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Motivations and Effects of Volunteer Divers Restoring Norwegian Kelp Forests

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Cover page: A diver in kelp forest, Northern Norway.
Photo provided by Max Emanuelson.

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"Instead of looking for hope, look for action. Then, and only then, hope will come."

Abstract

Kelp forests are in decline worldwide due to increasing anthropogenic pressures. Along the coastline of Northern Norway, spanning 15,000 kilometers, sea urchins have transformed the seabed from biodiverse kelp forests into barren grounds dominated by sea urchins. To address this issue, the initiative *The Guardians of the Kelp* engages volunteer divers in Northern Norway in monthly clearing events to remove sea urchins to allow for the re-establishment of kelp. Their Guardians of the Kelp aims to raise awareness of the degradation of the highly productive and biodiverse kelp forest —a transition below the surface of the ocean that has largely remained unnoticed by the public. This study explores the impact of this restoration initiative by analyzing the ecological effects of sea urchin removal on kelp biomass and colonizing fauna while exploring the volunteers' perceptions of the contribution from the restoration. Moreover, for the enhanced viability of this and future marine restoration projects, the motivations driving volunteer participation in this marine restoration project were investigated. The findings suggest a notable contribution to nature through the successful re-establishment of kelp and colonization by fauna. A sense of connection to the ocean was found to drive the volunteers' desire to help nature to regenerate, and to raise awareness and engage volunteers in restoration efforts. Advocating for the kelp forests facilitated important expansion to new diving clubs and attention at a high political level, supporting the future success of the project. In return, the volunteers received positive feelings and a heightened sense of hope about the positive nature change. This study contributes to a broader understanding of the role of volunteer engagement in addressing marine issues and contribute to improved management of the ocean, while fostering renewed relationships between people and nature to the benefit of both society and the planet.

Key words: nature restoration, kelp forest, sea urchins, coastal ecology, volunteering, marine citizenship,

1 Introduction

Ecosystem restoration is a key for reaching sustainability targets agreed upon for both people and nature (IPBES, 2019). The Kunming-Montreal Global Biodiversity Framework set an ambiguous target "to restore at least 30% of degraded ecosystems by 2030" (Target 2) (Convention on Biological Diversity 2022a). Here ecosystem restoration was defined as "assisting in the recovery of ecosystems that have been degraded or destroyed, as well as conserving the ecosystems that are still intact" (Convention on Biological Diversity, 2022b) (CBD/WG2020/5/4). The United Nations General Assembly has also declared 2021–2030 the UN Decade on Ecosystem Restoration supporting the mission of scaling up restoration to halt and reverse the degradation of all kinds of ecosystems in the world. Ecosystem restoration is thus a broad term that encompasses both passive restoration activities, in which ecosystems are protected and allowed to regenerate naturally, and active restoration, where society decide to accelerate the recovery of an ecosystem from a degraded state (IPBES, 2019).

Kelp forest ecosystems are among the ecosystems in need of restoration (Eger et al., 2022; Verbeek et al., 2021). Despite being one of the most productive ecosystems on the planet (Teagle et al., 2017), kelp forests are facing threats without receiving much attention from the public (Bennett et al., 2015; Galloway et al., 2023; Johnson et al., 2011; Norderhaug et al., 2021; Steneck et al., 2013). They are the least studied coastal ecosystem in terms of the provision of ecosystem services, compared to for instance coral reefs and mangroves (Bennett et al., 2015). Kelp forests are structurally complex, consisting of perennial brown algae that comprise a forests of high community complexity and food web structure of kelp-associated species, that are dependent on the forest for food, shelter and nursery (Christie et al., 2009; Norderhaug et al., 2007; Steneck et al., 2002; Steneck & Johnson, 2013). Kelp forest ecosystems provide supporting and regulatory services, with effects such as nutrient filtration, carbon sequestration, and mitigation against storm surges, while also supporting economically important fisheries and a high recreational value (Costanza et al., 2014; Verbeek et al., 2021). With the increasing need for solutions to climate change and biodiversity loss, the kelp forests' potential for climate change mitigation, conservation of biodiversity and economic contributions to society has lately been gaining greater recognition (Gouvêa et al., 2020; Krause-Jensen & Duarte, 2016; Miller et al., 2022).

Many of the kelp forests are degrading due to sea urchin herbivory, often initiated by pressures from fisheries which in turn are changing the food web structures and predatory control on the herbivores (Ling et al., 2015; Norderhaug et al., 2021; Steneck et al., 2002). The result has often been a shift in ecosystem state from biodiverse kelp forest to sea urchin dominated barren grounds, characterized by low productivity and food web complexity (Steneck et al., 2002; Teagle et al., 2017). Furthermore, sea urchin barrens constitute an alternative stable state, that without a major change or disturbance may persist for decades (Filbee-Dexter & Scheibling, 2014; Steneck et al., 2013). Once shifted, the sea urchins can maintain the barren ground at densities much lower than those required for the shift to occur (Ling et al., 2015), while their high phenotypic plasticity allows them to survive on low food availability even in high population densities, preventing kelp from re-establishing (Chapman, 1981; Russell, 1998).

Following a lack of success in more passive restoration attempts, such as improving water quality or establishing marine protected areas, more active restoration have been initiated (Carlsson & Christie, 2019; Eger et al., 2022). Some of these initiatives, such as commercial sea urchin harvest of divers in Tasmania (Tracey et al., 2015), plantation of crayweed in Australia by community members and scientists (Operation Crayweed, 2024) and the involvement of volunteers to restore a kelp forest in California (Caruso, 2017), have been successful in reestablishing kelp forests. Mobilizing volunteers for actively restoring ecosystems could contribute to benefits beyond the actual intervention, potentially changing awareness, knowledge, and values and capacity for halting degradations and accelerating regeneration of ecosystems (Buchan et al., 2023; Palomo et al., 2021). Such initiatives could help with some of the main challenges of restoring degraded kelp forests.

A volunteer diver initiative that has attracted attention is the Guardians of the Kelp (hereafter GK) in Norway. GK has removed urchins physically by engaging volunteer free divers and SCUBA divers in monthly restoration events. The GK initiative was established in 2021 by a small group of divers supported by researchers and the company "Urchinomics". Their aim has been to restore and raise awareness of the vast amount of kelp forests that have been degraded along the Northern Norwegian Coast since the 1970s. Sea urchins (mostly *Strongylocentrotus droebachiensis*) became the dominant species due to the reduction of predation pressure by overfishing, unleashing an intensive herbivory pressure on the kelp forests (Norderhaug et al., 2021). The result is a sea urchin barren ground (see figure 1), devoid of the rich kelp forest ecosystem that used to dominate Norwegian rocky shores, stretching from south of Nordland County and 15 000 km north to the Russian border. Moreover, the barren state has shown highly persistent and, without a disturbance to change the system, it is suggested it may persist for many decades to come (Chapman, 1981; Leinaas & Christie, 1996; Norderhaug & Christie, 2009). This has happened largely unrecognized for over five decades and illustrates the challenges posed when the problem remains invisible below the surface.

Volunteering in marine restoration programs such as GK can be characterized as marine citizenship (McKinley, 2010). More so are the leaders of GK and their role in advocating for the ocean, with the aim of increasing the marine citizenship in the population by the involvement of volunteer divers. *Marine citizenship* is defined as "having understanding of the individual rights and responsibilities towards the marine environment, having an awareness and concern for the marine environment and the impacts of individual and collective behaviour, and having a desire to have a role in ensuring on-going sustainable management of the marine environment" (McKinley, 2010). Through exposure to nature, human behavior can transform, leading to more pro-environmental actions and attitudes (Mayer & Frantz, 2004; Roszak, 1995; Schultz, 2000; Whitburn et al., 2020). This shift is regarded as a key for the care and protection of marine systems and for re-enforcing marine citizenship over time (Benayas et al., 2009; Buchan et al., 2024; Buchan et al., 2023).

Figure 1: A volunteer free diver in a sea urchin barren ground. Photo: Max Emanuelson.

The purpose of this thesis is to examine why volunteers are investing so much of their free time in restoring the kelp forest ecosystem by participating in the GK, and what this marine citizenship initiative can contribute to with increased kelp biomass, carbon storage, fauna recolonization, and the awareness and engagement of the public. Understanding the motivations for volunteer divers participating in the GK project is important for the viability of this and future marine restoration projects. Taking place under water, the need for skilled divers to restore ecosystems pose challenges due to barriers such as costly equipment, the time and knowledge requirements associated with diving (Lucrezi & Cilliers, 2023; Miller & Shears, 2023). In Norway there are strict regulations regarding paid diving, making the commitment of volunteer divers crucial for restoration. Furthermore, The GK project's location in the Arctic pose further challenges regarding freezing water temperature and limited daylight during winter. Research is lacking on what makes these volunteers willing to provide their time and effort and expose themselves to such cold temperature for restoring kelp forest.

I examine the ecological and societal contribution from the restoration work of GK. Furthermore, for future initiation and success of marine restoration projects I wish to understand what motivates the volunteers, including the self-reinforcing effect that marine volunteering may have through the connection to the ecosystems (Buchan et al., 2024), and the motivational effects of ecological results and awareness.

This led me to the following research questions:

1. What can volunteer divers contribute to the restoration of kelp forest ecosystems?
    a. What are the ecological effects of removing sea urchins to restore kelp forest ecosystems?
    b. How do the divers perceive the ecological and societal impacts of restoration?
2. What are their motivations to contribute to restoration activities?

My objectives are:

- To quantify the ecological effects of sea urchin removal on kelp fauna and biomass.
- To identify the volunteers' perceived impacts of kelp restoration, including the ecological, societal, and/or personal effects experienced by divers.
- To examine different motivations to contribute to restoration, including the influence by the perceived impacts by the volunteer divers.

Figure 2: Volunteer diver crushing sea urchins with a hammer. Photo: Max Emanuelson

2 Method and material

2.1 Description of the Guardians of the Kelp

In collaboration with the Norwegian Institute on Water Research (NIVA) and Urchinomics, the GK started up in 2021 as a volunteer organization aiming at restoring Norwegian kelp forests in study sites chosen by the researchers. During monthly clearing events, volunteer divers join the GK to crush sea urchins with hammers (see figure 2). Diving time, number of divers and number of sea urchin crushed has been recorded, providing new data on diving efforts and sea urchin removal that can be used for further research. The first restoration site, and study site for this thesis, was established at Nordspissen in Tromsø in 2021. During the last year of 2023 the GK engaged new diving clubs in Tromsø, Harstad and Lofoten, which are expanding the restoration by establishing new restoration sites. The GK organization consisted of two, recently scaling up to three, leaders with shared responsibility. These leaders are now working with the general management of the organization, administering funding and collaborations, whereas the practicalities and responsibility of the regular clearing events at Nordspissen have been transferred to the leaders of the diving club, Studentenes Undervannsklubb Tromsø (SUT). By engaging new diving clubs, the GK can place efforts into the engagement of more diving clubs, and contribute with dissemination of knowledge and outreach, while the active restoration work through sea urchin removal by divers are led by organizers within the diving clubs.

2.2 Study design and choice of methods

Interviews and biological studies were conducted to answer my research questions. Quantitative measures combined with a broader understanding with the interviews could complement each other where knowledge might be lacking (Young et al., 2018) and was considered the best approach also for understanding the ecological impacts of restoration due to limitations in samples sizes and sites. Samples were collected from restored kelp forests and sea urchin barrens to study the ecological effects from restoration. This was combined with interviews for an in-depth understanding of the volunteer's motivation to carry out the restoration and their perceptions of the impacts. This allowed me to understand both the potential of volunteer groups in kelp restoration, and the impacts they could have on ecosystems and society.

While interviews were conducted relating to the sites restored by the GK project, additional data was provided from a restoration site in Porsangerfjord. This site was not restored by the GK, but similar sampling of ecological effects was conducted by NIVA who had been engaged in a research project in this area (Figure 3). The data was supplementing the limited data on ecological effects of restored kelp forest conducted by GK in Nordspissen. Additional barren ground data was collected from selected sites in Dåfjord. Further description of the sites and the fieldwork is provided in chapter 2.3-2.6. In chapter 2.7. the conduction and analysis of interviews are described. The different sampling methods used and number of replicates at each site are presented in Table 1.

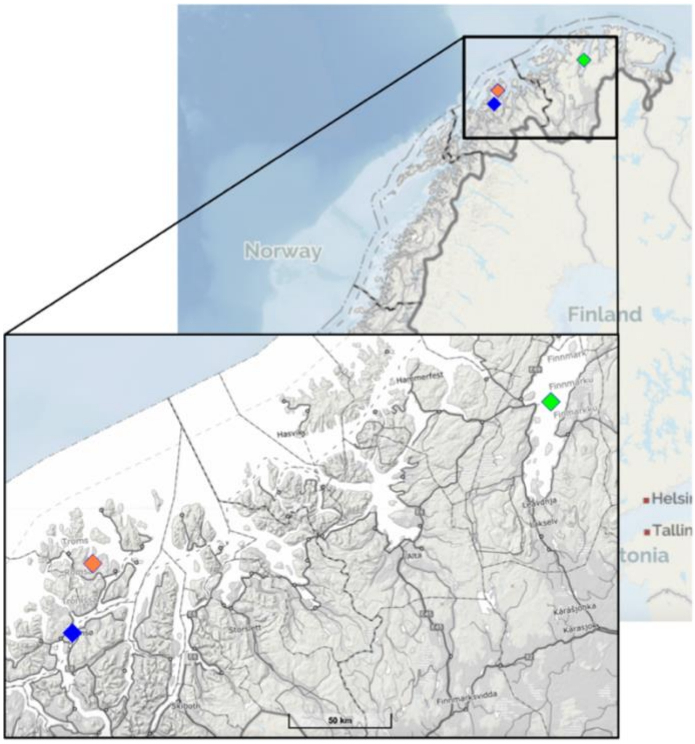

Figure 3: Study sites Map of study sites. Marked in blue: in Tromsø, one restored kelp forest site with two replicate zones and a barren ground site; orange: two barren ground sites in Dåfjord; green: one site of restored kelp forest in Porsangerfjord. The map is retrieved from norgeskart.no.

2.2.1 Restored kelp forest

The kelp restoration area was situated at a reef located at Nordspissen, Tromsø, in Northern Norway (Figure 3). The area was restored voluntarily by the GK and SUT. The reef had been cleared of sea urchins (mainly the green sea urchin *Strongylocentrotus droebachiensis*), with monthly clearing events to maintain and expand the area. Sandy bottom surrounding the reef acts as a barrier for sea urchins, which are mainly associated with hard bottom. Sea urchin removal was conducted by volunteer divers (SCUBA divers and free divers) mainly crushing the sea urchins with hammer. Sea urchins were also harvested for commercial purposes some days.

GK began by clearing one zone in May 2021, then an extended zone in March 2022, which together comprises approximately 1000 m2. Figure 4 shows the outline of the two zones. Since the removal of sea urchins started at different times within the two zones, the recovery phase was therefore at different successional stages. To explore biological differences related to time after sea urchin removal, the two zones were treated as independent localities in this study, hereby referred to as zone 1 and zone 2. Biological samples from the two replicate zones were collected in September 2023. Re-established kelp in zone 2 at time of sampling is illustrated in figure 5. The sites have been monitored by NIVA before and after removal since 2021 and the data are included in this thesis. In order to have more robust data for statistical analysis, the dataset from Nordspissen was supplemented with additional data from a restored kelp forest site in Porsangerfjorden. The study design did not include natural kelp forest as reference sites, as there was no known, naturally occurring kelp forest with similar environmental condition in the region.

Figure 4: The restored kelp forest consists of two sections of different succession stages, making up two restored forest zones; zone 1, to the left, first cleared in May 2021, zone 2, to the right, first cleared in May 2022. Restored area is approximately 1000 m^2 in total. The satelite image is retrieved from norgeskart.no.

2.2.2 Barren grounds

Three replicate barren ground sites were chosen (figure 3). One situated approximately 150 meters from the kelp forest at Nordspissen, and two sites located in Dåfjord, a sea urchin dominated fjord north-west of Tromsø, located 790 meters apart, at Bergneset and Vatnan. There was no observed kelp nearby and sea urchins were abundant on all barren ground sites.

Figure 5: Re-established kelp in the restored kelp forest at Nordspissen where sea urchin had been removed for one year. Photo: Janne Gitmark/NIVA.

2.3 Recording of species and sea urchin densities.

To examine differences in species diversity and sea urchin abundance among sites, benthic fauna and flora at all barren ground and kelp forest sites were recorded in 50x50 cm squares at 2–3-meter depth (figure 6). Depth, substrate, and percentage algae cover were recorded at all sites. Other observed benthic species were recorded on a semi quantitative scale from 1-4 or in numbers of individuals. Less replicates were recorded at the kelp sites due to longer recording time because of higher number of species, and limitations in dive time for the divers conducting the survey.

Existing data on sea urchin densities and species collected in 2021 and 2022, before and after the removal started, was included in the dataset, also registered in 50x50 cm frames. Sea urchin densities were registered in both zones, while algae cover and other observed species in zone 1 were registered after one year of removal, conducted in the same manner as described above.

Figure 6: Sea urchin barren ground before sea urchin removal in Nordspissen, during sea urchin densities registration by SCUBA divers. Photo: NIVA.

2.4 Kelp samples for kelp biomass, length and associated fauna

Kelp samples from six 20x20 cm frames were collected from the two restored kelp forest sites. All kelp holdfasts in the frames were scraped off the substrate and the whole kelp was collected in fine woven fabric bags to keep all biological material. The kelp samples were brought to the lab the same day and left in the freezer until defrosted for species identification and measurements.

Figure 7: Length measurement of a kelp sampled from zone 1, two years after removal.

The kelp and fabric bags were rinsed thoroughly in water into a bucket to make sure all biological material and organisms were rinsed out and kept in the bucket. The samples were then washed through a 250 µm sieve and the gathered material transferred to bottles and conserved on 70 % ethanol. Fauna from the samples were afterwards counted and identified as species or taxa. The sample was processed regardless of what part of the kelp they came from. *Spirorbis spp*., *foraminifera indet* and pelagic species (e.g. *copedoda indet*) were not counted, but presence were registered. Many of the kelp holdfasts were attached to barnacles, which were noted but not counted.

Kelp growth was estimated with measurement of biomass and lengths. Each individual kelp was identified and measured in length of stipes and blade (lamina), and width of holdfast (figure 7 and 8). Diameter of the stipe was measured, and cross-sections of the stipe was used for aging. Age of the kelp can be determined by counting age circles.

Biomass was measured as total dry weight and ash free dry weight (AFDW) of kelp from each sampled square. The kelp was dried for 24 hours in 70 degrees for measuring dry weight. AFDW was obtained for each sample by burning in a muffle furnace at 480 degrees for 7,75 hours. This was used for the calculation of the organic component. In this thesis the organic component is used as a proxy for carbon content, although the organic component also includes various elements such as carbon, nitrogen, phosphorus, and other essential nutrients. It encompasses all the living matter within the algal cells. For estimating the stored carbon per square meter, measured AFDW were subtracted from the dry weight and upscaled to square meter.

Figure 8: Seedling individuals of sampled kelp from zone 2, after one year of removal.

2.5 Collection of fauna from artificial sampling units

To compare the biodiversity of fauna between restored kelp forests and barren grounds, standardized fauna traps were deployed at all study sites. Few studies exist on restored kelp forests in Norway, and to better improve the data analysis on changes in biodiversity, data from an earlier study in Porsangerfjord was provided by NIVA and supplemented to my data set. In Porsangerfjorden, the sea urchins were removed chemically with quicklime (ref. Strand et al., 2020) but otherwise the same methodology with fauna traps and sampling one and two years after urchin removal was used in this study.

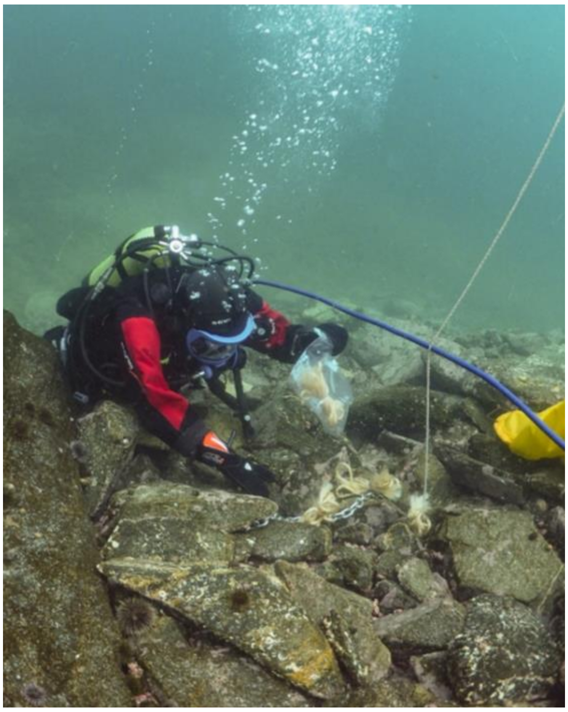

Figure 9: In situ collection of rope traps by SCUBA diver in barren ground with no sea urchin removal.

Fauna traps were constructed by splitting the strands of hemp rope and bundling them with cable ties. Five rope bundles were evenly distributed along 1-meter chains. The fauna traps were placed at the three barren ground sites and one in each zone of the kelp forest and left for three days on the sea floor at 2-3 meters depth at low tide. Traps made of metal scrubs were employed in the same manner to study sea urchin recruitment. These were placed out early in summer and left for two months during sea urchin settlements.

To minimize the loss of fauna while collecting the traps, each bundle or scrub was carefully placed in a zip-lock bag at the sea floor before cutting them loose from the chain and sealing the bags with additional seawater (figure 9). Then all bags and the chain were brought to the surface and within 24 hours to the lab.

All bags with trap were carefully rinsed in water through a 250 µm sieve. The gathered material was put on separate bottles with 70 % ethanol for conservation. Fauna in the samples were identified under microscope to species or taxa and counted. *Spirorbis spp*., *foraminifera indet* and species related to the water masses (e.g. *copedoda indet*) were not counted, but presence were registered. Number of sea urchins (early settlements, 0,2 – 5 mm in size) from the metal scrubs was identified under microscope and counted.

All *in situ* field surveys and data collections were conducted with SCUBA by scientists from NIVA.

Table 1: Number of replicates for each study for each treatment ("no removal", "one year of sea urchin removal" and "two years of sea urchin removal") in the three sites Nordspissen, Dåfjord and Porsanger). Replicates consisting of data from more than one year, are specified by number of years in total with parenthesis. Study description: Species recording = 50x50 cm frames measuring percentage algae cover and observed benthic species registered on a semi quantitative scale from 1-4; Kelp samples = Collected algae by scraping off all kelp holdfast and other algae in 20x20 cm squares. N/A means that kelp was not accessible to collect at these sites. Artificial fauna traps = 5 rope bundles or metal scrubs tied to one chain (equaling one replicate), left on the sea floor for three days and two months, respectively.

Treatment	**Species recording in frames (n)**	**Kelp samples**		**Artificial fauna traps (n (**1 = mean of 5 traps**))**
		Biomass and length	**Ass. fauna**	
Dåfjord				
No removal	40	N/A	N/A	4
Porsanger				
One year of sea urchin removal				2 (2 yrs.)
Two years of sea urchin removal				2 (2 yrs.)
Nordspissen				
No removal	40 (3 yrs.)	N/A	N/A	2
One year of sea urchin removal	20 (2 yrs.)	6	3	2
Two years of sea urchin removal	5	6	3	2
Total:				
No removal	80			3
One year of sea urchin removal	20	6	3	3
Two years of sea urchin removal	5	6	3	3

2.6 Statistical analyses

Table 1 outlines the different sampling methods employed at each site. For the sites with restored kelp forest, additional data from previous years provided multiple treatment levels for the kelp forest zones. Data were grouped by treatment in terms of duration of sea urchin removal (no removal, one year and two years of removal) for each study, according to treatment level at the time of sampling. Statistical analyses were conducted in R Studio 2023.06.0+421 (R Core Team, 2023). Quantification of species biodiversity was done for all fauna studies. To quantify diversity, Shannon-Wiener diversity index was used from the "vegan" package, which considers species richness and evenness (Oksanen et al., 2022). In addition, richness was measured as number of unique taxa (identification to the lowest possible taxonomic level) in each sample, and total fauna abundance was calculated as sum of individuals. Due to different scales for species recording according to fauna observations and algae cover, only richness was used for the species recording study. Equal data sampling for fauna in artificial fauna traps allowed for comparing differences between fauna in restored kelp forest and barren ground. Data from Nordspissen, Dåfjord and Porsangerfjord were combined for statistical analyses, grouped by treatment, being year of (or since in regards of Porsangerfjord) sea urchin removal. Each chain with five rope fauna traps was treated as one replicate to avoid pseudo-replication, measured as the mean diversity, richness, and abundance.

Species biodiversity, kelp biomass and length measurements were used for statistical testing, following assumption testing. Bartlett test from "stats" package and Levene's test from "car" package (Fox & Weisberg, 2019) were employed for homogeneity of variances, and log transformation was conducted when heterogeneity was identified (Quinn & Keough, 2002). To evaluate significant differences between two treatment groups, one-tailed Student's t-test was conducted to test the increase with the duration of treatment. Analysis of variance (ANOVA) was conducted for more than two groups. If assumptions were still not met after log transformation, a non-parametric Welsh's t-test or ANOVA was performed instead (Underwood, 1997). Post-hoc test (Student–Newman–Keuls (SNK) from the "agricolae" package (de Mendiburu, 2021)) were used with ANOVA to identify differences between groups. The effect of species composition (PERMANOVA) and the most influential species (simper test) between groups were tested with the "vegan" package (Oksanen et al., 2022) for kelp samples and artificial fauna traps. The data from Porsangerfjord was excluded from this analysis due to potentially different species compositions explained by geographical variation.

As several of the studies had low sample size, effect size with log response ratio (LRR) (random effects model and forest plot) from "metafor" package (Viechtbauer, 2010), and power analysis from "pwr" package (Champely, 2020) were conducted to further evaluate the significance of the results. Data visualization were conducted with the "ggplot2" package (Wickham, 2016).

2.7 Interviews

The goal of the interviews was to understand the motivations of the participation and the perceived impacts of the results by the leaders of GK and SUT, both ecologically and socially (Young et al., 2018). Semi-structured interviews were used to ensure flexibility in answering broad questions, enabling participants to answer freely and intuitively instead of leading them to specific answers (Kallio et al., 2016). The interview guide was designed with a structure to ensure that each interview covered all topics, while allowing for open-ended discussion. The interview participants were expected to favor some of these topics more than others, suggesting what remains the most important motivational factors for restoring kelp (Vecina & Marzana, 2019).

2.7.1 Design of the interview guide

I built up my questions for interviews based on the literature in the field of voluntary conservation work and what has previously been identified as important motivations for the volunteers working with nature. For understanding the psychological aspects of volunteerism, Clary et al. (1998) presented the Volunteer Function Inventory (VFI). It is a theoretical framework that covers the potential motivations for volunteering with a set of six motivational functions: values, understanding, enhancement, career, social and protective. Although VFI are mentioned among several studies in the field of environmental volunteer work, most emphasize the need to expand on motivations typical for volunteering in general, as motivations other than the VFI framework has been observed, such as helping nature and the environment (Guiney, 2009; Takase et al., 2019; Vecina & Marzana, 2019). Questions for the interview guide were based on a combination of the VFI for a general framework and literature on environmental citizenship and volunteering for a more comprehensive understanding of volunteering for nature (Hustinx et al., 2010). The final interview guide can be found in appendix A.

The ‘values’ function in the VFI is related to motivations based on altruistic or humanitarian values, often regarding providing help to others (Clary et al., 1998). The wish to help nature is found to be based on biospheric values which involves recognizing that humans are an integral part of the biosphere and that our well-being is deeply intertwined with the health of ecosystems (Chan et al., 2016; Mayer & Frantz, 2004). According to Guiney (2009) the motivation of helping nature is underestimated in the VFI, where the sense of connection and relationships between people and nature are formed when helping nature to recover. Helping nature is fundamental in the environmental citizenship concept (Ryan et al., 2001), and alludes to the studies of Clary et al. (1998) and Clary and Snyder (1999) which mention that volunteering can fulfill a personal need to help and contribute to something meaningful. Ryan et al. (2001) highlights in environmental volunteer work the importance of the reciprocal relationship between people and nature, providing benefits for both. The reciprocal benefits from environmental volunteer work have been highlighted in several studies; the volunteer work is directly benefiting nature, and the volunteers will directly and indirectly receive beneficial returns, including a sense of meaning and positive feelings. Motivations to participate in restoration activities is in such case rooted in the benefits for both partners (Guiney, 2009; Hagger et al., 2017; McDougle et al., 2011; Ryan et al., 2001; Takase et al., 2019). Based on these findings I therefore included questions in the interview guide on how they thought their work was important for society or nature, e.g. as a driver for helping nature, as well as indirect or direct personal benefits, such as what participation might provide them.

Guiney (2009) was exploring the connection with nature, finding that having a strong connection with nature, especially from childhood, is an important factor for increasing the chances for a person to engage in nature volunteer work. Whitburn et. al.'s (2020) findings support this, summarizing that a stronger connection makes pro-environmental behaviors more likely. Ryan et al. (2001) finds in their study that participation with environmental volunteering increased the attachment to the local natural areas and hence concern for the local environment. This further relates to the establishment of biospheric values (Mayer & Frantz, 2004), which could encourage the volunteers to reflect upon their relationships to nature, such as the role nature and the ocean in their life now and in their childhoods. Exploring the specific relation to the ocean was related to findings by Buchan et al. (2024), which highlighted a wish to protect the ocean among individuals who identified more strongly with it. Specific questions about their relationship to the ocean and identity were therefore added.

With a close connection to nature comes a deeper concern for the environment and knowledge about nature and environmental issues (Ryan et al., 2001). Having a higher initial knowledge and insights would increase the frequency of participation in nature volunteer work (McDougle et al., 2011; Ryan et al., 2001; Takase et al., 2019). And while learning more about nature is predicted to sustain the participation (Guiney, 2009; Takase et al., 2019), several studies found that learning more about nature was an important motivation for volunteering (Bramston et al., 2011; Ryan et al., 2001; Shum et al., 2023; Vecina & Marzana, 2019). This relates to the function 'understanding', and interview questions involved whether they learned from participation, and how much they knew from before. Questions about involvement in environmental actions, previous volunteering, and concern for the environment were included too.

The 'enhancement' function relates to acts on personal growth, which could be related to social returns such as expanding their social networks (Clary et al., 1998). In contrast, the 'social' function is related to the acting on shared interest within one's already established relations and could be based on what is expected of you within a group of friends (Clary et al., 1998). The benefits received through the social activities of the volunteer work has been highlighted as part of the main motivations by many, framed as being part of a community (Guiney, 2009), building a sense of belonging (Bramston et al., 2011) or to meeting new people (Hagger et al., 2017; Ryan et al., 2001; Takase et al., 2019). McDougle et al.

(2011) found that for young adults in conservation work it was particularly important to have the possibility to expand on their social networks and Takase et al. (2019) found in a study on volunteer conservation work in Japan that interaction with other people was the most important motivation, evaluating it as the influence on the variation in frequency of participation. These findings comprise the topic on social motivations in the interview guide, combining the two functions ‘enhancement’ and ‘social’ and other literature findings.

In the study by Takase et al. (2019) the second most important motivation was identified as the “enjoyment of cultural services from ecosystems”, being various ways of enjoying nature, such as recreational use and enjoyment of a hobby. As this was drawing on gains in physical and mental well-being, these findings align with Guiney (2009), which found that volunteers may improve their health and well-being through volunteer activities with nature and improving their connection to nature. Furthermore, human well-being is found to be intricately connected to the connection with nature (Chan et al., 2016; Mayer & Frantz, 2004). Based on this, questions on the activity of diving and what feelings they were left with afterwards were asked, related to ‘enhancement’ once more on the improvement or development of oneself, or ‘protective’ being the reduction of negative feelings.

Many studies find that helping or benefiting the environment is among the most important motivations for participation in volunteer programs (Bramston et al., 2011; Guiney, 2009; Hagger et al., 2017; Ryan et al., 2001; Takase et al., 2019) Several emphasize the importance of effectively communicating achieved goals and positive environmental outcomes to participants (Guiney, 2009; McAfee et al., 2019; Ryan et al., 2001; Shum et al., 2023). Guiney (2009) explored the connection between the outcomes and the volunteers’ motivations, and argued for the need of a positive angle, alluding to McAfee et al. (2019) emphasizing that engagement requires a sense of optimism. Ryan et al. (2001) highlights the rewarding feeling of seeing tangible benefits, functioning as another important driver and motivator for overcoming the inaction when facing complex global environmental challenges, that is not so easy to address at an individual level. Questions concerning how motivations were driven by experiencing results of their efforts were combined with questions regarding their perceived outcomes of the restoration work in the interview guide.

2.7.2 Participants characteristics

I chose to focus on the leaders of the GK and SUT as key informants of the motivations and impacts of volunteer kelp restoration as they would have the best insight into the organization, the clearing events and other people involved. The four volunteers had different roles in the project, which I expected to provide different insights based on their involvement. GK provided more thorough answers about the organization, outreach and history, while the SUT leaders were asked more about the particular clearing event happening at Nordspissen. Preferably I would have included volunteers that only participated in the clearing events, but time limitations hindered me from conducting more interviews. The four volunteers were asked about their general impression of why other participants have chosen to participate.

I contacted the volunteers directly by text message, providing more information by e-mail, asking if they would like to participate in a one-hour interview about their involvement in the project. The four volunteers were all women, aged between 25-34. They had important roles in the project, three being involved from the start in 2021, with one of them joining last year. Two volunteers were marine biology students at UiT, one had a master's degree in marine biology, working with sea urchins and kelp restoration next to volunteering in the project. The last volunteer was working in the maritime sector. Three out of four had relocated to Tromsø, while one grew up in the area and moved back after studying elsewhere.

2.7.3 Conducting the interviews

The interviews were conducted with each volunteer in a quiet space of their choice. I started the recording after information and rights were communicated to the volunteer and the consent form was signed. The interview was kept in a conversational manner in Norwegian, always trying to ask follow-up questions for the participant to elaborate.

2.7.4 Transcription and qualitative analysis

The audio recordings were conducted on teams including direct transcription, which afterwards was revised and re-written based on relistening to the audio recordings ensuring that the intended meaning of the interviews was retained. To analyze the interviews, thematic content analysis was used (Naeem et al., 2023). This allowed me to identify responses or meanings that could relate to the research questions and to the different categories of motivations included in the interview guide. Themes were categorized using a coding scheme relating to VFI and the other motivational factors identified in the literature above (see Table 2) (Naeem et al., 2023). To keep the narrative and fuller meaning, whole sequences were kept in the coding process to provide illustrative citations of motivations belonging to each theme (Riessman, 2008). Furthermore, a thorough understanding of each individual interview and keeping IDs for each sequence allowed accounting for potential differences and maintaining the integrity of each interview. The coding of volunteer motivations and contribution from work were done in the software program NVivo 14. The coding scheme allowed me to ensure each interview was thoroughly and equally analyzed.

Table 2: The answers in the interviews were categorized according to this coding scheme.

Research question	**Codes**
Motivations	Concern for nature and environment - Connection to nature - Concern relating to sea urchin barrens
	Diving interest
	Fun, recreation
	Wish to help the environment
	Relational values with nature
	Wish to increase awareness
	Results as motivation
	Nature or ocean interest
	Local connection
	VFI - Career - Enhancement - Protective - Social - Understanding - Values
	Other participants' potential motivation
Personal impacts	How it makes them feel
Social or societal impacts	Contribution to awareness
	Recruitment and mobilizing - Participants - New dive clubs
Ecological impacts	Results
	Perceived ecological contribution

2.7.5 Validity and reliability

Qualitative research differs from quantitative in obtaining validity and reliability, which must be accounted for to ensure integrity and credibility in conducting of the research and of the findings (Noble & Smith, 2015). Validity refers to the accuracy of the findings in reflecting the data, while reliability refers to accounting for biases in the research approach (Noble & Smith, 2015).

To enhance external validity I placed my analysis it in the context of prior research on nature and conservation volunteering (Drury et al., 2011). The small-sample size and the non-random sampling of individuals makes generalizability to other volunteer groups less certain, but parallels could be drawn to studies showing the same kind of motivation for restoration work. Given that the interviews were narrowed down to those few leaders that initiated and have led the organization, internal validity of their motivation was derived from analyzing their meaning and the motivational factors explained throughout the interviews. The internal validity of the interviews was ensured through the choice of conducting semi-structured interviews, where open-ended questions allowed for the volunteers to answer based on what they found more important, to cover the more prominent motivations and perceived outcomes. This way I also avoided leading their answer in a certain direction. Validity of questions regarding motivations among other participants cannot be considered as high but was included for a broader understanding.

Considering the reliability, I ensured consistency in sampling method by ensuring that all questions were understood, elaborating if needed (Long & Johnson, 2000). If the question was not understood I rephrased the question. Prior to the interviews I tested the interview guide with friends to see if there were any unclear questions or phrasings that would cause confusion (Zohrabi, 2013). The analysis ensured equal treatment when coding, accounting for d personal biases by analyzing content of the interviews in the light of my research questions and the coding scheme (Noble & Smith, 2015). Reliability can furthermore be enhanced through triangulation (Zohrabi, 2013), in which the biological sampling in the study provided a context for questions regarding achieved results. The transcript went through iterative rounds of coding to ensure that coding was consistently applied, noting and re-checking uncertainties in each round.

2.7.6 Ethical considerations

Ethical considerations were accounted for when conducting and analyzing of the interviews, considering the implications of voluntary participation in interviews (Allmark et al., 2009). Prior to the interviews, volunteers were informed about the interview process, privacy and their rights to ensure that their consent was fully informed before agreeing to participate. They were informed of the aim of the interview, the audio recording and who had access to the data to ensure privacy (only me and my supervisor would handle the data). They were also assured of their right to withdraw their interview at any time following the interview, and that they could answer the questions as they saw fit, to ensure their consent throughout the interview (Shaw, 2003). A consent form with the information was signed prior to audio recording. Interviews was done in a manner that prioritized the comfort of the volunteers, creating a safe space for open dialogue. Asking questions and responding to their answer were done supportively, by actively listening and understanding their perspectives. The open-ended questions allowed them to answer and elaborate to the extent they preferred.

Through the transcription process the intended meaning of their answers were preserved. Verbatim transcripts were maintained to accurately capture participants' verbal expressions, while whole sections were kept when categorized, to preserve the context and ensure the integrity. The participants were given the opportunity to read through the final transcript to approve the content. This way I was also able to show the volunteers acknowledgement and further gratitude for their participation.

2.7.7 Privacy policy

Privacy measures were implemented to secure the confidentiality of the volunteers. Firstly, an application was submitted to the Norwegian Centre for Research Data, to approve the appropriate handling of personal data in the project. Secondly, anonymity was ensured by assigning interview IDs for storing information. The corresponding names and transcripts are kept in a secure Teams group, accessible only to me and my supervisor. Audio recordings were kept there as well, until automatically deleted six months after recording.

3 Results

3.1 The ecological effect of removing sea urchins

The removal of sea urchins allowed for macroalgae to establish in both zones of the forest, with different succession stages based on how long sea urchins had been absent. The cross-sections of the sampled kelp stripes confirmed the age difference in the re-established kelp between these zones. All registered species and measurements can be found in appendixes.

3.1.1 Square registration of species in barren ground and restored kelp

Square registrations revealed an ecosystem change following the treatment in Nordspissen, with the decline of sea urchin densities and increase in species richness through the period from 2021 to 2023 (figure 10). Estimation of richness revealed an ecosystem change from being dominated by one species, only sea urchins, to a mean (± SD) species richness of 7.9 ± 1 (SE: 0.46, SEM: 0.47, range: 7, n = 15) in zone 1 after one year of removal, and after two years of removal the two zones combined had a mean richness of 14.9 ± 2.3 (SE: 1.03, SEM: 1.08, range: 9, n = 10).

A significant difference in richness was found between the two zones and treatments (ANOVA, $F_{4,40}$ = 146.2, p < 0.001). Post-hoc testing using the SNK test revealed a difference between all three treated groups, being zone 1 with one and two years of removal and zone 2 of one year of removal, while the two zones of no removal did not differ. Sea urchin densities decreased from an average of 33.35 ± 7.7 (SE: 3.7, SEM: 3.79, range: 65, n = 20) before removal to 0.25 ± 0.4 (SE: 0.2, SEM: 0.21, range: 4, n = 20) after one year, and to 1.0 ± 1.2 (SE: 0.45, SEM: 0.5, range: 2, n = 5) after two years, per 0.25 m^2 (ANOVA, $F_{(2,42)}$ = 48.6, p < 0.001).

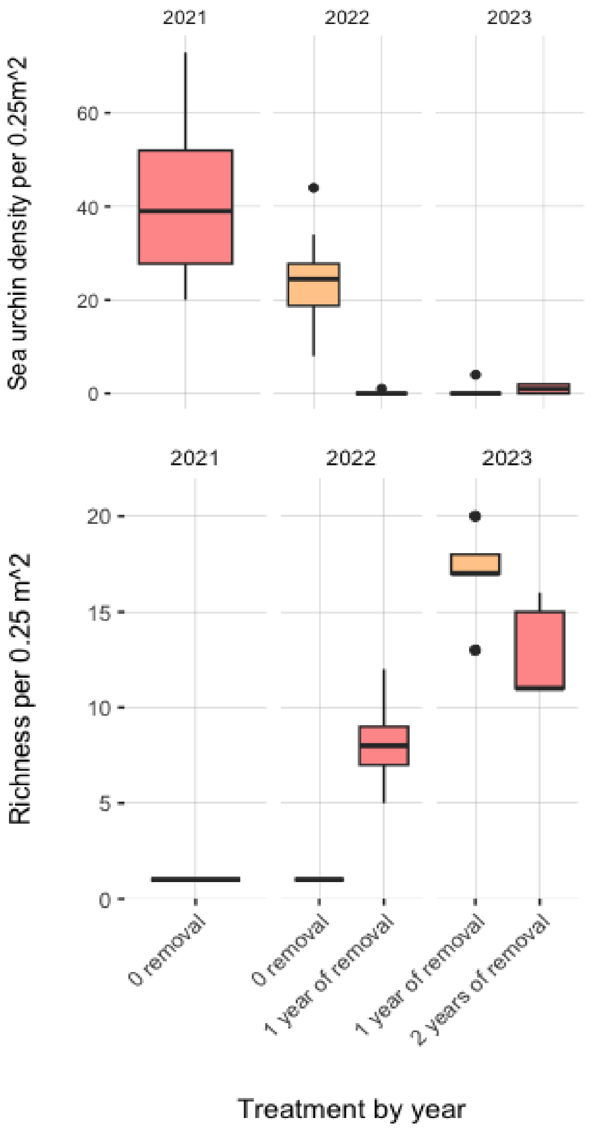

Figure 10: Recording of sea urchin densities (top) and species richness (bottom) in squares of 0.25 m2, over the three years of sea urchin removal in the restoration site at Nordspissen. In 2021 only zone 1 (pink) were recorded prior to removal. The two subsequent years the additional clearing of zone 2 (orange) provided two levels of treatment within each year.

The species registrations from Nordspissen were further combined with the registrations in the other barren ground sites, grouped by treatment at time of registration. The measured species richness for each treatment level are presented in figure 11. Assumption of homogeneity of variance was not met even after log transformation, and to account for that a Welsh one-way ANOVA was employed for statistical analysis. The test found significant differences in species richness ($F_{(2,10)}$ = 60.35, p-value < 0.001, test power: p = 0.61) when comparing registration in barren ground, one year and two years of removal. SNK post hoc test indicated significant differences in species richness between all three groups. LRR suggested large effects between zero and one year of removal (1.35 ±0.25), and between one and two years of removal (1.58 ±0.23), and moderate effect size between zero and two years (0.23 ±0.26).

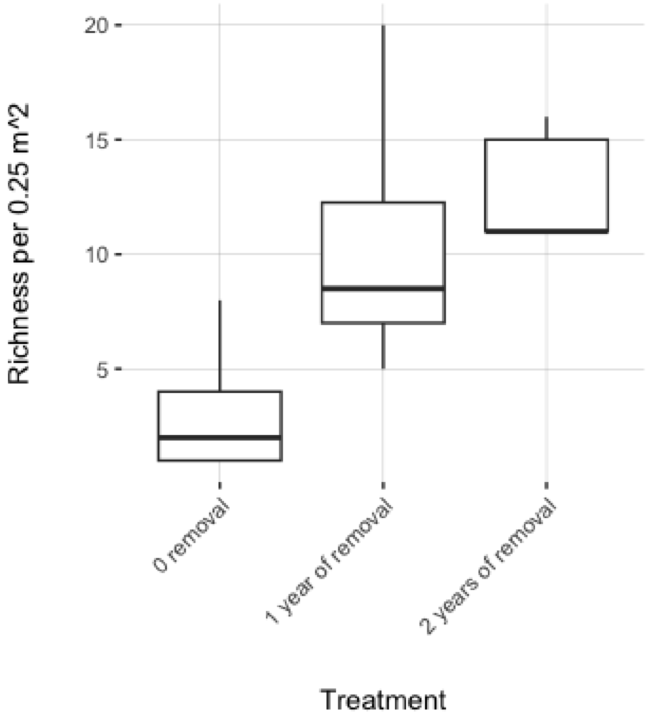

Figure 11: Species richness was measured from species registration in squares of 0.25 m^2 in three treatment levels of sea urchin removal.

3.1.2 Biomass, length and carbon in restored kelp forest

Weight and length measurements of kelp from the 20x20 cm frames are presented in table 3. The mean kelp biomass increased significantly after sea urchin removal (Student's t-test, $p = 0.002$, LRR = 0.55, test power = 0.11) from a mean kelp dry weight of 0.36 ± 0.21 kg m^{-2} (SE: 0.09, SEM: 0.1, range: 0.56, n = 6) after one year and 2.4 ± 2.2 kg m^{-2} (SE: 0.88, SEM: 1.0, range: 5.9, n = 6) after two years of removal with a significant increase between the means (figure 12).

After one and two years of urchin removal, estimated stored carbon per square meter from the standing biomass of kelp were 0.25 ±0.14 kg (SE: 0.06, SEM: 0.06, range: 0.36, n = 6) and 1.75 ±1.68 kg (SE: 0.69, SEM: range: 4.64, n = 6), respectively, with a significant increase from the first to second year of removal (Student's Two Sample t-test, $p = 0.002$, LRR = 0.3, test power = 0.1) (Figure 12). This further provided estimates of total carbon in the restored forest of approx. 700 kg in zone 1 and 150 kg in zone 2. Combined, in approx. 1000 m^2 it provides an estimated 850 kg of stored carbon.

Length measurement of kelp holdfast, stipes and lamina provided results of the kelp growth with the duration of treatment (figure 13). Specific means for each sampled kelp are summarized in table 2. A Welsh's two sample t-test were applied for statistical analysis for the increase in the means of the holdfast ($p < 0.001$, LRR = 0.77, test power = 0.62) and stipes ($p < 0.001$, LRR = 0.66, test power = 0.68), and a student's t-test was employed for the means of the lamina ($p < 0.001$, LRR = 0.4, test power = 0.3). Cross-sections of the stipes confirmed an age difference between the kelp in zone 1 and 2. Of the identified individuals there were 29 seedlings in the younger zone 2, while two seedlings in zone 1. *Saccharina latissima* where the dominant species, found in both zones, while some individuals of *Alaria escuelenta* were found only in the older zone.

Table 3: Mean of kelp biomass, carbon and length of different parts kelp sampled from 20x20 cm-squares from re-established kelp forest with one and two years of sea urchin removal. Number of replicates (n) was total biomass for each square, while length measurements was per individual kelp.

Measurement	Years of sea urchin removal	Mean (±SD)	SE	SEM	Range	n
Dry weight ($kg\ m^{-2}$)	1	14.3 ±8.47	3.46	3.79	22.2	6
	2	95.8 ±86.5	35.3	38.7	236.1	6
AFDW ($kg\ m^{-2}$)	1	4.35 ±3.21	1.31	1.44	7.73	6
	2	23.1 ±18.9	7.70	8.43	50.3	6
Amount carbon ($kg\ m^{-2}$)	1	10.0 ±5.50	2.25	2.64	14.5	6
	2	70.0 ±67.3	27.5	30.1	186	6
Hapter length (cm)	1	3.00 ±1.48	0.30	0.30	5.8	26
	2	7.58 ±3.26	0.65	0.68	12	24
Stipes length (cm)	1	9.44 ±8.29	1.14	1.15	36.2	53
	2	40.8 ±19.3	3.64	3.71	62.5	28
Lamina length (cm)	1	19.0 ±11.7	1.62	1.63	44.5	52
	2	74.3	10.4	10.6	164	23

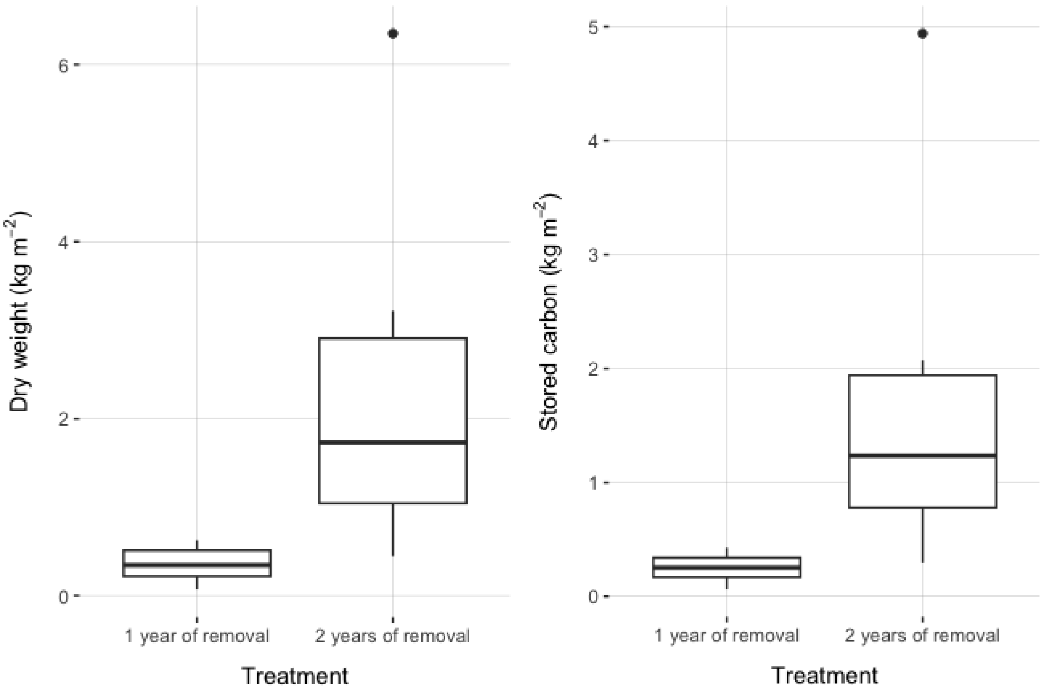

Figure 12: Dry weight (left) and amount of stored carbon (right) of the kelp from zones in the restored kelp forest with different duration of treatment is presented in the two plot as kg per square meter.

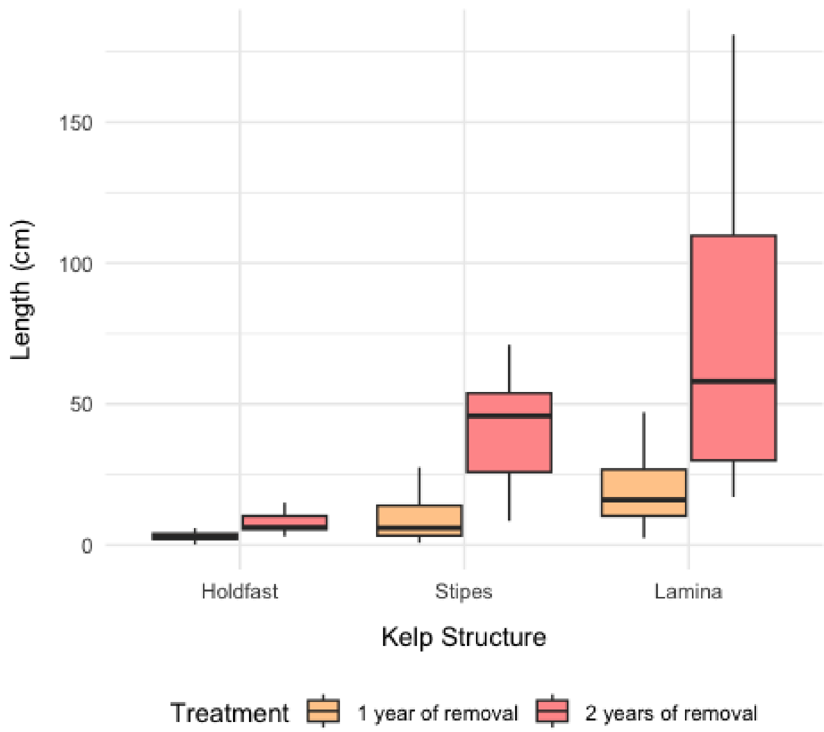

Figure 13: Length measurements from the holdfast, stipes, and lamina of individual kelps from kelp forest with different treatment of sea urchin removal.

3.1.3 Fauna from kelp samples

A total of 50 taxa of kelp associated fauna were identified within the restored kelp forest presented with estimations of biodiversity in figure 14. The older forest with two years of removal showed a higher mean species richness than after one year ($p = 0.04$, LRR = 0.24). There was no significant increase between the two kelp sites in terms of diversity ($p = 0.43$, LRR = 0.01) and abundance ($p = 0.10$, LRR = 1.16). All tests had a test power of less than 0.2. PERMANOVA did not find a statistically significant effect of site on species composition ($F = 1.4$, $p = 0.4$).

1 year of removal resulted in a mean of 293 ±147 individuals (SE: 85.0, SEM: 104, range: 287, n = 3), equal to 7333 ±3679 per square meter (SE: 2124, SEM: 2601, range: 7175). Two years of removal increased that number to 935 ±699 (SE: 404, SEM: 494, range: 1393, n = 3), equal to 23383 ±17478 per square meter (SE: 10091, SEM 12359, range: 34825). This provides an estimate of 15,358,000 individuals in total in the 1000 m^2 restored kelp forest.

3.1.4 Fauna sampling from artificial traps

The diversity of fauna from the rope traps showed little difference between treatment (ANOVA, $F_{2,6} = 4.10$, $p = 0.08$). SNK post hoc test did not detect any significant differences between the groups. In contrast, richness differed significantly among the groups (ANOVA, $F_{2,6} = 20.61$ $p = 0.002$), with the SNK test revealing a difference between barren ground (b) and kelp forests (a). SNK results obtained for abundance showed no difference between the groups, despite significant ANOVA ($F_{2,6} = 4.83$, $p = 0.0562$). LRR suggest a significant difference between barren ground and one year of removal (diversity: 0.49 ±0.32, richness: 0.81 ±0.24, abundance: 1.69 ±0.66) and between one year and two years of removal (diversity: 0.53±0.35, richness: 0.90 ±0.23, abundance: 1.51 ±0.78). Between barren and two years of removal the effect size was insignificant for all tests (diversity: 0.05 ±0.36, richness: 0.09 ±0.23, abundance: -0.18 ±0.38). The test power was 0.077. The differences in biodiversity is presented in figure 15.

PERMANOVA found that level of treatment had an influence on species composition ($F_{(4,22)} = 6.83$, $p = 0.001$). A simper analyses found that the most influential species were *Margarites* (71 %), *Mytilus edilus* (66 %), *Ischyrocerus angipus* (0.61 %) and *Nematoda* (0.56 %). Data from Porsangerfjord were excluded from this analysis.

From the metal fauna traps only one sea urchin was identified and gained no adequate results and was therefore excluded from the rest of this thesis.

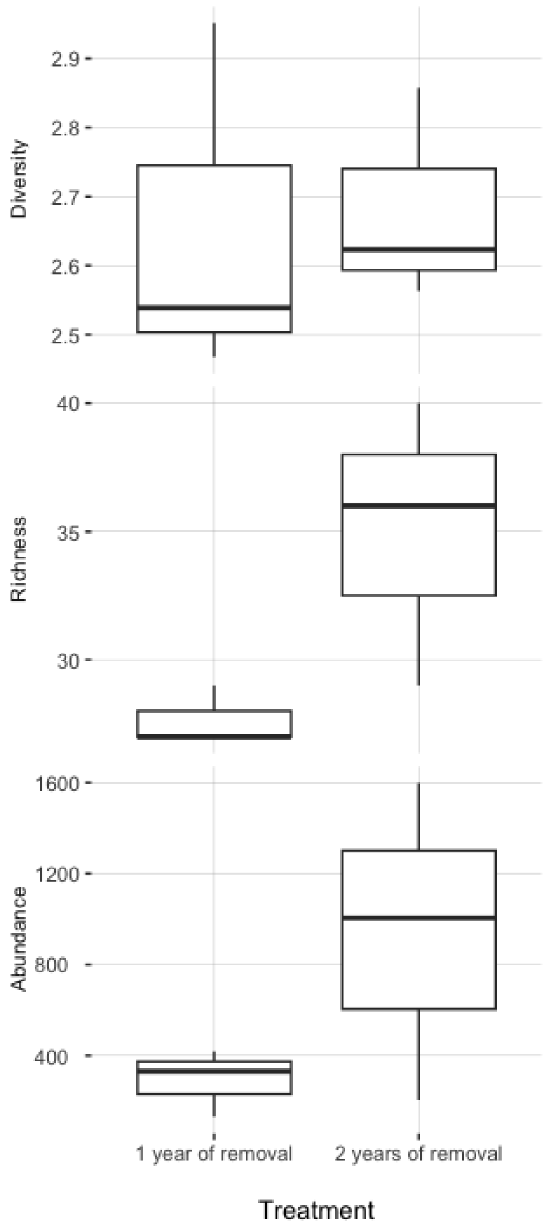

Figure 14: Species diversity, richness, and abundance in kelp samples from restored kelp forests after one and two years of sea urchin removal.

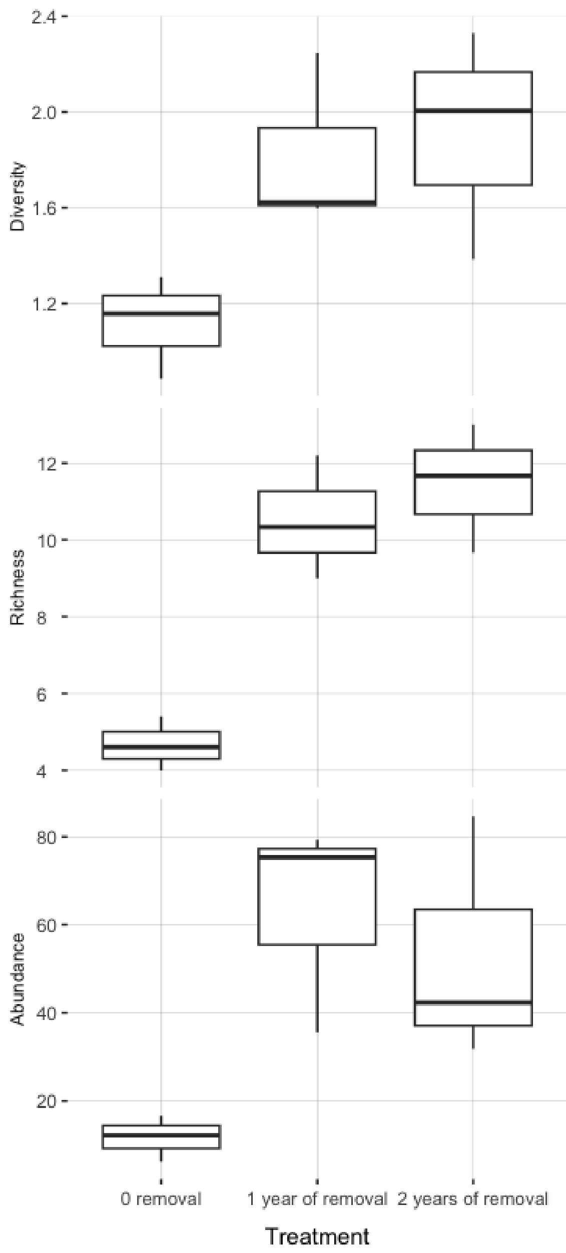

Figure 15: Species diversity, richness and abundance in artificial rope traps with zero, one and two years of sea urchin removal.

3.2 Volunteering for kelp restoration

3.2.1 Connection to nature

All the volunteer leaders' motivations for restoring kelp ecosystems were based on their relationships to nature and concerns about degradation. Their strong connection to nature, as described by the participants, began in their childhood, and remained a driving force in their adult lives. Nature was described as "*absolutely essential. I don't function without nature*", "*one of the most important things I have*", "*a place where I have spent my whole life looking for freedom and finding inspiration for what to do with my life".*

Being able to have nature in their everyday lives was a key driver for relocating to and living in Tromsø, because of the city's easy access to nature and outdoor activities, where diving played a major part. As a part of their interest in nature they felt a strong connection to the ocean and as kids they spent time in and by the ocean. Three of the participants have studied marine biology, expressing a fascination and curiosity for the ocean. They mentioned how we originate from the sea and completely dependent on it, and how being in the water made them "*be one with the sea*" or "*become completely absorbed in that world*". A feeling of oneness and belonging draws on the experiences of being in the water, as said by one of them:

> *"After I started diving, I just got an urge to do it a lot. I knew that I feel best when I'm in the water, so then it was very natural to also choose to live in a place where I could do it a lot. … you are in a world that is completely unique, and you don't belong in a way, but as a person that you still belong ... There is something about the fact that we come, after all, from the sea, and we are completely dependent on the sea to live and breathe, so it's just kind of yes, strange, that kind of gratitude and fascination for a world that you don't know." - GK leader 1*

3.2.2 Becoming aware of the sea urchin barrens.

Before diving in Tromsø none of the volunteers were aware of the extent of the problem with the sea urchin barrens of the northern Norwegian coast. The one volunteer who grew up in Tromsø had heard of the sea urchin barrens, but she had not reflected on the extent of the problem before she began diving in Tromsø. Seeing urchin barrens under water and how they are depleted of other marine life came as a sad reality to all of them:

> *"And when I came up here, I didn't know much, but then in a way this problem came up with the kelp forest not being there and so it came as a bit of a shock to me, because I knew nothing*

about it. No one had told me that 15,000 kilometers of Norway's coast lacks kelp forests and we really had a dead coast." – GK leader 1

Diving more, in more places and participating in the project made them increasingly aware about how widespread the loss of kelp forest is. Kelp forests had been degraded in areas where they were expected to occur, with only high numbers of sea urchins remaining. The divers also became aware of the connection between kelp forest and the presence of fish. They observe how patches of kelp forest attract fish.

3.2.3 The value of helping nature

Their new awareness of the sea urchin barrens and the ecological effects were key drivers behind their wish to contribute to solving the problem in the first place. All touched upon love and care about the ocean, and through GK they could combine something important and meaningful with a hobby they love and that provides a lot of fun.

Matching the motivations of volunteering to the VFI functions there seems to be that those values, including the deep relations and concern for to nature and the ocean, were the primary motivation for investing so much time in restoring kelp. They emphasized that career development was not the reason they chose to engage, although some of them became aware of the potential benefits for getting jobs and advancing their careers after they embarked the GK. Enhancement, such as meeting new friends and other diving buddies; understanding, such as practicing diving and learning more about the ocean; and social, strengthening existing relationships were expressed as a part of their engagement in kelp restoration. However, they were mainly reflecting upon these motivations as more important for other participants.

The strongest motivation among the leaders seemed rooted in their strong connection to nature and the ocean and awareness of the natural crisis that has happened with the overgrazing of kelp, expressed as a strong desire to help nature. Having central positions in the project, all the leaders observed the results from the efforts of removing sea urchins in the given area, witnessing a progression far exceeding their expectations. After just six months they witnessed kelp starting to grow. By the next year, it was already a flourishing kelp forest attracting various species of fauna. Every time they had a look, they could see changes resulting from their work, always observing new species. Fish and small fry like saithe (*Pollachius virens*) and cod (*Gadus morhua*), crabs (*Carcinus maenas* and *Hyas indet)*, sea spiders (*Pycnogonida*) and nudibranchs (*Nudibranchia*), among them species they have never seen before. Their observations of juvenile *cyclopterus* indicate that they are breeding in the forest, and of species that were absent and hard to find before they started the project emphasize the ecological importance of their restoration efforts.

The rapid regeneration of kelp forest ecosystems is a motivation for sustaining the efforts of removing urchins, by making the goals of restoring more appear more achievable. Being part of changing an ecosystem like this, even creating one with higher productivity and diversity and seeing tangible results from their work gave them feelings of reward, joy, and more motivation.

> *"To see what happens then, how it develops and see fish move into, as it were, an ecosystem that we have helped to create. It is perhaps one of the most rewarding things to* **s***ee in a way like ok that forest can be here because we helped the sea, because it comes back then. So to be completely honest it is perhaps the most rewarding thing and see that the sea is allowed to flourish as it does." – GK leader 2*

Being part of the GK was also a way to respond to the nature crisis. In a world of depressing news and varying faith among the volunteers for the future and in political action, tackling this issue directly they were contributing to a change that they themselves can witness. The kelp restoration was a way to convey renewed hope. This motivates them to continue and to prioritize the effort in their everyday lives.

> *"I was asked here on Sunday just like that, isn't it just depressing for you to see like 5,000 square kilometers of desert, i.e. the sea urchin desert and you have restored 3,000 square meters and you know how much hard work it is, is it not just really demotivating? But it actually only gives me hope because we have somehow managed to do it. We are like diving into the water on a voluntary basis. If we manage to do it that way, then you can do this on a large scale if you just put in the effort." – GK leader 2*

Giving back to nature, helping it to recover, when so much nature has been destroyed is also something that was emphasized:

> *"We see that every time new species come back, that's OK, but there is actually life in the sea. We just have to create a place where they can be, just help both on land and in the sea and help nature to re-establish itself. Give it a chance, since we've built so much, destroyed so much." – GK leader 2*

3.3 Recruitment and expansion

3.3.1 Increased awareness through participation

Becoming aware of the sea urchin barrens and seeing the positive effect of the restoration work, the volunteer leaders had a strong wish to share both the problem and the solution with more people. That way, more people could work together for upscaling the restoration. The clearing events may serve as a powerful tool in increasing awareness and engagement. As their main goal is to restore more kelp forests, another effect of it is what it gives the participants. While diving they are asked to check out the restored forest, showcasing the outcome of their efforts with a flourishing kelp forest. One volunteer told how effectful that experience is:

> *"[We] ask those who are involved in removing sea urchins to also take a trip to the kelp forest and see how it might turn out then. And just then to see their reaction when we come back just like that, and it's such a big difference, and it's like just look, like see the hope shining through their eyes, is like just something that works." - GK leader 2*

During the clearing events they could see how engaged other participants became. SUT 2 shared how it was sometimes hard to get the divers to stop and get out of the water, even when it was freezing cold and getting dark. Afterwards, the leaders are often told how much the other volunteers appreciate being able to contribute and make a difference and see that their help is useful.

Witnessing the ecosystem change from an impoverished state to a lush one full of life clearly brought a feeling of hope. The volunteers emphasized the impact of witnessing this transformation firsthand. SUT 1 compared it with another similar experience with a beach cleanup project, where digging up big pieces of plastic with their own hands had a significant impact on people, as they saw the issue and progress while doing the work.

Showing off the results of what they have achieved was described as rewarding and an important motivator for the volunteers, particularly the leaders of GK. It served as inspiration for more people and helped spread awareness, both on social media and among the divers. The volunteers found increased motivation as they witnessed the project gaining attention, which contributed to engagement. This brought about a feeling that people wanted to contribute and that they could collectively make a difference.

They have managed to engage a lot of people, and they expressed a lot of gratitude for how people are showing up, no matter the weather or temperature, and how fantastic it is that what started as a small initiative is growing as much as it is:

> *"But the fact that we have managed to engage so many people. Here, there has been a fantastic side effect of a small commitment that started in a diving club. The only driver has really just been that we're like, here's a problem that we can tackle directly in a way and do something about directly, and so we did." – GK leader 2*

Being a part of the project, the solution or making a difference were mentioned several times as important to them and other participants. The GK leaders expressed the hope that all volunteers recognized their role in the achieved results and felt a sense of belonging and unity. Regardless of the frequency of their contributions, they believed it is crucial for participants to feel connected to the project and recognize their impact. Also, after their participation, when for instance seeing the results after a year on social media, it could influence both their own future involvement and inspire others to join the project.

Along with involving more people in the clearing events with SUT at Nordspissen, the GK leaders have a goal of involving all the diving clubs in Northen Norway to start up new restoration sites close to the local dive clubs. Through their media coverage and social media platform they were encountered by diving clubs and divers wishing to do the same in their local community, and new restoration sites were established, one more site in Tromsø, as well as in Harstad and Lofoten. This shows how people wish to engage, and that media spread awareness.

They saw the value of establishing restoration sites in new local communities, reflecting on how the local population became engaged and appreciated taking part, and how the message was spread in the population through, for instance, encounters in local meeting places. With a local attachment they might be more committed to restoring the local kelp forest, as they have a deeper care for it. This was illustrated by a comment from a ten-year-old volunteer who talked about restoring "our kelp forest", with emphasis on "our". The volunteers also believed it could be valuable for local communities to restore a healthy ecosystem with the prospect of improving local coastal fish stocks.

3.3.2 Motivations among other participants

Besides wanting to contribute to the restoration, there might be other motivations for the other volunteers to come to the clearing events. And there might be many reasons for them to show up before they are introduced to the issue while diving. Motivations could be related to social, understanding and enhancement functions. The volunteers mentioned strategies to make participation easy and predictable, by how the clearing events were held regularly once a month, always as a low threshold, no commitment activity, new and returning members could join to dive for "ten minutes or two hours" or just help out on land. The dive club could use the events as a meeting point to engage their members. This could bring in more members to the club, and more people that wish to dive, also making it easy for those that wanted to try freediving for the first time for free in a safe environment. The SUT leaders also explained the need for a social arena for the club, for instance for meeting potential new diving buddies, which are a crucial factor of being able to go diving on your own.

However, even if it is fun, social, and they offer sauna and food after the dive, the underlying motivation was to remove sea urchins and bring back the life in the ocean, both for leaders and other volunteers. It was emphasized by GK leader 2 how it requires a lot of a person to be in the water, but by showing the results and that everyone can contribute, more people could be willing to put in that time and effort. Showing the restored forest to demonstrate what could have been as they witness the degrading effect of the sea urchins, and what they can retrieve, being the creation of a dive site or to see more fish – it could make more people willing to put more time into it.

3.4 The perceived contribution from the project

3.4.1 Knowledge and dissemination

Increased effort in the project, involving more people, restoring more areas, and having more results to show to, and contributing to raising awareness, was described by the GK leaders as a rolling snowball of positive feedback. The more they did and managed to spread their message, the more they received back from people contacting them, asking to contribute, and asking to cover them in the media – spreading the message even further. Also, internationally. They had noticed a shift in the diving culture and in people's knowledge about the sea, which they believed was a reason for why more people became interested.

The volunteers mentioned that they thought the biggest contributions from the project were knowledge and dissemination. They noticed how awareness and knowledge were increasing. The problem of the sea urchin barrens has been communicated for decades, since it was first researched in the 90s, but the public dissemination has been unsuccessful. Therefore, the attention that the GK project generated was important in their view. They explained how the achieved results were a big part of it. Considering the lack of information flow from science to the public since the problem was identified in the 90's, they believed it had a completely different effect when the information was now coming from volunteers. This way it becomes more personal and relatable coming from people, young adults, that do this work in their free time, because they care for and love the ocean, and have a strong wish to preserve it. It is a strong signal when all those people that volunteers choose to "defy all elements, just to bring the kelp forest back":

"I think many people can, in a way, relate more to a problem or natural crisis, when just an ordinary person talks about it, than a researcher. Because if a researcher comes out in the media or in another article, newspaper article, whatever and says something, then in a way it's, yes, it's that and that, there is a person who can do this and who should be able to do that, perhaps. But if you're in the newspaper and you're like 'this is a problem, I love the sea, and the sea is disappearing' or something like that, that it becomes a little closer and that you can somehow relate to it more. Maybe you don't dive or like the sea, but you see that this person is about to lose something they love or want to save something they care about." – GK leader 1

They valued the collaboration with Urchinomics and researchers from NIVA, seeing it as mutually beneficial. The research group provided knowledge and support while the project contributed with data. The researchers would not have been able to achieve the same results without the regular volunteer dives. The GK could also make the knowledge more accessible to more people. They have been able touch a wider part of the population compared to the scientists. Only during the last few months of conducting this study, the GK have been covered in a wide range of articles, news reports and several international film crews. The increased attention may be the reason for new and significant collaborations with governmental institutions and environmental organizations in early 2024 (Miljøstiftelsen Bellona, 2024a). The project has been covered in several news articles and reports following the announcement of the project and the visit from the Crown Prince of Norway (Knežević, 2024; Miljøstiftelsen Bellona, 2024b; Naturpress, 2024; NRK, 2024; Straumsnes et al., 2024). One of the volunteers stated in the news article that involvement from such high national level motivated further by how important it was for increasing the awareness (Straumsnes et al., 2024). GK leader 2 explained how the project could be a catalyst for more, to show that restoration can provide the many provisioning services from kelp forests, that can be valued economically beneficial and important for international commitments in nature and climate agreements, in which this new collaboration is a result of.

3.4.2 Increased hope

The volunteers perceived the increase in knowledge and awareness in the population as important for both nature and society. Even though it's a small-scale project, if they do something it is more than nothing, and seeing that they can touch people, the engagement they might spark may contribute positively to both nature and society. Eventually, with the engagement of politicians, wider ramifications and governmental initiatives for tackling the issue are emerging. This provided the volunteers with an increased sense of hope. Seeing how others engage, and how they too get more hope from taking part, they genuinely believe that more people need to see and feel this hope. A big motivation for them is to communicate this to a population with an increasing lack of faith for the future.

Because of this, they believe it can be of great value for people to get involved in something important, and something that can bring hope, based on their own experience of gaining hope despite their general concern for global environmental issues:

> *"I think people have a great need to feel that they are involved in something important, because that is how there is so much pessimism around the environment and climate. This is a happy thing, because it is very concrete and only when you are involved in it do you actually make a real contribution that gives real results that you can see and follow yourself. I think that has great value for many people." – SUT 2*

4 Discussion

I found the project of the Guardians of the Kelp to be successful in facilitating the re-establishment of a kelp forest and recolonization by some of the associated fauna. Significant ecosystem changes were identified following the removal of sea urchins, increasing the biodiversity already after one year. The perception of biodiversity recovery was shared by the volunteers, and the results functioned as a great motivation for the continuation of their work. The GK project also shows that volunteer diving could have a high impact in terms of awareness and engagement of the public, perhaps more than scientific dissemination an exemplifying what marine citizenship can promote (Buchan et al., 2023). The strong commitment by the leaders based on a fundamental connection to nature might have been a key element of the success and for this initiative to be sustained. They expressed a sense of oneness with the ocean, and their connection to nature appears to have channeled their strong wish to help the ocean. From being able to achieve results and involving more people, they expressed feelings of gratitude for being able to restore nature, and a sense of hope from being able to do something to address the nature crisis.

4.1 What are the ecological effects of removing sea urchins to restore kelp forest ecosystems?

This study reveals how the GK's efforts in maintaining a low urchin density, has successfully contributed to regeneration of kelp forests t. From a sea urchin dominated ecosystem of low complexity and productivity, the re-established kelp forest was housing fifty identified taxa of kelp- associated fauna after two years of sea urchin removal. In addition, the divers observed species of fish, crabs, nudibranchs, repeatedly observing new species when visiting the forest.

The re-establishment of kelp following a drastic reduction in sea urchin densities observed in this study is in alignment with the findings of several previous studies (e.g., Carlsson & Christie, 2019; Chapman, 1981; Leinaas & Christie, 1996; Miller, 1985). Significant increases were identified in species richness and abundance between the barren grounds with no and one year of removal of sea urchins, as evidenced by species registration and fauna traps (see figure 9, 10, and 14). The absence of sea urchins allowed for an early establishment of a high number of annual algal species after one year of sea urchin removal. Mostly seedling recruits of *S. latissima* and a higher species richness after one year compared to two years of removal aligns with findings by Leinaas and Christie (1996). The findings of no recruits and higher biomass of *S. latissima* in the older forest indicates a shift in species composition with time of succession to this dominant and perennial algae species, which normally takes over as the more dominant species in wave sheltered habitats (Leinaas & Christie, 1996). The continued efforts of keeping sea urchin densities low evidently allowed for the further growth of perennial kelp, gaining substantial increase in biomass and size with time of removal.

Furthermore, this study provides evidence for a quick colonization by faunal species soon after the kelp has re-established, with increased numbers of invertebrates collected after one year of sea urchin removal. Significantly higher diversity (Shannon-Weaver diversity index) was found in kelp forests compared to barren ground, with a further increase in the kelp forest with the duration of sea urchin removal and thus age of the forest. However, the artificial traps showed a decreasing species abundance from one year to two years of removal. The simultaneous increase in diversity and decrease in species abundance from younger to older kelp forest could suggest a shift in community composition towards a more even distribution of individuals among species.

On the other hand, kelp samples show a considerable increase in associated fauna abundance, from approximately 7,333 individuals per square meter after one year of urchin removal, to 23,383 individuals per square meter after two years of urchin removal (albeit not statistically significant). The duration of urchin removal provided significant increases in the growth of the kelp canopy, from the first to second year, on which fauna abundance depends (Norderhaug et al., 2007). Within five years the canopy grows to full size, and maximum species abundance is likely to follow the same pattern (Christie et al., 2009). Species diversity and richness, on the other hand, are more dependent on macrophyte complexity (Christie et al., 2009), which can explain the lack of increase in diversity from the first to second year. Longer time for growth facilitates a more complex architecture, that together with increased colonization time may allow for improved and more available biomass that can provide habitat for a bigger variety of species (Christie et al., 2009). On the contrary, my studies indicated an increase in species richness also to the second year, with a significant increase in richness in the kelp samples. This might again be the facilitation for new species to colonize with time. Longer timespan for monitoring the kelp forest will give more insights into this.

Minor biodiversity differences between the two levels of re-established kelp forest, could be due to high mobility among kelp associated fauna, providing a quick colonization of new kelp beds (Christie et al., 2009; Waage-Nielsen et al., 2003). The already established zone 1 could have contributed as a source of dispersal at the time of clearing zone 2, contributing to a higher colonization rate of new extended areas of the restored kelp forest. This pattern might further explain the higher species richness found in zone 2 compared to zone 1 within one year of removal. Limited data for zone 1 after one year of urchin removal prevents further investigation. Fauna collected from kelp samples showed evidence of an increase between the two kelp forest age levels in species richness and abundance, although no significant change in species diversity was found. The artificial traps were placed out for three days and will only reveal data on relatively mobile fauna. Kelp samples provide sampling that better reflects the composition of associated fauna, and include species of a bigger variety of mobility, where less mobile fauna inhabits the holdfast higher up on the kelp (Norderhaug et al., 2002). The less mobile fauna colonizes new kelp beds at a slower rate, which can explain the higher number of animals and species in the older than younger section of the forest.

The quick re-establishment of kelp with the colonization of fauna, may act as a barrier for the sea urchins to grow back in numbers (Leinaas & Christie, 1996). Findings of crustaceans, including juvenile hermit crab (*Paguridae* indet and *Galatheoidae* indet), and several species of amphipods in fauna samples provides evidence for the presence of potential sea urchins micropredation (McNaught, 1999). Amphipods were found by Christie et al. (2009) to be the most abundant taxa in artificial traps in natural kelp forests and may serve an important role in controlling sea urchin settlements by predation of early sea urchin life stages. Juvenile crabs, such as the spider crab (*Hyas Araneus*), have been found to prey on newly settled sea urchins (McNaught, 1999). Spider crabs are among the species commonly observed by divers in the restored kelp forest. Furthermore, the volunteers reported on observing a variety of bigger faunal species, for instance, fish and crabs. The divers' observation of juvenile lumpfish (*Cyclopterus lumpus*) indicates that the forest is already providing nursery for some species, as the *C. lumpus* mature in the forest it hatched in. Predation on sea urchins by fish are known to be an important regulatory mechanism in a healthy kelp forest (Chapman, 1981; Leinaas & Christie, 1996; Norderhaug & Christie, 2009). The re-established kelp could facilitate important feedback loops of micropredation of early sea urchin settlement, greatly reducing the sea urchin post-settlement survival within the forest (Steneck et al., 2002). Especially early establishment of *S. latissima* represent a breakpoint of which sea urchin recruitment is reduced, which was found in the restored forest (Leinaas & Christie, 1996).

Fully grown natural kelp forests are highly resilient systems capable of withstanding disturbances to a high degree (Christie et al., 2009). However, due to lack of natural kelp forests in the area around Nordspissen there were insufficient control sites to evaluate when the restored kelp forest would be reaching such a state. Providing control sites in other regions would also have been insufficient, since kelp forest structures may vary with latitude (Sjøtun et al., 1993) and wave exposure (Norderhaug & Christie, 2009). It would be interesting to see over a longer period whether the forest is increasingly colonized or if this rather low fauna complexity is the climax state, compared to species communities of other kelp forests (Abdullah & Fredriksen, 2004; Christie et al., 2007; Christie et al., 2009; Sjøtun et al., 1993). However, the rapid establishment of kelp observed by the volunteers within six months after the first removal aligns with other studies on kelp restoration (Carlsson & Christie, 2019; Christie et al., 2024). Other studies have also found active restoration, by directly removing the cause of the decline, such as the sea urchin, to be effective and providing immediate results (Eger et al., 2022).

However, even though the kelp re-establishes quickly at low sea urchin densities, sea urchins are quick to overgraze the kelp once density control is removed (Carlsson & Christie, 2019; Leinaas & Christie, 1996). Many kelp restoration projects have had little success, often due to being small-scale and short lived (Eger et al., 2022; Fredriksen et al., 2020). Not properly recognizing mechanisms for top-down control have been found to limit the success of kelp restoration and other restoration projects (Christie et al., 2009; Xu et al., 2023). Restoring a sea urchin predator population is suggested to be necessary for the vitality of restored kelp forest, also considering the high costs of maintained removal (Miller & Shears, 2023). Since the fish stocks reduced by overfishing have still not recovered (Norderhaug et al., 2021), ensuring the viability with retention and new recruitment of volunteers is essential (A. M. Eger et al., 2022). In the long-term the structure and functionality of the system could control sea urchin populations when restored (Norderhaug et al., 2021; Verbeek et al., 2021). The provision of related services from the restored forest, such as carbon capture, nutrient filtration, and providing nursery for important commercial fish stocks, makes restoration efforts rewarding (Verbeek et al., 2021). The continuous volunteer efforts once a month with sea urchin culling have here proven to establish, maintain and expand a kelp forest, providing carbon storage in the increased growth of biomass and facilitated for important habitat for fauna.

4.2 How do the divers perceive the ecological and societal impacts of restoration?

The volunteer leaders said the project positively impacted the natural coastal environment. The results provided hope and positive feelings which could benefit the volunteers and other participants. Furthermore, the communication of the issue and the achieved results contributed to increased general awareness and initiatives at a higher political level. This could contribute to increased marine citizenship, as it entails the increased awareness and care for marine issues (McKinley, 2010).

The volunteers' perception of contribution to nature was a main motivational factor for the participants. The motivation was strengthened by successfully achieving results and bringing back more life and providing homes and shelter for invertebrates and fish species. Helping nature was important to the participants, despite being a small but significant contributor to enhancing productivity and biodiversity. Furthermore, they valued the ramifications of the work and what it potentially could lead to. They felt that they could address a natural crisis that has happened out of sight, literally below the surface, yielding results beyond the kelp forests at Nordspissen. The expansion of new dive clubs and direct inquiries from more people about how they can do the same in their local community demonstrated the impact of the media outreach. Dissemination of the issue and the solution was perceived by the GK leaders as one of the project's major contributions. Through media coverage they have enhanced the public awareness and knowledge, which in other studies have been found to increase volunteer participation into environmental issues (McDougle et al., 2011; Ryan et al., 2001; Takase et al., 2019).

The close collaboration with NIVA strengthened the project's credibility due to its foundation in scientific research. In turn, the project also contributed to research, and played a role in bridging science and practice (Cooke et al., 2023), serving as an example of citizen science where action is taken in collaboration with scientific research. Furthermore, GK demonstrated how citizen engagement may contribute to raising awareness, more so than dissemination purely from the scientists (Norderhaug & Christie, 2009). New and significant collaborations with governmental institutions and environmental organizations emerged in early 2024, aimed at addressing the issue at a higher level (Miljøstiftelsen Bellona, 2024a). Not to mention how the visit from the Norwegian Crown Prince led to more media coverage and potentially awareness (Knežević, 2024). The increased awareness may have enhanced appreciation of the kelp forests and increased funding through collaborations (Bennett et al., 2015), crucial for the viability of the project (Cooke et al., 2023). GK leader's role as advocating leaders may have had a pivotal contribution to these important results. By advocating for the rights of citizens to participate in decision-making processes related to the marine environment, leaders could enforce marine citizenship initiatives (Bennett et al., 2018; Boeske, 2023; Buchan et al., 2023).

The involvement of new diving clubs might contribute positively to the local community. Ryan et al. (2001) found that participation increased the local attachment and appreciation for local nature. Furthermore, Moore et al. (2006) found that the increased sense of belonging to local communities through volunteer work would increase their efforts in contributing to the local community. The GK leaders expressed how the provision of nursery homes for important commercial species of fish could benefit the local fishing communities that are more dependent on a costal fishing fleet (Engen & Fauchland, 2022). In turn, the GK leaders expressed how the involvement of diving clubs in smaller communities could be positive for the increased local awareness. The diving clubs have the important role of arranging and facilitation for participants to the clearing events. Through the collaboration with SUT there has been sufficient participation for the re-establishment of the kelp forest.

The increased participation of the volunteers filled the leaders with gratitude by seeing that more people wished to dedicate their own free time to this project. More importantly, they gained increased feelings of hope. The positive feelings like increased hope was highlighted as a key contribution to the participants, counterbalancing negative feelings of hopelessness relating to the global nature and climate crises (Carrington, 2024; Livgard, 2023; Wilberg, 2023). For the volunteers, the restoration work provided a way to address their climate concerns. In combination of achieving results and seeing the engagement from more people, they were hopeful for what could be achieved through such a collective effort. Moreover, the involvement of others and their desire to contribute to the cause further reinforced the volunteers' hope and motivation. Seeing and knowing that other peoples also contribute have been found to be key for increasing for the general willingness to act solving environmental challenges (Andre et al., 2024).

The great deal of positive feelings that emerged from witnessing the success of their efforts aligns with Ryan et al. (2001) who found witnessing tangible results from volunteer work to bring rewarding feelings. Exposure to destroyed nature may increase the effort in environmental protection (Yu et al., 2024), while positive outcomes of conservation actions could sustain participation and thereby marine citizenship (Guiney, 2009; McAfee et al., 2019; Ryan et al., 2001; Shum et al., 2023). Volunteers get this experience first-hand through volunteering. Furthermore, social media could raise more awareness and engagement to a wider population than solely those able to participate in the clearing events. All the volunteers believed that participation and spreading optimism from the results could bring more hope to more people, and that more people could benefit from this same experience.

Sensory experience in the ocean is a foundation for emotional attachment to the ocean, which further can lead to more volunteering (Buchan et al., 2024). Learning more about nature and the ocean by being exposed and educated while participating in restoration efforts can also re-enforce their attachment and engagement (Guiney, 2009). Exposure to nature also increases health benefits, such as restorative effects (Hartig et al., 1991), cognitive benefits like improving attention (Schertz & Berman, 2019), improved self-esteem and functional ability (Wilson, 2000). Furthermore, there are several theories on the need for a relationship to nature for human well-being through a sense of belonging or connectedness to nature (Chan et al., 2016; Mayer & Frantz, 2004). Participating in a project like the GK can contribute to people’s well-being and might explain why people wish to participate in terms of spending time in nature.

4.3 What motivates the volunteers to contribute to restoration activities?

To enhance benefits that might derive from nature volunteer work, improved understanding of what motivates participation is needed (Ryan et al., 2001). The motivations that were explicitly stated by the volunteers were founded on their wish to help nature by changing the barren ground to a kelp forest, providing homes for more marine life. Witnessing how the efforts pay off as well as seeing how other people wish to participate enhanced their motivation further.

The volunteers' expression of environmental concern and a wish to help seemed rooted in their sense of interconnectedness with nature, and more precisely the ocean. Their values may be their main motivation for volunteering, where a biospheric worldview explains their wish to help nature in particular, which involves care for a living beings in the natural world (Chan et al., 2016; Mayer & Frantz, 2004). The volunteers emphasized a sense of connection to nature and expressed a wish and a need to involve nature in their everyday life to maintain it. Exposure to nature increased their feeling of connection to nature (Buchan et al., 2024). Furthermore, some volunteers emphasized the sense of belonging in the ocean and how we depend on it and what it provides us. Buchan et al. (2024) showed how marine place attachment built a dependency on the ocean, which again furthered marine citizenship. From using the ocean for diving while growing up, they established an attachment to the ocean and identified the ocean as part of their sense of self. Several authors find that having a connection to nature is a necessity for caring about nature and for a willingness to protecting it (Mayer & Frantz, 2004; Roszak, 1995; Schultz, 2000). Feeling threats to one's identity is also known to drive action (Breakwell, 1986; as cited in Buchan et al., 2024). Finding the ocean interesting is connected to a sense of marine identity (Buchan et al., 2024), where the volunteers' engagement in marine biology deepens and confirmed their marine identity. Leaders, such as the leaders of GK, can play a pivotal role in raising awareness and fostering a sense of marine identity, which are key drivers of the deeper marine citizenship (Buchan et al., 2023).

Increased awareness is not always found to promote more action, where initial values and worldviews will play a role in how the recipients will act (Buchan et al., 2023). Increasing peoples' connection to nature and the ocean may therefore be pivotal for long-term restoration success. The provision of marine-related activities to volunteers can close the gap between environmental concern and lack of engagement (Chen & Tsai, 2016). Spending time by and in the ocean has been found to promote ocean attachment and marine citizenship and willingness to contribute (Buchan et al., 2024; Chen & Tsai, 2016; Hynes et al., 2021). Moreover, the volunteer's motivation for increasing awareness to recruit more people was driven by their genuine belief that more people would benefit from seeing the results and receive positive feelings through directly taking part.

Understanding the initial motivations for why people wish to join the clearing events the first time would provide a valuable supplement to this study for how to bring more people into the self-reinforcing loop that volunteer restoration work can be. The high threshold for involvement in marine citizenship that involves diving provides further challenges for the recruitment. Furthermore, this Arctic restoration project is taking place in cold water and needs high-quality equipment. Despite these challenges, the GK project is evidently successful and unaffected by these limitations. While reflecting on what could motivate other to participate, the leaders expressed gratitude for the people that defy the elements to participate. More interviews with these other volunteers could have uncovered other motivations. For instance, the socializing and meeting new people have been highlighted as key motivations in several studies (Hagger et al., 2017; Ryan et al., 2001; Takase et al., 2019) and other interviews could provide deeper insights into the role of social networking and other motivations for participating in marine restoration. The leaders of SUT expressed a desire to use the clearing events as a social platform within the diving club, offering something to their members and create a space to meet people with similar interests.

5 Conclusion

In a world where marine ecosystems face significant threats and where there is a need for urgent action to address environmental challenges, this study has shed light on a potential strategy for fostering greater citizen engagement for the ocean. Furthermore, my study explored the reciprocal benefits that such engagement can yield. Through the collaborative efforts of volunteer divers in the Guardians of the Kelp project to remove sea urchins, a kelp forest has been successfully restored at Nordspissen, Tromsø. The site has been transformed from a barren ground dominated by sea urchins into a thriving ecosystem that support a diverse array of marine fauna. This study has demonstrated the ecological contribution of this project in terms of increased kelp biomass and biodiversity of kelp associated fauna, already after one year of sea urchin removal. Furthermore, the results brought a renewed hope among the volunteers highlighting restoration efforts as a remedy to deal with negative feelings in a world with depressing news about the future climate and nature.

My results show the importance of understanding the motivations behind volunteer participation and for recognizing the reciprocal benefits derived from nature volunteer work, as a foundation of conservation initiatives. The volunteers' sense of connection with nature and the ocean was here found to be the main driver for their wish to help the ocean through the restoration project. Exposure to nature and participation in restoration activities have the potential to change the people's perceptions and care towards the environment, providing a key pathway for halting decline of biological diversity through regeneration of degraded ecosystems.

Overall, this study underscores how citizen initiatives can play an important role in addressing global environmental challenges and drive positive change. By promoting a renewed relationship with nature and empowering individuals to act, we can work towards a more sustainable future for our oceans and planet. The Guardians of the Kelp project exemplifies how marine citizenship can drive positive change in marine ecosystems, contributing to the well-being of society and the planet.

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Appendix A. Interview Guide

The interview guide provides a structure for the interviews, where the goal is to cover the topics, allowing for the participant to discuss what they find most important with open-ended questions. Questions were adapted to the participants role in the project.

Before starting with the questions, the aim of the thesis and the interviews and why their participation important was introduced to the participant.

Table A1: General background and history with The Guardians of the Kelp

The first part will cover who you are, your interests, such as diving, and how you got involved in the project.

Topic	**Literature background and aim for questions**	**Questions**
Age	Group demography	How old are you?
Local connection	Is local connection important for participation? Attachement to local natural areas (Ganzevoort & van den Born, 2020) Wish to improve the well-being of the local community (Takase et al., 2019) The volunteer work increased the connection to the local natural areas (Ryan et al., 2001).	How long have you been living in Tromsø? What are you doing here? Work/studies, other interest?
Personal history with Tarevoktere, recruitment and participation in the project	Background in project. What factors seem to recruit the participants? Benefits from participating or to nature (Ryan et al., 2001). Positive outcomes (Guiney, 2009; McAfee et al., 2019; Ryan et al., 2001; Shum et al., 2023). VFI (Clary et al., 1998). Previous volunteering improves likelihood of more volunteering (Takase et al., 2019).	Your role in GK is.. - Have you engaged in any other way in the project? - Tell a bit about your role in the project. Do you have any expectations? For the project, or possibly personal? How did you first get involved? What are you looking forward to participating in the volunteer work? Have you been involved in voluntary work related to either climate or nature before?

Duration of volunteer participation	Frequency of volunteers' participation (Ganzevoort & van den Born, 2020; Guiney, 2009; Ryan et al., 2001; Takase et al., 2019)	How long have you been involved? How many times have you participated in volunteer dives? Would you consider doing it more often? - Is there anything preventing you from doing so?
Diving as hobby/ using nature as recreation.	Is recreation/activity important for participation? Recreational use or enjoyment of hobby in nature (Takase et al., 2019). Enhancement or learning (Clary et al., 1998).	Why do you participate in the dives, if you do? - Is diving a significant reason for your participation? Is diving something you regularly engage in? - Why do you do it - what do you enjoy about it? How much had you dived before joining GK / participating in volunteer dives? Does the volunteering give diving a sense of purpose? - Are you participating in the volunteer dives primarily for diving, or do you see diving as a means to get the job done? Are you participating as a free diver or using SCUBA equipment?

Table A2: Personal benefits from participation

Questions on what they personally feel they get from participation.

Personal benefits from participation	Personal well-being (Guiney, 2009; Mayer & Frantz, 2004; Takase et al., 2019). Learning about nature (Guiney, 2009; Ryan et al., 2001; Takase et al., 2019). Experience and knowledge (Shum et al., 2023). All motivational functions from VFI (Clary et al., 1998) Pleasure in doing something they're good at or working with their hands (Ganzevoort & van den Born, 2020).	What do you gain from participating as a volunteer? Is there anything specific about the volunteer activities that you would like to highlight as important for your participation? Is there something you hope to gain from participating? - Diving experience - Learning Do you believe it is important when applying for a job or further education?
Social	Building of community (Guiney, 2009; Takase et al., 2019) And meeting social needs (Asah & Blahna, 2013; Takase et al., 2019). McDougle et al. (2011) found that the social aspect and possibility to expand on their social network was the strongest predictor for participation. Sharing values (Takase et al., 2019) and meeting like minded people (Bramston et al., 2011). Social norms from friends and family, having similar concerns (Clary et al., 1998; Shum et al., 2023) Motivation in social, values, enhancement, protective or career (Clary et al., 1998).	Is the social aspect an important part of participating in volunteer dives? - Tell a bit more about what it's like to be there in terms of the social aspect. Are volunteer dives important for you to meet new people? If so, in what way? - Shared interests, making new friends... - Networking? Do many people come back for multiple dives? Do you feel a sense of camaraderie within the group? Do you feel a sense of belonging to the group?
Why join	Personally important motivation for joining	To summarize this part, what is important for you to attend? - Is there anything else we haven't discussed? - Is there anything that should be done differently?

Table A3: Relational values, volunteer connection and contribution from project in terms of nature restoration and social and ecological benefits?

The volunteer's perspective on nature and the environment, and their thoughts on what the work can contribute to both nature and society. How significant do they believe the project is for marine ecosystems and society, and how important is it for their own motivation?

Connection to nature / the ocean	Is relationship to nature important for participation? Connection is important for initial and sustained participation (Guiney, 2009). Stronger identification with ocean improves marine citizenship (Buchan et al., 2024). Relational value: Nature is providing more to humans that just the instrumental values, including human well-being (Chan et al., 2016). Important to stay connected to nature (Ganzevoort & van den Born, 2020). Is there a reciprocal relationship (Ryan et al., 2001)?	Is nature an important part of your life? How would you describe your connection to nature? - And more specifically, to the ocean? - As a child? What do you believe has been important for you to develop and maintain that connection?
Environmental concern and awareness	Increased concern for the environment with biospheric values and increased identification and connection with nature (Buchan et al., 2024; Chan et al., 2016; Mayer & Frantz, 2004), further promoting increased environmental citizenship (Mayer & Frantz, 2004; Roszak, 1995; Schultz, 2000). Interest in environmental issues before joining environmental volunteering may increase their participation (McDougle et al., 2011; Takase et al., 2019). The feeling of doing something meaningful (Clary & Snyder, 1999; Clary et al., 1998). Contributing to a sustainable world (Ganzevoort & van den Born, 2020).	How concerned are you about climate and nature-related issues, generally? Are you actively engaged in the topic? Do you have hope for the future? Do you believe we can mitigate climate change and biodiversity loss? - Do you have any thoughts on how?
How can volunteer conservation work contribute?	Environmental volunteering contributes to affect the nature, the volunteer, and society (Guiney, 2009).	In what way do you think the GK project is important? What did you know about the depletion of kelp forests before you started?

	Benefiting the environment is of the most important motivation in environmental volunteering (Bruyere & Rappe, 2007; Ryan et al., 2001), and volunteers wish to contribute (Shum et al., 2023). Hagger et al. (2017) biodiversity enhancement from conservation work to be the most important reason. Volunteer work can function as a valuable resource in achieving restoration targets (McKinley et al., 2017). Environmental volunteering can foster improved governmental management (Buchan et al., 2024; Buchan et al., 2023) . A deeper insight into environmental issues can increase volunteer participation (McDougle et al., 2011; Ryan et al., 2001; Takase et al., 2019).	How do you think the removal of sea urchins affects marine ecosystems? Would you say the restoration of kelp forests is important for nature and/or society? What do you think it would take to get more people involved and participate?
Results	Several studies emphasize the importance of communicating achieved goals and positive outcomes to improve motivation (Guiney, 2009; McAfee et al., 2019; Ryan et al., 2001; Shum et al., 2023). Ryan et al. (2001) highlights the rewarding feeling of seeing tangible benefits, being an important motivation. Important feeling that the little things are an important contribution (Shum et al.).	What results have you seen so far? How quickly did you see the initial results of the sea urchin removal? Are the results of the work important for your motivation to participate? What feelings do you have after participating, and if applicable, seeing the results of the work?
Increased awareness (to GK leaders)	Learning more will increase awareness and willingness to participate (Bramston et al., 2011; Guiney, 2009; Ryan et al., 2001; Takase et al., 2019). Environmental volunteering can foster improved governmental management (Buchan et al., 2024; Buchan et al., 2023) .	Have you noticed a change in interest in the project over time? What about changes in understanding, knowledge, or engagement regarding the spread of the sea urchin problem along the Norwegian coast? If yes, why do you think that is? What ripple effects have resulted from the recent media coverage the project has received?

Lastly, trying to catch any other motivations that the questions did not uncover:

Motivation for participating	What motivates you to join and to continue?	What is a key motivation for participating and continuing your involvement? Is there anything you would like to highlight based on our conversation? How does it feel to be a part of this?

Appendix B. Species recordings data

Table B1: Species recording in 50x50 cm squares in restored kelp forest.

Location	Zone 2					Zone 1				
Year after removal	1	1	1	1	1	2	2	2	2	2
Substrate	Rock									
Depth (m)	2,8	2,6	2,6	2,8	2,7	2,8	2,8	3,1	3	3
Canopy cover (%)	60	80	90	70	90	80	100	100	80	80
Number of Strongylocentrotus droebachiesis					4		2	1	2	
Kelp (Saccharina latissima) seedlings/small plants (number)										
Kelp (Saccharina latissima) large plants (number)	30	20	22	14	20					
Kelp (Saccharina latissima) stipes - missing blades - grazed? (number)						7	5	5	5	12
Kelp (Saccharina latissima) juveniles (number)						7			3	6
Serrated wrack (Fucus serratus) juveniles (% cover)	15	40	12	7	20	8	5		6	
Kelp seedlings (number)	5	1	5	5	5		<1	<1		1
Barnacles (%)	33								3	
Coralline algae (understory cover %)	5	10		5				20	20	5
Canopy cover (%)	25	20	10	30	25	50	40	5	5	10
Waved topshell (Purpursnegl)				1		5			5	
Elbow shell (Albuesnegl)										
Gibbula										
Winged kelp (Alaria esculenta) (number)										
Small snails (blue-striped, lacuna vincta, etc.)	5	10	5	4	15	8	14		3	4
Horse mussel (Modiolus modiolus) (number)										
Blue mussel (Mytilus edulis) (%)	3		2	3	2					

Sugar kelp (Laminaria digitata) + Oarweed (Laminaria hyperborea) (number)		1	<1							
European green crab (Carcinus maenas) (number)										
Smooth periwinkle (Littorina obtusata) (number)						1				
Common whelk (Buccinum undatum) (number)										
		4	2		1			1		
Dillisk (Ptilota gunneri) (%)										
Ceramium sp. (%)	<1									
Cystoclonium purpureum? (%)	5	10	20	10						<1
Desmarestia sp. (%)	5									
Ulva sp. (%)	5	10	5	1	5		10			1
Dictyosiphon chordaria (%)	5	2	5	<1						2
Red algae, crustose (%)	20	5		<1	1					
Red algae, various bushy forms (%)	50	40	40	20	50	5		5	20	5
Chiton (%)	1								10	<1
Chaetomorpha melagonium (%)	<1								1	
Polysiphonia stricta	<1									
Polychaeta sp.		5								5
Tangfern			1							
Ectocarpus			1							
Sphacelaria sp. (fucosa)				1						
Irish moss (Chondrus crispus)		5	5	5				<1	10	1
Kelp worm (Ulke)				1						
Lugworm (Furcellaria lumbricalis) (%)						1				
Hermit crab (Trollkrabbe)							10			
Pomatoceros triqueter (%)							2	3		
Derbesia marina									5	
Location										50

Table B2: Species found in species registering in 50x50 quares, in zone 1 of the restored kelp forest, after one year of removal.

ID	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
yr_after_removal	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Strongylocentrotus droebachiesis (number)	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Desmarestia sp. (%)	25	25							25	25					
Saccharina latissima, young/small plants (number)	13	11	0	2	0	7	0	0	12	6	2	8	8	10	0
Balanus (%)	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
Corallina officinalis (understory cover %)	25	50	70	40	40	40	50	40	60	30	50	70	30	40	40
Canopy cover (%)	70	60	70	80	100	50	60	60	80	100	80	100	100	100	60
Ulvales sp. (%)	5		5		5	5	5				5		5		
Pagurus bernhardus (number)	4	1							1						
Nucella lapillus	2	5	2	4		3		4				2		1	
Patella vulgata	1			4					3						
Gibbula cineraria	1														
Alaria esculenta (number)	2	7	13	12	6	9	5	10	8	4		2	9	0	
Littorina spp.	s	s	s	s	s	s	s	s	s	s					
Modiolus modiolus (number)	2														
Laminaria digitata + Laminaria hyperborea (number)			3		20	38									
Carcinus maenas (number)												1			
Littorina obtusata (number)		5			6				8						1

Table B3: Species recordings in barren ground sites, in 50x50 cm squares.

Site Bergneset	Species	skala	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	Ophiura	Semi quantitative (1-4)	2	2																		
	Corralina officinalis	Semi quantitative (1-4)			2	2		2														2
	Pomatoceros triqueter	Semi quantitative (1-4)		2					2		2	4	4	4	4							
	Gibbula cineraria	Semi quantitative (1-4)								2												
	Gastropod	Semi quantitative (1-4)								2												
	Pagarus sp.	Semi quantitative (1-4)								2												
Site Vatnan																						
	S. droebachiensis	Number	2	2	4	0	2	2	2	0	1	3	8	3	4	0	4	2	14	5	13	5
	Algae cover	Number	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Mytilus edulis	Semi quantitative (1-4)	1											1			2					
	Buccinum undatum	Semi quantitative (1-4)	1			1							1									
	Littorina littorea	Semi quantitative (1-4)	3	3	3	3	3	3					2	1								
	Echinus escuelentus	Number		1							1	1	1		1							

	Ophiura	Semi quantitative (1-4)							1													
	Gibbula cineraria	Semi quantitative (1-4)								2					3		3	3				
	S. pallidus	Number														1		1				
Site Nordspissen barren																						
	Algae cover	% cover	20	20	30		40	10														
	S. droebachiensis	Number	9	1	4	4	9	4	10	4	14	9	13	4	3	9	20	19	2	13	11	10
	Balanus	% cover	40	50	30	40	60	40	65	70	50	40	20	40	20	40	60	70	30	30	30	30
	Modiolus modiolus	Semi quantitative (1-4)	2	2	2	2	1	2	2	2	2			2	2		3	2		2	2	2
	Mytilus edulis	Semi quantitative (1-4)	2		2	2	2	2	2	2	2	2			2	2	2		2	2	1	
	Gibbula cineraria	Semi quantitative (1-4)	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	Littorina littorea	Semi quantitative (1-4)	2	2	2	2		2	2			2	2					2			2	
	Echinus escuelentus	Number																			1	
	S. pallidus	Number																			1	

Table B4: Sea urchin densities before removal in Nordspissen in 50x50 cm squares.

Sqaure id	Zone 1		Zone 2	
1	36		18	
2	40		8	
3	46		44	
4	20		34	
5	38		18	
6	65		28	
7	25		21	
8	73		25	
9	23		24	
10	54	Per m^2	27	Per m^2
	42	**168**	**24.7**	**98.8**

Appendix C. Kelp biomass data

Table C1: Dry weight and AFDW and measurements for carbon content for kelp samples from restored forest, and finding of kelp species in each sample.

Site	ID	Species	Dry weight (g)	AFDW	Diff.	Amount C (est. 100 % C)
1 year of removal	1	*Saccharina latissima, corralina officinalis, Desmarestia aculeata*	17	3,6568	13,627	0,78842616
	2	*Saccharina latissima* (mostly seedlings*), Desmarestia acuelata, Fucus serratus*	2,9	0,5501	2,6029	0,82553124
	3	*Saccharina, Demarestia, Fucus serratus, ulvae sp., Chaetopteris plumosa,*	8,2	1,6261	6,6647	0,80386694
	1	*Saccharina latissima, Corralina officinalis, Chaetopteris plumosa, Fucus serratus*	25,1	8,03	17,07	0,68007968

	2	*Saccharina latissima, Corralina officinalis, Chaetopteris plumosa, Fucus serratus*	10,7	3,95	6,75	0,63084112
	3	*Saccharina latissima, Corralina officinalis, Chaetopteris plumosa, Fucus serratus*	21,7	8,28	13,42	0,61843318
2 yrs. after removal	1	*Saccharina latissima*	78,8	16,0311	61,6298	0,79357566
	2	*Saccharina lattisima, Alaria esculenta, Fucus serratus, Corralina officinalis, Desmarestia acuelata, Chondrus crispus, Chaetopteris plumosa*	35,8	6,6107	29,202	0,81540906
	3	*Saccharina lattisima*	254	56,419	197,634	0,77792429
	1	*Corralina, Chaetopteris plumosa*	N/A	15,1	N/A	N/A
	1	*S. Latissima, alaria*	128,8	30,74	82,96	0,64409938
	2	*Alaria esculenta, S. Latissima*	59,7	22,67	37,03	0,62026801
	3	*Alaria esculenta, S. Latissima*	17,9	6,15	11,75	0,65642458
	3	*Red algea, ulvae sp., Fucus serratus*				

Appendix D. Fauna from kelp samples

Table D1: Number of observed individuals from kelp samples from restored kelp forest identified and counted.

Site		Data type	2 yrs. of removal			1 yr. of removal		
Sample			1	2	3	1	2	3
Sum			195	1579	996	99	327	416
Taxa								
Bivalvia	Indet	Number	0	0	0	0	0	0
	Mytilus edulis	Number	5	241	29	10	63	81
	Hiatella arctica	Number	7	17	21	0	1	0
	Turtonia minuta	Number	0	40	0	0	2	5
	Musculus discors	Number	7	178	12	3	5	15
	Modiolus modiolus	Number	6	30	10	0	2	9
	Anomiidae	Number	0	1	2	0	1	0
	Juvenile	Number	0	41	5	7	2	9
	Cardiidae	Number	0	2	0	0	0	0
Gastropoda	Indet	Number	0	1	0	0	0	0
	Littorina littorea	Number	0	2	0	1	0	1
	Littorina obtusata	Number	2	46	22	2	9	11
	Margarites	Number	36	151	120	3	33	21
	Onoba semicostata	Number	0	13	0	0	0	0
	Lacuna vincta	Number	58	54	200	12	67	89
	Neogastropoda	Number	0	0	0	0	0	0
	Acmaea	Number	7	4	12	4	1	0
	Lacuna parva	Number	2	0	0	0	0	0
	Gibbula	Number	0	0	0	1	0	0
	Nucella	Number	0	0	0	0	0	0
	Rissoa parva	Number	1	137	7	6	41	77
	Onoba semicostata	Number	0	0	12	0	0	1
	Nucella lapillus	Number	0	0	0	1	0	0
	Skenopsis	Number	0	68	0	0	0	14
	Juvenil	Number	2	120	26	11	28	16
Amphipoda	Indet	Number	0	3	5	1	0	0
	Ischyrocerus angipus	Number	3	21	17	6	9	8
	Ampithoe rubricata	Number	0	11	18	0	2	3

	Dexamine sp.	Number	3	54	2	0	4	9
	Corofium sp	Number	11	116	249	16	13	8
	Caprella	Number	0	0	0	0	5	0
	Tritaeta	Number	0	1	0	0	0	0
	Juvenile	Number	0	21	11	5	7	1
Isopoda	Idotea	Number	0	0			5	1
Nematoda	Indet	Number	11	138	90	6	13	9
Polychetae	Indet	Number	1	12	13	1	3	1
	Polynoidae	Number	0	2	4	0	0	0
	Phyllodocidae	Number	8	18	26	0	0	2
	Spirorbis	Obs	>10	<10	>10	>10	<10	0
Chironomidae larvae	Indet	Number	2	8	8	1	8	5
Acaridae	Indet	Number	2	14	0	1	2	19
Foraminifera	Indet	Obs	0	1	>10	>10	2	0
Bryozoa	Bryozoa indet	Obs	2	2	2	0	0	0
	Membranipora	Obs	1	1	1	0	0	0
	Electra	Obs	1	1	1	2	0	0
	Tubulipora	Number	4	1	44	0	0	0
	Dynamena	Obs	2	4	2	1	1	0
Balanidae	Indet	Number	3	1	2	1	1	0
Ostracoda	Indet	Obs	0	0	1	4	0	0
Copedode	Indet	Obs	1	1	2	5	1	1
Mysida	Indet	Number	5	0	6	0	0	0
Echinoidea	Indet	Number	0	0	2	0	0	0

Appendix E. Fauna from artificial traps

Table E1: Number of individuals identified and counted from rope traps, sampled from Nordspissen (kelp forest and barren) and Dåfjord (barren grounds, Bergneset and Vatnan). One sub sample = one rope bundle, five rope bundles = one samples in statistical analysis.

Site		Kelp forest, 2 yrs of removal					Kelp forest, 1 yr of removal					Bergneset, no removal					Vatnan, no removal					Nordspissen, no removal				
Sub sample		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Bivalvia	Bivalvia indet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Mytilus edulis	2	1	0	5	0	1	2	2	2	3	1	0	0	0	0	4	0	1	0	1	1	1	1	0	0
	Hiatella arctica	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Turtonia minuta	2	1	1	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Musculus discors	0	1	3	2	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Modiolus modiolus	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Anomiidae sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Bivalvia juvenile	1	1	1	1	1	4	4	0	2	0	10	6	10	6	10	12	4	9	15	13	1	0	2	0	0
Gastropoda	Gastropoda indet	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Littorina littorea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
	Littorina obtusata	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Margarites	4	3	3	4	2	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
	Onoba semicostata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Lacuna vincta	0	0	4	1	2	1	5	0	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
	Neogastropoda	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	Acmaea	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
	Lacuna parva	0	0	2	1	3	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0
	Gibbula	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	0	1	0	0	0
	Nucella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
	Rissoa parva	1	1	9	3	0	6	6	7	5	4	0	0	0	0	0	0	0	0	0	2	0	2	1	0	0
	Onoba semicostata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Nucella lapillus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Skeneopsis	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Gastropoda juvenil	5	6	10	5	3	10	5	6	8	4	0	0	1	0	0	3	1	2	1	1	0	0	1	0	2
	Amphipoda indet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Ischyrocerus angipus	0	1	2	3	1	5	8	4	1	1	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0
Amphipoda	Ampithoe rubricata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Dexamine	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Corofium	1	0	0	1	1	4	3	0	4	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Caprella	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Amphipoda juvenile	0	0	2	0	0	0	0	3	0	1	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0
Isopoda	Idotea	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nematoda	Nematoda indet	3	6	6	4	3	2	2	1	2	2	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2
	Polychaeta indet	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	2	0	1	0	0	0	0	0
Polychetae	Polynoidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Phyllodocidae	2	2	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	Spirorbis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chironomidae larvae	Indet	0	0	0	0	1	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Acaridae	Indet	0	5	4	3	2	5	3	2	7	4	1	1	1	0	0	0	0	0	0	0	0	1	1	2	2
Foraminifera	Indet	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Bryozoa	Bryozoa indet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	Membranipora	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Electra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Tubulipora	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Dynamena	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Balanidae	Indet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ostracoda	Indet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Copedoda	Indet	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0
Mysida	Indet	0	0	0	0	0	0	0	0	0	0	0	0	4	2	0	0	0	0	0	0	1	0	0	0	0
Echinoidea	Indet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ophiuridae	Indet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
	Paguridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Decapoda	Galatheidae	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0

Table E2: Data from restored kelp forest in Porsangerfjord, provided from NIVA. One sub sample = one rope bundle, three rope bundles = one samples in statistical analysis

Site	site3			site5			site3			site5		
Sub sample	1	2	3	1	2	3	1	2	3	1	2	3
Year	2014	2014	2014	2014	2014	2014	2015	2015	2015	2015	2015	2015
Years after removal	1	1	1	1	1	1	2	2	2	2	2	2
Hydroidae/Obelia	1											
Turbellaria									1			
Nematoda	1			1								
Nemertea												
Polychaeta												
Polynoidae						1			2			1
Phyllodocidae												
Crustacea												
Ostracoda	1			1			1	1	1	1	1	1
Copepoda Harpacticoida	1	1	1	1	1	1	1	1	1	1	1	1
Janira sp.												
Idotea sp							1	2	1	28	10	39

Idotea pelagica				1		1						
Idotea granulosa												
Idotea baltica												
Munna kroyeri												1
Stenothoidae			1									
Lyseanasidae												
Aoridae indet							2		1	1		
Apherusa bispinosa												
Apherusa jurinei												
Gammarellus homari												1
Calliopiidae	3											
Ischyrocerus angipes	5	25	5	17	17	3	2	4	8	38	48	34
Ischyrocerus sp/juv	32	44	16	52	40	19						
Dexamine thea				4		5	3	4	1	2	1	4
Amphithoe rubricata												
Plaustidae												
Corophium sp							1					
Gammarus juv												
Iphimedia												
Amphipoda indet						1						
Caprella sp	1			1	1	1						
Hippolyte												
Eualus												
Selerocrangon sp								1				
Pagurus												
Hyas							1		3			
Acmaea												
Gibbula cineraria												
Margarites				3	5	11		4	1	2	4	12
Lacuna sp.	10	4	3			2	23	7	6	3	5	2
Rissoa sp							5					
Onoba												
Skeneopsis							3					
Nucella												
Onchiodoridae												

Nudibranchia juv	3	3										
Mytilus	17	28	15	10	3	8	19	9	4	5	4	2
Hiatella arctica	3	4	9	1	7	6					1	
Musculus sp												
Cardidae												
Strongylocentrotus dr.									1			
Ophiopholis aculeata					1							
Ophiura sp												
Chironomodae	1							1				
Midd												
Pholis gunnellus												