Norwegian University of Life Sciences

Master's Thesis 2022 30 ECTS
Faculty of Landscape and Society

Navigating social-ecological dynamics through stakeholder assessment and historical profiling: a case study of the Oslofjord

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Declaration

I, Eline Elvira Brouwer, 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.....

Acknowledgements

I want to express my deepest appreciation to my supervisor Ian Bryceson. I am extremely grateful that I have had you as my supervisor. It has been quite a journey to develop this thesis, but you gave me very valuable advice through all the stages of my thesis. Your continuous support and patience is something I am extremely grateful for.

I would also like to thank all the interviewees and participants who devoted part of their valuable time to help me by providing very insightful information. Without their input, this thesis would not have existed.

I am also very thankful for my friends and family, who have supported and encouraged me while I was writing my thesis. I would also extend my sincere thanks to the Norwegian University of Life Sciences for the last two years. Since August 2020, I have had the pleasure of studying in Norway at this university. It has been a challenging period for completing a master's degree. However, the great staff, discussions, and learning environment at NMBU have made it a very pleasant experience!

Lastly, I would like to mention that I could not have undertaken this journey without my dog Daya. She has been of tremendous support while I was writing my thesis, whether it meant going on walks to clear my head or for emotional support.

Thank you all!

Abstract

Earlier studies and reports have demonstrated that the Oslofjord has encountered many environmental issues in the last two centuries. This study aims to contribute to understanding the complex social-ecological changes that have occurred in the inner Oslofjord from a resilience thinking perspective. Specifically, I have examined the issues through the perceptions of the Oslofjord's condition held by both residents and experts, and how they have experienced major social-ecological changes. Moreover, I drew upon a literature review to investigate when major events occurred and what the responses have been. The data were collected through questionnaires for residents and semi-structured interviews for experts.

The residents were asked about their opinions on the state of the Oslofjord, what major social-ecological changes they have observed, their perceptions of the main causes, and their willingness to change their own behavior. The results showed that the residents perceived the current state of the Oslofjord negatively. Most of them have observed social-ecological changes such as the decline in marine life, an increase in alien species, while also increased recreation, and growing interest in the fjord. Pollution, certain fishing practices, and increased infrastructure were viewed as the main causes of the social-ecological changes. Most of the residents expressed a willingness to change their behavior for a better Oslofjord, but are uncertain as to how they can change.

Some experts showed a more positive attitude about the current state of the Oslofjord, while acknowledging that the fjord is still in a poor condition. They also discussed major social-ecological changes that have occurred in the 20th and 21st centuries; mostly matters related to nutrient and heavy metal pollution, its social-ecological consequences, and the responses. Despite the strong negative perceptions, they contend that the fjord has gone through limited improvement.

To analyze the resilience of the social-ecological system of the Oslofjord, I utilized a series of adaptive cycles to illustrate the interactions of the social-ecological system of the Oslofjord and its transitions into new regimes over the past 110 years. Major pitfalls were identified, such as institutions not allowing space for experimenting, not acknowledging less dominant narratives, and lacking accountability, whilst rapid socioeconomic and technological changes were occurring. To conclude, it became increasingly evident that the lack of flexibility of bureaucracies was not conducive to solving the issues of the Oslofjord effectively.

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1. Introduction

1.1 Background to the research problem

The effects of human activities have been far-reaching and have had extensive consequences on the Earth's system (Steffen et al., 2006). In many ecosystems, abrupt changes are likely to become more frequent, longer lasting, and of greater magnitude. An ecosystem's ability to cope with change greatly depends on its resilience (Folke et al., 2002). Social-ecological systems (SES), where social and ecological systems are acknowledged as interdependent, change in resilience capacity when human disturbances affect its variables or from complex processes within the system (ibid.).

Environmental managers are posed with many challenges, such as ecosystem degradation, alien species, and climate change, but also when divergent interests from stakeholders do not match with management actions (Shackleton et al., 2019). Problems can arise when the perceptions of different stakeholders do not align with the implemented policies, leading to misunderstandings, inefficiency, and sometimes even conflict (ibid.). Finding common ground when managing a SES should begin with understanding people's perceptions (Kaur, 2020). The perceptions about a SES influence the awareness of the state's system and shape what feedback is given (Gallopín, 2006). Ultimately, impacting the resilience.

Individuals perceive social-ecological change differently, as they value different social or/and ecological aspects of a system. They might have cultural and emotional connections with certain places and activities (Andrachuk & Armitage, 2015; Loring et al., 2014). Therefore, what is desired by individuals in a SES is subjective and influences how social-ecological change is perceived. There is a need to understand people's perceptions for creating a deeper understanding of social-ecological change, developing effective management strategies, and building resilience (Christie et al., 2017).

In Norway, the inner Oslofjord has had a long history of pollution that still affects its condition today. Large parts of the fjord have a bad chemical status and a moderate ecological status (Miljødirektoratet, 2019a). In the 20th and 21st centuries, various action plans have been developed to improve the fjord's condition, yet, the condition is still not optimal. Using this case study of the inner Oslofjord, I have explored the complex social-ecological changes that have occurred in the last 110 years through the perceptions of residents and experts to investigate what factors impacted the resilience of the Oslofjord.

1.2 Aim of the study

This study seeks to contribute to understanding the complex social-ecological changes that have occurred in the inner Oslofjord from a resilience thinking perspective, by exploring major events that have occurred in the last 110 years.

1.3 Research question and research objectives

Research question

In what ways have the interactions between social and ecological systems affected the resilience of the inner Oslofjord during the last 110 years?

Research objectives

1. To examine the current perceptions of the Oslofjord's condition held by residents and experts, and whether these are similar or different;
2. To investigate how local residents and experts have perceived major social-ecological processes of change over the last 110 years;
3. To investigate what strengthened or weakened the social-ecological resilience of the Oslofjord.

1.4 Overview of the thesis

In **Chapter 2,** I describe the literature review of the social-ecological developments in the Oslofjord in the last 110 years. **Chapter 3** begins with a description of resilience and social-ecological systems. This is followed by an explanation of the adaptive cycle. In **Chapter 4,** I introduce the research design, sampling selection for the interviews and questionnaire, and data collection and analysis. I finish by reflecting on the ethical considerations and limitations of my methods. In **Chapter 5,** I illustrate how participants currently perceive the state of the Oslofjord. I also describe whether participants have observed social-ecological change or not, what they perceive as the main causes of change, and their willingness to change. In **Chapter 6,** I describe the perceptions of experts on the current condition of the Oslofjord along with a more detailed explanation of the social-ecological change that has occurred. Thereafter, I discuss the main causes and future perceptions of the Oslofjord given by the experts. Next, **Chapter 7,** builds on my previous sections by discussing how the perceptions of residents and experts align in a greater context. I also construct a social-ecological timeline to identify major changes. Moreover, I use the adaptive cycle to explore what factors strengthened and weakened the resilience of the Oslofjord. Finally, **Chapter 8,** concludes my findings and how this study attempts to contribute to the broader context of the identified pitfalls in social-ecological systems along with recommendations.

2. Literature review

2.1 Case study

The Oslofjord is located in the south-eastern part of Norway. It is the most populous area in Norway with around 1.6 million residents surrounding the fjord. The entire Oslofjord stretches 107 kilometers. At the fjord's narrowest point, the Drøbak Sound connects the inner and outer Oslofjord. This narrow (1600m) and shallow (19.5m) sound limits the water exchange between the inner and outer Oslofjord (Staalstrøm et al., 2012). The effects are particularly evident in waters that are below 19.5m in the inner Oslofjord (ibid.). Within the inner Oslofjord, the Vestfjord is located on the western part of the fjord and the Bunnefjord is located on the eastern part (see Figure 1).

Figure 1 The inner Oslofjord divided into Vestfjorden on the west and Bunnefjorden on the east. The Drøbak Sound is indicated with the arrow. Source: GoogleEarth (2018)

2.2 Social developments

2.2.1 Responses to growing pollution

In Kristiania (the former name of Oslo), water pollution had been a prevalent topic since the end of the 19th century. This was due to the expansion of industry, in particular paper mills, textile industry, and breweries that released organic and chemical waste (Ibsen, 1997). A. Holst, a professor at the University of Oslo, was assigned to study the effects of wastewater on public health (Oslo Kommune, 1907 as cited in Arnesen, 2001). High levels of bacteria were found in the contaminated water, resulting in potential health risks to the public. As a response, in the 1910s, the first wastewater treatment plants were developed (Oslo Kommune, 1914 as cited in Arnesen, 2001)

These treatment plants removed organic particles and bacteria from the wastewater, but they did not remove nutrients. With the introduction of toilets and continued population growth through the early 20th century, sewage became the leading source of pollution (Bergstøl et al., 1981). During the 1920s and the 1930s, pollution in the Oslofjord was widely discussed by professionals and the public (Arnesen, 2001). In the 1930s, the entire inner Oslofjord was

already affected by pollution, leading to high algal biomass and anoxic waters (ibid.). Through the decades following, the problems in the Oslofjord started to impact people's daily lives and triggered more public reactions. Consequently, the public became increasingly aware of the state of the fjord (ibid.)

More research had been conducted on the impacts of sewage and its biological effects (Braarud, 1945). However, the explanations provided by marine biologists were not accepted by the Oslo Sewage Authority (Arnesen, 2001). The Oslo Sewage Authority decided to focus on cleaning organic particles instead of nutrients, which then determined how they built their wastewater treatment plants. Organic particles were considered the main concern by the authority because they operated within the context of European wastewater engineering (ibid.). Although more research was conducted on the key role of nutrients in the Oslofjord, the sewage authority maintained the same line of thinking.

After World War II, Oslo experienced urban development and steady population growth. Sewage pollution became a larger problem than it had been before (Arnesen, 2001). Finally, the Oslo Sewage Authority acknowledged the importance of nutrients in the Oslofjord. Therefore, when adopting new technologies in the 1970s, a shift in mentality on how to handle wastewater occurred. This late shift caused a delay in effective wastewater treatment. Additionally, for most of the 20th century, industries discharged heavy metals such as mercury, cadmium, and copper directly into the Oslofjord (Lepland et al., 2010).

During the 1970s the pollution had reached its peak. The government introduced legislation and improved its methods for cleaning the wastewater (Oslo Kommune, 1975 as cited in Arnesen 2001). The new wastewater treatment plants, in particular Vestfjordens Avløpsselskap (VEAS), were capable of biologically and chemically treating the wastewater (Oslo Kommune, 1976 as cited in Arnesen 2001). These treatment plants initially removed organic particles, bacteria, and Phosphorus, but not Nitrogen, despite the fact that Nitrogen was the limiting nutrient to phytoplankton in the fjord, as is normally the case in seawater systems, whilst Phosphorus is often limiting in freshwaters.

In 1987, Norway signed the North Sea Declaration, which required Norway to reduce its Nitrogen discharge by 50% (Arnesen, 2001). To achieve these requirements, it was decided that Oslo had to cut its Nitrogen discharge by 70%. With the development of new filter material and improved cleaning techniques, VEAS was modified to also remove Nitrogen in 1991 (COWI, 2020).

Nowadays, Nitrogen cleaning remains a point of discussion between the national government and the municipalities along the Oslofjord (Sjuve, 2022). In the inner Oslofjord,

the municipalities clean for Nitrogen, but in the outer Oslofjord, they are not required to clean for Nitrogen. This has resulted in a conflict between the actors over the responsibility and funding of these issues.

The Oslo metropolitan area's population has grown significantly during the 20th and 21st centuries. Nowadays, around 1,07 million people live in the metropolitan area of Oslo. The projections predict that it will continue to increase in the following decades (populationstat.com, n.d.).

2.2.2 Wealth development

Norway is currently among the wealthiest countries in the world with a highly developed economy. It frequently holds the position of having the highest human development index for most of the 21st century (UNDP, 2019). The country has one of the lowest population densities in the world while it has a high abundance of natural resources, such as oil, gas, fish, and forests (Grytten, 2020). Norway's strong institutions are characterized by a functional and stable democracy, and a strong legal system (Grytten, 2020). The establishment of important and strong institutions provided Norway the opportunity to develop itself into one of the wealthiest countries in the world (ibid.).

2.2.3 Norwegian culture

The Norwegian culture values democracy, human rights, and the welfare state (Oslo Kommune, n.d.). In general, most Norwegians place a high degree of trust in their government and its decisions (OECD, 2022). With their low population density, there is a lot of nature available per inhabitant, which is the reason why many use it (Sandberg, 2012). Consequently, Norwegians generally have a strong connection with nature.

This is also the case for the Oslofjord as described by Chen et al. (2019), who state that residents around the Oslofjord highly value the ecosystem services provided by the fjord for recreation. Outdoor recreation contributes to people's quality of life. Therefore, the Oslofjord is of great importance to many. Although Norwegians have a strong connection with their environment, they don't feel as pressured by environmental issues as other countries (Jentoft & Buanes, 2005).

2.3 Ecological developments

2.1.1 Chemical changes

Water temperature

In the Oslofjord, temperature measurements have been conducted since 1937 (Miljødirektoratet, 2019a). During the last century, the fjord's temperature has significantly increased, but it has accelerated in the last 30 years (see Figure 2). Increased water temperature can affect biological changes, such as increased survival chances of warm-water species, changes in species composition, and increased phytoplankton production (Miljødirektoratet, 2019a).

Additionally, warmer water temperatures in combination with high nutrient concentrations can lead to an increase in disease-causing bacteria (Trtanj et al., 2016). The Norwegian public health officials have warned the public about these harmful bacteria and urged them to take extra precautions while bathing in the Oslofjord (Hauge & Norum, 2021).

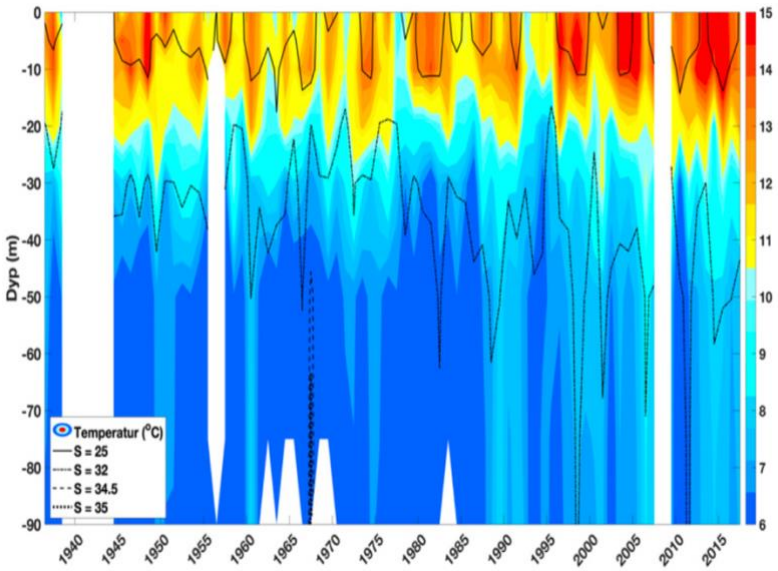

Figure 2 Temperature development at Steilene in the inner Oslofjord. The depth is indicated along the left axis, while the colour axis on the right indicates the temperature.

Nutrient concentrations and phytoplankton

Nitrogen and Phosphorus are the two primary nutrients in aquatic systems, and their availability heavily influences phytoplankton growth. The Oslofjord's nutrient load varies seasonally: It is the highest in the winter, followed by a steep decline in spring, and stays relatively low during the growing season when phytoplankton uses these nutrients for growth. The load increases again towards autumn (Staalstrøm et al., 2021).

On a longer temporal scale, various long-lasting changes have occurred since the 1910s (see Figure 3). Phosphorus levels rose during the 1910s and 1930s after the large-scale installments of toilets in Oslo (Bergstøl et al., 1981). In the subsequent decades, the Phosphorus concentrations continued to rise as toilets were installed around Oslo and Phosphorus-

containing cleaning products were introduced. While Phosphorus cleaning facilities were introduced in the 1970s, significant reductions did not occur until the 1980s. The Phosphorus concentrations declined only until the early 2000s (Guerrero & Sample, 2022; Miljødirektoratet, 2019a). From the early 2000s, the concentrations in the Oslofjord have shown a gradual increase (see Figure 4).

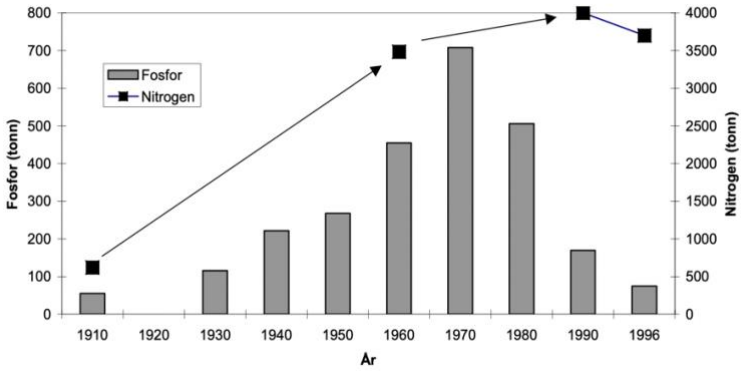

Figure 3 Phosphorus and nitrogen concentrations in the Oslofjord from 1910 until 1996. The left axis indicates the tons of Phosphorus, while the right axis indicates the tons of Nitrogen. Source: Magnusson et al. (1998)

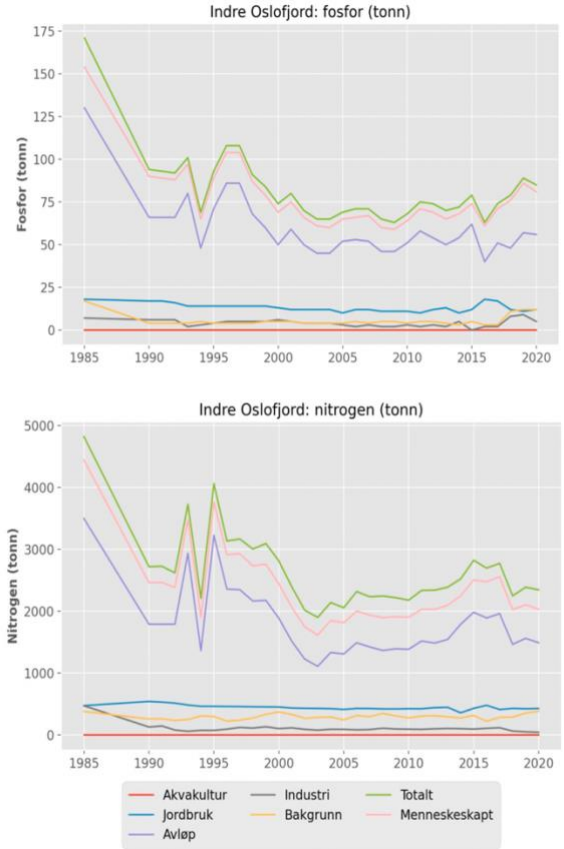

Figure 4 Phosphorus (top graph) and Nitrogen in Oslofjord (bottom graph) from 1985 to 2020. The coloured lines show the nutrient sources. Red for aquaculture, blue for agriculture, purple for sewage, grey for industry, orange for ecological background processes, green total nutrient levels, and pink nutrient levels caused by human activity. Source: Guerrero and Sample (2022)

The Nitrogen concentrations increased until 1995/1996 (Guerrero & Sample, 2022; Magnusson et al., 1998). A drop in Nitrogen concentrations occurred after the introduction of effective Nitrogen cleaning facilities (Guerrero & Sample, 2022). From 2003 until 2018, the Nitrogen concentrations in the Oslofjord were increasing, but from 2018 to 2020, they slightly reduced again. The Oslofjord has been receiving most of its Phosphorus and Nitrogen from municipal sewage discharge (see Figure 4).

Eutrophication, which occurs when nutrients are available in large quantities, can result in excessive (and sometimes toxic) algal blooms. The algal blooms deplete the oxygen levels in aquatic systems. This is a phenomenon that was detected in the Oslofjord as far back as the early 19th century (Braarud, 1945). Chlorophyll a concentrations can be used as a means to measure phytoplankton biomass in aquatic ecosystems.

According to the Miljødirektoratet (2019a) the chlorophyll a concentrations dropped between 1970 and 2010, but increased again from 2011 until 2017. Despite the increase in chlorophyll a, the phytoplankton levels in the Oslofjord are classified between moderate and good (Miljødirektoratet, 2019a).

The oxygen concentrations in the Oslofjord have improved in the last 15 to 20 years, but a negative trend could develop quickly due to climate change (Miljødirektoratet, 2019a). Yet, not all parts of the Oslofjord have had the same improvement over the last decades. In particular, the oxygen concentrations in the Bunnefjord are still classified as very poor.

Heavy metals and environmental toxins

Fjords are susceptible to high loads of contaminated sediment because of a hydrographic regime with a slow turnover rate combined with a relatively high supply of sediment (Lepland et al., 2010). For most of the 20th century, heavy metals such as Mercury, Cadmium, and Copper were directly discharged into the Oslofjord (Lepland et al., 2010). Between 1940 and 1955, Mercury discharge reached its highest level. The discharge of Cadmium peaked between 1955 and 1960. Meanwhile, Copper had its latest peak in the 1970s (Arnesen, 2001; Baalsrud & Magnusson, 2002).

The consequences of the heavy metal discharges can still be felt in both the ecological and the social systems. The metals bioaccumulate in the marine environment, and therefore, can lead to toxicity in marine organisms (Ruus et al., 2018). Consequently, humans are discouraged from eating organisms that have bioaccumulated heavy metals.

The extent that heavy metals harm organisms depends on whether they are biologically available. According to Lepland et al. (2010) the concentrations of biologically available heavy metals in the Oslofjord are declining due to sedimentation. However, disturbing the seafloor can lead to re-exposure to these heavy metals. Most of these toxins are very small and continue to float in the water after a disturbance has taken place (Baalsrud & Magnusson, 2002). Such re-exposure can have harmful impacts on the fjord's ecosystem. Nevertheless, the Norwegian Geotechnical Institute stated that these heavy metals are not dangerous to humans (NGI, 2021).

However, recent efforts have been made to remediate the effects of the heavy metals in the Oslofjord. In 2005, a deepwater landfill was created at Malmøykalven to move the contaminated sediments. According to NGI (2009), moving and capping off the contaminated sediment resulted in improved environmental conditions around the Oslo harbor. In 2019, the Miljødirektoratet (2019a) reported again that these activities had been successful. Oslo's administrative city council declared in 2005 that the pollution from the sediment should not

have any long-term effects on the ecosystem. Nevertheless, NIVA's results indicated that all environmental toxins are still above the international limits when they are measured in the digestive glands of mussels (Staalstrøm et al., 2021). Providing a cap on contaminated sediment will reduce the environment's exposure to pollutants in the short term (Popenda, 2020). However, major disadvantages related to the displacement of capping materials can lead to a re-exposure to the contaminated sediments, which can have damaging effects on the ecosystem. In Oslo, the public and independent scientists expressed strong negative reactions by protesting against this method (Aftenposten, 2006; VG.no, 2006). Some residents took it a step further and started to investigate the situation and created a documentary[1] about the deepwater landfill at Malmøykalven.

In April 2022, researchers at the Norwegian University of Life Sciences also suggested that this method for handling contaminated sediments was inadequate (Dahle & Fretheim, 2022). They argued that moving these sediments into a deepwater landfill destroyed the microbiological communities in the Oslofjord. The contaminated sediment does not provide a livable habitat for these communities because the essential bacteria cannot live under the contaminated sediment and are outcompeted by fast-growing bacteria. Consequently, the essential bacteria are unable to produce enough essential vitamins that flow through the food chain in the fjord. Furthermore, they expressed their concerns about how the authorities are not currently mentioning their own landfills as a problem in the Oslofjord (Dahle & Fretheim, 2022).

2.3.1 Ecological changes

Macroalgae and seagrasses

In 1974, the Norwegian Institute for Water Research started to monitor the most common macroalgae species in the Oslofjord (Miljødirektoratet, 2019a). In the 1970s and 1980s, the Oslofjord had dense populations of *Fucus evanescens* (Staalstrøm et al., 2021). This is an introduced species that originates in northern Norway, but it had already been present in the Oslofjord at the end of the 19th century (Baalsrud & Magnusson, 2002). In Southern Norway, this species mainly thrives in polluted areas. However, some parts of the Oslofjord were too polluted for *F. evanescens* to survive (Baalsrud & Magnusson, 2002). *F. evanescens* was highly abundant at all monitoring stations until the 1990s. The environmental conditions in the Oslofjord improved and the abundance of *F. evanescens* declined (Staalstrøm et al.,

[1] A documentary 'Lillebror ser deg' by Anne Berit Vestby investigated the dumping of contaminated sediments in the Oslofjord.

2021). Although the environmental conditions improved compared to multiple decades ago, the Oslofjord is still in a poor condition for other macroalgae like Knotted kelp (*Ascophyllum nodosum*) to thrive (ibid.).

Furthermore, a reduction has occurred in the lower depth limit of macroalgae. In the 1960s, macroalgae were registered at 30 meters deep (Statsforvalteren, 2019). Nowadays, the lower depth limit has been reduced to 12 to 14 meters. This decline can be associated with poorer visibility, and is probably exacerbated by the invasion of sea urchins, and sludge in sediment (Miljødirektoratet, 2019a). In addition, macroalgae are affected by the presence of filamentous algae. These are opportunistic and fast-growing species that can replace macroalgae (Moy et al., 2009). This type of algae is present in extensive abundance in areas with heavy nutrient pollution. The lower depth limit of macroalgae improved towards the 1990s, but during the last decade, it has been declining again (Staalstrøm et al., 2021).

In 2020, a seagrass monitoring program was implemented in the Oslofjord (Rinde et al., 2021). Despite the monitoring program's recent inception, the overall trend is that eelgrass meadows are declining in the last decade (ibid.). The decline in macroalgae and seagrasses can have major implications for the Oslofjord's ecosystem, including decreased productivity and biodiversity, a change in food sources, and habitat change.

Benthic fauna

As early as 1914, the benthic communities in the Bunnefjord were disappearing (Petersen, 1915, as cited in Miljødirektoratet, 2019a). The negative trend continued in the entire inner Oslofjord until at least 1993 (Miljødirektoratet, 2019a). In 2009, the last extensive survey of benthic fauna in the inner Oslofjord was conducted by Berge et al. (2011). According to this study, there has been a notable improvement in the benthic fauna community due to improved oxygen conditions. In the Oslofjord, the benthic fauna was classified between moderate to good, but in the deeper parts of the Bunnefjord, it is still classified as poor (Miljødirektoratet, 2019a).

In the past few years, the benthic fauna community has undergone a significant change due to the disappearance of blue mussels *(Mytilus edulis)* (Staalstrøm et al., 2021). Only very small mussels (1-4mm) or mussels of multiple years old can be found in the Oslofjord. There is no clear explanation of what happens to the mussels that are in the growing stage (ibid.). No prior data about the abundance of blue mussels in the Oslofjord exist due to the lack of systematic studies or measurements (ibid.)

The mussels are of great importance to the water quality of the fjord. They filter out particles and thereby they contribute to purifying the water. Staalstrøm et al. (2021) even stated that it would be almost impossible to obtain good water quality in the Oslofjord if the mussels would disappear.

Fish stocks

The fish communities in the Oslofjord have undergone major changes since the beginning of the 20th century. In the 1940s, 1950s, and 1960s sprat was highly abundant in the Oslofjord, but due to overfishing, the sprat stocks in the fjord had crashed (Miljødirektoratet, 2019a). This fish had an important ecological function because it converted zooplankton to fish biomass. Other species such as cod and pollock peaked in their abundance in the 1960s. Whiting reached its peak a few decades later, in the 1980s and 1990s. However, the number of whiting has been increasing in the last few years (Staalstrøm et al., 2021). At the end of the 1990s and the beginning of the 2000s, most of the fish stocks had collapsed. In particular, cod is of great concern.

Cod abundance has always shown fluctuations, consisting of periods in which it has a high abundance, followed by periods in which it has a low abundance (Ospar Commision, 2014). Espeland and Knutsen (2019) stated that the number of cod in the Oslofjord is at its historically lowest point since they started monitoring (see Figure 5).

The cod found in the Oslofjord are often juveniles and in poor physical condition. A study published in 2021 indicated that the cod population in the Oslofjord is not expanding (Craig, 2021). The absence of an apex predator, like cod, can have detrimental effects on different levels in the ecosystem (Frank et al., 2005). In return, more pelagic warm-water species can be found (Miljødirektoratet, 2019a).

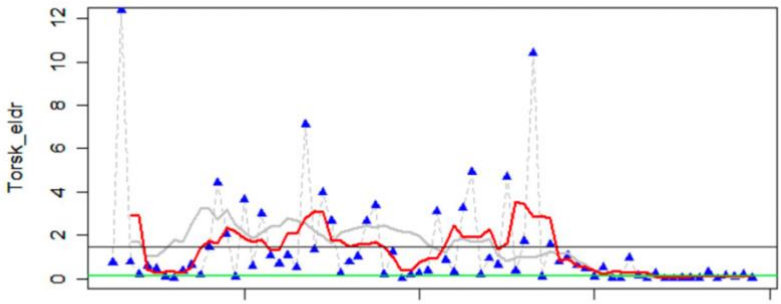

Figure 5 Adult cod populations in the inner Oslofjord. The blue triangles show the yearly catchment, the red line is the seven-year average. The grey line is the long-term average for the entire data series. Source: Espeland and Knutsen (2019)

Alien species

The Oslofjord is vulnerable to alien species because it has been heavily exposed to human impact in the past, which has resulted in ecological changes (Miljødirektoratet, 2019a). As of now, four species are of main concern in the Oslofjord:

Sargassum muticum, *Dasya baillouviana*, *Crassostrea gigas*, and *Caprella mutica*. In particular, the *Crassostrea gigas* (Pacific oyster) is of great concern (Miljødirektoratet, 2019a).

The Pacific Oyster had been present in Norway since 1979 for aquaculture (Wrange et al., 2010). Between 2006-2008, the Pacific Oyster had been found in areas outside of aquaculture. It took until 2012 before the species had been put on the Norwegian blacklist of alien species (Gederaas et al., 2012). According to the (Miljødirektoratet, 2019a), this species is of great concern because it competes with other oysters and blue mussels for resources and space in the Oslofjord, which threatens the ecosystem. Additionally, the Pacific Oyster can harm people because of its sharp shells. However, studies have also shown that the Pacific Oyster can be beneficial to the environment by creating a more diverse habitat and filtering the water (Troost, 2010).

3. Conceptual framework and theoretical approach

3.1 Resilience

The traditional view of natural systems is based on classical physics and its variations (Holling, 1973). It predisposes to highlight the importance of a quantitative over a qualitative view of behavior by taking a static equilibrium as a starting point as though natural systems are fixed. Whereas Holling contended that natural systems are influenced by random and non-random fluctuations that make the systems constantly variable.

Consequently, Holling (1973) coined the term resilience which he conceived it as 'a measure of the persistence of systems and their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables' (p. 14). The definition of resilience has not been static either. Walker et al. (2002) added to the definition of Holling by expressing that resilience contains:

> "(a) The amount of change a system can undergo (and, therefore, the amount of stress it can sustain) and still retain the same controls on function and structure. (b) the degree to which the system is capable of self-organization; (c) The degree to which the system expresses capacity for learning and adaptation". (p. 4)

In other words, when an ecosystem is resilient and it faces unavoidable change, it has the capacity to be able to reorganize itself during and after this change without major loss of the provision of ecosystem services (Folke et al., 2002).

A fundamental tenant of the resilience approach is the recognition that both local people's and experts' observations can be valuable in different ways. Local people generally possess experiential knowledge and diachronic information, with frequent observations and continuity over long periods of time. Experts' knowledge is based upon conventional science with the collection of synchronic data that is simultaneously observed during short periods of time (Berkes and Folke, 1998).

3.2 Social-ecological systems

Resilience theory has been used for social-ecological systems to describe changes in their resilience (Carpenter et al., 2005). Social-ecological systems (SESs) is a term that acknowledges that social and ecological systems are interdependent.

Social resilience refers to "the ability of groups or communities to cope with external stresses and disturbances as a result of social, political and environmental change" (Adger, 2000, p. 1). Social resilience can be observed through changes in institutions, economic

structure, and demography. It also includes social capital, inclusivity, and trust (Adger, 2000). Ecosystem resilience is described as "the capacity of an ecosystem to cope with disturbances, such as storms, fire, and pollution, without shifting into a qualitatively different state" (Folke et al., 2002, p. 2). These social and ecological systems are ever-changing. Hence, the resilience of a social-ecological system is determined by its capacity to cope with a wide variety of changes.

3.3 Observing resilience

Social-ecological resilience is difficult to operationalize and assess, and only limited knowledge exists about how changes affect a system's resilience (Carpenter et al., 2005). Direct measurements of resilience are barely attainable due to the dynamics within an SES that make it complicated to detect patterns. It is possible to describe the resilience of an ecosystem in a historical context. However, when trying to describe contemporary or future resilience, indirect measurements are needed. For example, Carpenter et al. (2005) described four pathways that could assist to assess the resilience of an SES: stakeholder assessment, model exploration, historical profiling, and case study comparison. Stakeholder assessment entails obtaining a common understanding of change in SES. Model exploration seeks to explore thresholds for change based on modeling scenarios. Historical profiling examines crucial events, when resilience mattered, what was changed, and how this was changed. Case study comparison compares different case studies with each other and seeks to understand why some SESs react differently to changes and how they are different in their resilience.

3.4 Adaptive cycle

As a means to describe the different phases systems develop through, Holling (1986) suggested four phases: exploitation, conservation, creative destruction, and renewal. Nowadays, this is also known as the adaptive cycle. Later revisions included renaming "creative destruction" to "release" and changing the name of "renewal" to "reorganization" (Holling & Gunderson, 2002). In addition,

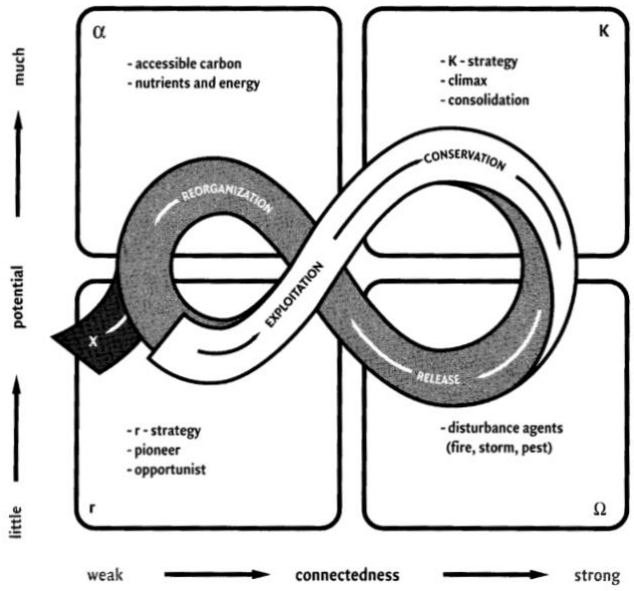

Figure 6 The four stages of the adaptive cycle: exploitation, conservation, release, and reorganization. The X on the figure indicates where a regime shift is most likely. Source: Berkes et al. (2002).

an extra component was added where it is most likely that a system flips into another regime (marked as X in Figure 6).

On the front loop, the "exploitation" stage can be described as a phase in which pioneer species are established (Berkes et al., 2002). These species are the opportunists that establish themselves after a disturbance. In this phase the system is very productive, resulting in increased competition. The resilience of the system is high but it is decreasing.

The second phase "conservation" is represented by slower growth compared to the exploitation stage. Resources have accumulated in the system. This period is characterized by increasing rigidity because of the increased connectedness in the system (Holling, 1986). The reduced flexibility also causes increased stability and certainty. However, this phase has low resilience and becomes more exposed to environmental disturbances (Berkes et al., 2002).

A disturbance can trigger moving to the third phase, which disrupts the system and releases the resources that have accumulated. From a temporal perspective, this is a very short phase.

In the final phase "reorganization", the system has opened up for innovation and is capable of establishing new structures. It has the greatest uncertainty, but it contains very high resilience. However, the system may switch into a new regime. This new regime is different from the previous regime because changes have occurred in its internal controls and feedbacks in the system (Scheffer & Carpenter, 2003). For example, in an ecological system, a regime shift can be characterized by different species composition, different land/seascapes, and other ecosystem services (Carpenter & Folke, 2006). A regime shift in the social system can be the consequence of changes in governance arrangements, institutions, norms and values, perceptions, and understanding of social-ecological systems (Olsson et al., 2006). Regime shifts can be triggered by external forces, as well as from complex interactions across scales within the system itself (Kinzig et al., 2006). The development of spatial, temporal, and organizational scales in the system heavily influences the thresholds of a system, and therefore, affects when a regime shift occurs.

A system's resilience can be desirable or undesirable depending on the preferences of involved actors (Carpenter et al., 2001). For example, highly polluted waters can be undesirable but highly resilient. These undesirable but highly resilient states are also known as lock-ins, in which systems are trapped within an unfavorable regime and are prevented to transform into a more favorable condition (Dornelles et al., 2020).

3.5 Managing resilience

In the previous sections, I described how social and ecological systems interdependent and ever-changing. Holling (1978) coined the term adaptive management to cope with the unpredictable interplay within and between the systems. He stressed the importance of learning and adapting to the feedback that is given from the systems.

Furthermore, Seixas and Berkes (2003) defined several factors that would strengthen and weaken the resilience of a social-ecological system (see Table 1):

Table 2 Factors that strengthen or weaken resilience according to Seixas and Berkes (2003, p. 193).

Strengthen resilience	**Weaken resilience**
Strong institutions (leadership and rule enforcement)	Breakdown of locally-devised institutions and authority
Good cross-scale communication (co-management of scientific and local knowledge)	Rapid technological changes leading to more efficient resource exploitation
Political space for experimentation	Rapid changes in the local socio-economic system
Equity in resource access	Institutional instability at higher political levels negatively affecting local management
Use of (local people's) memory and knowledge as a source of innovation and novelty	

When change occurs and a system goes through reorganization, Folke et al. (2003) stressed the importance of "(1) learning to live with change and uncertainty, (2) nurturing diversity for resilience, (3) combining different types of knowledge for learning, and (4) creating opportunity for self-organization towards social and ecological sustainability" (p. 354). These factors are of great importance during the reorganization phase where the system opened up for innovation and the establishment of new structures. Additionally, Leach (2008) also stressed the importance of being open to other approaches and acknowledging less dominant pathways.

4. Methods

4.1 Research design

This thesis aimed to illustrate in what ways the interactions between social and ecological systems have affected the resilience of the inner Oslofjord during the last 110 years. A mixed-method approach was the most appropriate for conducting this thesis because exploring people's perceptions and changes of the Oslofjord through quantitative and qualitative data collection would enable triangulation. Combining the strengths of the quantitative and qualitative data collection results in data consistency through the quantitative data collections methods and space for elaboration in the qualitative data collection. A mixed-method approach would enable to obtain a richer and more detailed understanding of the findings and a more informed conclusion (Scribbr.com, n.d.).

4.2 Literature review

Literature concerning the Oslofjord was selected based on its relevance to the study objectives. In the early stages of writing this thesis, I searched for literature that was available in English. However, in later stages, I discovered that many reports and articles are published in Norwegian. Therefore, most of the literature was extracted from sources in Norwegian such as the Norwegian Environmental Agency (in Norwegian: Miljødirektoratet), the Norwegian Institute for Water Research (in Norwegian: Norsk Institutt for Vannforskning (NIVA)), and the Norwegian Geotechnical Institute (in Norwegian: Norges Geotekniske Institutt (NGI)).

4.3 Sampling selection

The sampling selection process was divided into two categories. One for the people who were being interviewed and another for people who responded to the questionnaire. To avoid confusion, the people that have been interviewed are named 'interviewees' and people that have responded to the questionnaire are named 'participants' in this thesis.

4.3.1 Interviews

A total of 14 interviews were conducted between the 18th of January and the 21st of March 2022. Purposive sampling was used as the sampling strategy in which interviewees were selected based on their relevance to the study objectives (Bryman, 2012). This resulted in interviewees whose professions were often linked to the Oslofjord, such as marine biologists, volunteers, a pollution and sanitation specialist, a cod geneticist, a biologist, and a consultancy advisor. These interviewees were selected based on the following criteria: 1) over 18 years old; 2) have expertise through their daily interaction with the Oslofjord.

Furthermore, at the end of the interviews, the interviewees were asked if they could recommend other potential interviewees with extensive knowledge about the Oslofjord. Consequently, three interviewees were recruited through this approach. This sampling approach, also known as snowball sampling, opens up space for a diversity of interviewees with different expertise (Bryman, 2012).

4.3.2 Questionnaire

The questionnaire was published between the 16th of February and the 31st of March 2022 and received a total of 59 answers. It was published online as a Google Docs document, therefore, it was accessible to everyone that had a web link to the questionnaire. It was spread on various Facebook groups, Instagram, and it was published on a website. The participants were asked to answer what age they were and if they lived around the Oslofjord to check their relevance to the study objectives. None of the participants had to be excluded based on these criteria.

4.4 Data collection & analysis

4.4.1 Interviews

Qualitative interviews were used to collect the data. These interviews were conducted based on a semi-structured interview guide (Appendix 1). Using semi-structured interviews gave more flexibility, resulting in more space for asking in-depth questions about specific topics (Bryman, 2012). However, transcribing semi-structured interviews was a time-consuming task, thus it allowed to have only a limited number of interviewees (Bryman, 2012). There were no fixed sampling size criteria before conducting the interviews. In this thesis, the sample size was determined by reaching a degree of saturation and on time constraints.

Five of the interviews were held in person, while nine interviews were conducted via Zoom or Microsoft Teams. The face-to-face interviews were conducted at a location of the interviewees' preference. The duration of the interviews varied from 45 minutes to almost two hours.

The interviews were audio recorded and transcribed using intelligent verbatim transcription. Transcribing an interview in this manner eliminates unnecessary repetitions and filler material. This results in a more concise transcript in which it is easier to read and understand the key messages without major editing.

After conducting and transcribing all the interviews, the interviews were coded. This process helped to label and reduce the data obtained from the interviews (Bryman, 2012). All the transcripts were printed and coding was carried out by highlighting relevant parts to the

study objectives. In this study, I used an inductive coding approach by dividing the codes into different themes that would help to analyze the data from the interviews (Bryman, 2012). Using these themes, I was able to identify similarities, differences, trends, and/or inconsistencies in the statements made about a particular topic in the interviews.

4.4.2 Questionnaire

The questionnaire was developed in Google Docs. A pilot questionnaire was given to two master's students before the questionnaire was published. They provided insightful feedback that resulted in a few minor changes. Offering participants the choice of English (see Appendix 2) or Norwegian (see Appendix 3) for the questionnaires assured them with a level of comfort in which they could provide richer data and increase their willingness to respond.

A total of seven questions were asked to the participants. The first two questions were multiple-choice questions: the participants were asked about their age and how long they have been living around the Oslofjord. Consecutively, five open-ended questions were posed concerning the participants' perceptions about the Oslofjord and if they had observed changes. It was essential to ask these questions in an open-ended format because it would provide a deeper and more nuanced understanding of people's perceptions and observations. In addition, it enhanced the validity of the research as the participants independently provided the answers rather than being persuaded by multiple-choice options (Bryman, 2012).

The answers provided were carefully evaluated to determine whether the answers were illogical or of low quality. These answers were identified based on the following criteria (1) participants who try to complete the questionnaire as fast as possible by only stating very few words (2); participants who misrepresent themselves that fill out wrong information because they do not want to help the researcher. These criteria led to the removal of four participants; two participants were removed based on the first criterion, and two participants on the second criterion. Not all the participants answered all the questions of the questionnaire, but the answers they provided were included in the data analysis when they did not fulfill the exclusion criteria as described above. The main reason behind this was that there were too few participants to prove statistically significant results (will be discussed in section 4.6), so every reasonable response was included in the data analysis.

The data from the questionnaire was exported to the coding software NVivo 12. I used the research objectives as an initial framework to ensure the relevance of the coding. Afterward, the answers were coded using an inductive coding approach. This data was organized into larger themes to gain an overview of the information provided by participants.

4.5 Ethical consideration

During this research, the following ethical issues were carefully adhered to avoiding lack of informed consent, invasion of privacy, and harming the participants/interviewees. The Norwegian Center for Research Data (NSD) was notified before collecting the data. This notification form included matters regarding how to handle personal data, consent, data processing, and information security. The following practices were integrated when conducting this thesis: interviewees were asked to give consent and made aware of their rights during the interview (see Appendix 4), participants' email addresses were hidden from the researcher in the questionnaire, the data was handled and stored in accordance with the NSD, and all data is presented anonymously in this thesis. Additionally, personal data from the interviews, such as names and organizations where they work, was collected in a separate document and the interviewees were labeled as 'interviewee X' instead of their names. This document had been secured and was destroyed after finalizing this thesis.

4.6 Limitations

Language

This study is limited by the fact that I am not fluent in Norwegian. Although I have reached an upper-intermediate level in Norwegian, some meanings may get lost in translation. In total, two interviews and 35 responses to the questionnaire were in Norwegian. To avoid misinterpretation, the transcripts were not translated into English; only words that I could not understand were translated. This allowed space for valuable context information that could be lost in translation.

Time and resources

I only investigated the major changes in the inner Oslofjord and not other geographical areas that are connected to the fjord. I am aware that external factors, such as climate change and developments in other geographical areas, influence the inner Oslofjord. With the limited time and resources that I had, I was unable to incorporate these external factors. Several will be briefly discussed, but only those specific to the Oslofjord.

This thesis is an attempt at obtaining an overview of major changes through a literature review and people's perceptions of the inner Oslofjord during the last 110 years. Time constraints and the lack of in-depth knowledge about each topic may have resulted in overlooking important literature. Although efforts have been made to carry out an extensive literature review, it is not feasible to read all relevant literature regarding the fjord of the last 110 years in the time allocated for a 30-credit Master's thesis.

The data collection period of this thesis was roughly two months. During this period, I was able to obtain the data from a total of 59 participants and 14 interviewees. The distribution of ages among participants appears to be adequate, but this does not indicate that this is a fully representative sample. In order to obtain a sufficient sample size based on a 95 percent confidence interval, I would have needed approximately 385 participants. Therefore, no statistically significant conclusions can be drawn from this study. Based on time and resource constraints, it was not feasible to obtain 385 respondents for this thesis. Therefore, the findings of this study should not be generalized outside of this sampling population.

Limitations concerning reliability and validity

Additionally, the semi-structured interviews resulted in varying questions being asked to different interviewees. Therefore, the interviews addressed a large variety of topics giving a more comprehensive picture of the situation, yet might have harmed the study's reliability. Had time not been a limiting factor, I could have contacted a larger group of interviewees. The largest group of interviewees consisted of marine biologists. Although these marine biologists make up the majority of the interviewees, they are part of different organizations and focused on different aspects of the Oslofjord. Through the use of purposive sampling, I had the opportunity to reach out to interviewees with different perspectives about the Oslofjord, thus enhancing diversity among the interviewees.

Another limitation of this study is related to the validity of the answers given by the participants and interviewees. They may not accurately recall events or changes in the Oslofjord compared with when and how they happened. However, the mix-method approach in this study would enhance the validity of this research by drawing on different knowledge sources.

5. Results from the questionnaires

5.1 Characteristics participants

A total of 59 participants filled out the questionnaire. Four responses were removed because of low-quality or illogical answers, resulting in 55 useful responses. The questionnaire was published in English and Norwegian, and received 22 and 33 responses respectively. Not all the participants responded to all the questions.

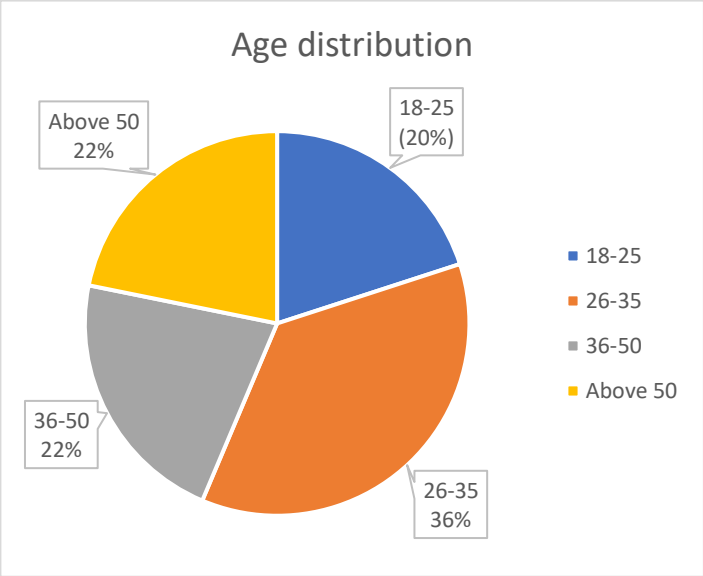

Figure 7 Age distribution of participants.

Figure 7 shows the age distribution of the participants. The largest group (36%) consisted of participants between 26 and 35 years old. The other age groups consisted of approximately the same number of participants.

Furthermore, the participants were asked how long they have been living around the Oslofjord (see Table 2). The largest group has been living around the Oslofjord between 21 and 40 years. Those who have been living within the Oslofjord area for less than five years were the second biggest group (27%). The other groups (5-10 years, 11-20 years, and more than 40 years) were notably smaller, 13%, 13%, and 11% respectively.

Table 2 Distribution of how long participants have been living around the Oslofjord.

How long have you been living around the Oslofjord?	Number of participants	Percentage
Less than five years	15	27%
Between 5 and 10 years	7	13%
Between 11 and 20 years	7	13%
Between 21 and 40 years	20	36%
Longer than 40 years	6	11%
Total	55	100%

5.2 Perception current state of the Oslofjord

The participants were asked to answer the question: “What is your opinion about the current state of the Oslofjord?”. This question was answered by 48 participants. The majority provided multiple aspects detailing how they perceive the current state of the Oslofjord. To obtain a more nuanced understanding, all the mentioned aspects were categorized into positive and negative aspects, leading to 129 aspects in total. The data showed that only 25 of the

mentioned aspects were positive perceptions of the Oslofjord, while 104 aspects were leaning towards more negative (see Figure 8).

Participants' main positive aspects focused on how they perceived the Oslofjord as clean (9 responses) and as safe (7 responses). Two participants mentioned that they enjoyed bathing in the Oslofjord. Other participants responded that the fjord has great recreational opportunities and is aesthetically pleasing.

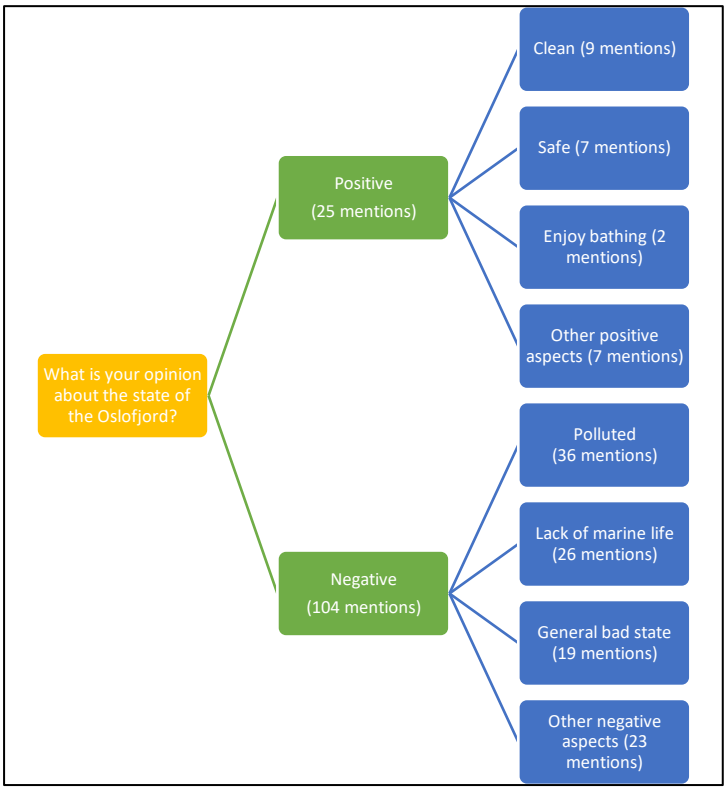

Figure 8 Responses to the question: What is your opinion about the state of the Oslofjord?

As stated earlier, the participants generally expressed many more negative aspects than positive ones. The most common issue was how participants perceived the Oslofjord negatively due to pollution: "smells like sewage", "bacteria in brackish water", "littered", and "contaminated". Other responses were linked to the general uncleanliness of the fjord: "dirty", "does not feel like clean water", and "nasty". The second biggest issue was related to how the Oslofjord lacks marine life, illustrated by the following expressions: "the fjord is dead", "marine life is almost gone", and "The marina is closer to a graveyard than to a healthy coastline". The participants also indicated 19 times that they view the fjord in a poor condition by responding: "worrisome", "seems very unhealthy", "has slowly become worse and worse" and "shameful". Other aspects such as negatively impacting their willingness to swim, and experiencing pessimistic emotions when thinking about the current state of the Oslofjord were mentioned multiple times by the participants as well.

5.3 Perceptions of change in the Oslofjord

5.3.1 Observed ecological changes

The question "Have you observed any changes in the Oslofjord from an ecological perspective? If so, what has changed, and when did you notice it? Were these changes fast or slow? Have these influenced your life positively or negatively?" received 51 responses. Four participants did not answer this question.

Nearly half of the respondents (24 out of 51) who answered this question said they had not observed any ecological changes themselves. Out of the 24 participants who did not observe any ecological changes, 18 have lived around the Oslofjord for less than ten years. Table 3 summarizes the key findings.

Table 3 Distribution of how many participants observed ecological change in the Oslofjord in relation to how long participants have been living around the Oslofjord.

How long have you been living around the Oslofjord?	Total number of participants that answered	No observed ecological change (% of the number of answers)	Observed ecological change (% of the number of answers)
Less than five years	14	13 (93%)	1 (7%)
Between 5 and 10 years	7	5 (71%)	2 (29%)
Between 11 and 20 years	6	4 (67%)	2 (33%)
Between 21 and 40 years	18	2 (11%)	16 (89%)
Longer than 40 years	6	0 (0%)	6 (100%)
Grand Total	51	24	27

There appears to be a connection between how long participants have lived around the Oslofjord and if they have observed ecological change. The overall trend indicates that participants who have lived around the Oslofjord for a longer time are more likely to have witnessed ecological changes.

In the following paragraphs, the type of ecological change they observed is described in more detail. Figure 9 provides an overview of all the mentioned changes by the participants. On multiple occasions, participants brought up different ecological changes, therefore, the total number of the mentioned ecological changes is greater than the number of participants.

The decline in marine life

The decline in marine life was the main ecological change that was observed by the participants. It was mentioned 29 times. The participants elaborated by providing multiple examples such as the decline of cod, wolffish, blue mussels, and kelp forests. Participants were also asked when they started to notice these changes, however, only seven participants answered this part of the question. Three participants observed the decline of marine life

throughout the last couple of years. The same number of participants have noticed these changes happening much longer ago, one participant stated that "I have been fishing in the fjord over 30 years, but the biggest changes have happened in the last 15 years mainly, and in the last 5 years where everything collapsed". Several participants described these changes as negatively affecting their lives, in particular, one participant elaborated on it: "It influences my life negatively as it provokes a feeling of hopelessness, anger, and sadness".

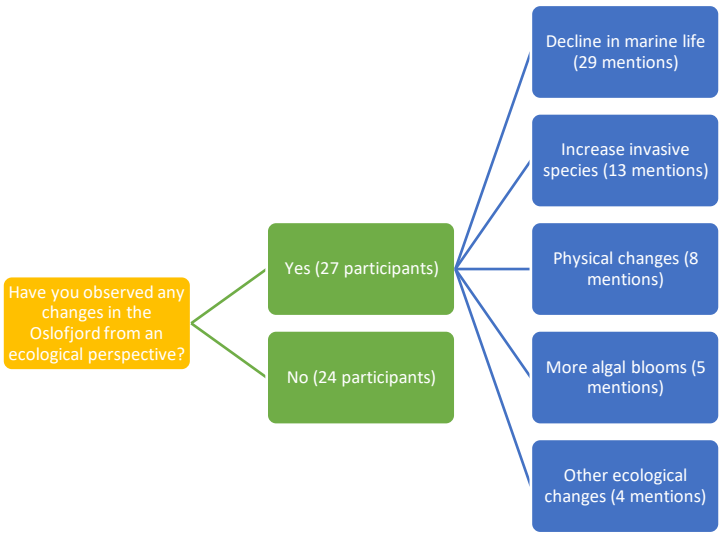

Figure 9 Responses to the question: Have you observed any changes in the Oslofjord from an ecological perspective?

Increase in alien species

The participants observed the increase in alien species 13 times, in particular, the Pacific Oyster (*Crassostrea gigas*) was brought up frequently. One participant responded: "I had not observed the pacific oyster until three years ago but I know they've been there longer". Another participant stated that they have observed the invasion of the Pacific Oyster since 2015. Another issue discussed, was how these oysters are spreading at a "furious pace" in the Oslofjord. The invasion of this species seems to be causing a rapid ecological change. Additionally, two participants reported seeing other alien species, such as warty comb jelly (*Mnemiopsis leidyi*).

Other ecological changes

The participants mentioned various physical changes in the Oslofjord, such as changes in the seafloor, watercolor, and water temperature. It was also brought up five times that algal blooms have been more prevalent. Additionally, some participants noted an increase in garbage on the seabed, fish with odd growth patterns, and wildlife returning during the COVID-19 lockdowns.

5.3.2 Observed social change

The next question the participants were asked was: "Have you observed any changes in the Oslofjord from a social perspective? If so, what has changed, and when did you notice it? Did it happen fast/slow? Have these influenced your life positively or negatively?". Two participants did not answer this question. One response was excluded from the dataset because the answer was illogical, resulting in a total of 52 responses. Out of 52 participants, seven said they did not observe any social changes around the Oslofjord. An overview of observed social changes is shown in Figure 10.

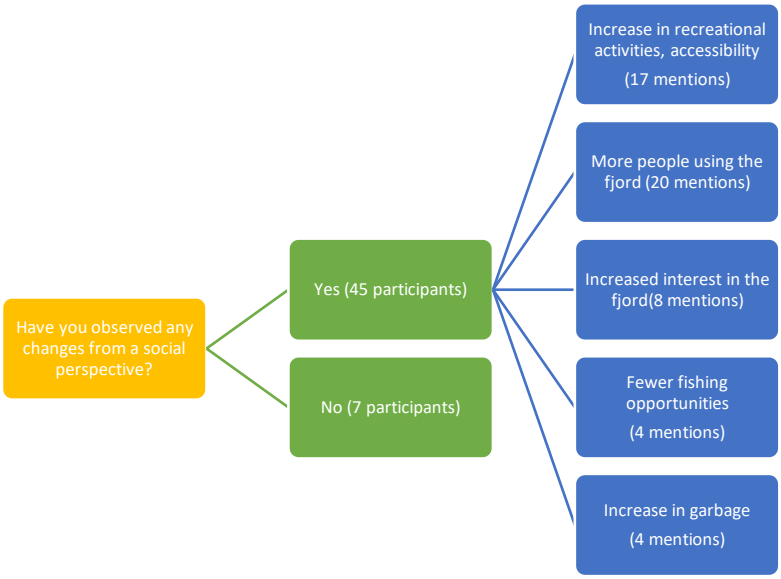

Figure 10 Responses to the question: Have you observed any changes from a social perspective?

Increase in recreational activities and accessibility

An increase in recreational activities and accessibility was mentioned 17 times by the participants. Bathing and sauna areas have been expanded according to the participants: "I use the sea much more after Bjørvika was developed. It is a positive contribution". Participants also reported the impacts of the improved accessibility: "The fjord has become much more accessible. You do not have to travel far to swim and there are both green, nature-friendly beach areas and city beaches. This creates a social arena around the fjord". Several participants expressed this development has a positive influence on their lives and that they are using the fjord more frequently. Other participants are more hesitant about these developments: "I see this [accessibility] as positive because it might make people appreciate and want to enjoy the water, however, it also contributes to way more waste and trash pollution". Therefore, participants perceived this development both positively and negatively.

More people using the fjord

It is likely due to the increased number of recreational activities and better accessibility that more people are using the fjord. It was mentioned 20 times that more people had been using the Oslofjord as participants observed more people swimming, kayaking, boating, and fishing.

Some view this as a positive development since more people can enjoy the fjord: “I think that more and more activities are being done around the fjords, which boosts people's ability to enjoy the outdoors and nature of the area”. However, several participants had a negative attitude regarding this change: “A lot more people are going there in the summer to bathe, as well as saunas in the winter. It turns negatively for me, as I see more pollution (trash) as well as it being a too crowded and busy spot”. Thus, there are divided opinions about these developments regarding recreational activities and the increase in users in and around the Oslofjord.

Increased interest in the fjord

Several participants responded that the Oslofjord is receiving more attention than before. Participants addressed that they see more media coverage, and how the fjord has become a theme that is frequently brought up. Furthermore, one participant responded: “More people are aware of the state the Oslofjord is in. It’s more about the situation in the news and people talk about it more now than when I first moved here five years ago”. Another participant reported that more people are interested in volunteering in clean-ups.

Other social changes

Four participants raised concerns about the increase in plastic pollution in the fjord. One participant expressed their views strongly: “At the marina where I spend a lot of time, there is often garbage floating on the surface, things from boats or boat equipment, beer cans or soda cans, styrofoam, or small pieces of plastic and cigarettes”. Also, four participants have stated that there are fewer opportunities to go on fishing trips. Furthermore, a few participants have pointed out a declining willingness to swim in the fjord because they perceive themselves as unclean after. This was also found in the responses regarding what people think about the current state of the Oslofjord.

5.4 Perceptions of the main causes of change

The participants were asked the question: ‘In your view, what are the main causes of these social and/or ecological changes?’. Four participants did not answer this question, and one answer was excluded because it included a low-quality answer. The participants responded with a large variety of what they think are the main causes of these social and/or ecological changes. In total, they responded with 118 drivers of what they think are the main causes of social and/or ecological change.

The majority of participants mentioned drivers that negatively affect the fjord. Only four participants mentioned drivers that can have a positive influence on the condition of the fjord,

such as a change in people's attitudes: "People wanting to do something about it and actually having a place where they can now intrinsically and tangibly make a difference".

The participants considered pollution as the main driver of change. Different types of pollution were mentioned, such as sewage, plastic, and runoff from agriculture. Furthermore, participants noted 13 times that drivers related to fishing practices are among the main causes of these changes. They responded with overfishing, trawling, and poaching as examples. Eight times, the participants expressed their views on how increased infrastructure is contributing to change. Moreover, participants responded four times that a higher population was among the main drivers of these changes. Figure 11 shows the main causes that were mentioned.

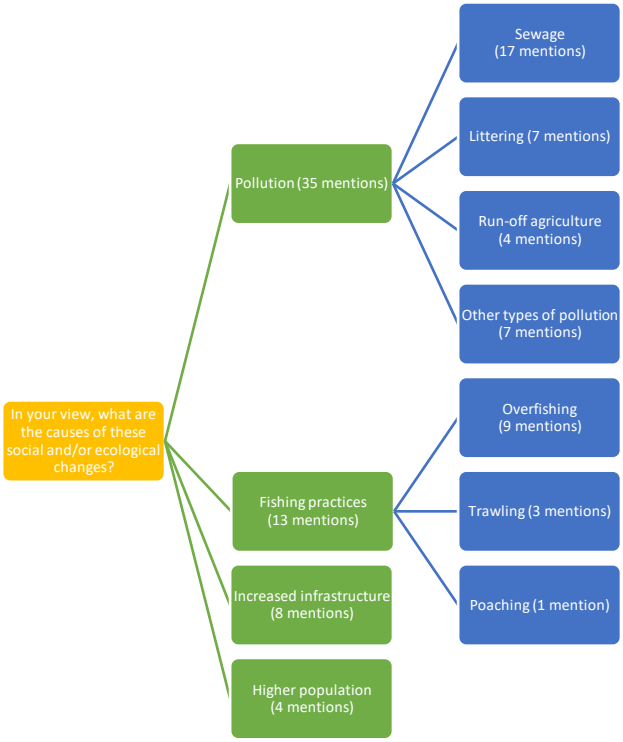

Figure 11 Responses to the question: In your view, what are the causes of these social and/or ecological changes?

5.5 Willingness to change

The last question the participants were asked was: "Would you be willing to change your lifestyle to improve the condition of the fjord? If so, why and what would you change?". This question was not answered by six participants; therefore, 49 responses were analyzed. Four participants said that they are not willing to change their lifestyle. Four were uncertain whether they wanted to change or not, and they stated that it depended on what needed to be changed. However, the far majority (43 participants) of the respondents stated that they are willing to make changes in their lifestyle that would lead to an improved condition of the fjord (see Figure 12).

Changes participants have already made

Twelve participants mentioned that they have already made changes in their lifestyle that contribute, according to them, to an improvement in the condition of the Oslofjord. For example, these participants mentioned being involved in clean-ups (7 responses), changing daily routines (5 responses), and stopped fishing in the Oslofjord (2 responses).

Changes participants are willing to make

The participants who responded that they are willing to make changes in their lifestyle gave a wide variety of answers (see Figure 12). However, most participants did not know what lifestyle changes can contribute to improving the Oslofjord's condition. It was mentioned four times that monetary incentives could help to improve the condition of the Oslofjord: “I can pay more taxes or municipal fees for better cleaning and reduction of runoff from agriculture”. Furthermore, participants mentioned four times that they are willing to be involved in clean-ups. Lastly, it was mentioned four times that they are willing to use more sustainable options such as alternatives to their current laundry detergent.

It was mentioned a few times that participants stated that bigger changes need to happen than what is feasible on the individual scale: “I seriously believe that we must change social structures and demands in the direction towards stricter regulations regarding how we harvest, build in the coastal zone and handle our waste”.

Figure 12 Responses of participants who are willing to change their lifestyle to better the Oslofjord's condition.

6. Results from the interviews

6.1 Characteristics interviewees

A total of 14 interviews were conducted with people who are familiar with the Oslofjord because of their daily interaction through their occupations (see Table 4). The interviews aimed to capture in-depth material on how these experts perceived the state of the Oslofjord and how they experienced major changes.

Table 4 Overview of occupations of interviewees

Occupations of interviewees	Number of interviewees
Marine biologist	5
Volunteer	3
Leader of an NGO	2
Pollution and sanitation specialist	1
Cod geneticist	1
Biologist	1
Consultancy advisor on environmental impact	1

6.2 Perceptions of the current state

The interviewees were asked about their opinion on the current state of the Oslofjord, and not all interviewees had the same opinions. Take, for example, the following quote: “The general state of the Oslofjord is really bad, and it’s looking bad… There's no sign of positive change”. The Oslofjord was frequently mentioned as an "ecological disaster", as "an ecosystem collapsing" or even as "dead" by other interviewees. The interviewees explained that the Oslofjord seems to have an unhealthy ecosystem due to the lack of marine life and a lot of rubbish. Similarly, interviewees stated that the Oslofjord does not have much recreational value for (free) diving compared to other Norwegian fjords.

However, not all interviewees perceived the Oslofjord in an extremely bad state, especially considering its historical context. Several interviewees mentioned that the Oslofjord is not a dead ecosystem and that it is quite diverse. One interviewee elaborated on how he believes that the public has the wrong opinion on the Oslofjord’s condition, take for example the following quote:

> “When we read about the Oslofjord is dead, we, that study the animals and plants that live in the water mass, don’t agree, because it’s far from dead, absolutely not. It’s actually quite diverse and in a good state, but it’s the bottom situation that is different, which is due to old sins.”

Several interviewees noted that the Oslofjord's condition used to be in a worse state than it is now. One interviewee remembered a childhood memory of Oslofjord's conditions in the 1970s:

> "When I was younger, coming to nice and warmer Oslo, and wanting to swim, and was so excited about it. And I just went into the sea a little bit, it was black, I couldn't see my feet. It was smelly. There was no swimming that day. That was pollution. (…) I thought to myself: what is happening here?"

The interviewees said on multiple occasions that the improved surface water conditions over the past 50 years were due to decreased pollution. Several interviewees viewed this development as "fantastic" that people can safely swim in the inner Oslofjord. Although the surface waters have improved a lot, several interviewees emphasized that more action is needed as the Oslofjord is facing new challenges.

6.3 Social-ecological development through time

The interviewees were asked a series of questions about the changes the Oslofjord has undergone and the factors that have contributed to those changes. The interviewees tended to discuss their areas of expertise concerning these questions, and therefore, they did not discuss the same topics or temporal periods. Even though attempts were made to pinpoint precisely when changes occurred, the interviewees did not always provide these details.

6.3.1 The early 1900s

The interviewees frequently brought up how the Oslofjord was thriving at the beginning of the 20th Century. According to them, the Oslofjord had large fish populations that were diverse and abundant, allowing a permanent fishing fleet. Many residents relied on the fjord as their primary source of income. Whales, kelp, seaweed, and many other species were abundant in the fjord. Interviewees stated that the fjord had a decent chemical condition with oxygen being present in the fjord's bottom layers. However, according to one interviewee, the Bunnefjord was already anoxic before human impact. Nutrient concentrations were not brought up by the interviewees in this period. As regular monitoring programs were absent until the 1930s, the data about the early 20th century was primarily derived from photographs.

6.3.2 The 1930s-1980s

According to the interviewees, scientists began studying the Oslofjord's phytoplankton in the 1930s. It was evident that human activities were affecting the Oslofjord. The fjord's condition deteriorated because of pollution, rubbish, and dirt that went straight into the fjord.

In addition, many construction projects were being carried out along the fjord's coast. The water quality of the Oslofjord worsened and accessible shores disappeared. As a result of these changes, bathing in many places in the Oslofjord was no longer possible. This development was considered unacceptable for the 40 municipalities along the Oslofjord. The municipalities agreed that there was a need for interference, resulting in the Oslofjordens Friluftsråd being formed in 1933. The interviewees did not elaborate on what happened after this establishment and its impact.

Forward to the 1950s, one interviewee mentioned a major change that happened and how it affected the Oslofjord:

> "In the 50s, we were implementing the water toilet. We saw that the rivers and streams were clean, up until they implement the water toilets. So the waste was floating free. It was a huge increase in the 50s and 60s, it deteriorated the quality of the streams. Which also impacted the fjord. There was no sewage treatment at that time."

Nitrogen and Phosphorus concentrations were highly abundant in the Oslofjord, resulting in increased phytoplankton growth. This growth was exacerbated by the lack of adequate wastewater treatment facilities.

The construction of the wastewater treatment plant Bekkelaget began in the 1960s. Interviewees mentioned that the phytoplankton biomass slightly decreased. Despite the high pollution, interviewees frequently stated that the Oslofjord was abundant with fish, kelp, and blue mussels in the 1950s and 1960. From a social perspective, one interviewee stated that during the 1960s and 1970s, the public was not really aware of the condition of the Oslofjord. In addition, the interviewees provided insights on the mentality of how environmental issues were handled: "In Oslo, they probably had the attitude: the fjord is so big, we don't need to treat the water". Another interviewee mentioned how fjord was perceived as very polluted, but with a high abundance of marine life.

The Oslofjord's condition continued to worsen in the 1970s and 1980s. Sewage and overfertilization of land were considered the primary drivers of the algal blooms. Sanitation guidelines were published, and attention was turned to sewage treatment. Initially, sewage treatment mainly focused on removing organic particles. In the years following, Phosphorus was also being removed from the wastewater. Several obstacles were met before the treatment plants were fully operating. Nevertheless, the nutrient concentrations in the fjord were so high that algal blooms became even more prevalent than before. The algal blooms did not only result in murky and smelly water, but some algal blooms caused toxicity in other organisms. Two interviewees pointed out that the chlorophyll concentrations, and thereby, the phytoplankton

biomass, started to decline in the 1970s/1980s. On the other hand, one interviewee stated that the algal blooms and algal biomass did not start to decline before the early 1990s.

Frequent monitoring began in 1973, which has led to a more comprehensive dataset. One interviewee mentioned that, based on sediment cores, the concentration of heavy metals continued to increase until the 1970s. Hazardous waste was directly discharged into the Oslofjord. However, in the 1970s the authorities issued guidelines on how to handle hazardous waste. In addition, interviewees noted that an increasing population has placed more pressure on the Oslofjord since the 1980s.

6.3.3 The 1990s-2000s

Interviewees pointed out that in the 1990s, Nitrogen cleaning facilities were constructed. However, one interviewee expressed a critical view of these facilities because of their high energy demands. As the process of removing Nitrogen from the water used high amounts of energy, more Nitrogen and Sulphur would be emitted into the atmosphere.

Furthermore, there was a proposal to the parliament from one of the interviewees to adopt a new type of environmentally friendly toilet. However, the parliament rejected this proposal, and the interviewee elaborated on this by:

> "This is probably due to the municipalities complaining about the costs involved. So, we suggested new solutions, but it's also hard for people to get out of their systems. But also the competence of how to handle these new systems; they want to run the systems as how they want to run it before."

Other obstacles arose as well when trying to propose and adopt new technologies, such as training people and sociological aspects. In particular, the sociological aspects of how people perceive and react to different technologies were at the center of the problems.

The reduction of inorganic nutrients combined with treating wastewater contributed to improved surface waters. Nevertheless, nitrogen concentrations have been increasing since the mid-2000s. As the composition of nutrient ratios changed, it also affected the phytoplankton species composition. According to one interviewee, the main groups in the diatoms and dinoflagellates remain the same at the genus level, but the species composition has changed. The abundance of the dinoflagellates has remained the same since the 1970s and the 1980s, however, the diatoms have been reduced. This interviewee stated that the phenomenon can be explained by the reduction of inorganic nutrients in the Oslofjord. The diatoms need these inorganic nutrients while the dinoflagellates can use other substances. The interviewees indicated that the Oslofjord had a high abundance of marine life in the 1990s, both blue mussels

and cod were still present. According to the interviewees, social change has occurred since the 1990s, for example, the increased popularity of using kayaks on the Oslofjord.

Despite the improvement of the surface water, the bottom layers of the Oslofjord remained to have issues. An interviewee mentioned that under 60-70 meters there is no oxygen, and that sediments are still polluted from the uncritical discharge in the past. The anaerobic sediments at the bottom will consume the oxygen rapidly, so the situation is hard to improve. Efforts were made to improve the condition of the bottom layers. One interviewee was involved in expressing their thoughts regarding how to handle the contaminated sludge and critiqued the authorities' plans to deal with the sludge. Despite the interviewee's expertise, the authorities ignored the interviewee's recommendations and chose a method that mixed pollutants in the water column and sediment layers. Another interviewee also mentioned a similar project with clay capping of household waste in the Oslofjord, so the organisms could not access the pollutants any more. According to this interviewee, as long as there is no physical disturbance of the seafloor, the pollutants on the bottom of the Oslofjord are no longer biologically available. This was refuted by another interviewee who discussed that pollutants still affect the ecosystem:

> "We have to be careful with the cod liver, don't eat it too often because of hazardous or organic chemicals. This is because we've been dumping things in the sea, and it's been accumulating in the food chain"

One interviewee mentioned that the ecological conditions in the upper water column were worse in the early 21st century than they are today. However, several other interviewees noted that in the early 21st century cod was still present in relatively high abundance:

> "If you speak about cod, I can remember we were at Fornebu. We could see a lot of cod swimming along. (…) And a lot of small animals living in the sand, a lot of fish swimming around. Around 15-20 years ago, a very big change has happened"

In addition, two interviewees mentioned that cabin prices around Oslofjord have risen substantially over the past 20 years. Not all people can have access to cabins anymore because they do not have a suitable income to either rent or buy a cabin along the Oslofjord. Nevertheless, organizations are trying to make cabins accessible to everyone, independent of their financial situation. These organizations are not always receiving adequate financial support from the government that would support their operations.

6.3.4 The 2010s

Most of the interviewees mentioned changes that have occurred in the last decade. Hence, these changes are discussed in greater detail than the previous decades.

Seagrass & kelp

A significant drop in seagrasses and kelp has occurred in the last 10 to 15 years. According to the interviewees, this is probably due to increased temperature, climate change, overfishing, and sea urchins. The increased temperature stimulates the growth of filamentous algae. The filamentous algae deplete and reduce the survival of seaweed and kelp. Furthermore, climate change resulting in increased storm events lead to additional run-off from nutrients which damages the seagrass meadows and kelp forests. Overfishing affects seaweed and kelp by altering relationships between organisms. One interviewee elaborated on this:

> "We had coastal fisheries that have removed a lot of the cod population all along the coast actually, but also in the Oslofjord, and when you have all this fishing over species that will impact the whole system. If you, for instance, remove the cod, you have a growth in populations of other fish species. Maybe they eat differently."

Furthermore, one interviewee stated sea urchins are seriously affecting seaweed and kelp. This problem occurs all along the Norwegian coast, not only in the Oslofjord. Consequently, the community dynamics in the Oslofjord are changing. On the bright side, seaweed and kelp recover fairly quickly when disturbances are not present anymore. According to the interviewees, the seaweed meadows and kelp forests are key to restoring the Oslofjord because they create spawning areas and provide food to other marine organisms.

One interviewee stated that they had been involved in a project related to regenerative farming of kelp in the Oslofjord and sees potential: "For me, it seems like a miracle cure, and it puts oxygen in. It's something that can be done, and you can do it on a large scale". This interviewee stated that excessive nutrients are not a problem as long as there is sufficient vegetation to use these nutrients. The interviewee added that humans can positively influence the fjord and they should not wait for the fjord to fix itself. Furthermore, another interviewee who is also involved in re-establishing vegetation in the Oslofjord expressed why NGOs are taking action:

> "Because the government moves at the speed of a snail. And they have laws and systems that stop them from even understanding why they can or can't do something. Bureaucracy at its finest. I would say that the way their system is set up is not conducive to solving this problem.

> It is too slow, too conservative, too risk averse, and not innovative enough. This problem needs to be outside of government action."

Blue mussels

Interviewees frequently addressed the decline in blue mussels in the Oslofjord compared to the previous decades. In particular, they observed a large reduction of blue mussels in the last 10 years. Interviewees provided a variety of explanations for the disappearance of blue mussels, such as blue mussels being grazed down by benthic animals, sea stars, and birds. Other theories involved parasites or increased heating of the seawater. The decrease in phytoplankton might have contributed to the decrease in blue mussels. A slight reduction of phytoplankton algae occurred compared to the 20th century. Yet, according to an interviewee, the Oslofjord still retains enough algae to feed blue mussels.

Fish populations

The interviewees observed declining cod populations in the Oslofjord, in particular, a steep decline in the last 10 years. In 2019, the authorities introduced a fishing ban on cod in the Oslofjord with a catch and release policy. One interviewee expressed her concerns that this policy is not sufficient:

> "I think one of the problems is that you're still allowed to fish, but you have to release it. And I think that's a mistake. I think it would be easier to police if we just said no fishing is allowed. If you saw someone fishing, that would be illegal, so it's easier to police. Whereas if you see someone standing now with a rod, they could be fishing for mackerel or something else. And also if you captured and release it, you could very damage the fish very much. (…) Catch and release a fish. It's ridiculous."

Another interviewee had a different opinion about this policy and expressed that similar policies have worked in the past and can be used to preserve fish populations. Another interviewee agreed with this statement: "Norway is a country where [it] works to make rules and people follow them. So when we say don't fish cod, people don't fish cod". However, several interviewees mentioned seeing people take cod home or tear off the flesh and throw the carcass back into the water.

The interviewees mentioned that the decline of cod is primarily due to too high fishing pressure in Oslofjord. In the past, fishing for cod was easy, so both commercial and recreational fishermen took out large cod populations. However, various interviewees pointed out that the decline of the cod population is not a straightforward question to answer, as it is due to a

complex variety of factors. In addition to overfishing, they mentioned agricultural and industrial development, as well as climate change, as contributing factors to the decline in cod populations. One interviewee stated that the decline in cod is not just a problem that occurs in the Oslofjord, but has been an issue in other places as well:

> "On the Swedish side, which is very similar to the Norwegian side, the few fjords have been empty for decades, and cod doesn't seem to really come back, even though they are protected from fishing et cetera. Probably part of that is because you have these locally adapted cod populations that are more vulnerable than you would think"

The cod that can still be found in the Oslofjord can be described as: "typically skinny, like big heads and long slim bodies. For me it looks like a sign that they are not getting the food they need". The cod in the Oslofjord is considered to be in very poor physical shape when compared to cod in other Norwegian fjords. Despite all the negative developments on the cod abundance in the Oslofjord, one interviewee pointed out that cod has a remarkable ability to adapt because it is a very generalist species. Their main obstacle is warmer water temperatures, but even in summer in Oslo, the deeper waters still provide suitable temperatures. Cod has a high fecundity rate, so they can recover relatively quickly compared to many other species. However, this interviewee also stated that: "It seems like that something very critical is happening so that it's not possible for the cod to bounce back. So it might be too late already". This interviewee elaborated on this by emphasizing that the big old females are the ones that produce more and higher-quality eggs. Most likely these females have been taken out of the Oslofjord because of the high fishing pressure in the previous decades. The cod that are still left in the Oslofjord, are of "bad spawning quality".

Other changes in the fish populations included a more frequent observation of Mackerel. However, the interviewees mentioned that it is currently unknown how these fish impact the Oslofjord.

In addition, interviewees also pointed out that there is no consistency among the methods that are used to measure the abundance of fish in the Oslofjord. Different methods exist to measure, but it is limited to what degree of comparison is possible. Also, an interviewee stated that cod is a cultural species that is closely associated with childhood memories for many people. This participant stated if cod would disappear from Norway, people would get upset about it.

6.3.5 The 2020s

Although a two-year span is a short time to observe changes in the social-ecological systems, some interviewees have noticed changes in both the ecological and the social systems.

One interviewee mentioned a fast change that has happened in the past couple of years: "Out on the island, the last two years there used to grow kelp and mussels, but there's nothing left now. Now it's just the pacific oyster". Another interviewee pointed out that nowadays they see some recruitment of blue mussels, but they disappear when they grow older. Although a variety of theories have been offered to explain this disappearance, it continued to be "A bit of a mystery". Furthermore, the invasion of the Pacific Oyster is impacting people. According to interviewees, Pacific oysters cause large cut injuries that result in hospitalization each year.

Interviewees mentioned how climate change is already affecting the Oslofjord by the increased number and intensity of storm events in the last couple of years. The storm events create run-off from land, impact vegetation, and stimulate coastal erosion around the Oslofjord. In addition, climate change will affect the deep-water renewals in the Oslofjord, which are essential for providing oxygen in the lower layers of the water column.

Other ecological changes that interviewees have observed are more dead birds and the survival of a specific type of green algae in the winter of 2021 to 2022.

In addition, interviewees mentioned that social changes have been happening around the Oslofjord. They observed increased awareness of the condition of the fjord among residents and it is being discussed more in the media. In the last few years, more and more residents have started to realize how valuable the Oslofjord is. It has become more visible that people are enjoying the Oslofjord, which also influences the political agenda. According to the interviewees, political parties are more active on issues in the Oslofjord now than before. Also, more people are involved in clean-ups. One interviewee pointed out that ecological changes also caused a change in people's behavior:

> "Towards the late last summer, there was a bacteria or something in the water that made it stink immensely in the Oslofjord. And then following that we had a lot of interest in people wanting to get involved [in clean-ups] because it was very noticeable"

During the last two years, residents were often not able to travel out of Norway for recreational purposes due to the COVID-19 pandemic. According to interviewees, the fjord has become easier to access and recreational activities have increased, resulting in increased pressure on the surface waters. Nowadays, plastic is of great concern to various interviewees. One interviewee

stated: “We should start finding a way to stop that [plastic] from going in because we don't even know what all this microplastic does to the organisms that live in the fjord”.

Interviewees also frequently discussed how the higher temperatures are impacting the macroalgae and seagrasses, cod, and other ecological processes. One interviewee also mentioned that higher water temperatures are contributing to recreational activities along the Oslofjord:

> “We have some summers with temperatures up to 25 degrees in the inner parts of Oslofjord. This is something untypical and a bit strange. I can remember that I was swimming in the Oslofjord and I was always freezing to death because the water temperature was the 17-18 and maybe 19 if you were lucky. (…) But at the same time, people are like: well, we don't have to go to Spain because the temperature in the sea here is 25 degrees.”

Several interviewees also mentioned the importance of culture. Norwegians generally like being outdoors, and around Oslo, the main attractions are the forest region Nordmarka and the Oslofjord. Being connected to nature is embedded in the Norwegian culture. However, one interviewee stated that some residents may believe the misconception that Norway is excellent at managing its natural resources. This interviewee stated that Norwegians have been spoiled with the available nature and are not considering their impacts.

6.4 Main causes of change

The ecological change has been caused primarily by overfishing, eutrophication, and climate change, according to the interviewees. They elaborated that these are the drivers that cause the system to be out of balance. The interviewees also pointed out that it is not just one factor that influences the state of the fjord; it is a combination of factors that are amplifying each other. One interviewee brought this up by the following: “I think we're doing a lot of wrong things at the same time”. Furthermore, they also brought up how deteriorated marine ecosystems are less visible than, for example, degraded forest ecosystems.

6.5 Perceptions of the future

6.5.1 Future challenges

The interviewees were asked what challenges they think the Oslofjord will face over the next few decades. They frequently mentioned that climate change will pose among the biggest challenges by altering the temperature of the surface waters and changing precipitation patterns. Furthermore, the increased nutrient inflow was another challenge that was commonly brought up. Only one interviewee disagreed with this development. The interviewee stated that

eutrophication will not be a part of the challenges the Oslofjord faces because Nitrogen and Phosphorus levels have been managed well, because based on total organic carbon, the situation has almost recovered to reference conditions. Other challenges that were mentioned by interviewees were: pollution from residents, population increase, alien species, people living too close to the fjord, and overcoming sociological obstacles.

6.5.2 Perception future condition

The interviewees presented a number of different visions of how they think the fjord will look in the future. When the 'future' will be, was not pre-defined by the researcher or the interviewees. One interviewee explicitly stated: "I don't think it will be much better in 20 years. I think it will be in a worse condition than now". On the other hand, many of those interviewed expressed optimism for the Oslofjord, since the fjord has been in worse conditions than it is now. Most of them stated that the situation will not worsen, but intervention is needed in order to improve the situation.

The interviewees expressed that getting the government to spend money on the Oslofjord will be the main obstacle. Money is needed for both intervention and monitoring programs. One interviewee pointed out that institutions typically begin monitoring when they are facing trouble, leading to no available data about reference conditions. They also discussed the importance of monitoring in the future:

> "So they usually say: you only protect what you love. But you only protect what you know. So we have to know what we are supposed to have in the fjord and what we have lost. Then we can start discussing how to get that back".

Interviewees pointed out that monitoring programs are still lacking for various parts of the fjord, for instance, zooplankton.

When the changes come to the point that ordinary activities of people are changed, then people start to notice. In terms of opportunities, one interviewee stated that the "sky is the limit" and that we have to "increase the ambitions". In addition, the interviewees also discussed that people are most likely to change some of their behaviour that will be good for the fjord, but not all. One interviewee mentioned that people are looking at changing things that do not cost effort.

7. Discussion

7.1 Perceptions of the state of the Oslofjord

The importance of perceptions lies in their role in influencing the management of marine resources (Levine et al., 2015). As perceptions about a social-ecological system (SES) shape the awareness of the state of the system and how it is acted upon, these then influence policies and decision-making processes (Gallopín, 2006).

Perceptions of previous decades

In this thesis, I did not collect substantial data about the perceptions of the state of the Oslofjord in the previous decades, however, some interviewees expressed how the Oslofjord's condition had been perceived previously. Interviewees mentioned that people's perceptions and attitudes have changed over time. In particular, how the fjord was viewed as big and resilient enough to absorb all the wastewater. In subsequent years, increasing complaints from the public about the state of the fjord (Arnesen, 2001) brought about a change in thinking on how to handle wastewater, resulting in the introduction of chemical and biological cleaning facilities (Oslo Kommune, 1976). However, the cleaning facilities were not effective immediately, and the fjord was still perceived as very polluted despite a high abundance of marine life.

Perceptions were important once again during the 1990s when environmentally friendly toilets were proposed to the parliament. Not only were the costs involved an obstacle, but also how people perceived and reacted to different technologies. For example, one interviewee mentioned that people wanted to operate the system as they did before. Consequently, the proposal was rejected by the parliament.

Perceptions of the current state

The participants mainly commented on negative aspects of the fjord, such as the lack of marine life, pollution, and its generally bad condition. The state of the Oslofjord was perceived more negatively by the participants as opposed to the interviewees due to the wide variety of responses by the interviewees. Some interviewees expressed very strong opinions about how the Oslofjord was an "ecological disaster" while some others pointed out that its general state is rather poor but not as bad as the media portrays it. Concerning this, one interviewee specified the following: "I felt the public had the wrong opinion about the Oslofjord".

There is often a mismatch between public and expert knowledge about marine ecosystems due to the different sources of information they use (Santos & Wong-Parodi, 2022). In the last couple of years, the state of the Oslofjord has been communicated through the media

such as NRK, Aftenposten, and Dagbladet. The fjord is frequently brought up in the news with a narrative that it needs to be saved and that action must be taken now (see Solvang (2021), Høgås (2021) and Dahle and Fretheim (2022)). Residents often rely on personal experiences and information that is provided to them through the media (Santos & Wong-Parodi, 2022). Although scientists' perceptions are influenced by scientific data, their perceptions can greatly vary depending on the nature of the research and their epistemological and ontological positions. For example, through the methods and interpretation that the researchers choose. Therefore, scientists' perceptions vary when studying the same phenomenon as was observed in this thesis. Furthermore, in this thesis, I made multiple observations that various aspects of the Oslofjord are not (systematically) monitored such as benthic fauna and zooplankton, or that recent systematic monitoring data is scarce, for example for seagrasses (Rinde et al., 2021).

Perception main causes of change

Lotze et al. (2018) identified that the public often perceives pollution, overfishing, habitat alteration, and climate change as the biggest threats to marine ecosystems. This partly aligns with the main causes identified by residents in this study, as they mostly mentioned pollution, fishing practices, increased infrastructure, and population growth. Infrastructure expansion can be seen as habitat alteration by building houses, roads, or other buildings on shorelines. The interviewees mentioned overfishing, eutrophication (through pollution), and climate change as the biggest threats to the Oslofjord. Apart from population growth, the perceptions of the greatest threats to marine ecosystems align with the study by Lotze et al. (2018).

Despite the strong negative perceptions, the fjord has gone through limited improvement. One of the reasons behind it is explained by one interviewee when copping with issues in marine ecosystems: "I think that because the problem is not visible, and it is not in people's faces when they look out on the fjord". In addition, Norwegians generally trust their government to make appropriate decisions (OECD, 2022). However, the authorities' decisions can lead to questionable outcomes, as was evident when the government used controversial methods to deal with contaminated sediment in the mid-2000s. In 2019, the Norwegian Environmental Agency announced an action plan to improve the Oslofjord's chemical and ecological condition (Miljødirektoratet, 2019b; Miljødirektoratet, 2021). Nevertheless, some interviewees commented that they are still dissatisfied with the actions of the Norwegian government to handle problems in the Oslofjord. Consequently, these interviewees are seeking

solutions for improving the fjord without the support of the government. For example, through organizing clean-ups and finding ways to re-establish macroalgae.

Shifting baseline syndrome

It is important to be aware of shifting baseline syndrome when investigating people's perceptions. The shifting baseline syndrome can be defined as a psychological and sociological phenomenon that affects people's perceptions of environmental conditions (Soga & Gaston, 2018). Little past experience or lack of knowledge about historical conditions can lead to a general acceptance of current environmental conditions into which younger generations were born. In accordance with this syndrome, the results of this thesis indicate that younger generations have observed fewer changes in the Oslofjord. Whether the shifting baseline syndrome also applies to the residents of the fjord or not, will be described in greater detail below.

Soga and Gaston (2018) offer several explanations for developing the shifting baseline syndrome: "(1) lack of data on the natural environment, (2) loss of interaction with the natural environment, and (3) lack of familiarity with the natural environment" (p. 224).

The first explanation can be partially accepted for the Oslofjord. Before the 1970s, limited regular monitoring programs existed for the fjord. This was also the period in which pollution had reached its peak, therefore, limited knowledge exists about its former state. Paleoecological studies in the Oslofjord have been conducted to obtain more data through proxy indicators, however, uncertainties exist about these types of datasets (Nieto-Lugilde et al., 2021). According to one interviewee, there is a lack of monitoring programmes in the fjord and monitoring starts when problems arise. Therefore, reference conditions rarely exist. As a consequence, the lack of data can contribute to the shifting baseline syndrome. Nevertheless, the current monitoring programs enable the collection of data on the fjord, reducing the risk of baseline shifting in the future.

Residents and interviewees have noted that recreation on the Oslofjord has increased, resulting in a greater interaction with the natural environment and thus refuting the second explanation. Nowadays, people are interacting with the fjord more than ever before because of positive developments such as improved accessibility and better surface water quality. However, further investigation will be needed on the type of recreational activities and their impact on the perception of the fjord's condition as different activities can contribute to different perceptions. For example, interviewees and participants who mentioned that (free)

diving in the fjord is rather disappointing while other participants who stated they enjoy bathing perceive the situation differently.

The third explanation for the shifting baseline syndrome is not as straightforward as the others. Younger generations are more exposed to the fjord due to increased interaction. Although their interaction has occurred on a shorter temporal scale compared to older generations, it might influence how familiar they become with the fjord in the future. However, the results of this study indicated that the younger generations generally observe less ecological change in the Oslofjord than the older generations. This phenomenon was also observed in another case study by Aswani et al. (2018). The inter-generational differences can be explained through changes in lifestyle and societies, that can decrease the transmission of knowledge to younger generations (Aswani et al., 2018). Nevertheless, these younger generations are exposed to many social media outlets that discuss the state of the fjord, thereby impacting their awareness of its condition.

In comparison to older generations, younger generations have data available about the Oslofjord, have increased interaction with the fjord, and potentially will become more familiar with the fjord. Thereby, impacting their perception of the Oslofjord's condition.

7.2 Timeline of social-ecological change

Ways to observe social-ecological resilience are presented in section 3.3 In short, Carpenter et al. (2005) expressed four ways to observe resilience in a social-ecological system (SES): stakeholder assessment, model exploration, historical profiling, and case study comparison. In this study, I have used stakeholder assessment and historical profiling to observe the resilience of the Oslofjord. Most of the data gained from the different sources aligned with each other, but some discrepancies existed. In the following paragraphs, I will discuss the similarities and discrepancies of the data related to the Oslofjord and in a wider context during the past 110 years (Figure 13).

Water temperature – Some participants and interviewees mentioned increased water temperature over the last few decades. The data provided by the Miljødirektoratet (2019a) indeed shows that the temperature in the Oslofjord has been increasing, in particular, a steep increase has occurred in the last 30 years. Several participants and interviewees pointed out that temperature is a driving factor that alters the interactions in the SES of the Oslofjord. For example, at higher temperatures, the fjord becomes more appealing to bath in, but also it impacts the algal production.

Year	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000	2010	2020
Water temperature	Gradually increasing temperature								Steep increase in temperature			
Nitrogen levels	Increase from slightly 500 tons in 1910 to almost 4000 tons in 1990									Decreasing until 2003, 1900 tons	Increase until 2015, 2800 tons	Decreasing until 2020, 2350 tons
Phosphorus levels	Steep increase from 50 tons in 1910 to 700 tons in 1970.							Steep decrease to approximately 70 tons			Increasing again until 2019, 89 tons	
Phytoplankton - eutrophication	Eutrophication already detected		Increasing phytoplankton biomass			Extremely high algal biomass and toxic algal blooms		Start of change in species composition phytoplankton			Observed increased algal blooms	
									Decline in chlorophyll levels		Slight increase until 2017	
Oxygen concentrations			Declining oxygen concentrations							Improving oxygen concentrations		
Heavy metal concentrations				Mecury concentrations peaked		Cadmium concentration peaked	Copper concentration peaked			Moving and covering contaminated sediments		
Water quality		Deteriorated stream quality. Murky, smelly and polluted waters in the Oslofjord							Improving surface waters, deeper water still bad condition			
Macroalgae & seagrass	High abundance of macroalgae and seagrasses						High density of macroalgae F. Evanescens				Reduction *F. evanescens*	
							Improving lower depth limit macroalgae				Reduction lower depth growth macroalgae	
Benthic fauna	Benthic fauna in Bunnefjorden disappearing		Continued negative developments - fewer species - less abundant						Improving benthic fauna		Blue mussels disappearing	
Fish stocks & fishing pressure	High fish populations			High abundance of sprat		Highest peak in abundance of cod & pollock			Highest peak in abundance of whiting	Start stagnant recruiment cod	Increased pelagic warm water species and cod and pollock populations collapsed	
											Recovery of whiting populations	
Alien species							High density of macroalgae *F. evanescens*			2005-2008: spreading of Pacific Oyster larvae	Increased amount of Pacific Oyster	
											Reduction *F. evanescens*	
Responses to change	Implementation of water toilet										Public starts to notice Pacific Oyster and regular hospitalization due to cuts	
	Start researching effects of pollution on human health	Increased urban development leading to inaccessibility of shores	1933: establishment Oslofjorden Friluftsråd		1958: establishment NIVA	Conducting a lot of research on the Oslofjord	Proper monitoring of different aspects Oslofjord	1987: Norway signed the North sea declaration		2005: Efforts to clean heavy metals from sediments	2011: standardized trawling program	More political parties are involved on issues in the Oslofjord
	1910: first wastewater treatment plant		First biological studies conducted			Starting to clean sewage chemically and biologically	Phosphorus cleaning facilities		Introducing nitrogen cleaning facilities		2019: ban on fishing cod 2019: holistic action plan Oslofjord	Increased media attention and increased awareness state of the fjord
		Sewage broadly discussed on the media		1945: the public discovers that the fjord has issues	More public complains more about state of the fjord	A lot of recreational fishers fishing cod	Change of thinking on how to handle wastewater			Increased recreation		
										Steep increase in population growth		
Perception	Attitude: the fjord is big and resilient enough that sewage treatment is not needed					General perception: very polluted but with high abundance of marine life						General public: negative attitude about Oslofjord Experts: more mixed opinion

Figure 13 An overview of the social-ecological changes in the Oslofjord during the past 110 years.

Nutrient concentrations and phytoplankton – Large changes have occurred in the nutrient load (Phosphorus and Nitrogen) and phytoplankton biomass (chlorophyll a) since the 1910s. Eutrophication was already detected in the Oslofjord in the early 19th century (Braarud, 1945). Phosphorus, Nitrogen, and chlorophyll a rapidly increased until at least the 1970s. Several interviewees and the data from the Miljødirektoratet (2019a) disagreed on when the chlorophyll a concentrations started to decline. According to the Miljødirektoratet (2019a), the chlorophyll a concentrations already started to decrease in the 1970s. However, one interviewee pointed out that the concentrations did not start to decrease until the 1990s. In addition, interviews consistently reported that algae blooms were very prevalent in the Oslofjord in the 1970s and 1980s.

The steep increase in Phosphorus concentrations, from 50 tons in 1910 to 700 tons in 1970 (Magnusson et al., 1998), made the nutrient abundantly available for phytoplankton growth. The Nitrogen concentrations increased slower, from 500 tons in 1910 to 3500 tons in 1970 (Magnusson et al., 1998). According to the Redfield ratio (Redfield, 1934), the overall nutrient requirement for marine phytoplankton growth in oceans is that Nitrogen is needed in larger quantities than Phosphorus (N:P being 16:1). In terms of the Oslofjord, it meant that the ratio went from 10:1 in 1910, to 5:1 in 1970, showing that Nitrogen has been the limiting nutrient in the fjord. Periods with heavy freshwater runoff can cause stratified layers with brackish surface water in the fjord in which algal growth is typically limited by Phosphorus instead of Nitrogen. However, these periods are of short duration due to water circulation. Therefore, it is debatable whether the chlorophyll a levels already started to decrease in the 1970s while Nitrogen concentrations were still increasing until the 1990s.

Inconsistencies in the literature are also found. For example, Magnusson et al. (1998) reported 4000 tons of Nitrogen and 150 tons of Phosphorus in 1990, while Guerrero and Sample (2022) reported 2720 tons of Nitrogen and 94 tons of Phosphorus in the same year. It is difficult to compare the nutrient concentrations from 1910 to 1996 from Magnusson et al. (1998) with Guerrero and Sample's (2022) nutrient concentrations from 1985 to 2020 given the major differences in presented concentrations. Depending on which source one uses, it makes the difference whether Nitrogen or Phosphorus was the limiting nutrient in the Oslofjord during the 1990s (see Table 5). Nevertheless, both nutrients can still be found in large quantities in the fjord compared to the early 20th century.

Table 5 Overview of the available Nitrogen (N) and Phosphorus (P) concentration in relation to the required N/P for algal growth from 1970 until 1990. Showing the limiting nutrient.

Year	Available N	Available P	Required P for available N (available N / 16)	Required N for available P (available P * 16)	Limiting nutrient
1970	3500	700	218	11.200	Nitrogen
1980	3700	500	232	8000	Nitrogen
1990	4000 / 2720	180 / 94	250 / 170	2880 / 1503	Phosphorus / Nitrogen
2000	2817	94	176	1504	Phosphorus
2010	2187	74	136	1184	Phosphorus
2020	2348	85	146	1360	Phosphorus

In accordance with the results of this thesis, the interviewees and participants have observed more algal blooms in the Oslofjord in the last decade. This aligns with the increased nutrient load (Guerrero & Sample, 2022) and higher chlorophyll a levels (Miljødirektoratet, 2019a) in recent years.

Oxygen concentration – The oxygen concentrations in the Oslofjord dropped during the 20th century, however during the last 15 to 20 years, the oxygen concentrations have been improving (Miljødirektoratet, 2019a). One interviewee pointed out that the absence of oxygen absolutely deteriorates the fjord's condition. Although some species (e.g. anaerobic bacteria) would benefit from the oxygen deficiencies, most species are harmed by it.

Heavy metal concentrations – The discharges of heavy metals and environmental toxins were not mentioned by any participants. Some interviewees briefly mentioned the consequences of the high discharge of heavy metals, such as dietary restrictions, but two interviewees gave their opinions on how the heavy metals have been handled. Before discussing these interviewees' perspectives on the heavy metal concentrations. It is important to note that these concentrations peaked during the 20th century, with Mercury between 1940 and 1955, Cadmium between 1955 and 1960, and Copper in the 1970s (Lepland et al., 2010). Fewer heavy metals had been discharged in the Oslofjord due to new guidelines on how to handle hazardous waste (Baalsrud & Magnusson, 2002).

Efforts to remediate the effects of the heavy metals were made. Two interviewees shared their perspectives on cleaning the contaminated sediment in the Oslofjord at Malmøykalven in the mid-2000s. One of them stated that this had been a success because the pollutants in the

sediment are not biologically available anymore. This view is supported by a document from NGI (2009) in which they stated that the environmental situation has improved because contaminated sediments have been moved and are capped off with clean materials. A more recent document from the Miljødirektoratet (2019a) supported this view as well. When the plans to treat the sediment were developed, the Oslo Kommune (2005) stated that:

> "Contaminated sediments shall not be an obstacle to port operations, commercial fishing, outdoor life (leisure boats, recreational fishing, swimming, and recreation), and urban development. The use of the inner Oslo Fjord shall not lead to long-term, negative effects on the ecosystem".

Nevertheless, the contaminated sediments are still affecting the social-ecological system of the Oslofjord. Staalstrøm et al. (2021) measured the environmental toxins in the digestive glands of mussels in the Oslofjord and showed that they were still above the international limits. Interestingly, in 2021, NGI (2021) also reported that at many locations in the fjord the levels of contaminated sediments have exceeded the risk of spread, human health, and ecological effects, particularly in the area of Malmøykalven where the risks are very high. However, it is surprising that the public authorities of healthy and safe food, still state that blue mussels in the inner Oslofjord are currently (May 2022) safe for consumption Matportalen.no (n.d.). Probably because they only measure hazardous limits concerning (toxic) algae and not environmental toxins while they are obliged to correctly inform the public about potential health hazards.

The results of this thesis indicated that not all involved experts were in favor of the way the authorities handled the contaminated sediments because the method presented was not suitable for this type of pollution. One interviewee was invited by the authorities to give their views on how to manage these contaminated sediments. However, the authorities did not take into consideration their perspectives. A similar phenomenon has been described in a study by Sparrevik and Breedveld (2010). Their study revealed that the management of coping with contaminated sediments is making ad hoc decisions in Norway. These ad hoc decisions preclude multicriteria evaluations in the management process, which are crucial when dealing with many different stakeholders. The public and various researchers disagreed by protesting against using this method at Malmøykalven (Aftenposten, 2006; VG.no, 2006). Whether these ad hoc decisions would lead to sustainable management decisions is questionable if different views on issues that involve a wide range of stakeholders are not taken into account.

Water quality – An interviewee mentioned that running-water toilets in the area around streams that flow into the Oslofjord deteriorated the water quality of the streams in the 1950s and 1960s. However, Bergstøl et al. (1981) discussed that toilets were already implemented in Oslo in the early 20th century, but around Oslo in the decades following. Thereby, sewage already became the largest source of pollution (Bergstøl et al., 1981). The fjord received polluted water, resulting in the fjord becoming murky and smelly. The interviewees stated that since the 1990s, the surface water quality has improved after introduced regulations. Nevertheless, they stated deeper layers in the water column are still in a poor condition.

Macroalgae and seagrasses – Some interviewees stated that the Oslofjord contained rich marine life in most of the 20th century with a high abundance of macroalgae and seagrasses. In recent decades, the interviewees and participants both mentioned that a reduction in macroalgae and seagrasses has occurred in the last 10 to 15 years in the Oslofjord. The literature confirms this as well (Miljødirektoratet, 2019a; Staalstrøm et al., 2021; Statsforvalteren, 2019). However, this perceived decrease might be due to a decrease in the abundance of *Fucus evanescens*, an alien species not mentioned by interviewees and participants. This seaweed is originally from northern Norway but thrives in areas with high pollution in southern Norway, such as the Oslofjord during the 1970s, 1980s, and 1990s (Staalstrøm et al., 2021). The water quality of the fjord has improved considerably in the last few decades, resulting in a less suitable habitat for *F. evanescens*. Consequently, its abundance declined. So, indeed, participants and interviewees could have observed a decline in macroalgae, but this could possibly have been *F. evanescens*. Nevertheless, the water quality of the Oslofjord is still too poor for other macroalgae, such as the knotted kelp (*Ascophyllum nodosum*), to thrive. Additionally, the lower depth limit of macroalgae has been reducing since the 1990s, while in the former decades it had been increasing (Staalstrøm et al., 2021).

Seagrass monitoring programmes were launched in 2020 (Rinde et al., 2021). The most common seagrasses, *Zotera marina*, and *Laminaria hyperborea*, were already mapped between 2007 and 2010 in the Oslofjord. It appears that eelgrass meadows have been disappearing from the fjord from 2007/2010 to 2020 (Rinde et al., 2021). The authors argued that multiple factors simultaneously affect seagrasses, making it impossible to pinpoint a single variable. This aligns with the diverse explanations given by the interviewees, such as eutrophication, increased temperature and thus increased growth of filamentous algae, increased storm events, and the indirect effects of overfishing. Observations of seagrass disappearance are not unique to the Oslofjord, but can be seen all around the world (UNEP, 2020).

Benthic fauna – Benthic fauna communities were already vanishing in the early 20th century (Petersen, 1915). Until at least 1993, benthic fauna decreased in terms of species richness and species abundance (Miljødirektoratet, 2019a). Since the 1990s, the benthic fauna has shown a positive trend until at least 2009, when the last comprehensive study of the benthic fauna in the inner Oslofjord was conducted (Berge et al., 2011).

Apart from blue mussels (*Mytilus edulis*), the participants and interviewees did not mention other benthic fauna. They have observed a significant reduction in the abundance of blue mussels in the last decade. According to Staalstrøm et al. (2021), there is no systematic monitoring for blue mussels in the Oslofjord. As a result, there are no reference conditions.

Fish stocks and fishing pressure – Participants and interviewees both stated that they have seen a decline in fish stocks in the Oslofjord. They stated that they have seen a much higher population during the 20th century than in the 21st century. The decline of marine life was the largest ecological change that the participants observed. The data provided by Espeland and Knutsen (2019) shows that indeed the fish populations were higher during the 20th century compared to the 21st century. Their data also shows that the recruitment of cod in the Oslofjord has been stagnant since the beginning of the 21st century. Miljødirektoratet, 2019a described that sprat was highly abundant during the 1940s, 1950s, and 1960s. Cod, pollock, and whiting species peaked in the decades following (Miljødirektoratet, 2019a). Nevertheless, cod and pollock populations collapsed in the decades following the. In return, more pelagic warm-water species can be found (Miljødirektoratet, 2019a). For example, two interviewees stated that have observed more mackerel in the Oslofjord. This is also confirmed by Barceló et al. (2016) mentioned that mackerel has become more prevalent in the fjord.

However, interviewees pointed out that different methods to measure the abundance of fish in the Oslofjord existed, thus making the historical and more recent data not completely comparable. Since 2011, a standardized trawling programme has been carried out four times a year in the Oslofjord (Staalstrøm et al., 2021). Although their data does not show any long-term development yet, they show that the fish community has changed from being dominated by benthic species along with cod, to a community dominated now by whiting.

In the Oslofjord, participants and interviewees noted that the declining fish stocks are primarily a result of overfishing, but surprisingly little data is available on the fishing pressure. Two organizations were contacted about whether they had more data available regarding fish populations or fishing pressure, however, neither of them responded. Only Statistics Norway (Ssb.no, n.d.) described fish outtake per district. Nevertheless, they only have data available

from 2014 until 2019. Pauly et al. (2005) described indicators for overfishing, such as the presence of juvenile fish but the absence of older individuals. Some interviewees and participants also observed this phenomenon; when they find cod in the Oslofjord, they are juveniles.

Other theories about the decline in cod include the lack of essential vitamins for growth (Dahle & Fretheim, 2022) or climate change that changes the species composition of phytoplankton, an important food source for cod (nrk.no, 2019). On a global scale, overexploitation of marine organisms still remains the greatest threat to the biodiversity of ecosystems (Knapp et al., 2017). Based on what was mentioned by the interviewees and participants combined with the indicators for overfishing and the global main driver of threats to the biodiversity of an ecosystem, it is likely that overfishing had detrimental effects on the fish populations of the Oslofjord.

Alien species – Alien species were frequently mentioned by the participants, but to a lesser degree by the interviewees. Shackleton et al. (2019) highlighted the interaction of social, ecological, and economic factors influencing how people perceive invasive species. Invasive species may be beneficial or harmful on different levels. For example, on the social level, the Pacific Oysters (*Crassostrea Gigas*) have sharp shells, which has resulted in many people getting cuts when they accidentally step on one. Therefore, people may experience this invasion as negatively. Whereas people who only experienced the Oslofjord with this oyster will probably perceive this invasion differently. The first larvae of the *C. gigas* were already found between 2005 and 2008 in the Oslofjord and added to the Norwegian blacklist of alien species in 2012 (Gederaas et al., 2012). With most of the participants (61%) living around the Oslofjord for longer than ten years, their former knowledge about the fjord without the Pacific Oyster most likely influenced their perception of this invasion. The participants generally stated that they started to observe the Pacific Oyster in the Oslofjord from 2015 to 2018. They described this as a rapid ecological change because some parts of the Oslofjord's ecosystem suddenly changed from an ecosystem characterized by seaweed and blue mussels to an ecosystem dominated by Pacific Oysters. They perceived this as a very negative change with tremendous ecological and social consequences, such as taking over habitats that used to be dominated by blue mussels and kelps. The sharp shells of oysters also cause hospitalizations by cutting people.

Responses to change – The major responses to change are connected to pollution in the Oslofjord. In the early 20th century, research was being conducted on the health risks related to

wastewater pollution (Oslo Kommune, 1907 as cited in Arnesen, 2001). The first wastewater treatment plant was established in 1910, which mechanically removed organic particles from the wastewater (Oslo Kommune, 1914 as cited in Arnesen, 2001). . Other methods for cleaning sewage took many decades to emerge. According to one interviewee, the first biological studies were conducted in the 1930s on phytoplankton in the Oslofjord. While sewage was widely covered in the media during the 1920s and 1930s, it was only in 1945 that the public realized that it was causing pollution, resulting in more public complaints about the fjord's condition (Arnesen, 2001). During the 1970s, wastewater treatment began to shift focus from organic particles as the problem to nutrient treatment (ibid.). Initially, only Phosphorus was removed from the water (Oslo Kommune, 1976 as cited in Arnesen 2001) and in 1987, Norway signed the North Sea Declaration, which forced Norway to reduce its Nitrogen output. Consequently, the biggest wastewater treatment plant (VEAS) was modified to clean for Nitrogen in the 1990s (COWI, 2020). The surface water quality improved, and the Oslofjord opened up for recreational activities. The interviewees and participants stated that recreation in the fjord has increased since the late 1990s.

There were also other responses, such as establishing organizations that focused on researching the fjord, understanding the dynamics of its system, and attempting to achieve a cleaner Oslofjord. In the 1970s, this also included the establishment of a systematic monitoring programme.

In more recent years, responses to change were related to cleaning up sediments in the mid-2000s (Oslo Kommune, 2005), a fishing ban on cod in 2019 (Fiskeridirektoratet, 2019), and the development of a holistic action plan in 2019 (Miljødirektoratet, 2019b). Interviewees and participants commented that they observed increased media attention about the Oslofjord's condition, but also that the public is becoming increasingly aware; a change is occurring in the norms and values that the residents have regarding the perception of the Oslofjord. Moreover, they mentioned that political parties have been more active on issues in the Oslofjord than before.

The current perception of the state of the Oslofjord, as discussed in section 7.1, is that residents perceive it more negatively than experts. Public awareness of these issues was not as high previously as it is now, according to some interviewees.

7.3 Navigating the dynamics of Oslofjord

In the previous section, I discussed the major social-ecological changes that have occurred in the last 110 years in the Oslofjord. In this section, I use the adaptive cycle (Holling, 1986) to illustrate the phases in the Oslofjord's social-ecological system (SES) and the regime shifts that have taken place (Figure 14). Thereby, impacting its social-ecological resilience. In short, the phases of the adaptive cycle are: exploitation (r), conservation (K), release (Ω), and reorganization (α). A system can flip into a new domain (marked as X) when its internal controls and feedback have changed (Holling & Gunderson, 2002). This includes but is not limited to different species composition, other ecosystem services, new governance arrangements, and different values and perceptions (Olsson et al., 2006).

Rapid technological development

The period from the 1910s until the 1940s is characterized by rapid technological development. The rapid population growth, urban development, and the implementation of the water toilet contributed to major socioeconomic and technological changes around Oslo. The city was growing, and the discharge of polluted water became problematic. The pollution accumulated in the fjord and began to affect the entire biological condition of the Oslofjord and created health risks for swimming. Due to this rapid socioeconomic and technological development, the resilience of the SES decreased. Nevertheless, it provided an opportunity for conducting more research and the development of the first wastewater treatment plants.

Increased pollution

From the 1940s to the 1970s, the Oslofjord began losing its social-ecological resilience, but it increased towards the reorganization phase. In addition to continued population growth and industrialization, wastewater and heavy metals were discharged at high levels into the fjord. In these decades, pollution became a major issue. The wastewater management operated in the European wastewater-engineering context that focused on organic particles without acknowledging nutrient pollution. Resulting in nutrients accumulating in the fjord. Therefore, their ability to self-organize and to learn and adapt were poor during this stage. There was little political room to experiment with different methods besides the ones they already adopted. It took excessive (toxic) algal blooms, smelly and murky waters, and even greater health risks when swimming to acknowledge their focus was not appropriate. The reorganization of the Oslofjord's SES was a result of recognizing the importance of nutrients in the fjord and developing technologies to reduce Phosphorus inputs. As a result, a transformation to a new era of nutrient cleaning facilities was possible.

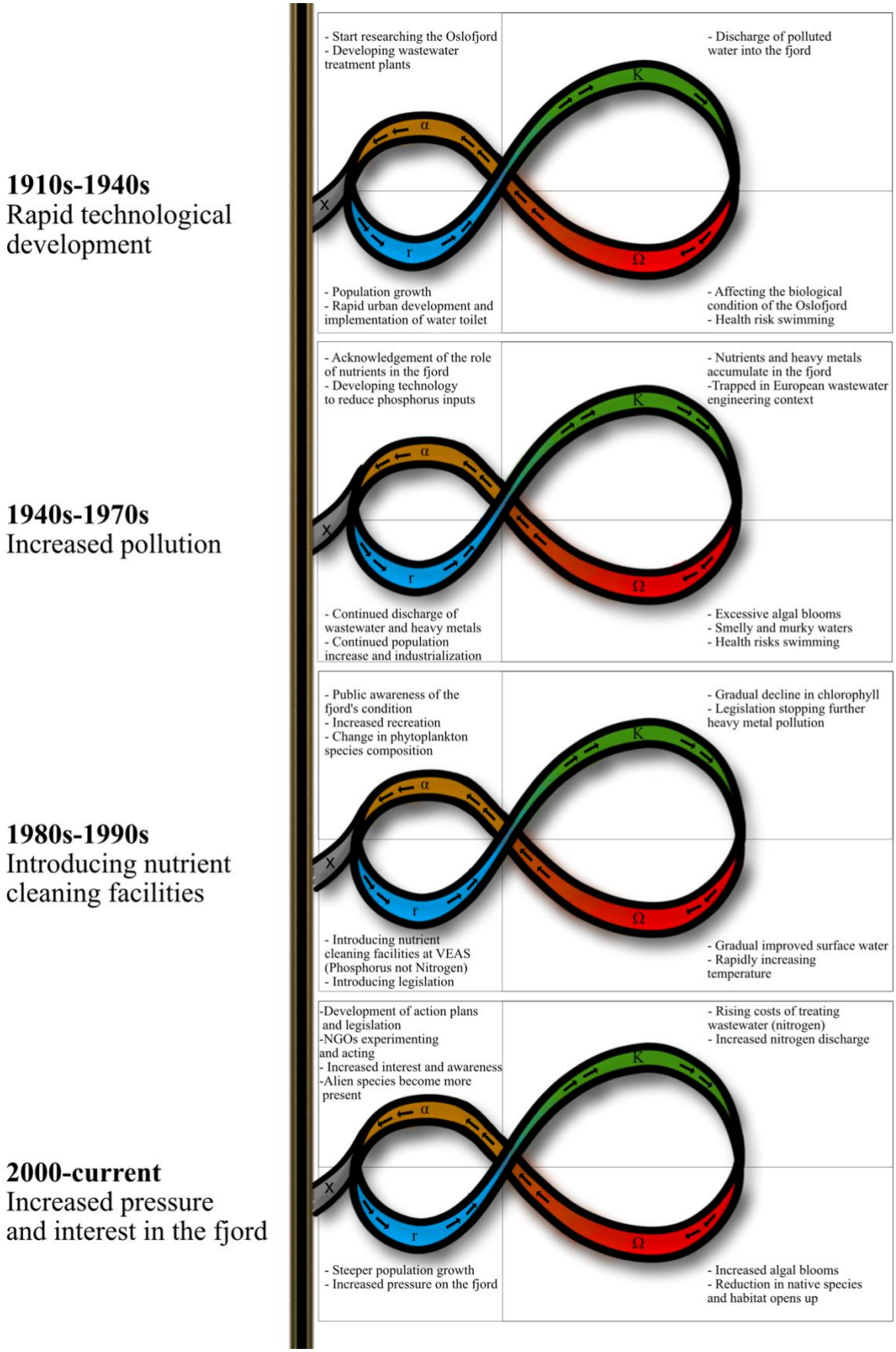

Figure 14 The four adaptive cycles of the social-ecological system of the Oslofjord. Each adaptive cycle entered a new regime shift after exiting the reorganization phase through the 'X' marked on the figure. Adapted from Holling (1986) and Seixas & Berkes.

Introducing nutrient cleaning facilities

The reorganization in the previous era opened up space for learning and adapting to new situations, which was needed to restore the resilience that was lost between the 1940s and the 1970s. Wastewater treatment plants were constructed or modified to clean for nutrients. In particular, the largest treatment plant, VEAS, played a major role in this. Initially, only Phosphorus was treated, not Nitrogen. Nitrogen cleaning facilities were introduced during the 1990s, resulting in a gradual decline in chlorophyll concentrations. Furthermore, the authorities introduced legislation to stop further heavy metal pollution in the fjord. Consequently, the surface water improved gradually. Although increasing temperatures were prevalent in the former decades, the water temperature in the Oslofjord started to increase rapidly from this period. The fjord's surface water gradually improved, making more recreation possible. The public was able to reconnect with the fjord, therefore, impacting the public's awareness. Additionally, the changed chemical conditions of the surface water changed the phytoplankton species composition.

Increased pressure and interest in the fjord

The Oslofjord's resilience began to deteriorate again from the 2000s due to increased rigidity, and a range of social and ecological changes followed. Increased pressure from various stakeholders and steeper population growth created tension in the Oslofjord. The results of this study indicated that more people are interested in the fjord and are aware of the issues related to the fjord. However, this might result in having contradicted states, ideas, or perceptions of what the Oslofjord should look like. The tension can be felt when discussions emerge around the topic of the rising costs of treating wastewater. In particular, the debate between municipalities and the government is creating tension about who is responsible for bearing the costs of wastewater treatment (Sjuve, 2022). Especially cleaning for Nitrogen is costly. The Nitrogen concentrations have risen from 2003 until 2018, with a slight reduction until 2020 (Guerrero & Sample, 2022). However, limited action has been taken.

A reduction in the abundance of cod, blue mussels, macroalgae and seagrasses, and multiple other species have occurred in the last two decades. The warming of water temperatures and the reduction of native species opened up habitats for alien species. In particular, the Pacific Oyster has been able to move into opened-up habitats. Throughout these decades, multiple plans have been developed and organizations have been established to improve the condition of the Oslofjord, yet progress has been limited. As a response, NGOs are taking action and have started to experiment with various technologies to improve the condition

of the fjord. Due to extensive bureaucracy, the NGOs are not receiving enough support from the government to fully conduct these experiments. The government shows little flexibility on the management of the fjord, even when experimentations could provide insightful information on the management trajectories. This rigidity was also shown once again by the statement of the former minister of climate and the environment "We know enough and we know what type of measures will function, now it's about implementing" (Myhrer, 2021).

To sum up, the Oslofjord's social-ecological system has been undergoing multiple phases impacting its resilience and resulting in regime shifts after approximately 20 to 30 years. The impact of some regime shifts has been more positive than others.

Future perspectives

Based on the perceptions of the interviewees and participants, the Oslofjord is currently in an undesirable state. Although the adaptive cycle illustrated in Figure 14 is not a predictive model, it seems that it is likely that a new regime shift will occur over the course of the next few years or is already happening. The reorganization phase in which the SES of the Oslofjord is in right now, provides space for improvement or deterioration, depending on the responses to change. In this thesis, the interviewees expressed mixed views on what the Oslofjord will look like in the future. Some were somewhat optimistic by stating that the fjord has been in worse conditions than it is now, while others do not think it will improve in the near future.

In this research, most participants responded that they are willing to make changes in their lifestyle to improve the condition of the Oslofjord. However, they mainly stated that they do not know what changes could contribute to its improvement. Therefore, it is important that science, media, and government provide clear information about possible solutions and actions that residents can implement to improve the state of the Oslofjord. Educating residents on the local issues has been shown to have positive effects on the conservation of the area (Ardoin et al., 2020). In particular, in periods where people have opened up for changes to happen, the authorities must seize this opportunity to create an environment in which self-organization towards sustainability would be stimulated.

8. Conclusion and recommendations

8.1 Conclusion

In this thesis, I examined and challenged certain scientific narratives that Norway has chosen to cope with social and ecological changes in the Oslofjord during the past 110 years. I have attempted to illuminate how these changes have affected the resilience of the social-ecological system of the fjord. I investigated current perceptions of the Oslofjord's condition held by residents and experts, and demonstrated that their perceptions did not always align. In particular, residents generally showed a more negative perception of the ecological state of the Oslofjord compared to the experts. Nevertheless, most of the experts did state that the Oslofjord is in a poor state despite the fact that attempts at improving the Oslofjord have been made. Furthermore, I explored the main changes and processes in the social and ecological systems over the past 110 years that had been perceived by residents and experts. Both residents and experts mentioned a wide variety of pressing issues and processes. In the ecological system, major changes were related to various types of pollution and their direct consequences on the ecosystem, and although actions have been implemented to limit or control pollution, the Oslofjord still suffers markedly from the consequences of past and current pollution. The major changes in the social system were linked to the establishment of institutions and organizations that have responsibility for, or are concerned about, the state of the Oslofjord. Furthermore, both the development of action plans to improve the state of the Oslofjord, and increased recreation, have been important social developments.

I utilized a series of adaptive cycles to analyze the interactions of the social-ecological system of the Oslofjord and its transitions into a new regime over periods of time. Major pitfalls that have caused decreasing resilience in the Oslofjord were linked. Institutions not allowing space for experimenting, not acknowledging less-dominant narratives, and lacking accountability, whilst rapid socioeconomic and technological changes were occurring. It became evident that the lack of flexibility of bureaucracies was not conducive to solving the issues with the fjord effectively. These pitfalls have greatly affected the trajectory of the state of the Oslofjord.

Norway is among the wealthiest countries in the world and portrays itself as an environmentally leading country. However, this study has shown that Norway's rigid institutional approaches and actions concerning environmental issues are not effectively responding to problems, nor benefiting the resilience of the social-ecological system of the Oslofjord. As abrupt changes are likely to become more frequent in the future, to last longer,

and to have a greater impact, it will surely be of even greater importance to adequately respond to changing conditions effectively. Therefore, I wish to elaborate on two recommendations in the following section for developing higher resilience in the Oslofjord's social-ecological system.

8.2 Recommendations

An adaptive management approach can contribute to the resilience of the Oslofjord. In case of the Oslofjord, this includes that more and continually updated knowledge is needed to understand the entire ecosystem dynamics of the inner Oslofjord. Various organizations are contributing to generating detailed knowledge for understanding certain aspects of the Oslofjord, however, in periods of rapid change, understanding the ecosystem dynamics and processes on larger scales (including the outer Oslofjord and Skagerrak) could positively contribute to managing the trajectory of the ecosystem. Knowledge should not only be derived from scientific studies but also from other actors who have regular interaction with the ecosystem and can observe broader ecosystem changes when they occur. For example, fishers and residents who live close to the fjord make frequent observations of changes occurring. Furthermore, independent and critical research projects should also be funded by the government, even when they might not align with the government's own perceptions of the state of the issue. This thesis has suggested some possible bases for potential further broader research of the social-ecological system in the Oslofjord.

Secondly, the Norwegian government has shown major rigidity on multiple occasions, that did not allow space for experimenting or acknowledging less-dominant narratives. Developing a more flexible government with less bureaucratic rigidity would open up space for organizations and institutions to experiment and learn dynamically, which could be of major importance for learning and understanding. In this thesis, I have shown that some institutions are willing to experiment and learn, but the government does not provide the flexibility to conduct small-scale experiments in the Oslofjord. Overall, more knowledge and flexibility would enhance the social-ecological resilience of the Oslofjord.

10. References

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11. Appendices

I. Appendix 1: Interview guide

Background information:

1. Name:
2. Organization:
3. Occupation / profession:
4. Number of years in position:
5. What are your responsibilities and tasks in this position?

Perception and changes

1. Could you tell me something about the history of the Oslofjord? Pollution, ecological/chemical development? What influences this state?
2. What is your opinion about the current state of the Oslofjord?
3. Have you observed any changes in the Oslofjord from an ecological perspective?
    a. If changed, what has changed? When and how did you notice it?
    b. Have these changes occurred fast or slow? Did they have a lot of impact?
    c. According to you, what are the main causes that cause these changes?
    d. Have these changes positively or negatively affected your life? If so, how and why?
    e. Are there particular social drivers that have influenced the ecological system?
4. Have you observed any changes in the Oslofjord from a social perspective?
    a. If changed, what has changed? When and how did you notice it?
    b. Have these changes occurred fast or slow? Did they have a lot of impact?
    c. According to you, what are the main causes that cause these changes?
    d. Have these changes positively or negatively affected your life? If so, how and why?
    e. Are there particular ecological drivers that have influenced the social system?
5. Who do you think is responsible for these social-ecological changes? And why?

6. Can you tell me something about how industries and people are currently using and/or misusing the Oslofjord?
    a. Are people/businesses aware of their impact on the Oslofjord?

Improvement of the Oslofjord

7. Have you heard about projects to improve the fjord?
    a. If so, where have you heard these? How did you get the information? What were these projects?
    b. Do you know anything about the success/failure of these projects?
8. What do you think could be done to improve the condition of the Oslofjord?
    a. By communities?
    b. By the government?
9. What kind of opportunities and obstacles do you think are there to improve the condition of the Oslofjord?
10. What measures do you think should be taken to improve the fjord?
11. What parts of the ecological system in the Oslofjord do you think are currently vulnerable and are likely to be affected in the near future?
12. What do you believe is more important to residents around the Oslofjord: protect the Oslofjord, or keep up with their current livelihood?
    a. What do you think influences or hinders social change?

Future state of the fjord + impact of changes

13. How would you like to see the Oslofjord in the future? Give up?
14. What kind of future challenges do you think the Oslofjord will face?
15. How do you think the Oslofjord will look in the future?
16. Do you think change will occur? If so, what kind of change and why?
17. Who do you think will be affected the most by these changes? Why, and what are they losing?

II. Appendix 2: questionnaire English version

1. What is your age?
    a. Below 18
    b. 18-25
    c. 26-35
    d. 36-50
    e. Above 50
2. How long have you been living around the Oslofjord? (up until circa 20km radius from the fjord)
    a. Less than five years
    b. Between 5 and 10 years
    c. Between 11 and 20 years
    d. Between 21 and 40 years
    e. Longer than 40 years
    f. I don't live around the Oslofjord.
3. What is your opinion about the current state of the Oslofjord?
4. Have you observed any changes in the Oslofjord from an ecological perspective? If so, what has changed, and when did you notice it? Did these happen fast/slow? Have these influenced your life positively or negatively?
5. Have you observed any changes in the Oslofjord from a social perspective? If so, what has changed, and when did you notice it? Did it happen fast/slow? Have these influenced your life positively or negatively?
6. In your view, what are the main causes of these social and/or ecological changes?
7. Would you be willing to change your lifestyle to improve the condition of the fjord? If so, why and what would you change?

III. Appendix 3: questionnaire Norwegian version

1. Hvor gammel er du?
    a. Under 18
    b. 18-25
    c. 26-35
    d. 35-50
    e. Eldre enn 50
2. Hvor lenge har du bodd rundt Oslofjorden (opp til ca. 20km radius fra fjorden)
    a. Mindre enn 5 år
    b. Mellom 5 og 10 år
    c. Mellom 11 og 20 år
    d. Mellom 21 og 40 år
    e. Mer enn 40 år
    f. Jeg bor ikke rundt Oslofjorden
3. Hva synes du om dagens tilstand i Oslofjorden?
4. Har du observert endringer i Oslofjorden fra et økologisk perspektiv? I så fall, hva har endret seg, og når la du merke til det? Skjedde det raskt eller sakte? Har disse påvirket livet ditt positivt eller negativt?
5. Har du observert endringer i Oslofjorden fra et sosial perspektiv? I så fall, hva har endret seg, og når la du merke til det? Skjedde det raskt eller sakte? Har disse påvirket livet ditt positivt eller negativt?
6. Hva er etter ditt syn hovedårsakene til disse sosiale og/eller økologiske endringene?
7. Ville du vært villig til å endre livsstil for å forbedre tilstanden til fjorden? Hvis ja, hvorfor og hva ville du endret?

IV. Appendix 4: consent form

1. Do you agree to participate in the interview?
2. Do you agree that you have received information about what the study is about and what it will be used for?
3. Do you agree that this interview will be audio-recorded?
4. Do you agree that your information will be processed anonymous and that quotes from this interview will be stated without your name?
5. Do you confirm that all the information you provide will be treated confidentially?
6. Do you agree that the interview may be quoted in the thesis, which will be open to public reading?
7. Do you confirm that you can withdraw at any time or refuse to answer any question without any consequences of any kind.
8. Do you confirm that you can ask for a copy of the interview transcript at any time and that you may make edits if you feel you would need to.
9. Do you confirm that you can contact the researcher at any time to ask any future questions?

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