries, and the Norwegian Environment Agency (Færder Nasjonalpark,

2021). Recent management decisions like the protection of the spawning grounds, fishing gear regulations and fishing bans are based on a precautionary perspective (Bakke, 2018). The integrated ocean management plans also recognize that stakeholders are a central part of the marine ecosystem (Ministry of Climate and Environment, 2021). These movements are set to improve the systems capacity to sustain the cod populations. However, currently, stakeholders' participation barely included in any of these approaches. It is only officially realized in the Advisory Meetings of domestic quota allocation (Norwegian Ministry of Fisheries and Coastal Affairs, 2007). The knowledge basis for decision making is almost exclusively coming from ICES and IMR (Norwegian Ministry of Fisheries and Coastal Affairs, 2007) and knowledge from outside of these institutions is rarely included. However, successful common pool resource management relies on stakeholder involvement (Scoones et al., 2007; Leach et al., 2010; Lockwood et al., 2010; Forsyth & Johnson, 2014; Vatn, 2015). This study suggests that the inclusion of stakeholders' perspectives and can contribute to overcome limitations and to strengthen the advantages of the current governance system relevant for management of cod in the Skagerrak/Oslofjord.

5 CONCLUSION

This research aimed at understanding stakeholders' perspectives about the management system of the cod in the Skagerrak to identify perceived limitations and beneficial aspects of the management system's capacity for sustaining the cod populations. Based on qualitative interviews with the most prominent stakeholders in the management system, stakeholders' perceptions about the status of the cod, the reasons for the decline, the management, and the distribution responsibility for the protection of the cod could be identified. While the status of the cod in the Skagerrak was mostly perceived as critically low, the perspectives about the other topics presented a great diversity. It was found that including multiple stakeholders from varying backgrounds and with diverse interests can be greatly beneficial for the ecology of the cod. Through the application of the Knowledge-Action Framework it could be concluded that the main limitations are concerning the communication and collaboration between stakeholders and their attitudes. A lack of knowledge about the resource was an additional issue often referred to. While generally, more limitations were mentioned than advantages, several stakeholders addressed a positive progress towards more communication and cooperation between stakeholder groups. Greater stakeholder involvement was often found to be suitable to tackle current limitations in the management system and strengthen the advantages. Based on the findings, stakeholders should consider increased knowledge co-production to achieve a more holistic natural resource management.

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APPENDIX

APPENDIX 1: STUDY AREA SKAGERRAK AND OSLOFJORD

The Skagerrak (Figure 1) is a strait of the North Sea located between Norway and Sweden in the northeast and Denmark in the southeast. In front of the coast of Norway, where the Norwegian trench is located, it reaches depths of up to 700 m. The Atlantic current with high-saline water is the major current entering the Skagerrak coming from the west (Bøe eta., 1998). Denmark, Norway and Sweden are highly industrialized countries, which are densely populated around the coasts of Skagerrak and North Sea. In 2010, almost 40 % of the Norwegian population was living in municipalities bordering the North Sea and Skagerrak, with the tendency to increase. Moreover, almost half of the population is living less than 500 m away from shore (Miljøstatus, 2021). The Skagerrak connects the Baltic Sea and Kattegat with the North Sea and thus the rest of the world, leading to heavy shipping traffic. In fact, it belongs to the heaviest traffic sea routes in the world (Ødegård et al., 2018) with about 70.000 ships (excluding fishing vessels) that annually pass through the Kattegat and Skagerrak (Danish Maritime Authority, 2021). Shipping and other industries like the petroleum industry, fisheries, offshore renewable energy production and tourism from this area contribute considerably to value creation in Norway (Miljøstatus, 2021). Consequently, human activities strongly influence the Skagerrak and lead to pollution problems and substantial pressures on biodiversity (Klima- og Forurensnings- Direktoratet, 2012).

The Oslofjord extends from the northeast end of the Skagerrak northwards towards the city of Oslo and experiences similar pressures like the Skagerrak. The fjord itself is separated into the inner and outer Oslofjord by a sill near Drøbak. Here, the water depth only reaches a maximum of 19.5 m, hindering greater water exchange (Powell et al., 2018). The area around the Oslofjord is the most densely populated area in Norway and discharges of wastewater are led into the fjord. As a result, the aquatic system suffers from environmental pollution (Powell et al., 2018). Additionally, eutrophication, and reduced oxygen in the bottom water as well as bottom trawling and altered light penetration, increase the pressure on the ecosystem. Combined with the absence of appropriate management, this resulted in the vast reduction of many fish stocks (Havforskningsinstituttet, 2021).

APPENDIX 2: STUDY SPECIES ATLANTIC COD (*GADUS MORHUA*)

Atlantic cod (*Gadus morhua*) is part of the gadoids, cod-like fishes and belong to the family of the Gadidae (ICES, 2021b). It is a key predator species that can get up to 35 years old, 200 cm in length and 96 kg in mass. Cod inhabits both sites of the Atlantic Ocean, in the east ranging from the Barents Sea in the North down to Biscaya in the South (marinebio, 2021). It is a cold adapted species with temperature niche ranging from -1.5 °C to 19 °C (Righton et al., 2010). In the southern areas of cod, it spawns in between January and mid-February. Further north, the spawning season is around April. One mature female of about 10 kg can carry up to a million eggs. The older a female fish, the bigger the eggs and higher the chances of survival of the egg. Feeding habits of cod change through its life. While still a larva, cod mainly feed on copepods. Later in life, their diet consists of fish and crustaceans (ICES, 2021b). Cod can be harvested using a variety of techniques and equipment.

APPENDIX 3: POPULATION DEVELOPMENT AND PRESSURES ON COD IN NORTH SEA, SKAGERRAK, AND ENGLISH CHANNEL

Description of figure 7A:

Panel A presents the development of total catches of cod in 1000 t from 1960 to 2020. The catches are divided into landing and discards. Highest catches and discard were around 1980. After that, catches declined drastically. Since 2000, there is little change in catches.

Panel B presents the development of the recruitment to age 1 from 1960 to 2021 in billions. Recruitment was highest around 1980 and drastically declined afterwards. Since 2000, recruitment is at a low level.

Panel C presents the development of the fishing pressure from 1960 to 2021. Fishing pressure increased over the years until it was greatest around 2000. After that, fishing pressure decreased drastically.

Panel D presents the development of the Spawning Stock Biomass from 1960 to 2021. The Spawning Stock Biomass was greatest around 1970, got drastically reduced in the following 20 years and has not increased again since.

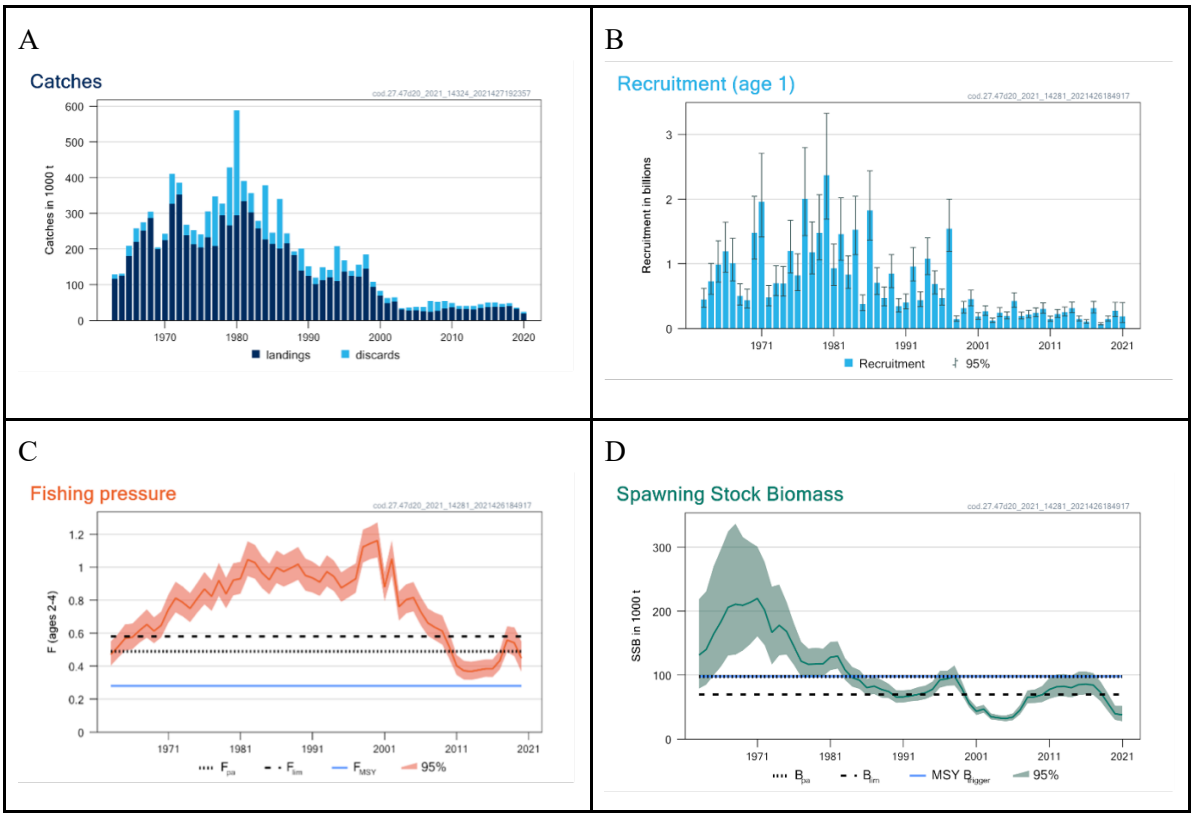

FIGURE A7:Catches (A), Recruitment to age 1 (B), Fishing pressure (C) and Spawning Stock biomass (D) for cod in the North Sea, Skagerrak, and English Channel. (from ICES, 2021a, p. 1)

APPENDIX 4: QUALITATIVE STUDY

To understand the perspectives of stakeholders and provide information about the current management system, qualitative methods were applied. Qualitative methods are valuable to reveal experiences and individual interpretations of events or situations from actors with different backgrounds. It also allows the research to pay attention to more uncommon views and ideas (Sofaer, 1999). In management research especially, the use of qualitative methods can facilitate the understanding and importance of context and persona and factors influencing these like social properties, common sense, and subjectivity (Gummesson, 2006).

Semi-structured interviews allow for a great degree of flexibility in the responses and the interviewees have the possibility to highlight their own ideas and their main emphasis regarding the questions (Bryman, 2012).

APPENDIX 5: SAMPLING SELECTION AND THEORY

Within the Knowledge (co)Production sphere are traditionally research scientists, universities, institutions, and the government. However, the inclusion of knowledge users in knowledge production is growing through practices like 'knowledge co-production' and 'citizen science' (Nguyen et al., 2017). Applied to this case study, research scientists working with or on the cod in the Skagerrak represent one stakeholder group, here referred to as 'researchers'. Actors within the Knowledge Action sphere include, among other actors, decision makers, resource managers, resource users and environmental educators (Nguyen et al., 2017). While researchers are also included in this group (Nguyen et al., 2017), they were representatives of the knowledge production in this study. Based on the Knowledge Action sphere, the second stakeholder group was composed of decision makers and environmental advisors from different levels. In this study, this group is often referred to as 'manager'. The third and fourth stakeholder groups were the fishing industry, 'industrial fisher' and recreational fishers, 'recreational fisher'. Both groups fit the framework because they represent the main resource users in the area, but also because they are partly involved in scientific research.

APPENDIX 6: INTERVIEW GUIDES

Interview Guide – Industrial fishers

GENERAL

1. What do you fish for?
2. For how long have you been doing that?
3. What is your interest in fish?
4. What got you interested?
5. How important is the cod for you?
6. Has that changed?

About stocks

7. Have you noticed any change in cod stocks in particular?
8. When did the change occur?
9. What do you think are the reasons for the change?

About management

10. What is your impression of the environmental authorities?
11. Do you think they set the correct regulations?
12. If not, what do you think should be changed?
13. Do you feel like they listen to what you say?

About fishermen

14. Do you know how many recreational fishermen are active? And what do they mostly fish for?
15. Do you know if there has been a change in what they fish for?
16. How big is the impact of recreational fishers you think?

About science

17. What is your impression of the scientific community?
18. How important do you think are the scientific findings for the protection of the cod?
19. Do you think they are communicated well enough?
20. How much do you know about scientific findings?
21. Where and how do you get access to this information?
22. How does this knowledge change your behavior?

About communication

23. How is the communication between stakeholders?
24. Do you feel your voice is heard?

Self reflection:

25. If you talk about the cod with friends and colleagues, what are common topics?
26. How big do you think is the impact the industry has on the cod stocks?
27. What is the general attitude of industry towards this problem?

Responsibility

28. How would you describe your role and responsibility in the protection of the cod?
29. In your opinion, who has the responsibility to ensure the protection of the cod?

Anything you want to add? Anything that I have missed?

Interview Guide – Managers

GENERAL

1. What do you do?
2. For how long have you been doing that?
3. What is your interest in fish?
4. What got you interested?
5. How important is the cod for you?
6. Has the importance of cod changed with the decline of the stocks?

About stocks

7. Have you noticed any change in cod stocks in particular?
8. When did the change occur?
9. What do you think are the reasons for the change?

About fishermen

10. Do you know how many recreational fishermen are active? And what do they mostly fish for?
11. Do you know if there has been a change in what they fish for?
12. How big is the impact of recreational fishers you think?
13. Do you know how many industrial fishermen are active? And what do they mostly fish for?
14. Do you know if there has been a change in what they fish for?
15. How big is the impact of industrial fishing on the cod?

About science

16. How important do you think are the scientific findings for the protection of the cod?
17. Do you think they are communicated well enough?
18. How much information reaches you?
19. Where and how do you get access to this information?
20. How does this knowledge change your behavior?

About communication

1. How is the communication between stakeholders?
2. Do you think that increased communication could lead to better management and more satisfaction?

Self reflection:

3. With how many different stakeholders do you interact to make a decision?
4. What is the main goal of the current management?
5. What are the driving perspectives for management decisions?
6. Where are trade-offs and difficulties in the current management system?

Responsibility

7. How would you describe your role and responsibility in the protection of the cod?
8. In your opinion, who has the responsibility to ensure the protection of the cod?

Anything you want to add? Anything that I have missed?

Interview Guide – Recreational Fishers

GENERAL

1. What do you do?
2. For how long have you been doing that?
3. What is your interest in fish?
4. What got you interested?
5. How important is the cod for you?
6. Has the importance of cod changed with the decline of the stocks?

About stocks

7. Have you noticed any change in cod stocks in particular?
8. When did the change occur?
9. What do you think are the reasons for the change?

About fishermen

10. Do you know how many industrial fishermen are active? And what do they mostly fish for?
11. Do you know if there has been a change in what they fish for?
12. How big is the impact of industrial fishing on the cod?

About science

13. How important do you think are the scientific findings for the protection of the cod?
14. Do you think they are communicated well enough?
15. How much information reaches you?
16. Where and how do you get access to this information?
17. How does this knowledge change your behavior?

About management

18. What is your impression of the environmental authorities?
19. Do you think they set the correct regulations?
20. If not, what do you think should be changed?
21. Do you feel like they listen to what you say?

About communication

22. How is the communication/dialog between stakeholders?
23. Do you think that increased communication could lead to better management and more satisfaction?

Self reflection:

24. Do you know how many recreational fishermen are active? And what do they mostly fish for?
25. What is his impression of fellow fishing enthusiasts: has the hobby changed with the changing ecology?
26. How big is the impact of recreational fishers you think?
27. What is the general attitude of the recreational fishermen towards the cod?

Responsibility

28. How would you describe your role and responsibility in the protection of the cod?
29. In your opinion, who has the responsibility to ensure the protection of the cod?

Anything you want to add? Anything that I have missed?

Interview guide - Researchers

GENERAL

1. What is your interest in fish?
2. What got you interested?
3. For how long have you been doing that?
4. (How was it for you/ is it for you?)
5. How important is the cod for you?

About stocks

6. Have you noticed any change in the fish stocks in general?
7. Have you noticed any change in cod stocks in particular?
8. When did the change occur?
9. What do you think are the reasons for the change?

About management

10. What is your impression of the environmental authorities?
11. Do you think they set the correct regulations?
12. If not, what do you think should be changed?
13. Do you feel like they listen to what you say?

About fishermen

14. Do you know how many industrial fishermen are active right now?
15. Do you know what they fish for?
16. Do you know how many recreational fishermen are active? And what do they mostly fish for?
17. Do you know if there has been a change in fishing and trade?
18. How big is the impact from industry and recreational fishing in your opinion?

About communication

19. How is the communication between stakeholders?
20. Do you feel your voice is heard?

Self reflection:

21. If you talk about the cod with friends and colleagues, what are common topics?
22. How important do you think are the scientific findings for the protection of the cod?
23. How are they communicated? And how are they implemented?

Responsibility

24. How would you describe your role and responsibility in the protection of the cod?
25. In your opinion, who has the responsibility to ensure the protection of the cod?

Anything you want to add? Anything that I have missed?

APPENDIX 7: CONFIRMATION OF CONSENT FORM

Confirmation of Consent

Do you want to participate in the research project
"The cod crisis – Stakeholders' perceptions."?

This is a question for you to participate in a research project where the purpose is to learn about the perceptions of people connected to the Atlantic cod in any way. I am interested in your opinion about the status of the Atlantic cod in the Skagerrak and its management.
In this letter, we give you information about the goals of the project and what participation will mean for you.

Purpose
With this study I am aiming at understanding the perceptions of different groups involved with the Atlantic cod in the Skagerrak. The specifics groups are scientists, policy makers, industrial and recreational fishers. I want to understand the opinions and attitudes towards the management of the Atlantic cod by each group and analyze similarities and dissimilarities in the thought process.
The information will only be used for this single purpose.

Who is responsible for the research project?
I, Griet Nobis, am conducting this study as a master student from the Norwegian University of Life Sciences (*Norges miljø- og biovitenskapelige universitet*, NMBU).

Why are you asked to participate?
You are selected because you are either a scientist currently working on the Atlantic cod in the Skagerrak (or in the past), or because you are involved in the policy making around the management of the Atlantic cod or because you are a fisher (recreational or Industrial) in the Skagerrak region. In total, I am aiming at interviewing about 4 participants from each group.

What does it mean for you to participate?
If you choose to participate in the project, it means that I will interview you. The interview will have open question where you can express your opinion. It will take you approx. 30 minutes. Your answers from the interview will be recorded in order for me to transcribe it later.

It is voluntary to participate
It is voluntary to participate in the project. If you choose to participate, you can withdraw your consent at any time without giving any reason. All your personal information will then be deleted. It will not have any negative consequences for you if you do not want to participate or later choose to withdraw.

Your privacy - how I store and use your information
I will only use the information about you for the purposes I have described in this article. I treat the information confidentially and in accordance with the privacy regulations. Only I will have access to the data. To make sure your data is safe, I will replace your name and contact information with a code that is stored on a name list separated from other data.
In the publication it will not be possible to recognize that you were a participant in this study.

What happens to your information when we end the research project?

The information is anonymized when the project ends, which according to the plan is June 2021. Your personal information and any recordings will be deleted at the end of the project.

Your rights
As long as you can be identified in the data material, you have the right to:
- access to which personal information is registered about you, and to receive a copy of the information,
- to have personal information about you corrected,
to have personal information about you deleted, and
- to send a complaint to the Data Inspectorate about the processing of your personal data.

What entitles us to process personal information about you?
We process information about you based on your consent.

On behalf of Griet Nobis, NSD - Norwegian Center for Research Data AS has assessed that the processing of personal data in this project is in accordance with the privacy regulations.

Where can I find out more?
If you have questions about the study, or want to exercise your rights, please contact:
Griet Nobis: griet.nobis@web.de
Lars Kåre Grimsby: lars.grimsby@nmbu.no

If you have questions related to NSD's assessment of the project, you can contact:
NSD - Norwegian Center for Research Data AS by email (personverntjenester@nsd.no) or by phone: 55 58 21 17.

If you would like to contact NMBU's data protection officer, please contact:
Hanne Pernille Gulbrandsen
Mobil: 402 81 558
E-post: personvernombud@nmbu.no

With best regards

Project manager Griet Nobis

Declaration of consent

APPENDIX 8: ETHICAL CONSIDERATIONS

In social research, it is essential to address ethical issues all throughout the research process (Bryman, 2012). The basis for ethical guidelines for this study were the Ethical guidelines for Norwegian University of Life Sciences (2015). For research and research ethics, the guidelines focus on eight different aspects of ethics. The eight aspects focus on a diversity of

ethical issues ranging from academic freedom and responsibility to the protection of humans, animals and the environment involved in the research (Norwegian University of Life Sciences, 2015). This study obeyed the instructions both regarding the general research ethics like academic freedom, social responsibility, and good research practices in good conscience. For this project the ethics regarding the protection of humans involved in research are especially relevant, as their perceptions were the main focus of the study. Fundamental respect for human life, as well as the integrity, freedom and co-determination of participants are of great importance. Additionally, informed consent is required to conduct social research (Norwegian University of Life Sciences, 2015). The study and methodology of data collection, processing and storing was designed to be in accordance with these ethical considerations. For all participants, informed consent was given about the purpose of the study, the responsible of the study, circumstances of participation and data storage and personal rights.

To confirm ethical mode of operation in this study, the Norwegian Centre for Research Data (NSD) was consulted. NSD approved the methods used for collecting, storing, and managing the data. One of the main services from NSD is data protection, advising universities, university colleges and health trusts on their projects. For this project, NSD assigned it to be in accordance with the data protection legislation. Underlying this classification is the legal basis of consent, which confirms that the legal basis for processing general categories of personal data is. Consent is given freely, specific, informed, and unambiguous and can be withdrawn at any given point. Next to this, the processing of data in this project is found to be in accordance with the principles under the General Data Protection Regulations. This includes that processing is lawful, fair, and transparent because the information given prior to interviews was sufficient and consent was given. During this project, the data is collected only for the sake of this thesis, a specific, explicit, and legitimate purpose. It will not be used for other, incompatible purposes. Furthermore, the project only collects data relevant for the study and it will not be stored longer than necessary to realize the purpose of the project. Participants in this study will have the right to access, rectify, erase, restrict processing and data portability as long as participants can be identified in the data collected.

APPENDIX 9: THEORY

In the case of the Norwegian Management of the cod stocks in the Skagerrak and Oslofjord, the actions taken are based on scientific evidence mainly produced by International Council for the Explorations of the Sea (ICES) and, for more local regulations, the Institute of Marine Research (IMR). Based on empirical evidence showing the ongoing decline of the cod stocks in the Skagerrak and the absence of recovery (Aglen et al., 2016) it is to assume that the current actions taken by the management are not sufficient to secure the cod populations. Stakeholders play a vital role in resource management and their involvement and relations greatly influence the success of such (Forsyth & Johnson, 2014). A gap between knowledge production and its application in the management, often referred to as a knowledge-action gap, can thus be related to the resource users. Differing norms, practices and expectations of knowledge producers and users have an impact on the transfer of knowledge (Brownscombe et al., 2019). Studies show that movement, exchange, application and interactions of knowledge affect the effectiveness of knowledge on natural resource management (Nguyen et al., 2017). It is also shown that successful natural resource management emphasizes the inclusion of stakeholders (Forsyth & Johnson, 2014). Applied to the case study cod in Skagerrak, it means that the gap between knowledge and action can originate because of interactions and characteristics of actors and knowledge. Identifying the variables influencing the outcome is essential to recognize and understand potentials and barriers within the system.

There have already been several efforts to try and identify the gap between knowledge and action (e.g., Lauber et al., 2011; Cook et al., 2013; Taylor et al., 2017; Nguyen et al., 2017). Previous attempts are often case specific and do not provide an overarching framework (Lauber et al., 2011; Cook et al., 2013; Taylor et al., 2017, Nguyen et al., 2017). However, a framework aids at gathering and combining information (Ostrom, 2009). Nguyen et al., (2017) developed a framework, called the Knowledge-Action Framework, which describes the process and variables within the ‘gap’ of the knowledge action gap. It facilitates easy identification, synthetization and comparability of knowledge movement and mobilization towards implementation into natural resource management within one case study or between several. In other words, the Knowledge-Action Framework aims at unravelling the process within the knowledge mobilization and exchange, the stages between the production of new knowledge and the application of knowledge in management (Nguyen et al., 2017).

By applying this framework, the goal is to unravel the process between the production of the knowledge of the cod in the Skagerrak and the implementation of management regulations based on this knowledge. This is one attempt to understand the processes leading to insufficient management action. With the use of this theory it will be possible to give an explanatory understanding of the barriers but also potentials in the current knowledge to action transfer that affect the outcome, i.e. the regulations in place to secure the cod populations in the Skagerrak.

The framework consists of three main elements, the Knowledge Production, the Knowledge Mediation Sphere, and the Knowledge Action all connected through nonlinear processes that influence the way information travels and is absorbed (Figure 1) (Nguyen et al., 2017). While Knowledge Production and Knowledge Action represent the basis and its outcome, it is not the main emphasis of the framework. The phase in between, the Knowledge Mediation Sphere, describing the 'gap' in the movement of knowledge to action, is the core of the framework (Nguyen et al., 2017). According to the framework, the basis for informed action is knowledge. While traditionally, knowledge can be produced by scientists, academic institutions and other researchers, citizen science and traditional and local knowledge is gradually incorporated into the knowledge creation process (Nguyen et al., 2017). For the sake of this framework, no differentiation of the different types of knowledge production and actors involved is made. The produced knowledge is then transferred to and absorbed in the Knowledge Mediation Sphere (Nguyen et al., 2017). Here, all kinds of multidirectional interactions with the knowledge and what can influence the interaction with knowledge are described. Within the knowledge network, four elements were defined to have an influence on the movement and mobilization of knowledge, i.e., 'knowledge actors', 'characteristics and perception of actors', 'relational dimension', 'characteristics of knowledge' (Table 1) (Nguyen et al., 2017). In other words, the number and type of actors, their agenda, skills and how they are perceived by other actors, as well as the relationships and communication between actors and the complexity of the knowledge itself can have an impact on the translation into action. However, there might be external circumstances that can also have an impact on the movement and mobilization of knowledge. Such can be for example political and economic circumstances or government processes. In the framework, these external forces are described as the 'environmental and contextual dimension' of the Knowledge Mediation Sphere (Nguyen et al., 2017). It is important to note that, depending on the specific

context, interactions can take place at different scales and may have different magnitudes (Nguyen et al., 2017). Eventually, the knowledge produced has moved through the knowledge mediation sphere and, if fruitful, is integrated into management action; the Knowledge Action element of the framework (Nguyen et al., 2017). Here, examples of successful actions are the implementation of a policy or altering the behaviour to a more sustainable approach. However, Nguyen et al., (2017) highlight that successful action outcomes are very context dependent and that there is no universal method to assess it. For this case study, management outcomes will not be evaluated.

During the analysis, the focus will be, as in the framework itself, on the Knowledge Mediation Sphere with the 'knowledge network' and the 'environmental and contextual dimension' influencing the outcome. Neither Knowledge Production, nor Knowledge Action will be analysed in detail as potentially being the reason for the unsuccessfulness of the actions, this is not in the scope of this study and would possibly need another approach to clarify why action taken are not sufficient enough to ensure the protection of the cod stocks.

The theory, even though being a relatively new concept, has already been applied in the field of natural resource management. Nguyen et al., (2018) and Nguyen et al., (2019) successfully used the framework to explore the limitation of incorporating new knowledge or technologies into informed action in management. In both studies, the framework was extended by the element of time, ranging from time needed for scientific knowledge to be produced to time needed to incorporate it into the management (Nguyen et al., 2018; Nguyen et al., 2019). This is an element not directly discussed in the framework, but potentially also relevant for this case study. As the framework is constructed in a way that still allows for addition of elements based on empirical evidence (Nguyen et al., 2017), this study will take additional elements into account. Especially the element of time, as being added in both applications of the framework (Nguyen et al., 2018; Nguyen et al., 2019) will be considered as an addition if found necessary. Other additions to the main elements of the framework were mismatches with scales and culture (Nguyen et al., 2018) and knowledge transfer (Nguyen et al., 2019), which will also be considered if necessary as they have proven to be a possible element of the framework.
When comparing the two applications of the framework of Nguyen et al., (2018) and Nguyen et al., (2019) to this particular case study, it is important to note that both of these studies

aimed at identifying barriers for the incorporation of new knowledge into the management action. However, the case study of the Atlantic cod aims at understanding the barriers of why the knowledge produced and actions taken based on this knowledge have not been successful in securing the cod stocks in the Skagerrak. Potentials for successful integration of knowledge into action will additionally be analysed. The approach of this study is to investigate if the movement and mediation of the knowledge can potentially have an impact on the outcome in this case. Nguyen et al., (2018) and Nguyen et al., (2019) apply the framework in order to map barriers for incorporating new knowledge into management. This study however deductively applied the framework to an already informed management system. The dimension and categories of the framework are used to understand the movement of knowledge and thus identify and understand barriers and potentials of the current system as perceived by the main knowledge actors. As the aim of all three studies are similar, i.e., uncovering the barriers of knowledge movement from production to action, the usage of the framework for this case study is legitimized.

The Knowledge-Action Framework which aims at identifying the gaps between knowledge production and management action, will facilitate the organisation and structuring of the analysis. A thorough understanding of perceived challenges and potentials of the knowledge actors will be achieved. Applying the same concepts to this case study additionally provides a guide on generalizing and comparing studies of similar kind.

APPENDIX 10: VALIDITY AND RELIABILITY

Validity and reliability in quantitative research are measures of the quality of the research. While validity assesses whether the researchers measured or observed the phenomena, they claim to be and how generalizable the findings are, reliability describes the degree of replicability. In qualitative research, the application of validity and reliability poses difficulties (Bryman, 2012). While the nature of qualitative research allows the researcher to seriously understand the studied community, a high level of analogy between developed concepts and underlying observations can be guaranteed. However, qualitative studies are often focused on case studies and small sample populations, which hinders generalization and reduces the validity of the research. Moreover, as it is not possible to halt social settings,

meaning that the circumstances one is in are always changing and thus possibly also perceptions, a researcher cannot expect to produce the same results. This is valid even if he/she follows the exact same methodology (LeCompte and Goetz, 1982, cited in Bryman, 2012). Reliability in terms of replicability is thus low.

To combat these issues, the terms authenticity and trustworthiness were suggested in qualitative research to ensure the quality of the research (Guba and Lincoln, 1994; cited in Bryman, 2012). Authenticity in qualitative research is made up of different criteria, all concerning the broader political impact of the study and highlighting practical outcomes of the study. Trustworthiness however is more concerned with the practical, correct and most objective execution of the research (Bryman, 2012). While general good practices like referencing of academic sources, the conceptualization of the study, clarity of research methods, arguing for choices and clearly presented results can greatly enhance the trustworthiness of a study, personal reflections of the researcher are as important. Reflecting on the influence of the researcher's own background and possible influence, called reflexivity, is an efficient strategy to strengthen the trustworthiness of the study (Krefting, 1991). Additional reflections on the reactivity of the participants, or how interviewees adapt their behaviour based on being studied (Bryman, 2012), are necessary. In the case of this study, I have tried to minimize my influence on the participants by asking non-directional interview questions and by omitting any kind of judgement in my responses. Each interview was conducted in a way where the main emphasis was based purely on the interviewee and their personal experiences and perceptions of the situation. I presented myself as friendly, approachable, and understanding of any kind of perceptions during the interviews, in order to encourage the interviewees. It was important for me to continuously reflect on possible influence from my side and to be aware of it throughout the whole research process. Additionally, I have kept a field journal to order methodological approaches, ideas and impressions from the interviews. A field journal can help to detect biases during the data collection process (Krefting, 1991). Furthermore, being aware and addressing positionality of the researcher during the study process is of great importance to be aware of the effects on the outcome of the research. Positionality refers to the researcher’s background, experience and positioning in society (Jafar, 2018). In my case, this means that I need to be aware of the fact that my choice of study, international environmental studies, a natural science bachelor, and my values in connection to this, might influence me in a way towards favouring scientific perspectives. Throughout the whole data collection and data analysis process too, I need to be

conscious that this might indirectly influence me. A similar situation applies to my potential bias towards the Institute of marine research, where I interned for several months. However, my initial aim for this study was to listen to what people have to say and to reach my own conclusions based on what I have learned throughout the interviews. For me, this attitude was always of great importance.

APPENDIX 11: RSTUDIO CODE FOR ALLUVIAL PLOT IN FIGURE 2

```
library("alluvial")
library("titanic")

library("ggalluvial")

setwd()
library(readxl)
Titanic1 <- read_excel("data")
Titanic1

#########with my data
cbPalette <- c("#999999", "#E69F00", "#56B4E9", "#009E73", "#F0E442", "#0072B2",
"#D55E00", "#CC79A7")

theme_void

gg = ggplot(as.data.frame(Titanic1),
      aes(y = freq., axis1 = responsibility, axis2 = management, axis3 = statusofcod,
axis4=stakeholder)) +
  geom_alluvium(aes(fill = stakeholder),
              width = 0, knot.pos = 0, reverse = FALSE, curve_type = "cubic") +
  guides(fill = "none") +
  geom_stratum(width = 1/8, reverse = FALSE) +
  geom_text(stat = "stratum", aes(label = after_stat(stratum)),
          reverse = FALSE) +
  scale_x_continuous(breaks = 1:4, labels = c("  responsibility to protect the cod",
"introduce/ keep fishing ban", "status of cod", "stakeholder group")) +
  scale_color_manual(values=c("#DCE319FF", "#55C667FF", "#238A8DFF",
"#404788FF"), labels = c("I", "M", "RF", "S")) +
  coord_flip() +
  theme_void() +
  scale_fill_viridis_d() +
  ggtitle("")
gg
```

```
#################
gg1 = ggplot(as.data.frame(Titanic1),
          aes(y = freq., axis1 = responsibility, axis2 = management, axis3 = statusofcod,
axis4=stakeholder)) +
  geom_alluvium(aes(fill = stakeholder),
              width = 0, knot.pos = 0, reverse = FALSE, curve_type = "cubic") +
  guides(fill = "none") +
  geom_stratum(width = 1/8, reverse = FALSE) +
  geom_text(stat = "stratum", aes(label = after_stat(stratum)),
          reverse = FALSE) +
  scale_x_continuous(breaks = 1:4, labels = c("  responsibility", "fishing ban", "status of
cod", "stakeholder")) +
  scale_color_manual(values=c("#DCE319FF", "#55C667FF", "#238A8DFF",
"#404788FF"), labels = c("I", "M", "RF", "S")) +
  coord_flip() +
  scale_fill_viridis_d() +
  ggtitle("")
gg1


gg2 <- gg1 + theme_void()
gg2

gg3 <- gg2 + theme_void() + theme(axis.text.y  = element_text(angle = 0, debug = FALSE,
face= "bold", size = 11 ))
gg3
```

APPENDIX 12: RSTUDIO CODE FOR BUBBLE PLOT IN FIGURE 3

```
setwd()
library(readxl)
R_data_decline_new_test <- read_excel("data")
View(R_data_decline_new_test)
pc = R_data_decline_new_test
library(ggplot2)
library(reshape2)
#convert data frame from a "wide" format to a "long" format
pcm = melt(pc, id = c("Sample"))

pcm$Sample <- factor(pcm$Sample,levels=unique(pcm$Sample))

#bubble plot
```

```
bubblepalette <- c("black", "black", "black", "black", "black", "black", "black", "black")
cbPalette <- c("#999999", "#E69F00", "#56B4E9", "#009E73", "#F0E442", "#0072B2",
"#D55E00", "#CC79A7")
xx = ggplot(pcm, aes(x = Sample, y = variable)) +
  annotate("rect", xmin = 0.5, xmax = 3.5, ymin = 0.5, ymax = 8.5,
           alpha = .2,fill = "#35B779FF") +
  annotate("rect", xmin = 3.5, xmax = 8.5, ymin = 0.5, ymax = 8.5,
           alpha = .2,fill = "#FDE725FF") +
  annotate("rect", xmin = 8.5, xmax = 11.5, ymin = 0.5, ymax = 8.5,
           alpha = .2,fill = "#440154FF") +
  annotate("rect", xmin = 11.5, xmax = 14.5, ymin = 0.5, ymax = 8.5,
           alpha = .2,fill = "#31688EFF") +
  geom_point(aes(size = value, fill = variable), alpha = 1, shape = 21) +
  scale_size_continuous(limits = c(0.001, 3), range = c(1,18), breaks = c(0.001,1)) +
  labs( x= " Recreation                Science                Industry          Management",  y =
"", fill = "")  +
  theme(legend.key=element_blank(),
        axis.text.x = element_text(colour = "black", size = 12, face = "bold", angle = 90, vjust = 0.3,
hjust = 1),
        axis.text.y = element_text(colour = "black", face = "bold", size = 11),
        legend.text = element_text(size = 10, face ="bold", colour ="black"),
        legend.title = element_text(size = 12, face = "bold"),
        panel.background = element_blank(), panel.border = element_rect(colour = "black", fill = NA,
size = 1.5),
        legend.position = "right") +
  scale_x_discrete() +
  scale_fill_manual(values = bubblepalette, guide = "none") +
  scale_y_discrete(limits = rev(levels(pcm$variable)))

xx
```

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