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Effects of brown seaweed harvesting on sea- and shorebirds in Norway. Assessment of existing knowledge, spatial overlap and attitudes of interest groups

Nina Dehnhard, Jenny Mattisson, Signe Christensen-Dalsgaard, Berit Junker-Köhler, Tessa Bargmann, Thomas Kvalnes

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Dehnhard, N., Mattisson, J., Christensen-Dalsgaard, S., Junker-Köhler, B., Bargmann, T., Kvalnes, T. 2024. Effects of brown seaweed harvesting on sea- and shorebirds in Norway. Assessment of existing knowledge, spatial overlap and attitudes of interest groups. NINA Report 2502. Norwegian Institute for Nature Research.

Trondheim, November 2024

ISSN: 1504-3312
ISBN: 978-82-426-5316-1

AVAILABILITY
Open

PUBLICATION TYPE
Digital document (pdf)

QUALITY CONTROLLED BY
Bård G. Stokke

SIGNATURE OF RESPONSIBLE PERSON
Research director Svein-Håkon Lorentsen (sign.)

CLIENT(S)/SUBSCRIBER(S)
Statsforvalteren i Trøndelag

CLIENTS/SUBSCRIBER CONTACT PERSON(S)
Ingrid Bjørklund, Carina Ulsund

COVER PICTURE
Foraging purple sandpiper *Calidris maritima* © Thomas Kvalnes

KEY WORDS
- Norway, Trøndelag
- seabirds, shorebirds, waders
- brown seaweed, kelp, tangle, knotted wrack
- *Laminaria hyperborea Ascophyllum nodosum*
- harvesting, trawling
- effect, consequence
- literature review
- attitudes of interest groups
- information effect

NØKKELORD
- Norge, Trøndelag
- sjøfugl, vadefugl
- alge, tare, grisetang, stortare
- *Laminaria hyperborea, Ascophyllum nodosum*
- høsting, tangskjæring, taretråling
- effekt, konsekvens
- litteraturstudie
- holdninger til interessegrupper
- effekt av informasjon

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Abstract

Dehnhard, N., Mattisson, J., Christensen-Dalsgaard, S., Junker-Köhler, B., Bargmann, T., Kvalnes, T. 2024. Effects of brown seaweed harvesting on sea- and shorebirds in Norway. Assessment of existing knowledge, spatial overlap and attitudes of interest groups. NINA Report 2502. Norwegian Institute for Nature Research.

There is a high commercial interest in harvest of wild brown seaweed internationally and in Norway. In Norway, harvest of wild seaweed almost exclusively targets two species: the kelp species tangle (*Laminaria hyperborea*) that grows in the subtidal zone, and knotted wrack (*Ascophyllum nodosum*), which grows in the intertidal zone. Despite the increasingly mechanized harvest being practiced since the 1970s, relatively little is known about the effects of harvesting on the ecosystem and especially on seabirds and shorebirds that use these habitats.

The aims of this report were to 1) collate information about how much seaweed is harvested annually, monthly and by region, 2) review the existing literature on effects of seaweed harvest on birds, to summarise existing knowledge and identify knowledge gaps, 3) investigate the spatial overlap between areas harvested for kelp and three species of seabirds - a multiyear case study in the region north of Vikna, central Norway, and 4) assess the attitudes of different interest groups towards harvesting of seaweed.

Between 2016 and 2023, on average 149 506 tonnes of kelp and 17 954 tonnes of knotted wrack were harvested in Norway annually. The peak of harvesting for both types of seaweed occurred in the period April-October, which coincides with the migration period and the breeding season of birds.

The literature review identified seven articles that investigated effects of seaweed harvest on birds. One study found acute disturbance effects during harvest on a shorebird species. The other six articles investigated how the modification of the habitat after seaweed removal affected birds, with two articles focusing on tangle (kelp), two on knotted wrack, and one on the removal of beach-cast seaweed. The last article was a review article focusing on ecosystem-effects of kelp harvesting. Overall, the literature review reflected that effects of harvest on seabirds and shorebirds are poorly understood and little studied. For most seabird and shorebird species that occur in the coastal zone in Norway, it remains unclear if and how harvest of seaweed affects food availability and what consequences disturbance during harvest has.

Our case study found a large spatial overlap between areas for kelp harvest and foraging locations of European shags (*Gulosus aristotelis*) and black guillemots (*Cepphus grylle*) breeding at Sklinna (65.2°N, 10.99°E). Common guillemots (*Uria aalge*) from Sklinna and black guillemots from Muddvær, Vega (65.6°N, 11.7°E; located about 50 north of Sklinna) did not use harvested areas much. These results highlight that the overlap between commercially harvested areas can be substantial for some seabird species during the breeding period, but also differ among populations and species. Hence potential effects of kelp harvesting may impact some populations and species more than others.

The survey revealed an overall negative attitude and cautious stance towards the harvesting of seaweed among respondents from all interest groups. Overall, respondents were in support of protective measures like restricting harvest to areas outside of protected areas and limiting it to periods outside of the migration and breeding seasons.

Many seabird and shorebird populations worldwide are experiencing severe declines caused predominantly by anthropogenic impacts. Ecosystem-based management and the reduction of human impact in areas that are important for wildlife, can contribute to stop and reverse this trend. Our report identified numerous knowledge gaps about possible effects of seaweed harvest on seabirds and shorebirds. Closing these knowledge gaps and managing seaweed harvest according to the best knowledge available, are important steps to improve the situation for seabirds and shorebirds.

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Sammendrag

Dehnhard, N., Mattisson, J., Christensen-Dalsgaard, S., Junker-Köhler, B., Bargmann, T., Kvalnes, T. 2024. Effekter av tang- og tarehøsting på sjøfugl og vadefugl i Norge. Evaluering av eksisterende kunnskap, romlig overlapp og folks holdninger. NINA Rapport 2502. Norsk institutt for naturforskning.

Det er stor interesse for å høste tang og tare kommersielt både i Norge og internasjonalt. Den kommersielle tang- og tarehøstingen i Norge fokuserer i all hovedsak på to arter: stortare (*Laminaria hyperborea*), som vokser i den sublitorale sonen, og grisetang (*Ascophyllum nodosum*), som vokser i den litorale sonen. Til tross for at den i økende grad mekaniserte høstingen har pågått helt siden 1970-tallet er det svært begrenset kunnskap om effekter av høstingen på økosystemet, og på sjø- og vadefugler i dette habitatet.

Formålet med denne rapporten er 1) å samle og systematisere informasjon om hvor mye tang og tare som høstes, fordelt på år, måneder og region, 2) å gjøre en litteraturstudie av effekten av høsting av tang og tare på fugler, for å oppsummere eksisterende kunnskap og identifisere kunnskapsmangler, 3) å undersøke den romlige overlappen mellom områder hvor tare høstes og tre sjøfuglarter – i en flerårig studie i området nord for Vikna, midt-Norge, og 4) å undersøke ulike interessegruppers holdning til høsting av tang og tare.

I perioden 2016 til 2023 ble det i gjennomsnitt høstet 149 506 tonn med stortare og 17 954 tonn med grisetang per år. Fordelingen av høstingen gjennom året viser at både stortare og grisetang har en høstingstopp i perioden april-oktober, en periode som sammenfaller med trekkperiodene og hekkesesongen til fugler i området.

Litteraturstudiet identifiserte syv vitenskapelige arbeider som undersøkte effekten av tang- og tarehøsting på fugler. Av disse var det en studie som så på og fant akutte forstyrrelseseffekter av høsting på en vadefuglart. De andre seks studiene så på hvordan endringer av habitatet som følge av tang- og tarehøsting påvirket fugler. To studier fokuserte på tarehøsting, to på høsting av grisetang, og en på fjerning av tangvoller i strandsonen. Det siste studiet var en litteraturstudie som fokuserte på økosystemeffekter av tarehøsting. Generelt reflekterte funnene i vår litteraturstudie at en har lite kunnskap om og få studier av effekten av tang- og tarehøsting på sjø- og vadefugl. For de fleste sjø- og vadefuglene som opptrer langs kysten av Norge er det uklart hvordan og i hvilken grad tang- og tarehøsting påvirker næringstilgang og hvilke konsekvenser forstyrrelser under høsting har.

Resultatene i studiet fra Vikna viste at det er stor romlig overlapp mellom områdene for høsting av tare og områdene for næringssøk for toppskarv (*Gulosus aristotelis*) og teist (*Cepphus grylle*) på Sklinna (65.2°N, 10.99°Ø). Lomvi (*Uria aalge*) på Sklinna og teist på Muddvær, Vega (65.6°N, 11.7°Ø; 50 km nord for Sklinna) brukte i mindre grad områder hvor høsting av tare foregikk. Disse resultatene viser av overlappen mellom områder for kommersiell tarehøsting kan være omfattende for en del sjøfuglarter under hekkesesongen, men at det kan være forskjeller mellom bestander og arter. Påvirkningen fra tarehøsting vil dermed kunne variere tilsvarende.

Spørreundersøkelsen vår avdekket at respondentene fra alle interessegrupper generelt viste en tydelig negativ holdning til tang- og tarehøsting og ønske om forsiktighet ved utøvelse av høsting. Respondentene støttet bevaringstiltak som å begrense høsting til områder utenfor verneområder og til perioder som ikke sammenfaller med trekkperiodene eller hekkesesongen.

Mange bestander av sjø- og vadefugler i verden viser kraftige bestandsnedganger, der den viktigste årsaken er antropogene påvirkninger. Økosystembasert forvaltning og reduksjon i menneskeskapte påvirkninger i områder som er viktige for bestander kan bidra til å stoppe og reversere denne trenden. I rapporten vår har vi identifisert en rekke kunnskapsmangler om effekten av tang- og tarehøsting på sjø- og vadefugler. Kunnskapsinnhenting og bærekraftig forvaltning

av tang- og tarehøsting i henhold til best mulig praksis, vil være viktige steg framover for å forbedre situasjonen for sjø- og vadefugler og forhindre utilsiktede negative påvirkninger.

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Contents

Foreword

The County Governor of Trøndelag in Central Norway is working with the designation of new protected areas as well as the revision and extension of existing protected areas covering both land and sea areas. For revising and defining the regulations within protected areas, the county governor requested additional information about the effects of seaweed harvesting on shorebirds and seabirds. For this purpose, the Norwegian Institute for Nature Research was commissioned by the County Governor of Trøndelag to carry out a project in order to report about existing knowledge and knowledge gaps on the effects of harvesting seaweed on seabirds and shore-birds, to conduct a case study to investigate spatial overlap among seabirds and kelp harvesting in the area around Sklinna and Vega, and to investigate the public opinion about harvesting seaweed.

The case study comparing overlap between seabirds and areas where seaweed is harvested would not have been possible without existing GPS-tracking data. At Sklinna, data were collected as part of the SEAPOP program (www.seapop.no/en), which is financed by the Norwegian Ministry of Climate and Environment via the Norwegian Environment Agency, the Norwegian Ministry of Petroleum and Energy via the Norwegian Research Council (grant 192141), and the Norwegian Oil and Gas Association (now Offshore Norge). Fieldwork at Sklinna was facilitated through a rental agreement with the Norwegian Coastal Administration for the lighthouse station, which allowed extended stays on the island. Data collection at Muddvær was co-funded by Stiftelsen Vegaøyan Verdensarv, Vega Verneområdestyre and the County Governor in Nordland through the Norwegian Environment Agency. Thanks also to Jannike Wika, Rita Johansen and Oddleif Dahlen for local support at Muddvær,and thanks to the numerous field assistants on Sklinna and Muddvær who helped collecting the GPS tracking data used in the case-study.

We would like to thank our contact persons at the County Governor, Ingrid Bjørklund and Carina Ulsund. We also thank the Norwegian Directorate of Fisheries that made the fine-scale data on kelp harvest available to us and provided us with contact information for tourist angling businesses. A big thank you also to everyone who filled out the survey. Finally, we would like to thank Bård Gunnar Stokke for doing the quality control of the report.

15th November 2024, Nina Dehnhard

1 Introduction

There is a high commercial interest in harvesting wild grown seaweed to extract alginate and produce seaweed flour (Monagail et al. 2017, Lotze et al. 2019). Traditionally, seaweeds were harvested at a small scale by hand, but commercial harvest is now increasingly mechanized and intensified (Monagail et al. 2017). This results in much larger quantities being harvested covering larger areas than previously. The impacts of seaweed harvest on primary consumers as well as secondary and tertiary consumers such as birds needs to be taken into account in the management of seaweed exploitation to ensure that harvest is sustainable and does not lead to unintended adverse effects.

Knotted wrack (*Ascophyllum nodosum*; “grisetang” in Norwegian) and the kelp species tangle (*Laminaria hyperborea*; “stortare” in Norwegian) are the two main species of brown seaweed which are harvested for commercial purposes on a large scale in Europe (Monagail et al. 2017; **Figure 1**). Knotted wrack grows on rocky shores in the intertidal zone down to about 2 m deep and forms a wide canopy at high tide (Pereira et al. 2020). Tangle usually grows between about 5-30 m deep and forms large subtidal kelp forests (Bekkby et al. 2009). When harvested, large tangle plants are pulled up from the bottom by trawling along the seabed (Vea & Ask 2011) leaving the youngest and smallest plants within the stretches of clearings along the bottom. Knotted wrack is sucked up and cut above the rocks they grow on, using specially designed vessels that can cover large sections of the intertidal zone during high tide (Monagail et al. 2017). The regrowth of tangle from the remaining understory of small individuals takes approximately four years before its biomass has reached its pre-harvest height (Steen et al. 2016). However, it has been found that while the density is higher after regrowth, the height and mean age of the tangle after four years is still lower than before harvest (Steen et al. 2016). Trawled areas of kelp forests are also more homogenous than before harvest as the understory after four years has still has not reached its pre-disturbed density (Steen et al. 2016). Complete regrowth of the canopy of knotted wrack may take around 6-8 years (Ingólfsson and Hawkins 2008), and other species such as bladder wrack (*Fucus vesiculosus*) can increase in abundance and dominate the harvested area in the meantime (Cervin et al. 2004).

Both tangle and knotted wrack play important roles in shaping the local species community by providing areas with high habitat complexity where algae and sessile invertebrates can grow (Christie et al. 2003, Norderhaug et al. 2002, 2015, Teagle et al. 2017), and mobile invertebrates, fish and birds can find shelter and/or foraging grounds at both high and low tide (Rangeley & Kramer 1998, Pavia et al. 1999, Hamilton 2001, Lorentsen et al. 2010, Johnston et al. 2021). For instance, Hamilton (2001) found that the height of knotted wrack is important for eider ducklings (*Somateria mollissima*) during their first weeks when they are not able to dive for food but dabble for invertebrates in the floating canopy. Lorentsen et al. (2010) showed that great cormorants (*Phalacrocorax carbo*) favoured areas with kelp forest when foraging and similar results have been found for European shags (*Gulosus aristotelis; hereafter: shags*) and black guillemots (*Cepphus grylle*) (Christensen-Dalsgaard et al. 2017, Dehnhard et al. 2022, 2023). Cote et al. (2001) found that juvenile cod (*Gadus morhua*) favoured areas with kelp for shelter, while older individuals seem less strongly associated with kelp areas (Cote et al. 2003). Natural detritus of seaweeds which have broken loose from the bottom and are washed ashore also play an important role in the ecosystem by forming belts and piles of rotting seaweed (“tarevoller” in Norwegian), which are rich in invertebrates that help breaking down the biomass (Kirkman & Kendrick 1997, Ulaski et al. 2023). Piles of beach-casted seaweeds form important foraging sites for shorebirds along the coastline (Johnston et al. 2021).

In Norway, kelp harvest, targeting primarily tangle, is managed by dividing the coastline into smaller sectors, most of which are opened for harvest every five years. Each sector is one nautical mile (1.852 km) wide (0.5 nautical miles in Nordland county), and the sectors go from the coastline to deep water. There are no limits set to the amount of kelp which can be harvested within open sectors. However, the sectors do not account for the topography or depth of the seabed, and hence harvest is limited to those areas where kelp forests occur and are available for trawling. Knotted wrack, on the other hand, is mainly harvested along the shores in shallow water and only requires the approvement from landowners on private ground. Private ground for properties which border towards the sea in Norway commonly includes areas at sea out to the beach step (“marbakken” in Norwegian) or to two meters depth at middle low tide. Hence, large areas with knotted wrack in Norway can be harvested without consulting nature management authorities, and therefore harvest of knotted wrack is overall less regulated than that of tangle. Harvesting of knotted wrack typically takes place with a frequency of 4-6 years, but it is not forbidden to harvest the same area in consecutive years (Steen 2005; Steen et al. 2024). Harvesting of tangle and knotted wrack is – depending on the regulations and reasons for protecting an area –allowed within the boundaries of some protected areas in Norway, sometimes with restrictions on which parts of the year harvest is allowed. For instance, Muddværet bird conservation area (Nordland county) allows the harvest of knotted wrack outside the nesting period for birds, but harvest of tangle is not allowed at any time (Forskrift om Muddværet fuglefredningsområde 2002), while Kvaløy and Raudøy nature reserve (Trøndelag county) allows harvest of knotted wrack and tangle year-round (Forskrift om fredning av Kvaløy og Rauøy 1973). At Grandefjæra nature reserve (Trøndelag county), which is part of the larger Ramsar Site ‘Ørland Wetland System’ (Ramsar Sites Information Service 2023) due to its international importance as a stopover site for migratory waders and waterbirds, harvest of tangle and knotted wrack is allowed year-round but requires a permit from the County Governor (Forskrift om Grandefjæra våtmarksreservat, Ørland 1983). Local concerns have been brought forward to the County Governor about the fact that knotted wrack has been harvested at Grandefjæra right before the start of the spring migration (I. Bjørklund personal communication).

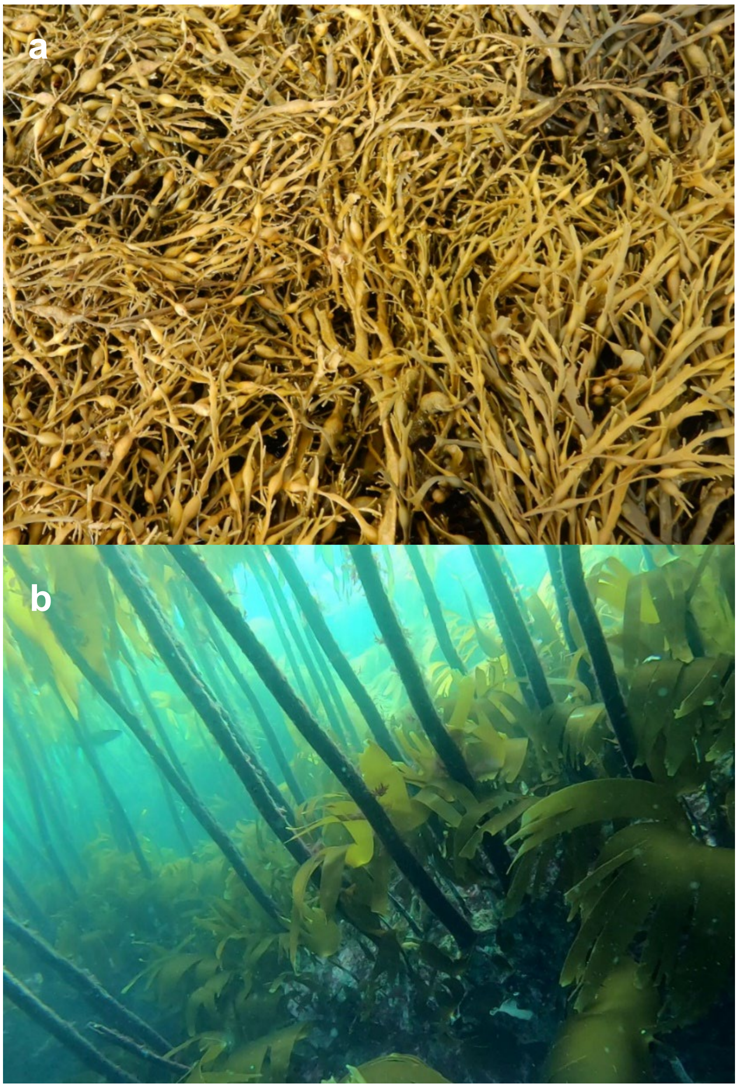

Figure 1*. Knotted wrack (a), also called grisetang in Norwegian, forming a dense layer on the rocks at low tide. Foto: Nina Dehnhard. (b) Tangle (stortare in Norwegian) is forming three-dimensional kelp forests under water. Foto: Johanna Järnegren.*

There are two main impacts of seaweed harvest on birds associated with the seaweed ecosystem: disturbance from the harvest activity itself (e.g. due to the presence of the boats and noise of the operating gear) and habitat modification from the removal of seaweeds potentially altering prey availability (e.g. causing a reduction of invertebrates and fish that find shelter in the seaweed habitat, or a reduction of beach-casted seaweed). The magnitude of these effects will depend on the frequency and timing of harvest, the size of the harvested area and the amount of available seaweed in an area which is harvested each time. The intensity and scale of commercial mechanical harvest compared to harvest by hand have raised concerns among nature managers, commercial and recreational fishers and local bird enthusiasts whether the seaweed harvest have negative impacts on biodiversity at higher trophic levels.

1.1 Study objectives

The high commercial interest in harvesting wild grown seaweed is happening at the same time as the global biodiversity crisis is being acknowledged and the need for ecosystem-based, sustainable management of natural resources is being put forward (e.g. Cardona Santos et al. 2023; Pförtner et al. 2023; Fortuna et al. 2024). Many seabird and wader populations are declining globally (Paleczny et al. 2015; Stroud et al. 2006), and Norway is no exception to this pattern (Fauchald et al. 2015; Lislevand et al. 2021; Stokke et al. 2021). This highlights the need for sustainable, knowledge-based management of the marine and coastal zones including human impacts such as harvest of seaweed. The aim of this report is to summarize existing knowledge about brown seaweed harvesting in Norway, effects on seabirds and shorebirds, and to identify potential knowledge gaps.

Public opinion can influence the designation of protected areas or the revision of regulations in existing protected areas. Thus, we wanted to investigate attitudes to and concerns about environmental issues related to seaweed harvesting. Our survey included questions about harvesting seaweed in protected areas and during specific times of the year, such as during the breeding season or migration period, when birds may be particularly sensitive to disturbance and habitat modification. Previous research has shown that factual information can impact attitudes towards nature management (Ajzen 1991; Tabi et al. 2014) and strengthen support for conservation measures (Sundt-Hansen et al. 2021). We therefore provided respondents with information and state of the art research findings about seaweed harvesting in the middle section of the survey to test if attitudes and concerns changed.

In detail, we identified four different study objectives with specific questions we wanted to answer:

1. Collate background information: How much seaweed is currently being harvested in Norway and how is the harvest spatially and temporally distributed?
2. Review of the existing literature: What do we know about the effects of seaweed harvest on sea- and shorebirds? What are the knowledge gaps?
3. Case study between Vikna and Vega to quantify the overlap between seabirds and kelp harvesting: How many foraging locations of seabirds are in areas where kelp is being harvested, and how many foraging locations are in local protected areas?
4. Assessment of the attitudes of different interest groups towards seaweed harvesting: What are the attitudes and the potential for learning of different interest groups concerning potential environmental issues related to seaweed harvest? Do people change their attitudes after they have received additional information about scientific findings on impacts of harvesting on birds, how, when and where harvesting is performed?

2 Material and Methods

2.1 Data on seaweed harvest in Norway

Data on seaweed harvest in Norway from 2016 to 2023 was collected from the Directorate of Fisheries (Directorate of Fisheries 2024a). We limited the data to 2016 and onwards as we focus on the current status for seaweed harvest. These data are reported by vessels that harvest seaweed (from “landings- og sluttseddelregisteret”) and include data about the vessel which harvested, gross weight (kg) and species which was harvested, and the date and place of harvest. Tangle and knotted wrack, the species harvested at an industrial scale in Norway, are included in the statistics and only small and sporadic amounts of other species are harvested. Thus, the data was limited to these two species but may also include small amounts of other kelp species in the years 2016-2018, as the records did not differentiate between species of kelp in these years. Each record of harvested seaweed is assigned to an important fishing area (“hovedområde” in Norwegian, **Figure 2**), which are quite large regions for reporting commercial harvest defined by ICES (International Council for the Exploration of the Sea) and the Directorate of Fisheries (Directorate of Fisheries 2024b). For tangle, which is harvested in regulated sectors (**Figure 3,** Directorate of Fisheries 2024b), more fine scaled locations within each major fisheries area are also recorded. This information is not available for intertidal seaweed such as knotted wrack.

Tangle is not harvested north of Vega (Nordland), and the sectors in Nordland, which is the northernmost harvest area in Norway, were first opened for harvesting in 2022 after a trial period starting in 2013. In Nordland, the sectors are 0.5 nautical miles wide, while they are 1 nautical mile wide elsewhere (**Figure 2**). Kelp forests further north than Vega are absent or in the state of slow recovery after the collapse in the 1970s and 1980s due to overgrazing by the green sea urchin (*Strongylocentrotus droebachiensis*) (Christie et al. 2019).

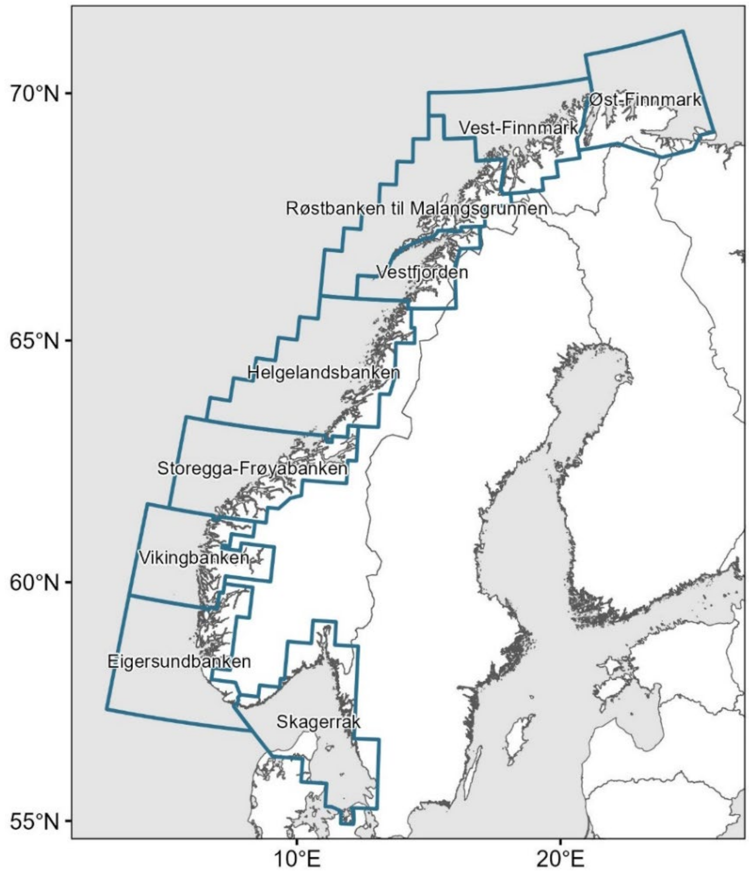

***Figure 2**. Overview of the important fishing areas (“hovedområder”) along the coast of Norway, defined by ICES and the Directorate of Fisheries.*

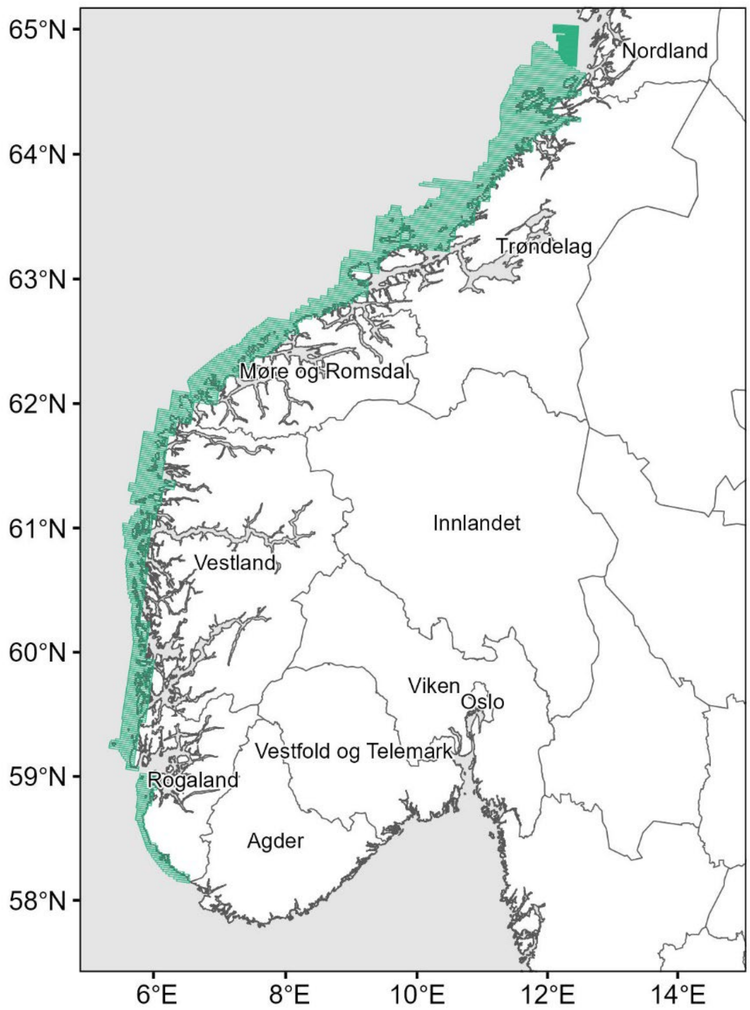

Figure 3. *Overview of the sectors for kelp harvest. Each sector is 1 nautical mile wide and goes from the coastline to the deep water. The harvest is regulated such that each sector is harvested every fifth year, with exceptions in Rogaland and Nordland. In Rogaland each sector is harvested every fourth year. In Nordland each sector is 0.5 nautical miles wide and half the sectors are harvested every fifth year, and the other half every tenth year.*

2.2 Literature review

The literature search was focused on identifying existing knowledge about effects of seaweed harvest on sea- and shorebirds. We limited the search to scientific papers indexed in the search engine Web of Science Core Collection (WoS). WoS is a comprehensive database which indexes scientific articles from 1987 to present. This search engine makes it easy to find relevant articles and allows for structured searches. Grey literature was not included in the literature review but reports on seaweed harvest in Norwegian and English which were found when writing up the report were browsed to ensure no primary literature were missed. To structure the literature search we used the PICO-framework, where relevant search terms are formulated for each of four different groups: P – Population, I – Intervention, C – Comparison and O – Outcome (**Table 1**). The P category set the focal group, I set the treatment or intervention of interest which the P category is subjected to, and O set the effect or outcome of interest. C – Comparison was left blank as we did not have a second invention for comparison with harvest. To formulate search strings, the search terms within the categories P, I and O were combined with OR and the categories were combined with AND. To ensure that we had included the search terms necessary to capture the literature of interest we selected a few benchmark papers which the search results were compared against (**Supplementary Materials 6.1**).

Table 1. *Overview of search terms used in the PICO-framework for the literature search. * was used to capture all forms of a word. C – Comparison in the PICO-framework is used to define search terms for what the intervention is compared to but was found not to be feasible for this search.*

P – Population	I - Invention	O - Outcome
Seaweed	harvest*	seabird*
Kelp	trawl*	shorebird*
Macroalgae	removal	gull*
Brown alg*	experiment*	tern OR terns
Knotted wrack*		wader*
Rockweed		bird OR birds
Ascophyllum*		auk OR auks
Fucus*		waterbird*
Laminaria*		seaduck*
Saccharina		waterfowl*
Macrocystis		
Himanthalia*		

To further enhance the ability of the literature search to discover relevant literature we performed citation chasing on the benchmark papers which we had identified using the tool Citationchaser (Haddaway et al. 2022). This tool searches the open-source scientific literature data base *lens.org* for all papers which are referenced by or have a reference to the benchmark papers. The final selection of literature found in the literature search was screened for relevance using Rayyan (https://www.rayyan.ai/). Rayyan is a tool for literature screening which allows a streamlined and efficient filtering of papers based on titles and abstracts. We performed a two-step screening on the literature. First, duplicates were removed, then we screened the titles and abstracts and applied the inclusion and exclusion criteria in **Table 2** to decide which papers were included in the second screening step. In the second screening step, the main text of the articles was assessed using the same criteria (**Table 2**) to exclude any articles which after all did not meet the criteria set. Removal of duplicates and the screening of articles were performed by one person (Thomas Kvalnes).

Table 2. *Inclusion and exclusion criteria for literature found using the search terms in* ***Table 1****.*

Include	Exclude
Literature studies/ systematic reviews	Does not include birds
Experimental studies	Not relevant for Norwegian seas
Observational studies	No measures of effects
Relevant for Norwegian seas	Not relevant for harvesting
Qualitative indicators	Does not measure effects on birds
Quantitative indicators	
Clear reporting of effect	
Effects on birds	

2.3 Case study: Quantifying the overlap in seabird foraging areas and kelp harvesting between Vikna and Vega

2.3.1 Existing GPS tracking data

Sklinna (65° 13’ N, 10° 58’ E) is the largest seabird colony in Trøndelag county (**Figure 4**), and one of the best studied within the geographic range where kelp is harvested in Norway. Sklinna consists of a small archipelago (approximately 4 x 4 km in size) that is located about 40 km from the mainland, and about 20 km north of Vikna. Seabird populations on Sklinna have been monitored since the start of the 1980s, and this monitoring became part of the National Monitoring Programme for seabirds from 1988 onwards. In 2007, Sklinna was defined as a key site within SEAPOP (www.seapop.no/en), and breeding success, adult survival and diet of several species have been monitored annually since. In addition, GPS tracking data of shags, common guillemots and black guillemots have been collected at Sklinna.

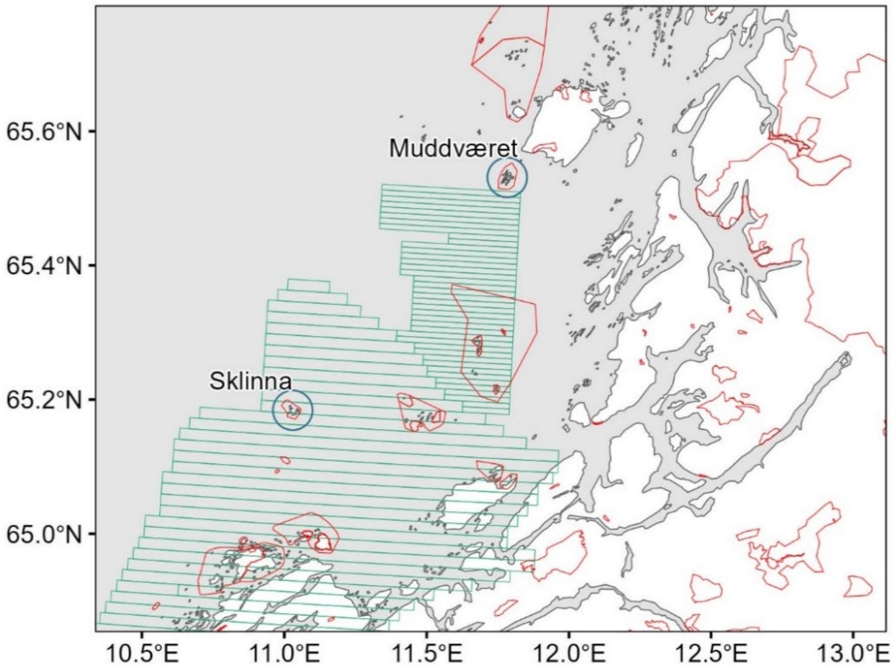

Figure 4. *Map showing the locations of the seabird colonies at Sklinna and Muddværet in Trøndelag and Nordland counties. The borders of protected areas are shown in red and sectors for kelp harvest are shown in green. Overlap of harvesting sectors and protected areas does not necessarily imply that harvest is occurring within protected areas – see Results Section 3.3.*

Approximately 2000 pairs of shags breed on Sklinna, which makes it one of the largest colonies in the world. The conservation status of shags is considered as *least concern* (LC) and is hence not red-listed in Norway (Stokke et al. 2021), but shags are a species of special concern ("norsk ansvarsart") as Norway holds approximately one third of the European population. The common guillemot population on Sklinna is one of few populations that is increasing within Norway and was estimated to be 1870 pairs in 2024. The species is red-listed as *critically endangered* (CR) on the Norwegian red list, while black guillemots are red-listed as *near threatened* (NT) (Stokke et al. 2021). Sklinna holds about 450 breeding pairs.

Foraging behaviour and space use of shags breeding on Sklinna have been studied using GPS-loggers since 2010, and data from 10-67 individuals has been collected annually (**Table 3**). For this purpose, adult breeding birds (mostly attending chicks younger than 3 weeks) were equipped with either a GPS-logger or a combination of a GPS-logger and a temperature-depth recorder (TDR). Most GPS-loggers were of the type I-gotU GT-120 (Mobile Action Technology, China), which was modified and put into heat shrink for waterproofing. The average mass of GPS-loggers was 24 g, while GPS- and TDR-loggers together weighed about 31 g. Loggers were mounted on the tail of shags using black Tesa tape for a duration of 1-3 days, after which birds were recaptured, and loggers were retrieved to obtain the data. During this period, GPS-loggers recorded positions once per minute (see Dehnhard et al. 2022 for more details about the instrumentation).

In 2020-2022 an additional 10 shags annually were equipped with solar-powered Pathtrack nanofix GPS loggers (Pathtrack Ltd, Otley, UK). This type of logger downloads collected data to a base station via UHF and thus allows to track birds over a longer period. Birds were equipped with loggers during incubation or early chick-rearing in mid-June, and some of the loggers collected data until mid-September, several weeks after chicks had fledged (**Table 3**). Pathtrack loggers were programmed so that they collected data every 5 min if their batteries were full, but intervals automatically became longer if the charging status became worse (10 min, 15 min, 20 min and so on).

Common guillemots on Sklinna have been equipped with PathTrack nanofix GPS loggers annually since 2019. These GPS-loggers download data automatically to a base station. GPS-intervals were 4 min, and loggers were attached with black Tesa tape to the feathers on the lower back of the birds. Only birds that had small to medium-sized chicks were equipped with loggers, and the deployment period covered the first two weeks of July (**Table 3**).

Black guillemots on Sklinna were instrumented with GPS-loggers in 2013, 2018 and 2019. In 2013 Mataki GPS-loggers (Debugs Innovations, Cambridge, UK) were used. In 2018 and 2019, Pathtrack nanofix GPS loggers were used. Both logger types download data automatically to a basestation. Loggers were attached with black Tesa tape on the lower part of the back. Birds were equipped during the first two weeks of July, which coincides with late incubation or early chick-rearing (**Table 3**). Birds were caught either on their nests or when approaching or leaving the nesting areas, using mist nets or noose mats. For birds not caught on the nests, the nest content was not known, and it is possible that some of the birds tracked were in fact non-breeders.

Black guillemots were also tracked as part of another project on the small archipelago Muddvær (65°34′N, 11°41′E; 3 x 2 km in size) located in Nordland county (**Figure 4**). Muddvær is located 53 km north of Sklinna and four km south of Vega, and the colony holds about 100 breeding pairs of black guillemots. Muddvær is one of the southernmost archipelagos and breeding sites within the Vega Unesco World heritage area, which got its Unesco status for its tradition centered on the eider down harvesting. Black guillemots on Muddvær were tracked with Pathtrack nanofix GPS loggers (remote download) during the second half of July of the year 2021, coinciding with the chick-rearing period (**Table 3**). Birds were captured when approaching or leaving their nests, using noose mats, and as for Sklinna, the nest content was not known in all cases, meaning that some of the birds tracked may have been non-breeders. More details about the instrumentation of black guillemots on both Sklinna and Muddvær can be found in Dehnhard et al. 2023).

We obtained permits to work at Sklinna from the County governors of Trøndelag and permits to work on Muddvær from the local landowners. Ethical permits to catch birds and attach loggers were granted by the Norwegian Environment Agency and The Norwegian Food Safety Authority.

2.3.2 Harvest data

Detailed data on kelp harvest between 1 October 2013 and 30 September 2022 was made available by the Directorate of Fisheries in Norway (www.fiskeridir.no). The data was a combination of two different data sources: Daily catch and activity report (DCA) and vessel monitoring system (VMS). The DCA is part of the daily capture diary where the skipper marks a start and stop location and total biomass harvested for each day. The VMS is data from a tracking device on the kelp trawlers, which reports the time, location, speed and heading every 10 minutes while harvesting. Data from VMS was used to define the spatial and temporal location of the harvest. The received VMS data was already cleaned by the Directorate of Fisheries to only include locations where the trawler travelled with a maximum speed of 1.5 knots (2.78 km/hr), indicating harvest (higher speeds indicates travel between harvest locations). As the trawlers do not harvest in straight lines but follow a zig-zag pattern, spatial location of trawling activity could not be determined continually but were restricted to locations every 10 minute. To overcome this uncertainty, we created a buffer with a 200 m radius around each harvest location reported by the VMS to identify areas potentially effected by harvested.

Table 3. *Overview of number of existing GPS tracking data from Sklinna and Muddvær that was used to assess the seabirds' overlap with harvest areas. Presented are the details about logger types and logger masses, tracking period (range of dates), breeding stage during the tracking period, number of individuals tracked, number of GPS locations (excluding outliers and positions near the colony; see section 2.3.3), and number of identified foraging locations per species and colony. TDR = temperature depth recorder, inc = incubation, cr = chick-rearing, post fl = post fledging.*

Species	Colony	Year	Logger types	Logger mass	Tracking period	Breeding stage	Individuals	GPS locations	Foraging locations
European shag	Sklinna	2010-2022	IgotU GT-120 + TDR	24-31g	08.06-15.07	inc & cr	550	345,833	242,003
European shag	Sklinna	2020-2022	Pathtrack nanoFixR + TDR	31g	11.06-15.07	inc & cr	30	26,375	19,109
European shag	Sklinna	2020-2022	Pathtrack nanoFixR	22g	15.07-21.09	late cr & post fl	25	43,496	29,386
Common guillemot	Sklinna	2019-2021	Pathtrack nanoFixR	11-13g	04.07–14.07	cr	43	19,215	16,457
Black guillemot	Sklinna	2013	Mataki GPS logger	18g	03.07–12.07	inc / cr	6	1,490	387
Black guillemot	Sklinna	2018-2019	Pathtrack nanoFixR	11g	01.07–14.07	inc / cr	25	6,705	5,753
Black guillemot	Muddvær	2021	Pathtrack nanoFixR	11g	20.07–29.07	cr	9	3,853	3,226

2.3.3 Statistical analyses

GPS data were collected from a total of 580 shags (2010-2022), 43 common guillemots (2019-2022), 31 black guillemots at Sklinna (2013, 2018-2019) and 9 black guillemots at Muddvær (2021) (**Table 3**). GPS positions were checked for outliers and erroneous GPS positions were removed using a speed filter with a maximum speed of 30 m/s, and a speed filter of 15 m/s was applied on strongly curvaceous flight paths (angle cos > 0.97), following previous procedures (Lorentsen et al. 2019, Dehnhard et al. 2022). We removed locations near the colony (500 m buffer for shags and common guillemots around their respective colonies, 300 m buffer around the colony for black guillemots), as birds are mostly roosting on the water or on rocks near the colony and show little foraging behaviour, while the focus of this study was on foraging behaviour outside of the actual colony.

GPS data show where birds have been, but it is more difficult to assess if they have been using an area for foraging or not. TDR-loggers, showing diving behaviour, can help to identify foraging activity, but TDR data were only available for shags during the early breeding period, and only for some of the common guillemots equipped with loggers in 2022. We therefore used a method called «Expectation Maximization binary Clustering (EMbC)» to classify behaviour for each GPS time-stamp. The EMbC classification is based on speed and turning angle and can give an indication if birds are foraging or travelling between their colony and foraging locations. For shags equipped simultaneously with GPS- and TRD-loggers, EMbC worked well to identify foraging locations: GPS time-stamps that according to the EMbC represented foraging locations (low speed, and either high or low turning angle), corresponded to locations where TDR-loggers registered dive activity (Dehnhard et al. 2022). We also used EMbC recently to identify likely foraging locations of black guillemots, although we were lacking to possibility to validate this information (Dehnhard et al. 2023). Thus, in this current analysis, we used EMbC for all three species as an indicator for foraging and classified GPS-time stamps that were associated with low speed and either high or low turning angle as “foraging locations”. The number of GPS locations and foraging locations per species, colony and tracking period is given in **Table 3**.

Each foraging location from the birds were spatially related to either a harvest area (within 200 m buffer, see 2.3.2), a protected area, or outside both of these areas (“other areas”). Data on the borders of protected areas were collected from Geonorge (Geonorge 2024). We did not separate harvested areas into pre- and post-harvest but rather showed the amount of overlap with foraging areas as a potential impact.

2.4 Web-based survey to assess attitudes of different interest groups

We designed a web-based survey which consisted of several multiple choice and open questions. The questionnaire, including the information provided to respondents can be found in the Appendix (**Supplementary material 6.5**). The survey itself was divided into four main sections. The first section focused on questions related to the respondent, such as gender, interest group category and how important certain activities related to tangle and knotted wrack harvesting was to the participant. The second section asked questions about respondent’s attitudes to harvesting tangle and knotted wrack, while the third section provided some information about the environmental impact of these activities on birds. This information was based on state-of-the art research, as well as some statements on the harvesting methods, including a short video showing knotted wrack harvesting. The final section contained a selection of the same questions that were asked in the second section to see what difference, if any, the information given in the third section had on responses.

When gathering potential respondents for our survey, we chose to focus on interest groups that use areas where tangle and knotted wrack harvesting is conducted, in addition to groups who may have economic interests in seaweed harvesting. We tried to obtain a sample that was as representative as possible. However, due to the nature of the survey, we expected different response rates from different groups and chose to send the survey to more recreational angling businesses (264) and commercial fishers (48), for example, than to NGOs (9). This was to ensure that we would get responses from all the different interest groups.

Our survey was sent to 395 respondents. The survey was sent out to most interest groups by email on the 4th of July, 2024. Boat owners with commercial fishing businesses did not receive the invitation and the link to the survey by text message until September, since we did not have email addresses for these potential participants or the possibility to send it to them earlier. The recipients who received the survey by email (347) received three reminders to complete the survey. Recipients who received the survey by text message (48) received two reminders. The survey remained open for everyone until the 23rd of October.

Respondents from research, public administration and NGOs were chosen based on the existing network that members of the project team have, and who are known to work with the subject matter that is relevant to the survey questions. These respondents were supplemented with additional individuals that were suggested by feedback from the respondents. To find relevant people representing the recreational sector and groups that may have an interest in tangle and knotted wrack harvesting, we used Google searches to find local registered boating, hunting, kayaking, fishing, hiking, diving and sailing associations. We also obtained e-mail addresses for tourist angling businesses in the region from the Norwegian Directorate of Fisheries. Respondents from the industry were also mostly found using Google searches and media articles about companies operating tangle and knotted wrack harvesting. The same is true for commercial fish landing sites (“Fiskemottak” in Norwegian). Contact information for commercial fishers was found using the boat registry at the Norwegian Directorate of Fisheries. Since the extraction of contact information in this case was rather time intensive, we chose a sample of a maximum of five commercial fishers per municipality in the region of interest (11 municipalities in Trøndelag). Three of the 11 municipalities had less than five registered vessel operators.

Potential participants came from public administration (municipalities, county governors and the Norwegian environmental agency), NGOs working with environmental issues, scientific and research institutions, interest groups such as local outdoor sports, boating, fishing and hunting organizations, and industry. The latter group was diverse, as it included the tourism industry (tourism angling businesses), commercial fishers, and companies that extract and process seaweed. The first question in the survey asked which of these groups the respondents identify most with (industry, research, public administration, NGO, commercial fishers, recreation, other category). In our analyses we grouped respondents by the category they identify most with because this is likely to influence how they respond to the questions in the survey.

When analysing the survey results, we followed the categorization that respondents chose to identify with. The overlap between how we categorized respondents and how they categorized themselves do not correspond completely. This can be because people often have multiple roles in society or choose to respond to surveys using a different starting point. For example, they may work in one field but consider that the subject of the survey is more relevant to their hobby. It is therefore more important to consider how the respondents categorise themselves, because this is what will influence their responses.

We sent an official proposal for approval to conduct the survey to the Norwegian Data Protection Services (SIKT) in spring 2024 and received their approval to conduct the study as planned. In our survey invitation we also indicated to the respondents that their personal data will be treated confidentially (**Supplementary material 6.4**). Confidentiality has also been assured by referring only to interest groups and not to specific respondents in this report.

We used the software program Qualtrics to design and send the questionnaire as well as the reminders to the respondents**.** After finishing data collection, we transferred all data into the statistical software program SPSS (IBM, Version 27). There we prepared the data for analysis. In order to analyse potential changes in attitudes between the pre- and post-information measurements, we selected only those cases where respondents had answered both respective questions. Then we conducted paired sample t-tests for those questions with interval scales, and Wilcoxon`s signed rank test for those with ordinal scales. Tests were run pooled for all interest groups together (i.e. one test per survey question), to avoid multiple testing and effects of small sample size within groups. Effect sizes were presented as Cohen's d values for the paired samples t-tests and Z-values for Wilcoxon`s signed rank test. P-values were considered significant at a value of < 0.05. The number of respondents that answered both the pre- and post-information part of the survey ranged from N = 20-29 (industry), 8-12 (research), 7-10 (administration), 4-6 (NGO), 14-19 (commercial fishing), 9-16 (recreation), and 6-9 (other).

3 Results

3.1 Seaweed harvest in Norway

Knotted wrack and kelp (primarily tangle) are mainly harvested in the important fishing areas Helgelandsbanken and Storegga-Frøyabanken in Norway (**Figure 5**). Kelp is additionally harvested in Vikingbanken and Eigersundbanken (**Figure 5**). A very small amount of kelp was harvested in Vest-Finnmark in 2021, outside the harvest sectors. For knotted wrack, a small amount was harvested in Vestfjorden in 2019. In the years 2016 to 2023 an average of 149 476 tonnes (SD = 11 184) of kelp and 18 076 tonnes (SD = 2 170) of knotted wrack have been harvested annually. Thus, about 10 times more kelp than knotted wrack has been harvested each year. Seasonally, the peak of harvesting for both knotted wrack and kelp is in the period from April to October (**Figure 6**), with less harvesting happening during winter. The more detailed records of kelp harvest allowed the harvest records to be divided into counties (**Figure 7**), showing that Trøndelag and Møre og Romsdal are the two counties with the highest amounts of kelp harvested in Norway. The harvest sectors for kelp in Nordland county opened for the first time in 2022 (**Figure 7**). The harvested kelp in Nordland is a small proportion of the total harvest of kelp in 2022 and 2023, but the sectors in Nordland also do not cover as large areas as in the other counties where the whole coastline have sectors for kelp harvest (see **Figure 3** and **Figure 4**).

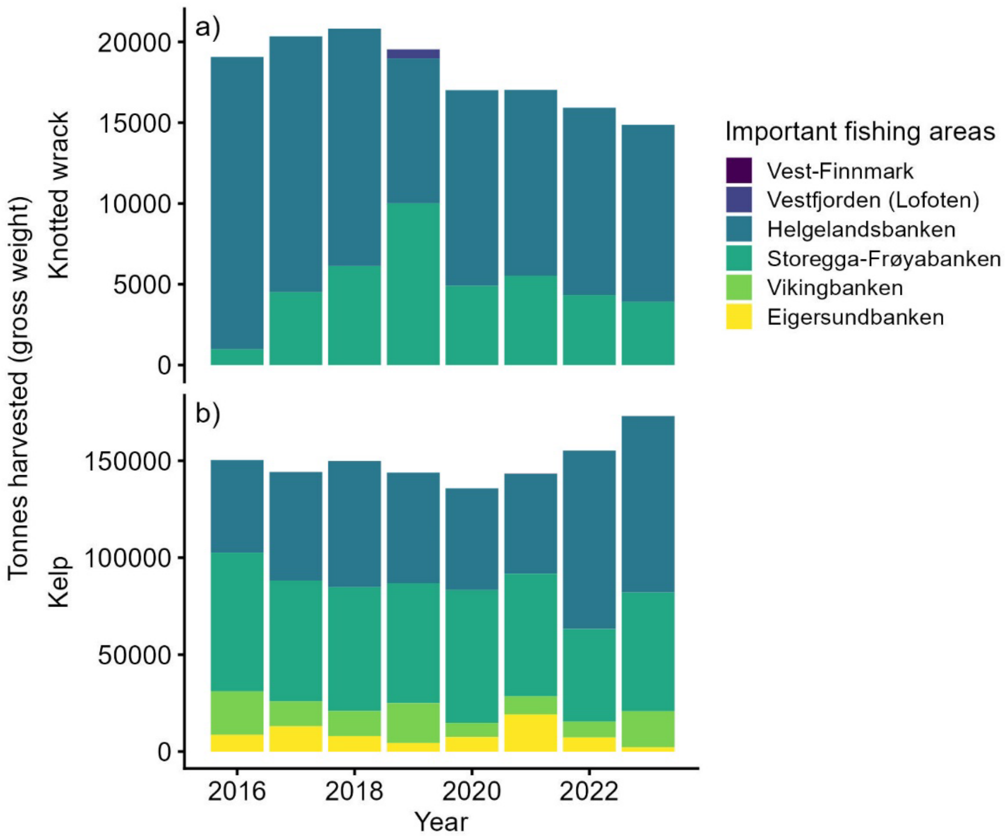

Figure 5. *Total recorded harvest (in tonnes) pear year of a) knotted wrack and b) kelp in the years 2016-2023 in important fishing areas in Norway.*

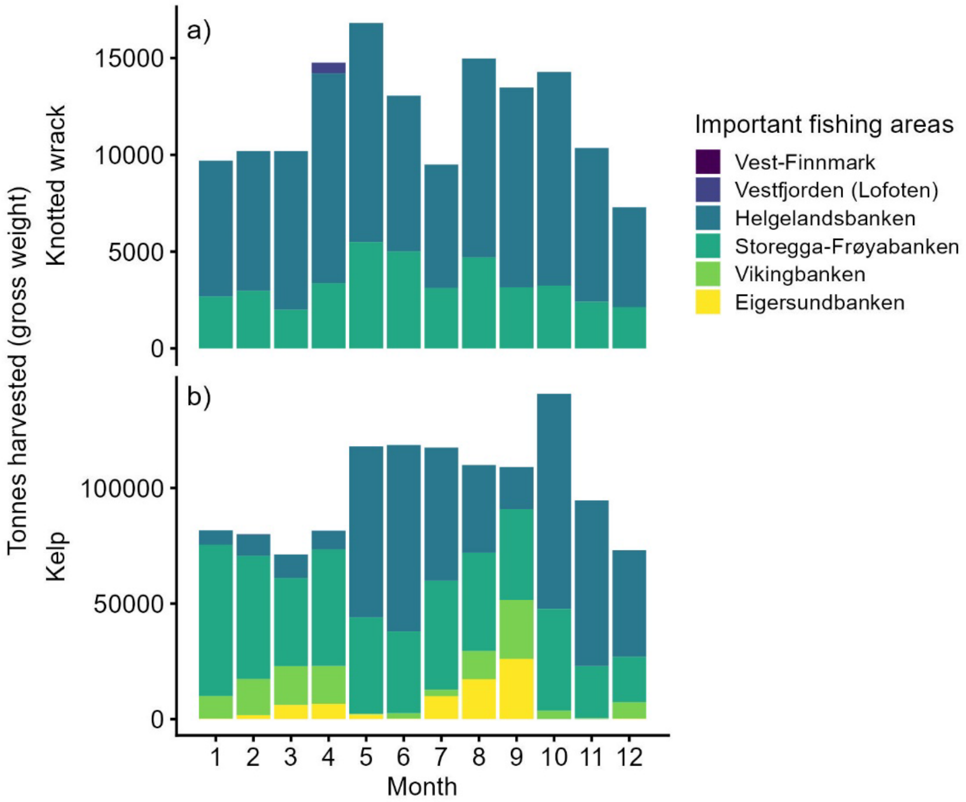

Figure 6. *Total recorded harvest (in tonnes) per month of **a**) knotted wrack and **b**) kelp in the years 2016-2023 in important fishing areas in Norway.*

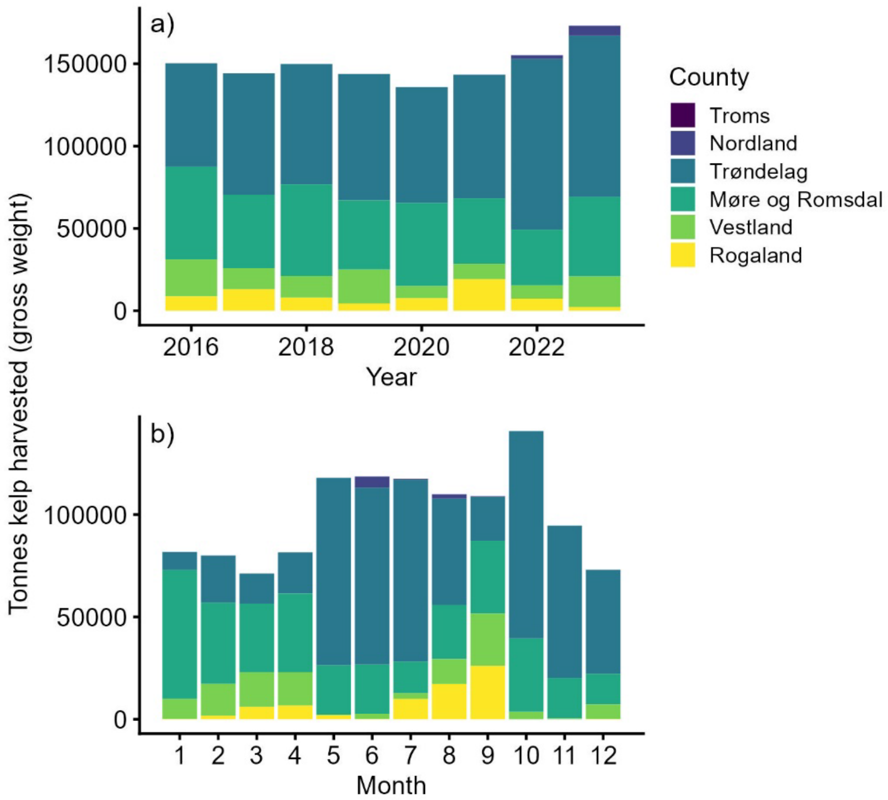

Figure 7. *Total recorded harvest of kelp (in tonnes) per **a**) year and **b**) month in the counties of Norway.*

3.2 Literature review

In total 296 unique articles were found in the literature review and included in the screening for relevance. Of these, 140 were found in the literature search on WoS, 161 were found using citation chasing and five were found in both searches. Excluding those which could not be related to the effects of seaweed harvest on birds, only seven articles were found to fit the criteria (**Table 2, Supplementary Materials 6.2**). Two articles assessed the effect of subtidal seaweed (tangle) harvest on the foraging behaviour in seabirds, one on shags (Christensen-Dalsgaard et al. 2020) and the other on great cormorants (Lorentsen et al. 2010). Three articles assessed the effect of intertidal seaweed (knotted wrack) harvest on birds. Two of these investigated effects on abundance, where the first assessed the abundance of all observed sea- and shorebirds (Johnston et al. 2024) and the other assessed the abundance of common Eider ducklings Blinn et al. 2008). The third article investigated the disturbance of intertidal seaweed harvest (*Agarophyton chilensis*) on a shorebird, Hudsonian godwit (*Limosa haemastica*) (Navedo et al. 2019). In the last article which was found, Dugan et al. (2003) investigated the effect of clearing beach-casted seaweed on the abundance of shorebirds. Finally, in a recently published article Carranza et al. (2024) performed a review of ecological consequences of kelp removal to assess the research effort in this area, the trends in effects and the groups of species which are studied.

One out of two articles assessing the effects of subtidal seaweed harvesting found an effect of kelp harvesting on feeding behaviour of cormorants and shags. In the study by Lorentsen et al. (2010), great cormorant foraging was studied in unharvested sites and nearby harvested sites in the Sula archipelago (Trøndelag county, central Norway). A combination of visual field observations in one year (2003) and radio-tracking of 11 great cormorants (in the period 2001-2002) were used. They found that radio-tracked great cormorants preferred to forage in areas with kelp, compared to areas without kelp which were used according to their availability in the area and areas deeper than 30 meter which were used less than their availability. The field observations showed that areas which were unharvested and had >50% kelp cover were associated with an increased number of foraging great cormorants, while areas harvested the previous year had equal number of foraging cormorants as unharvested areas with <25% kelp cover. Furthermore, great cormorants performed less dives in areas which were unharvested and had >50% kelp cover compared to areas which were unharvested and had <25% kelp cover. The areas harvested the previous year did not differ from the two other types of areas but showed results more similar to areas with low kelp cover. These findings were interpreted as an increased foraging effort due to lower foraging yield when the kelp cover was low. Christensen-Dalsgaard et al. (2020) performed a similar comparison for shags from Sklinna (Trøndelag county, central Norway), however using a before-after-control-impact (BACI) approach. Shags were instrumented with GPS-loggers and depth recorders in the years 2013 to 2018, with a total of 24-57 individuals instrumented each year. Despite considerable spatial overlap in areas used between shags and areas trawled, they did not find any difference in dive behaviour during foraging in harvested and unharvested sites while the proportion of kelp significantly increased dive activity. However, the probability to observe diving activity was higher in harvested sites after harvest than in control sites. Thus, shags had a higher probability of diving in harvested sites but did not increase the numbers of dives. However, the spatial resolution of the data specifying the harvested areas was on the scale of 1843 × 780 meters, quite large relative to the width of trawl tracks, and the temporal resolution (data was assembled per month) made it difficult to link and compare it to the fine-scale, high-resolution data collected by tracking the birds with GPS and dive loggers. Hence, behavioural changes within harvested patches may have occurred at a finer temporal and spatial scale although they could not be detected in the study. Christensen-Dalsgaard et al. (2020) therefore concluded with highlighting the need for further research before concluding whether kelp harvesting has effects on seabird populations or not. The two studies on the effect of kelp harvesting on feeding behaviour of cormorants and shags are conducted differently in term of temporal length (one year versus six years) and methods (observations and tracking vs. tracking). Any of these differences can contribute to the different results obtained and makes it difficult to generalize. The two studies mentioned above were the only studies on effects of kelp harvest on birds out of 69 articles found in a recently published review article which assessed ecological or environmental effects of kelp harvesting (Carranza et al. 2024). Carranza et al. (2024) identified that there was a lack of long-term studies of the impact of kelp harvest at larger spatial scales which takes into account the patchy mosaic of kelp forests. Most studies only focused on kelp forest population effects and effects on local algae and sessile fauna associated with the kelp forests.

The two articles on effects of intertidal seaweed (knotted wrack) harvest on bird abundance both found indications of negative effects of seaweed harvest. Blinn et al. (2008) studied the abundance of common eider ducklings in an observational study over two years (2000 and 2001) at Bay of Fundy, New Brunswick, Canada. From June to August weekly visits to count ducklings were made to a set of eight harvested and four control sites. Regulations in New Brunswick set a minimum cutting height of 25 cm. The number of common eider ducklings along the shoreline was found to be lower at harvested than unharvested sites when the shoreline had a steep slope, but such an effect was not found at gradual sloped sites, where the available intertidal habitat is larger. The study did not reveal how much time passed between harvesting and bird surveys. The abundance of ducklings was slightly positively related to the availability of knotted wrack after removal of one site where the seaweed *Fucus vesiculosus* ("blæretang" in Norwegian) were relatively abundant. However, the density of knotted wrack was quite high at both harvested and unharvested sites, and no difference between the two types of sites was found. The other study used a repeated-measures before-after-control-impact (BACI) methodology and focused on the abundance of all species of birds in the intertidal zone along the shoreline both high and low tide (Johnston et al. 2024). The study was conducted at 21 harvested and 19 unharvested sites in the years 2018 to 2020 in Maine, USA. Pre-harvest surveys were conducted once for each site from August to October 2018 and were followed up with two surveys per site shortly after harvest in August to December 2019 (year during which harvest occurred) and two surveys per site one year after harvest in August to November 2020. The harvest was conducted between June and November 2019 and regulations in Maine sets a minimum cutting height of 40,6 cm and maximal harvest intensity of 17 % of biomass per year. Overall, bird abundance decreased from pre-harvest to the year during which harvest occurred but increased again one-year post harvest. This effect was most clear in the low-tide assemblage of species, which mostly consisted of gulls and waders. However, effect sizes were small (amounting to less than one bird), and bird numbers were overall low in the area. Most of the observations were of common eiders, double-crested cormorants (*Phalacrocorax auratus*), American crows (*Corvus brachyrhynchos*) and herring gulls (*Larus argentatus*). The study did not find any general relationship between the average biomass of knotted wrack and the number of birds observed across sites and concluded that the overall effects of knotted wrack harvesting on birds were likely rather small.

There was only one study on the disturbance effect of seaweed harvest. Navedo et al. (2019) performed monthly surveys to count wintering Hudsonian godwit (hereafter godwits) at Chiloé Island in Chile from October-November to February-March in 2013-2014 and 2014-2015. They performed the counts at one harvested and one unharvested site. The harvested site was harvested by hand for the red algae *Agarophyton chilensis*, which earlier grew naturally at the site but now is cultivated due to a collapse of the natural seaweed bed. Humans were often accompanied by dogs during harvest. Both sites were found to have large numbers of foraging godwits during low tide. They found that the abundance of foraging godwits decreased with increasing number of people in the harvested site. The foraging activity (proportion of birds present which forage) was higher in the unharvested than the harvested site, but there was no effect of the number of people on foraging activity in the harvested site. The literature review did not yield any studies that investigated the disturbance effects on birds of seaweed harvest using vessels.

The final study found can also be related to effects of intertidal seaweed harvest. Dugan et al. (2003) collected data on the monthly number of shorebirds from November 1996 to May 1997 at 15 sandy beaches in southern California, USA. with beach-cast seaweed. Birds are often attracted to beach-cast seaweed as they commonly have a rich community of macrofauna, primarily arthropods. At beaches where beach-cast seaweed was groomed or removed, there was a decreased abundance of two species of shorebirds with decreased cover of beach-casted seaweed and no effect on the abundance of four other shorebird species (Dugan et al. 2003). Dugan et al. (2003) attributed the difference in effect to species differences in the foraging behaviour, where species which capture prey on the surface or in the air are more affected than species which search for buried prey.

3.3 Case study: Quantifying the overlap in seabird foraging areas and kelp harvesting between Vikna and Vega

The GPS tracking dataset covered three seabird species from two different colonies. Tracking effort varied between species and colonies. Black guillemots at Muddværet were tracked only during one year (2021), and data from 9 different individuals were collected. In contrast, the dataset of shags from Sklinna covered 605 individuals tracked over a period 13 years (2010-2022; see **Table 3**).

Harvested areas were used at a relatively high degree by both foraging shags (36% of all foraging locations overlapped with harvested areas) and black guillemots at Sklinna (56% of foraging locations overlapped with harvested areas, **Table 4**). While shags utilized protected areas more than harvested areas (51% of foraging locations in protected areas), the opposite was observed for black guillemots (23% of foraging locations in protected areas). Common guillemots at Sklinna and black guillemots at Muddvær did not use neither harvested nor protected areas much (≤ 8%, **Table 4**). There was some variation in the use of harvested areas between years (**Figure 8**), but there was no general trend which could be related to the increasing number of areas being harvested or re-harvested. Thus, birds (here mainly shags) used harvested areas at an equal proportion independent of whether it was pre- or post-harvest.

Both shags and black guillemots at Sklinna forage in the surroundings of Sklinna and their foraging areas overlap to a large degree with harvested and protected areas (**Figure 9 and 10**). On the other hand, common guillemots at Sklinna forage more pelagic and thus use harvested and protected areas less (**Figure 11**). The foraging area of black guillemot at Muddvær overlap with several patches of kelp forest which are neither protected nor affected by harvest (by 30 September 2022). However, some of the areas used by the black guillemots are within sectors where harvest is allowed (**Figure 12**).

Almost all individual birds at Sklinna used harvested areas for foraging at least once: 97% of the shags (90-100% per year), 93% of the common guillemots (89-100 % per year) and 94% of the black guillemots (86-100 % per year). Of the nine black guillemots instrumented at Muddvær in 2021, only one individual used harvested areas for foraging and only during one trip.

Shags from Sklinna were foraging in nine different protected areas, in four of which the harvest of kelp and knotted wrack were explicitly prohibited (**Table 5**). Black guillemots from Sklinna used five different protected areas, and common guillemots four, with four and three of these prohibiting the harvest of both kelp and knotted wrack year-round. Black guillemots from Muddvær used only one protected area, Muddværet fuglefredningsområde, where commercial harvest of knotted wrack is allowed outside of the breeding season (**Table 5**). According to harvest data made available for us, kelp harvesting did not occur in any of the protected areas but very close to the border. A short (40 minutes) trip was observed into Leknesøyene dyrelivsfredning but we cannot be certain that harvest actually occurred during this trip (**Figure 9-12**).

Table 4. *Proportion of GPS locations located in marine protected areas and in harvest areas separated between bird species and colony. For shags, we separated between data covering the incubation and chick-rearing period (early, < 15 July) and the late chick-rearing and post-fledging period (late > 15 July).*

			% of all GPS locations		% of foraging locations	
Species	**Colony**	**Stage**	**Protected**	**Harvest**	**Protected**	**Harvest**
European shag	Sklinna	Early	43	33	51	36
European shag	Sklinna	Late	39	32	46	36
Common guillemot	Sklinna	-	6	5	6	5
Black guillemot	Sklinna	-	25	53	23	56
Black guillemot	Muddvær	-	8	<1	7	<1

Table 5. *Marine protected areas used by the different seabird species at Sklinna and Muddværet for foraging. Names of protected areas listed in bold letters indicate that intertidal and subtidal (kelp) seaweed is protected under the legal regulations. Numbers in superscript indicate that: [1] harvesting of intertidal (knotted wrack) and subtidal (kelp) seaweed are excepted from the legal regulations (allowed); [2] the harvest of intertidal seaweed (knotted wrack) is excepted from the legal regulations (allowed) during parts of the year (1st August – 31st March); [3] the harvest of intertidal seaweed (knotted wrack) is excepted from the legal regulations (allowed) during parts of the year (1st August – 31st March), but harvest has to occur with traditional methods; [4] the regulations specify that all vegetation which is important for birds are protected; while they do not explicitly mention seaweed, the municipality area plan ("Kommuneplanens arealdel" in Norwegian) states that harvest of seaweed is generally not allowed within protected areas. All the protected areas in the table are within sectors for kelp harvest, except for Horsvær naturreservat (where approximately three quarters of the area is within sectors) and Muddværet fuglefredningsområde.*

Species	Colony	Protected areas used for foraging
European shag	Sklinna	Sklinna naturreservat[3]
		Sklinnaflesin biotopvernområde
		Kvaløy og Rauøy naturreservat[1]
		Borgan og Frelsøy dyrelivsfredning[1]
		Borgan og Frelsøy naturreservat[1]
		Horta naturreservat
		Horta fuglefredningsområde
		Horsvær naturreservat[2]
		Leknesøyene dyrefredningsområde[4]
Common guillemot	Sklinna	Sklinna naturreservat[3]
		Sklinnaflesin biotopvernområde
		Horta naturreservat
		Horta fuglefredningsområde
		Horsvær naturreservat[2]
Black guillemot	Sklinna	Sklinna naturreservat[3]
		Sklinnaflesin biotopvernområde
		Horta naturreservat
		Kvaløy og Rauøy naturreservat[1]
	Muddvær	Muddværet fuglefredningsområde[2]

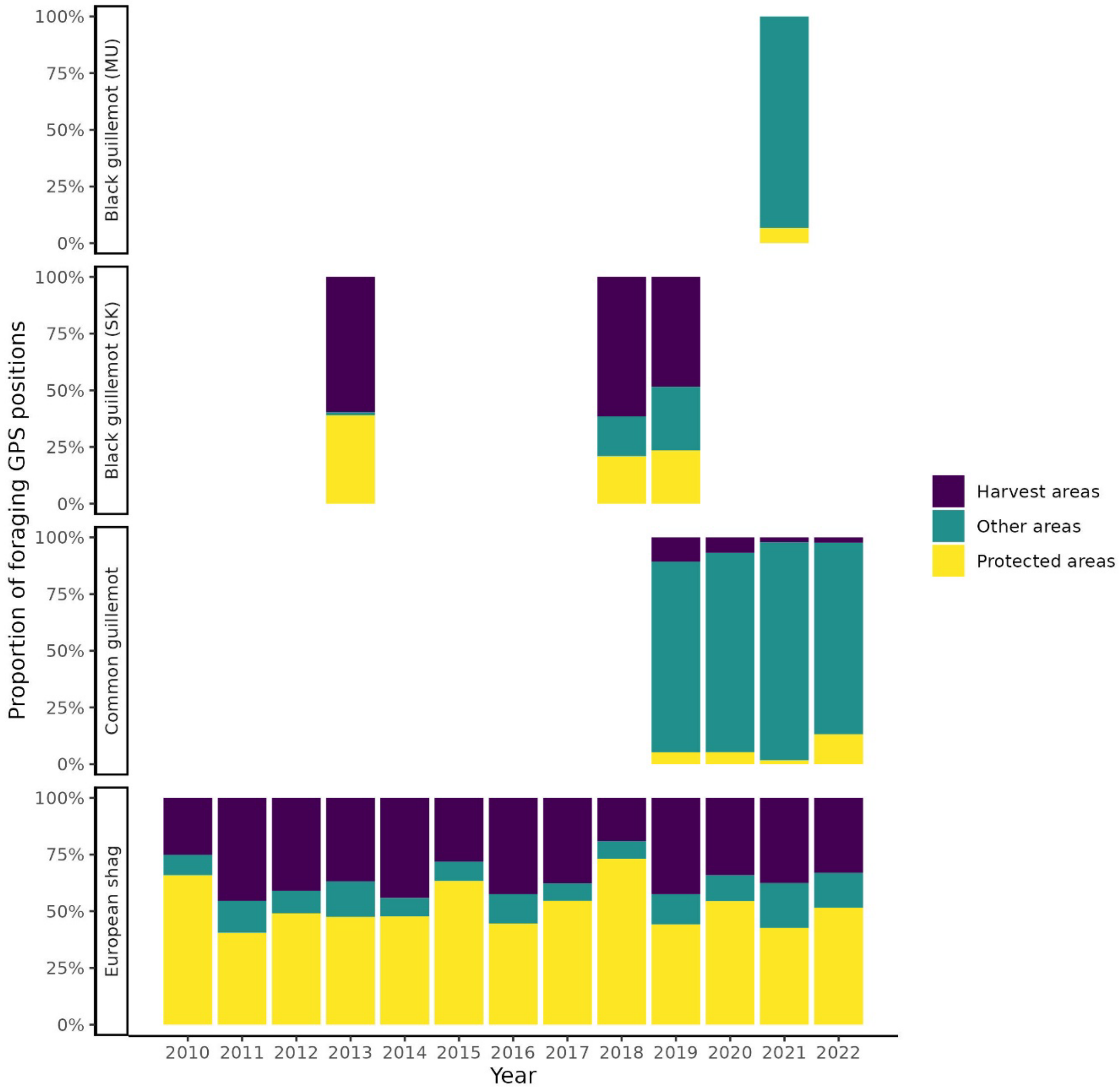

Figure 8. *Annual variation in proportion of foraging locations within protected areas (yellow), harvest areas (dark purple) and other areas (green) for three species of seabirds from two colonies. Harvest started 26 June 2014 in the study area, and all use of harvest areas < 2015 are pre-harvest. Areas being harvested or re-harvested increased continuously throughout the years and in 2022 all harvest areas used by birds from Sklinna have been harvested at least once.*

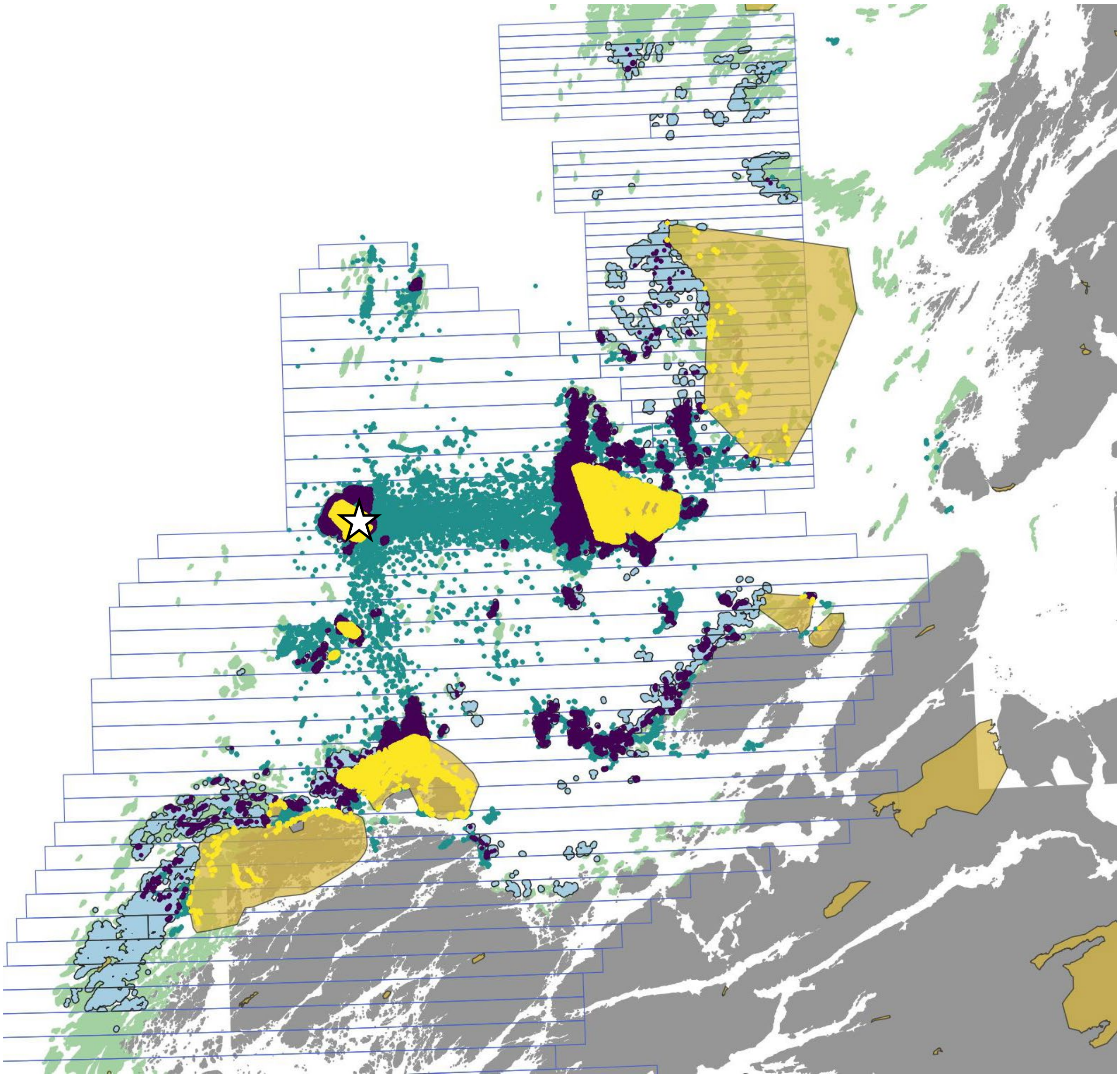

Figure 9. Foraging locations (small dots) of European shags at Sklinna (white star), coloured depending on location: yellow in protected areas, dark purple in harvested areas and green in other areas. Green polygons show kelp forest occurrence, pale yellow polygons protected areas and light blue polygons harvested areas. Land is shown in grey. The horizontal rectangular lines show harvest sectors. Note that the dots merge together in well used areas.

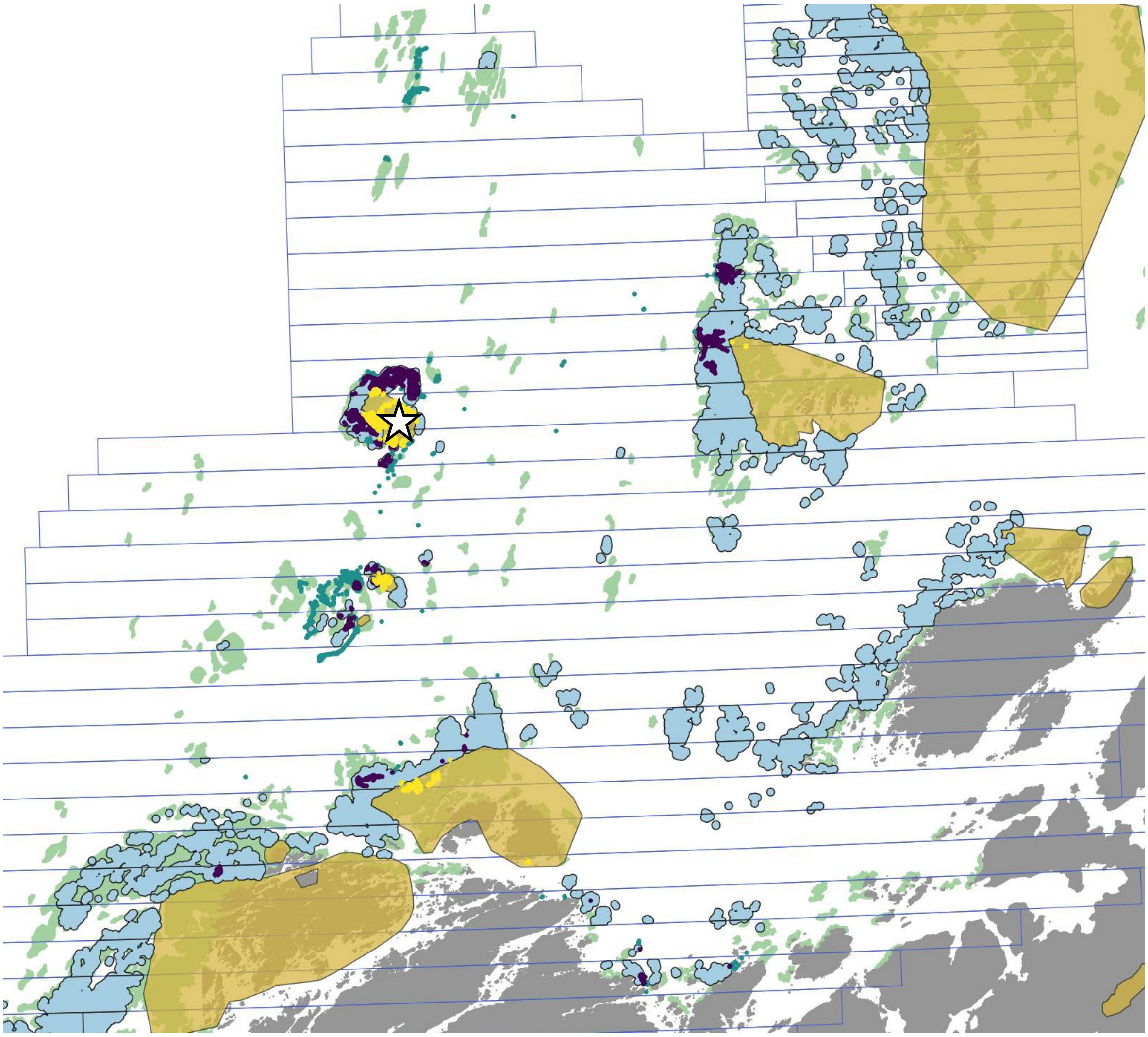

Figure 10. *Foraging locations (small dots) of black guillemot at Sklinna (white star), coloured depending on location: yellow in protected areas, dark purple in harvested areas and green in other areas. Green polygons show kelp forest occurrence, pale yellow polygons protected areas and light blue polygons harvested areas. Land is shown in grey. The horizontal rectangular lines show harvest sectors. Note that the dots merge together in well used areas.*

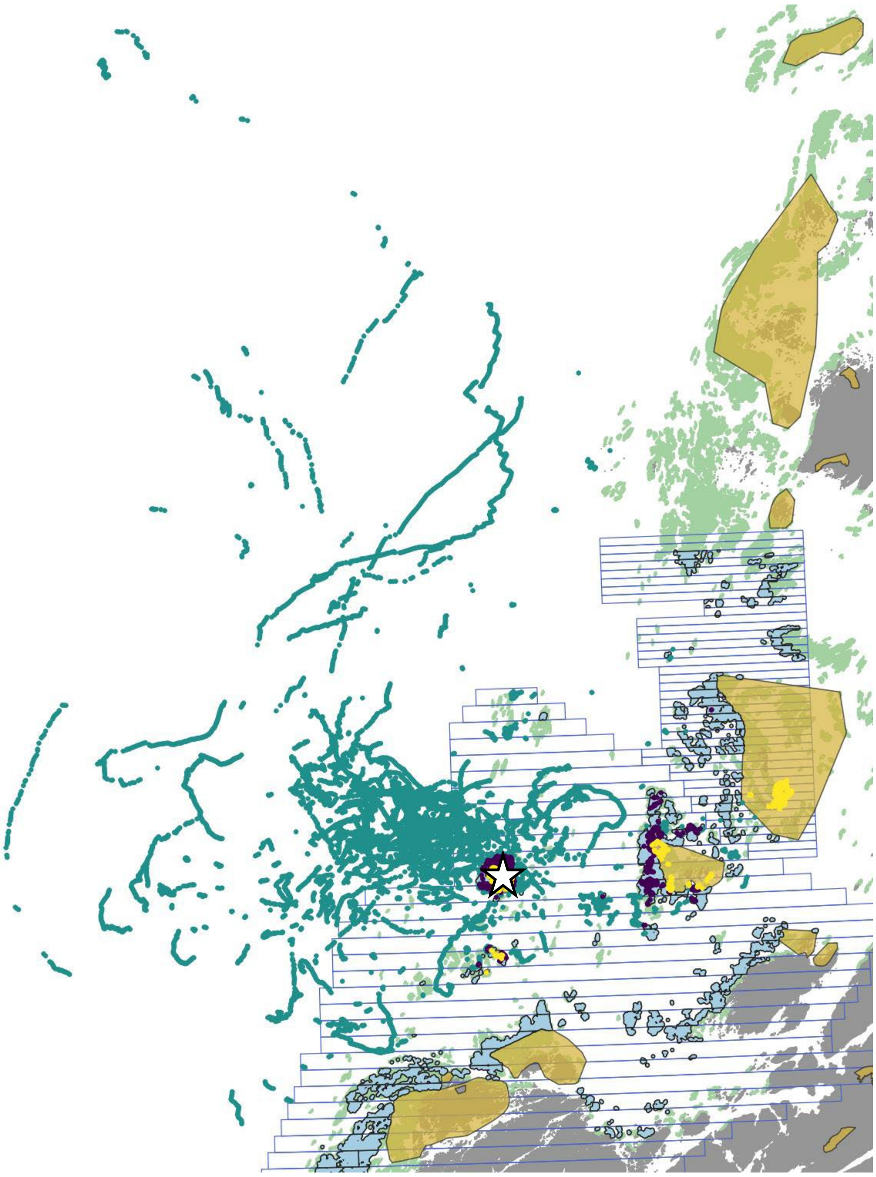

Figure 11. *Foraging locations (small dots) of common guillemot at Sklinna (white star), coloured depending on location: yellow in protected areas, dark purple in harvested areas and green in other areas. Green polygons show kelp forest occurrence, pale yellow polygon protected areas and light blue polygons harvested areas. Land is shown in grey. The horizontal rectangular lines show harvest sectors. Note that the dots merge together in well used areas.*

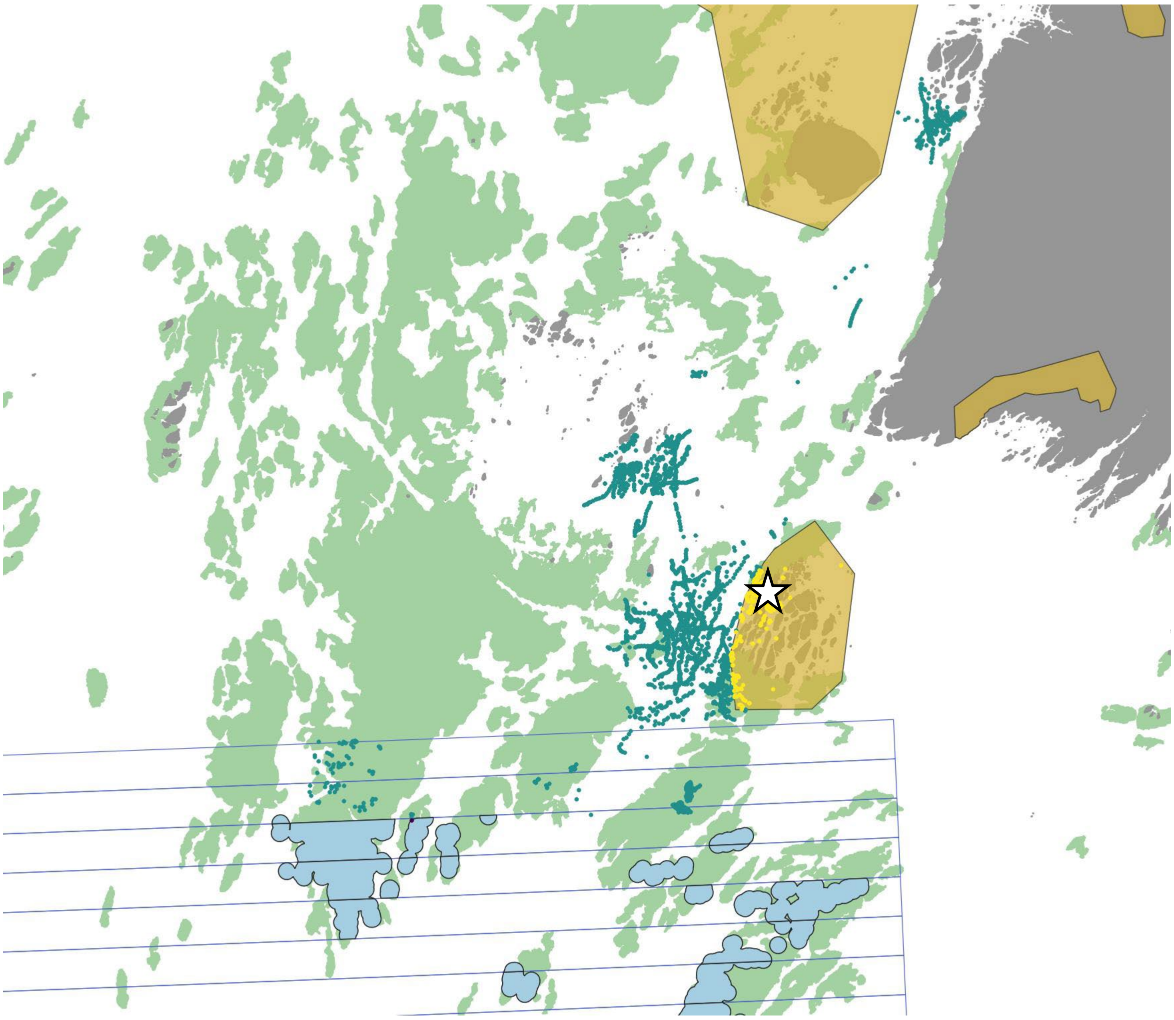

Figure 12. *Foraging locations (small dots) of black guillemot at Muddvær (white star), coloured depending on location: yellow in protected areas, dark purple in harvested areas and green in other areas. Green polygons show kelp forest occurrence, pale yellow polygon protected areas and light blue polygons harvested areas. Land is shown in grey. The horizontal rectangular lines show harvest sectors. Note that the dots merge together in well used areas.*

3.4 Results of the web-based survey to assess attitudes and perceptions of different interest groups

3.4.1 Respondent categorisation and relevant activities

We received 105 responses to our online survey, which equals a response rate of 26.6%. However, not all respondents answered all questions.

Eighty-two (78%) of respondents were male, 20 (19%) were female, and three (3%) did not wish to respond to this question. Thirty (29%) respondents answered that they identified most with the interest group industry, 12 (12%) with research, 10 (10%) with public administration, 5 (5%) with NGOs, 20 (19%) were commercial fishers, 17 (16%) indicated that they were answering the survey from a recreational user standpoint, and 10 (9%) marked the “other” category. Of the respondents that indicated that they were answering the survey from a recreational user standpoint, only one specified that they were a recreational fisher. None of the “other” respondents specified in which additional category they considered themselves.

Boating and fishing were the most important recreational activities for the respondents of our survey (**Supplement Figure 6.3.1**). The mean values ranking importance of the activity regardless of interest group were 4.12 for boating, 4.19 for fishing, 2.16 for hunting, 3.45 for bird watching, and 3.85 for other activities, where 0 was not important and 5 was very important. There were 22 “other” activities mentioned; among these were diving (6), walking/experiencing nature (4), and tourism (3).

Boating and fishing were at least somewhat important to all interest groups except the respondents from the NGOs, who considered bird watching and other activities more important (**Supplement Figure 6.3.2**). Bird watching was at least somewhat important to all respondents apart from those working in industry. Hunting was of very little or no importance for respondents in public administration, research and NGOs, of neutral importance for industrial and recreational respondents, and somewhat important for commercial fishers and respondents who categorised themselves as belonging to another interest group.

Respondents were also asked how important different industrial activities along the coast were to them (**Supplement Figure 6.3.3**). The mean values ranking importance of the activity regardless of interest group were 4.07 for fishing, 2.67 for aquaculture, 3.08 for tourism and 2.17 for other economic activities (from 0 = not important, to 5 = very important). Fishing was also the most important industrial activity for all interest groups except respondents from the research sector, who considered tourism slightly more important. However, respondents from the research sector generally did not consider any of the industrial activities particularly important to them. Responses from the NGO respondents were similar in that respondents generally considered all the industrial activities to be either of neutral, little, or no importance. Respondents from public administration ranked the industrial activities as neutral (aquaculture and tourism) or somewhat important (fishing and other activities). Respondents from the industry considered all industrial activities at least somewhat important, in the following order fishing, tourism and other activities. Commercial fishers considered fishing and aquaculture important, and tourism and other activities less so.

3.4.2 Attitudes to the harvesting of tangle

Most respondents were opposed to the harvesting of tangle, either strongly opposed or opposed (60.8%). Approximately one fifth of the respondents was in favour whereas only 1% of all respondents were strongly in favour of tangle harvesting (**Figure 13**).

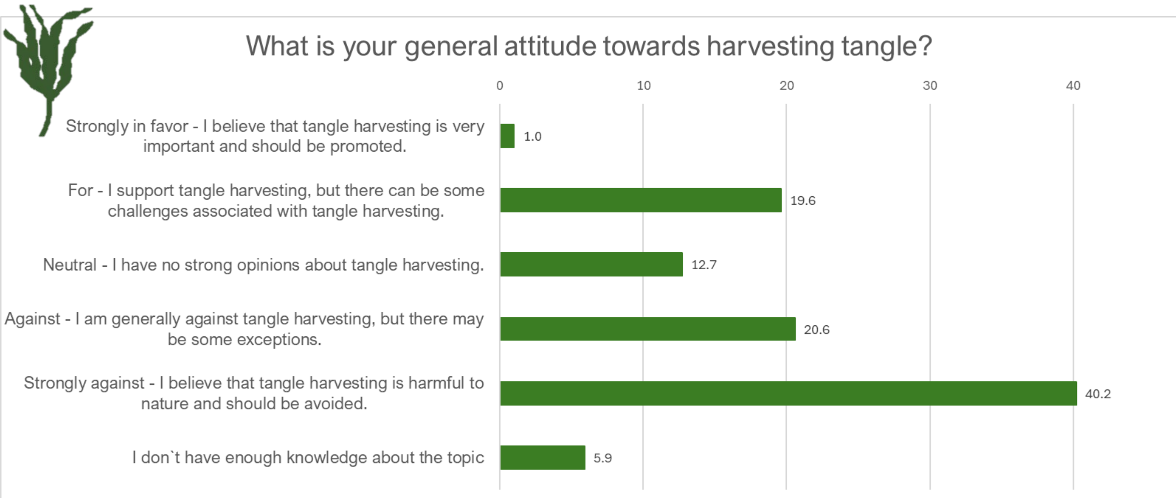

Figure 13. *Percent of respondents that agree with general statements about their attitude to harvesting (N = 102)*

Commercial fishers were most opposed to the harvest of tangle (mean 4.6, where 1 is strongly in favour and 5 is strongly against), followed by industrial respondents and NGOs (mean 4.0 for both). Respondents who classified themselves in research and as “other” were the least opposed to tangle harvest (mean 3.6), but still leaning towards being against harvesting tangle (**Figure 14**).

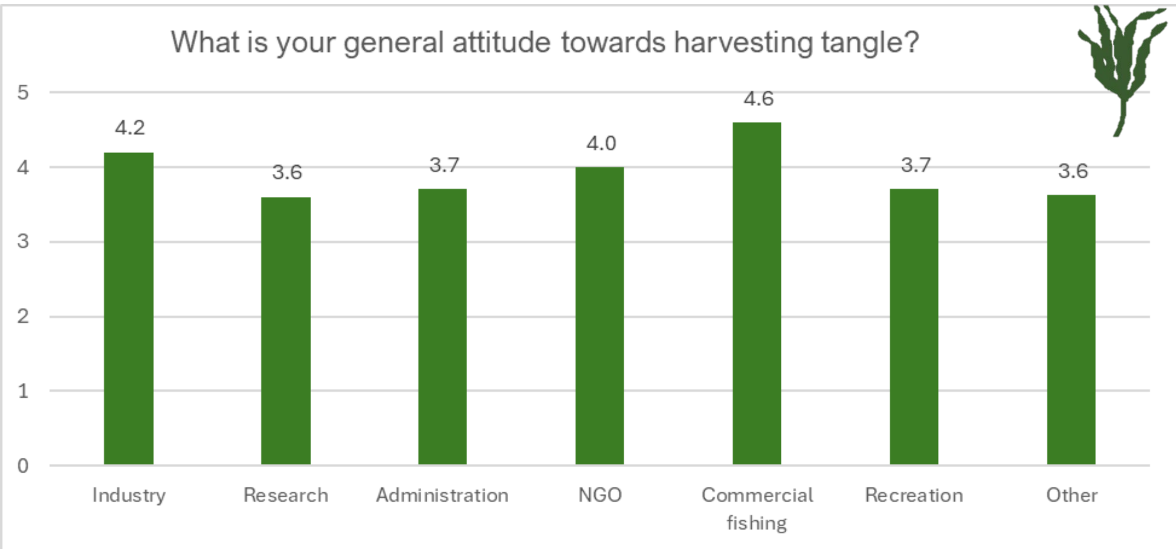

Figure 14. *Mean values for attitudes toward tangle harvesting per interest group. Scale: (1) Strongly in favour, (2) For, (3) Neutral, (4) Against, (5) Strongly against.*

In response to the question about the frequency of harvesting, respondents mostly thought that tangle should never be harvested (33%), or that it should be harvested less or much less frequently (43%) than is currently the case. 12% said they thought harvesting should occur as frequently as today (approximately every five years). 12% said that they had no opinion or did not know enough about the subject.

Respondents of the survey felt more strongly about the harvest of tangle in protected areas. 75.5% of respondents thought it should be prohibited to harvest tangle in all protected areas. Some respondents thought it should be allowed in some protected areas (9%). 10% of the respondents were unsure, and 3% had other views. No one specified what these other views were. Only 3% thought tangle harvesting should be allowed everywhere, also in protected areas. Similarly, respondents were also very strongly in favour (74.5%) or somewhat in favour (15%) of banning harvesting of tangle during the breeding season where birds are particularly vulnerable. 4% felt neutral to such a ban, and only 3% were strongly against such a ban. The remainder of respondents did not have an opinion or said that they did not know enough about the subject.

The survey also asked respondents about how they thought harvesting tangle impacts animals, on a scale from 1 (very positive impacts) to 6 (very negative impacts). Respondents were concerned about the negative impact on fish (mean 4.94), food availability for birds (mean 4.94), and the occurrence of other marine animals aside from mammals (mean 4.85) (**Figure 15**). However, they were also concerned (though to a slightly lower degree) about disturbance effects that harvesting activities can have on birds (mean 4.49), marine mammals (mean 4.28) and “other” (mean 4.20). Very few participants thought that harvesting activities could have positive effects on any of the categories: fewer than 8 respondents (7%) thought that these activities could have very positive or moderately positive effects.

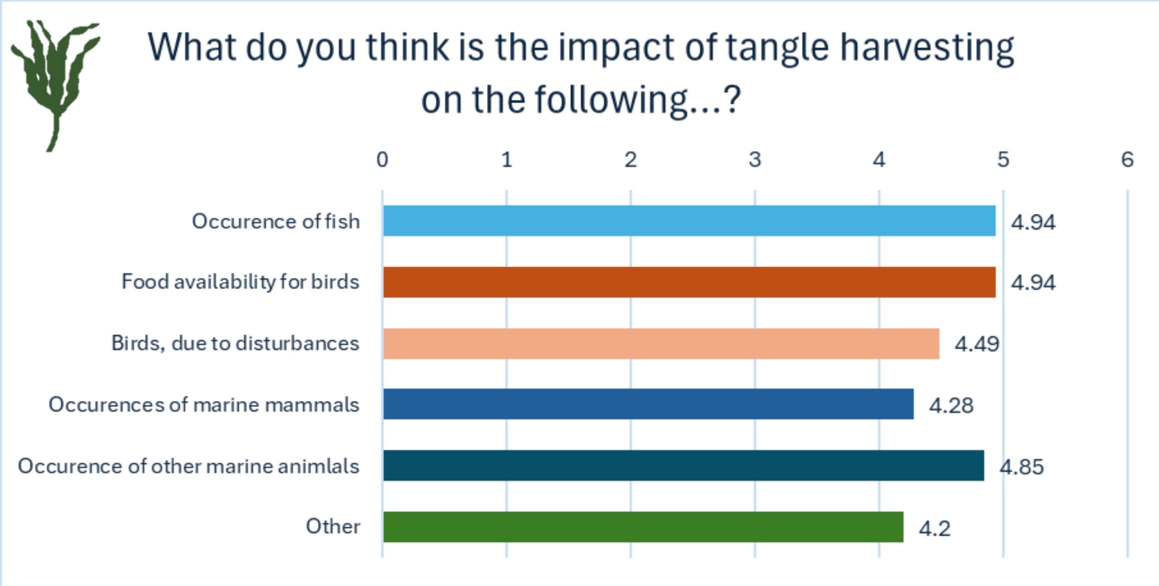

Figure 15. *Mean values for views on the different impacts of tangle harvesting on a scale: (1) very positive, (2) positive, (3) neutral, (4) somewhat negative, (5) negative, (6) very negative.*

When we asked the respondents to indicate whether they are worried that there will be too much tangle harvesting in the future, they indicated that they were very worried (average 80.1%, N = 88) on a scale from 0%, not worried, to extremely worried at 100%.

We also asked an open question to find out if respondents had any other thoughts about tangle harvesting. Many respondents wrote about the different ways that tangle forests are important ecologically, as ecosystems and as habitats for fish and other animals. A concern that was voiced often is that the way that tangle is harvested (by trawling) is what is the most problematic, not tangle harvesting itself. Many respondents think that this method is too destructive, and that harvesting is done in an uninformed way, and managed by people with insufficient knowledge about how the harvest affects important spawning grounds, amongst other things. Some respondents were worried about greenwashing (tangle harvest seen as a "green solution") and that although there is a tendency that the time-interval between trawling the same areas is increasing, the time-interval is still too short. Respondents expressed repeatedly that they were worried that the economic benefits of tangle harvesting will outweigh the ecological concerns, particularly since there are foreign investors that are controlling this economy.

3.4.3 Attitudes to the harvesting of knotted wrack

The general attitude to the harvesting of knotted wrack were comparable to attitudes to the harvesting of tangle, though respondents were slightly less opposed to harvesting of knotted wrack (See **Figure 16**). Still, most respondents either strongly opposed (26%) or opposed (27%) harvesting, and only 2% of respondents were strongly in favour of harvesting of knotted wrack. 21% were in favour, and 19% were neutral to this activity.

As for harvest of tangle, commercial fishers were among the most opposed to the harvest of knotted wrack (mean 4.1, where 1 is strongly in favour and 5 is strongly against), but the opposition was even stronger amongst respondents from NGOs (mean 4.3) (**Figure 17**). As with the responses to tangle harvesting, respondents who classified themselves in the researchers` interest group were also the least opposed to the harvest of knotted wrack (mean 3.1). The remaining respondents leaned towards being against the harvest of knotted wrack (means of 3.3 and 3.4).

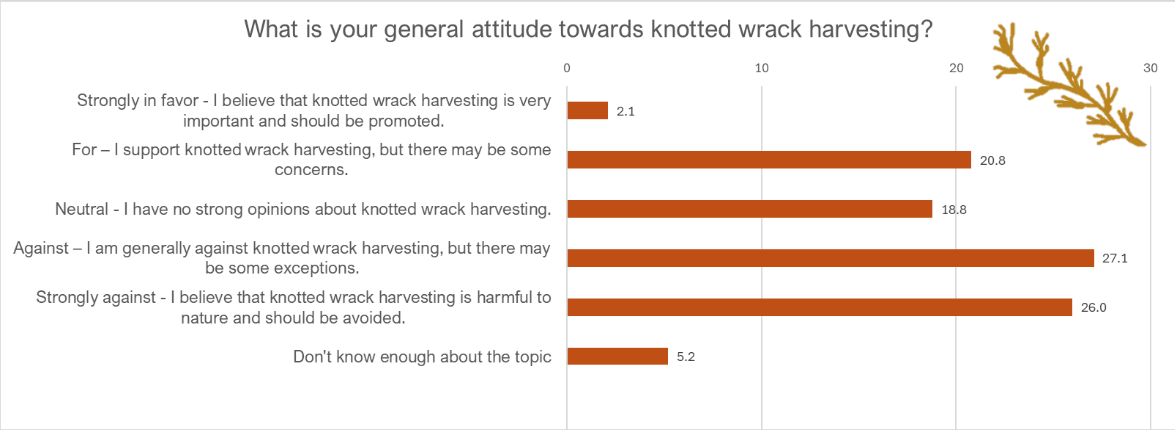

Figure 16. *Percent of respondents that agree with general statements about their attitude to harvesting knotted wrack.*

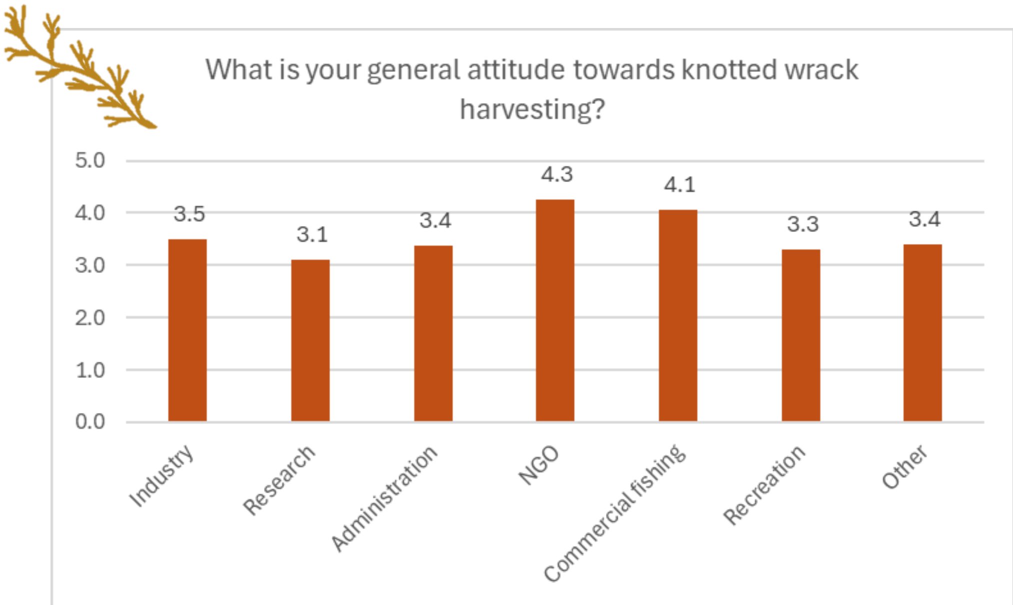

Figure 17. *Mean values for attitudes toward knotted wrack harvesting per interest group. Scale: (1) Strongly in favour, (2) For, (3) Neutral, (4) Against, (5) Strongly against.*

In response to the question about the frequency of harvesting, respondents mostly thought that knotted wrack should be harvested less frequently (41%) than is currently the case (approximately every 4-6 years), or that it should never be harvested (22%). 16% said they thought harvesting should occur as frequently as is the case today, and 21% said that they had no opinion or did not know enough about the subject. Only 1% of respondents thought that knotted wrack should be harvested more frequently. Respondents were also asked about the method used to harvest knotted wrack, and how much they thought it impacted birds, fish or other marine animals. Most respondents thought that this harvesting method affected animals to a very large degree (40%), or to a large degree (35%). 10% thought that the method has a neutral effect, or that it affects animals to a small extent (5%). The remaining respondents did not know enough about the subject (9%).

Respondents of the survey also felt very strongly about the harvest of knotted wrack in protected areas, with responses being very similar to those for tangle harvesting. 74% of respondents thought it should be prohibited to harvest knotted wrack in all protected areas. Some respondents thought it is appropriate that harvesting is allowed in some protected areas (10.5%). A similar percentage of respondents were unsure (11.5%), and 1% had other views. These other views were related to harvesting intensity – that is, the respondent thought that very low intensity harvest per region was the best solution. Only 3% thought harvesting knotted wrack should be allowed everywhere, also in protected areas. Similarly, respondents were also very strongly in favour (73%) or somewhat in favour (12%) of banning harvesting of knotted wrack during the breeding season and the migration period where birds are particularly vulnerable. 4% felt neutral to such a ban, and 3% were somewhat against or strongly against such a ban. The remainder of respondents did not have an opinion or said that they did not know enough about the subject (7%).

The survey also asked respondents about how they thought harvesting knotted wrack impacts animals (**Figure 18**). Again, responses were similar to those given for harvesting tangle. Respondents were very concerned about the negative impact on fish (mean 4.83), food availability for birds (mean 4.83), and other marine animals aside from mammals (mean 4.89). They were also concerned about disturbance effects that harvesting activities can have on birds (mean 4.65), marine mammals (mean 4.15) and other impacts (mean 4.14). Very few participants thought that harvesting activities could have positive effects on any of the categories, with fewer than 6 (7%) respondents that thought these activities could have very positive or moderately positive effects.

When we asked the respondents to indicate whether they are worried that there will be too much knotted wrack harvesting in the future, they indicated that they were very worried (average 74,4%; N = 81) on a scale from 0%, not worried, to extremely worried at 100%.

The responses to the open question for respondents to give more feedback about the harvesting of knotted wrack were along similar lines as for tangle. Respondents described how important they thought knotted wrack is ecologically, and that they are very worried about future developments. In comparison to tangle, respondents were perhaps less worried about current harvesting levels, but more worried about the potential for negative effects, since this activity is even less regulated than tangle harvesting. An additional concern, since knotted wrack is found closer to shore, is the potential conflict with landowners on the coast. Respondents hoped that the development of this harvesting activity becomes more controlled in the future.

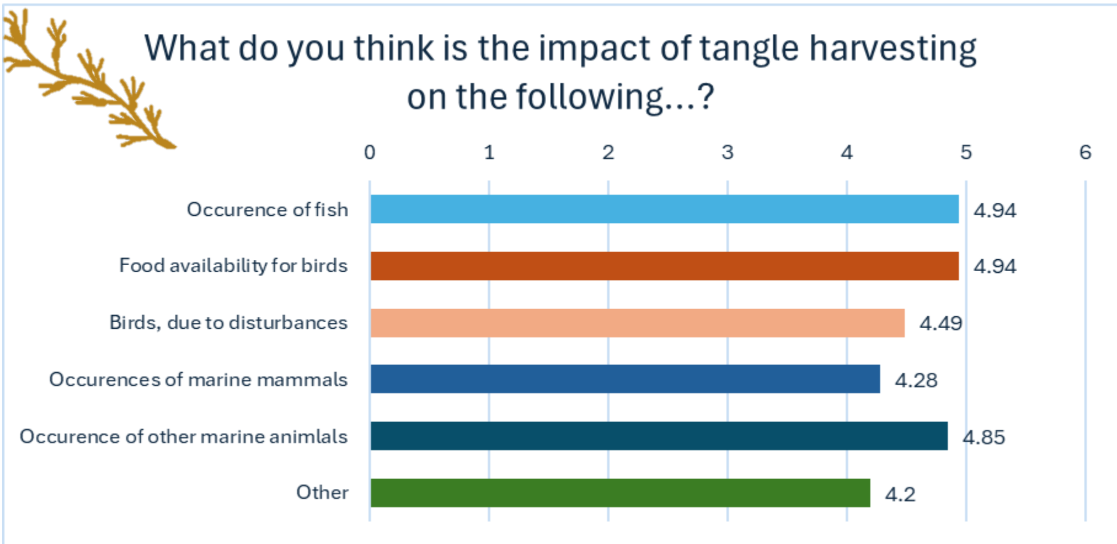

Figure 18. *Mean values for views on the different impacts of harvesting knotted wrack on a scale: (1) very positive, (2) positive, (3) neutral, (4) somewhat negative, (5) negative, (6) very negative.*

3.4.4 Change in attitudes to harvesting of tangle and knotted wrack

In each of the question sections about tangle and knotted wrack, participants were asked to rate their own knowledge level about the harvesting of tangle and knotted wrack, respectively. Most respondents felt that they had an adequate amount of knowledge (40% tangle, 42% knotted wrack). 36% and 29% of respondents felt that they had a lot or an exceptional amount of knowledge about tangle and knotted wrack harvesting, respectively. The remainder of respondents felt they had little or very little knowledge about tangle and knotted wrack harvesting (24% tangle, 30% knotted wrack).

In the analysis of potential changes in attitudes based on increased knowledge, we have only included respondents that have responded to the questions both before and after information was given.

Tangle

There was an indication that reading the information provided about the environmental effects of tangle harvesting impacted the stated attitude of the respondents in general (mean values before = 3.86 and after = 4.00; paired t-test: Cohen's d = 0.27, p = 0.02, N = 80). Visual inspection of the results showed that respondents from some interest groups (industry, NGOs and commercial fishing) showed a tendency to be more negative towards harvesting of tangle, while respondents of other interest groups did not change their opinion (e.g. research, recreation and "other") (**Figure 19**).

When looking at the question "What do you think about harvesting tangle in protected areas?", we did not find any significant changes in attitudes after respondents were given more information about the effects of tangle harvesting (Wilcoxon signed rank test, Z = 0.09, p = 0.084, N = 74). However, after being given information, most of the respondents that answered that they "don't know" before the information (8 respondents) changed their opinion towards that tangle harvest should be prohibited in protected areas afterwards (7 of these 8 respondents) (**Figure 20**).

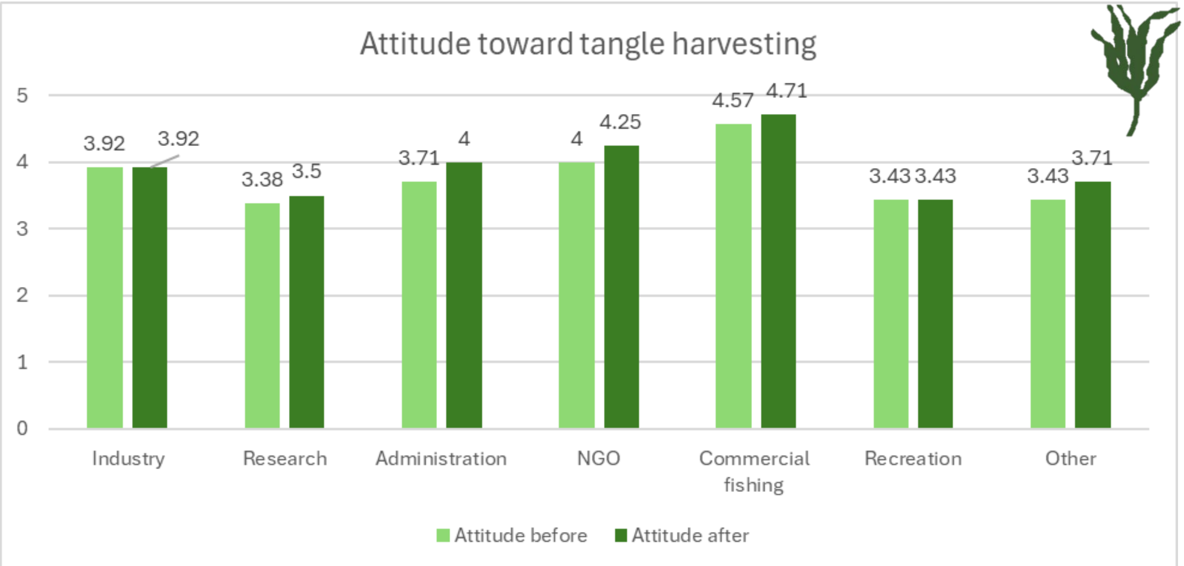

Figure 19. *Change in general attitude to tangle harvesting before and after reading the provided information - mean values of responses per interest group. Scale: (1) Strongly in favour, (2) Somewhat in favour, (3) Neutral, (4) Somewhat against, (5) Strongly against.*

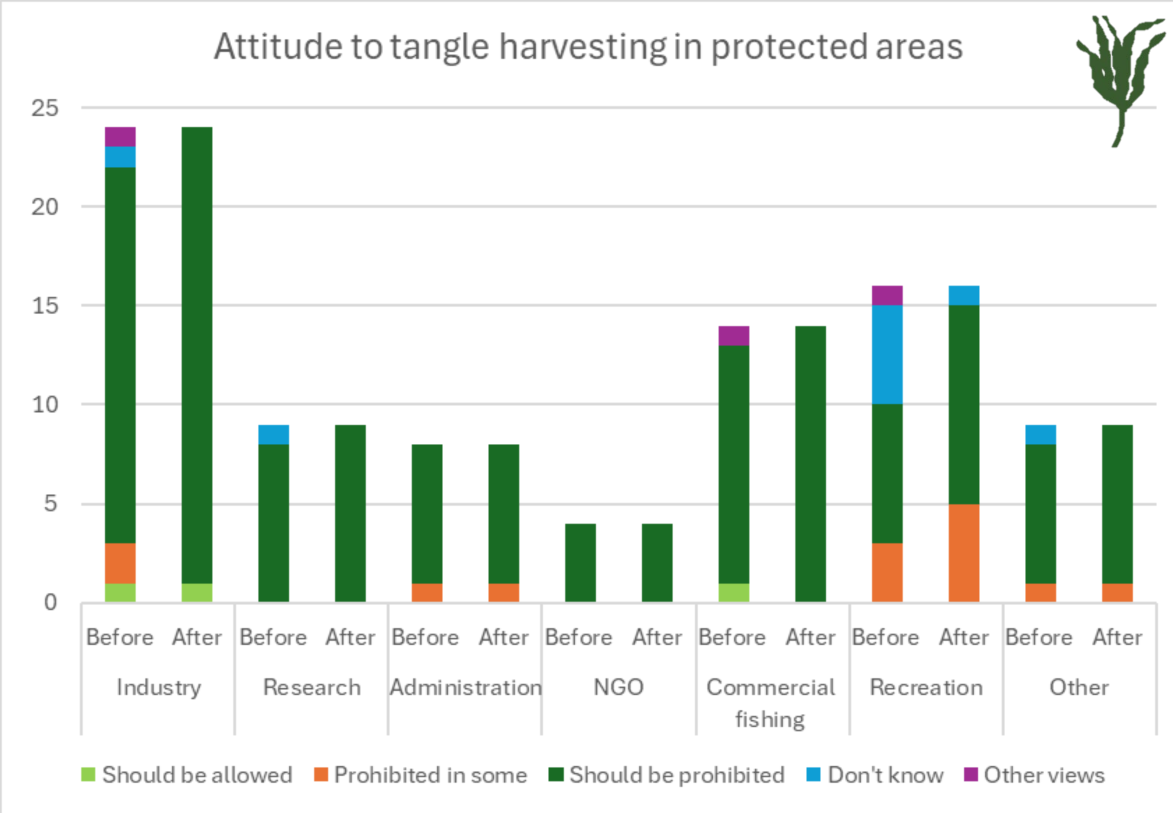

Figure 20. *Change in attitudes to harvesting tangle in protected areas. Frequency of responses per interest group.*

On the question if there should be protection against tangle harvesting during breeding and migration periods for seabirds, respondents across all the interest groups showed a decreased willingness for such a protection of areas after receiving the additional information (mean values before = 1.32 and after = 1.66; on the answer scale: (1) Strongly in favour, (2) Somewhat in favour (3) Neutral, (4) Somewhat against, (5) Strongly against, paired t-test: Cohen's d = -0.28, p = 0.012, N = 81).

This tendency for respondents to change their answer to being less strongly in favour of protection in the breeding and migration seasons after being given more information was similar across interest groups (**Figure 21**). Respondents from all interest groups who had no opinion or felt that they did not know enough about the subject all changed their answers after being given more information about tangle harvesting.

In contrast to these results, the respondents expected the impact of harvesting tangle on birds to be more negative after receiving information (both by means of food availability and disturbances, paired t-tests: mean values before = 5.08 (food availability) and 4.65 (disturbance) versus mean values after = 6.17 (food availability) and 5.87 (disturbance); for both tests p > 0.001; Z = 1.11 (food availability) and 1.21 (disturbance); N=84 for both tests).

In response to the question whether the respondents were worried that there will be too much tangle harvesting in the future, respondents from all interest groups were more concerned after receiving additional information (mean = 84.2%) than before (mean = 81.3%) on a scale from 0%, not worried, to 100%, extremely worried (**Supplement Figure 6.3.4**, paired t-test: Cohen`s d = 0.25, p = 0.012, N = 73).

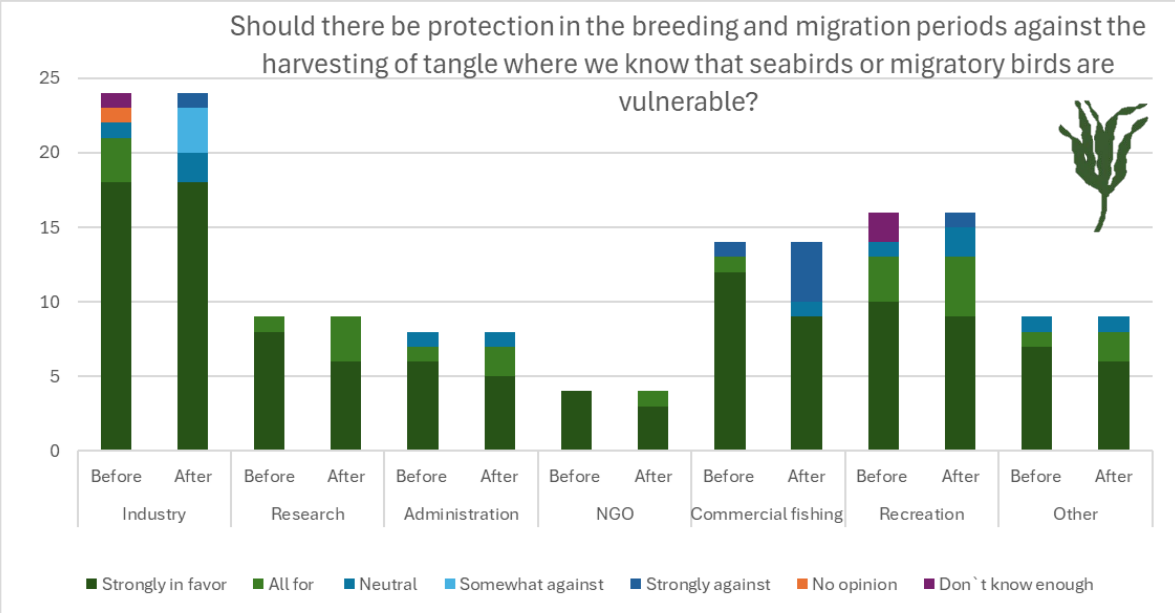

Figure 21. *Change in attitudes to harvesting tangle during migration and breeding periods – responses per interest group. Frequency of responses per interest group.*

Knotted wrack

Respondents were significantly more opposed to knotted wrack harvesting after reading the information we provided. We found a pre-info mean value of 3.56, and a post-info mean value of 3.97 (paired t-test: Cohen`s d = 0.65, p-value < 0.001, N = 78; **Figure 22**). Visual inspection of the different interest groups showed that this change was likely driven by respondents from industry, public administration, commercial fishers and those classifying themselves as “other”, who all tended to answer more strongly against harvesting after being provided with additional information. The interest group representing recreational users of the coastal zone, however, appeared less opposed to knotted wrack harvesting after reading the provided information.

On the question “What do you think about harvesting knotted wrack in protected areas?”, respondents were significantly more in favour of better protection against harvesting in protected areas (Wilcoxon signed rank test: Z = 2.33, p = 0.02, N = 75). As was the case for tangle, there were fewer respondents who answered that they “don’t know” after receiving the additional information (8 respondents before and 1 after; **Figure 23**).

On the question if there should be protection from harvesting in the breeding and migratory periods in areas, where it is known that seabirds or migratory birds are vulnerable, respondents overall shifted to be significantly less against harvesting (mean value before = 1.28; mean value after = 1.69 on the answer scale: (1) Strongly in favour, (2) Somewhat in favour, (3) Neutral, (4) Somewhat against, (5) Strongly against; paired t-test: Cohen’s d = -0.38, p < 0.001, N =78). Visual inspection of the frequency of answers showed that there was a tendency towards less strong support of protection from harvesting in these periods in almost all interest groups after receiving information, which was especially pronounced among industry, commercial fishers and recreation (**Figure 24**).

In contrast to these results, respondents expected the impact of knotted wrack harvest to be more negative for disturbance (4.74 before and 5.83 after; paired t-test: Cohen’s d = 0.83, p < 0.001, N = 84) and food availability (4.95 before and 6.27 after; paired t-test: Cohen’s d = 1.06, p < 0.001, N = 83) for birds after additional information was provided. The answer scale for this question was: (1) very positive, (2) positive, (3) neutral, (4) somewhat negative, (5) negative, (6) very negative.

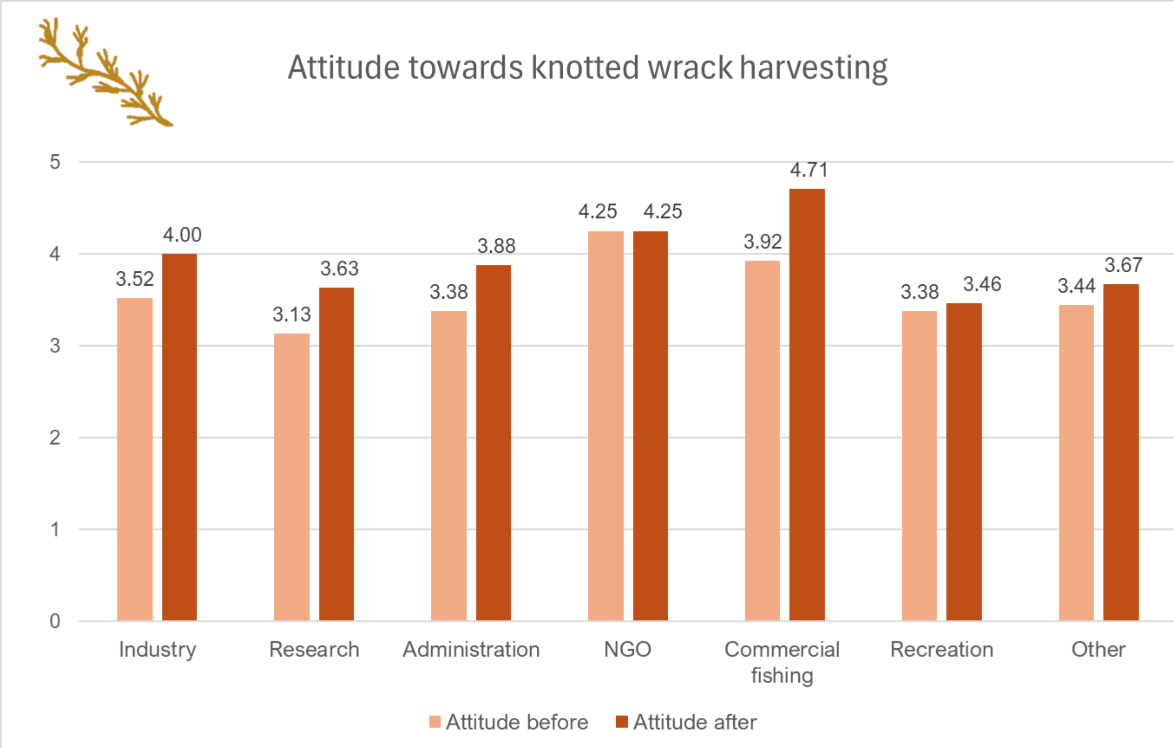

Figure 22. *Change in general attitude to knotted wrack harvesting - responses per interest group (N = 77). Scale: (1) Strongly in favour, (2) Somewhat in favour, (3) Neutral, (4) Somewhat against, (5) Strongly against.*

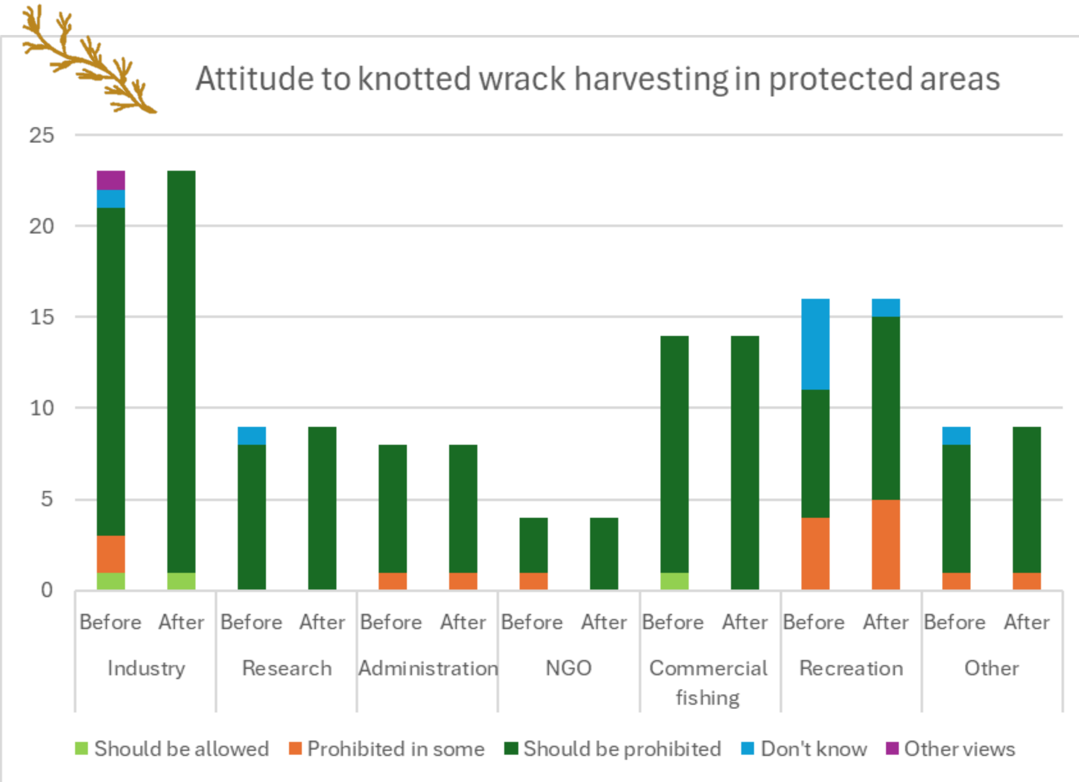

Figure 23. *Change in attitudes to harvesting of knotted wrack in protected areas. Frequency of responses per interest group.*

For the question whether respondents are worried that there will be too much knotted wrack harvesting in the future, we found that overall, they were significantly more concerned after receiving additional information (mean value 81.3%) compared to before (mean value 77.0%) on a scale from scale from 0%, not worried, to 100%, extremely worried (**Supplement Figure 6.3.5**, paired t-test: Cohen`s d = 0.42, p = 0.001, N = 72). The level of concern visually increased for all interest groups, with the strongest effect seen for NGOs, followed by research, recreation and public administration, while the smallest effect was found among commercial fishers.

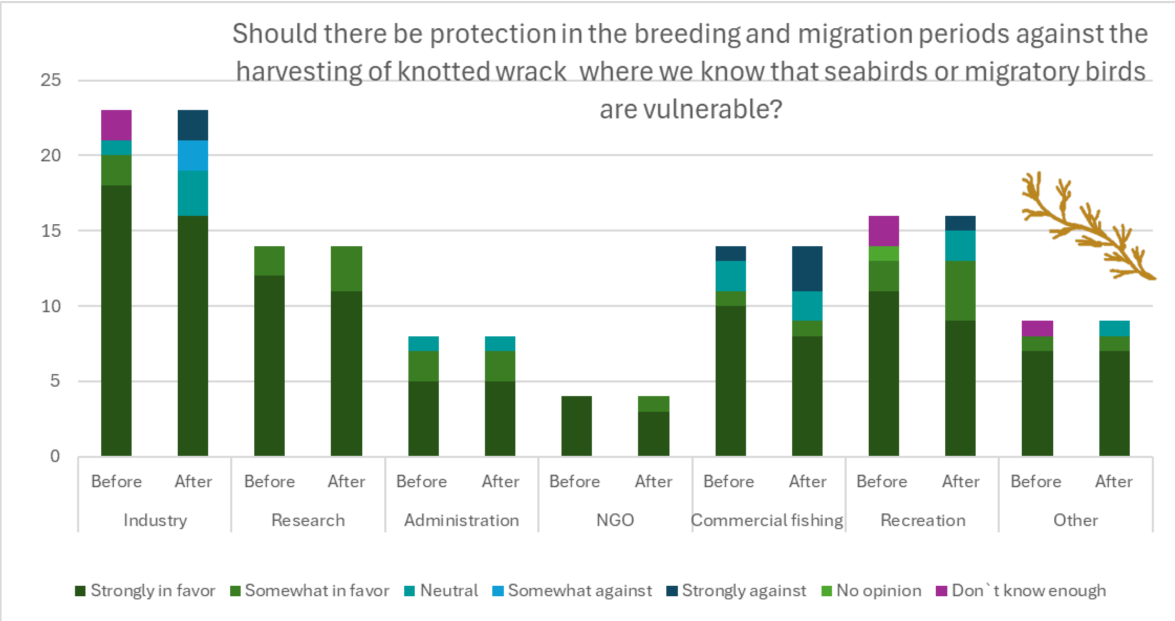

Figure 24. *Change in attitudes to knotted wrack harvesting during migration and breeding periods. Frequency of responses per interest group.*

4 Discussion

4.1 Intensity and timing of harvest

Our results show that the amount of knotted wrack and kelp harvested annually in Norway is relatively stable but show a slight decrease the latest years for knotted wrack and slight increase for kelp, with the amount of kelp exceeding that of knotted wrack by a factor 10. The standing biomass of tangle has recently been estimated to be 56 million tons, with kelp forests covering 5355 km^2 along the coastline of Norway (Gundersen et al. 2021). The amount harvested annually (on average 149 476 tons) thus corresponds to <0.3% of the standing stock of tangle within Norway. Gundersen et al. (2021) also found that the largest tangle plants were located in central Norway, suggesting that optimal conditions for tangle were found at the Norwegian coast at around 64 degrees north, likely due to optimal sea water temperatures and light conditions. Nevertheless, there was no significant relationship between standing biomass (kg/m^2) and latitude (Gundersen et al. 2021). The proportion of standing biomass that is harvested in an area depends on the availability of trawlers, ocean depth and the bathymetry of the seabed. Thus, the harvest intensity is spatially heterogenous, and some areas will be more intensively harvested than other less available areas (Rinde et al. 2006).

The standing stock of knotted wrack in Norway was previously estimated to be about 1.8 million tons (Baardseth 1970). More recent estimates about the standing stock in Norway are not available. Assuming numbers have not changed during the past 50-60 years, the average annual harvest of knotted wrack (18 076 tons) would correspond to just under 1% of the standing stock in Norway. Knotted wrack is mostly harvested in the coastal areas in the fishing areas along Helgelandsbanken and Storegga-Frøyabanken, corresponding to Møre og Romsdal, Trøndelag and Nordland counties. The proportion of the standing stocks which is harvested within these counties are unknown.

The harvest of both knotted wrack and kelp was more pronounced during April through to October, which coincides with the spring and autumn migration for waders (March-May and late August-October, respectively) as well as with the breeding period for seabirds and waders (May-August) and the moult period for seaducks (August-September). Thus, harvest in these months raises the possibility for acute disturbance effects from the harvest on the birds, as well as the effects of habitat modification after removal of seaweed during these two periods when birds have high energy requirements.

4.2 Existing knowledge about effects of seaweed harvesting on seabirds and waders

Our literature review found only seven articles that investigated the effects of seaweed harvest on birds and reflects that few studies on this topic have been published. This is also reflected in a comprehensive review on the consequences of kelp removal by Carranza et al (2024), which only cited two studies conducted on seabirds. Only one of the seven studies identified in our review looked at the acute disturbance effects that occur during the harvest, while five studies investigated effects of habitat modification after harvest or removal of seaweed.

4.2.1 Acute disturbance effects

In the study that investigated acute disturbance effects, harvest was performed by cutting intertidal seaweed by hand, and the people who harvested were often accompanied by one or several dogs, which had impacts on the number of shorebirds in the area (Navedo et al. 2019). This type of harvest is very different from the ship-based harvest performed in Norway and other countries, and thus results cannot be transferred directly. The lack of studies on potential effects of acute disturbance from commercial harvesting activities on seabirds and shorebirds therefore creates a large knowledge gap. There is, however, information available on effects of other ship and boat traffic on seabirds. Although this does not cover all aspects of commercial harvest (e.g. noise of operating the fork when trawling for tangle, and the prolonged time spent close to the shore when harvesting knotted wrack) and ignores effects on shorebirds altogether, this is the best and only knowledge available on this topic. Studies on ship and boat traffic suggest that seabirds perceive vessels as a threat, and their response depends on the size and speed of the vessel (Fliessbach et al. 2019). Responses are, however, species dependent. Within the Northeast Atlantic, red-throated divers (*Gavia stellata*) show the highest sensitivity towards approaching vessels, i.e. escaping earlier and at a larger distance than other species (Fliessbach et al. 2019). Black guillemots ranked second on this assessment, followed by black-throated divers (*Gavia arctica*), velvet scoters (*Melanitta fusca*) and red-breasted mergansers (*Mergus serrator*), while gulls and terns were the least sensitive species to vessel traffic (Fiessbach et al. 2019). Shags were not part of the study by Fliessbach et al. (2019), and we thus do not how they rank compared to the other species. However, research in the Mediterranean has shown that shags are also sensitive to vessel traffic and avoid areas with recreational boats, even if these are in the birds' preferred foraging areas (Velando & Munilla 2011). Furthermore, timing of the disturbance can be of high importance. A study on common eiders performed during the moult period, when seaducks are flightless as they are shifting their flight feathers, showed considerably higher escape distances than outside of the moult period, despite approaching with a smaller, slower-moving boat (Dehnhard et al. 2020). Despite the fact that common eiders were flightless, they moved large distances as a response to the disturbance and were displaced into less preferred (deeper) habitat (Dehnhard et al. 2020). Disturbance due to boat traffic has also been shown to negatively affect survival of ducklings as it increases the risk of predation (Åhlund & Götmark 1989), and female common eiders with broods may try to avoid areas with frequent boat traffic (Blinn et al. 2008). Common eiders can thus be considered specifically sensitive against boat and ship disturbance during moult (late summer) and when raising ducklings (early summer), both of which fall into the peak period for seaweed harvest as well as recreational boat traffic. Escaping from the perceived threat is a common response in birds, but in some situations a strategy of staying still to avoid detection is also used. This is particularly common for breeding birds on a nest. Such a reaction may still entail a cost to the bird in form of a physiological response. For instance, Gabrielsen (1987) showed that incubating common eiders at Svalbard showed a physiological response to an approaching boat or human in form of elevated heart rates and breathing frequency. This lasted for the length of the disturbance period.

Overall, it is thus likely that seabirds – if they happen to be in the area during harvest – show an acute disturbance effect towards commercial, ship-based seaweed harvesting, based on their reaction towards vessels in general. How such a reaction is amplified by e.g. sound, and how shorebirds react towards vessels, is unknown, and should be further investigated. It is further unknown if acute disturbance events have any long-term consequences for the birds (e.g. reduced reproductive success or survival). This may depend on frequency and timing of the disturbance, and the presence of predators or other threats in the surrounding area.

4.2.2 Habitat modification effects

Of the six studies that investigated habitat modification effects, two focused on kelp-harvesting effects on seabirds, one on kelp-harvesting effects on ecosystems in general, two on effects of harvesting knotted wrack on seabirds, and the last one investigated the effects of removing beach-cast seaweeds on the presence of shorebirds on the beaches.

Lorentsen et al. (2010) investigated if fish abundance and area use of great cormorants differed between harvested and non-harvested areas of kelp forests and found that abundance of small (<15 cm long) gadoids were lower in harvested than in unharvested areas. This explained why great cormorants preferred to feed in non-harvested areas. The reduced abundance of small gadoids is also in line with a study by Norderhaug et al. (2020), who found a reduction of juvenile gadoids (either saithe (*Pollachius virens*) or pollack (*Pollachius pollachius*) < 16 cm) by 75% after harvesting, compared to non-harvested control areas. In addition, the number of adult pollack, goldsinny wrasse (*Ctenolabrus rupestris*) as well as sessile invertebrates decreased after harvesting (Norderhaug et al. 2020). Nevertheless, a later study in shags, which also prefer small sized gadoid as food, did not find effects of harvesting on the dive behaviour of shags before / after harvest (Christensen-Dalsgaard et al. 2020). Possibly, this suggests that great cormorants are impacted by harvesting, while shags are not, and hence species differ in their vulnerability. However, it is important to keep in mind that seabirds do not directly feed on the kelp plants, but feed on fish which in turn feed on invertebrates that use the kelp forests as shelter. Thus, kelp harvesting is not directly leading to a removal of the seabird's prey but may rather lead to a different distribution of the fish, e.g. if fish disperse to patches that were not harvested, a possibility that was also discussed by Christensen-Dalsgaard et al. (2020). This may make fish more available to seabirds in these patches and could thus even be positive for seabirds, if e.g. non-harvested areas are closer to the colonies than the harvested areas. It is further possible that – due to the lack of shelter – it is easier for seabirds to forage in relatively recently trawled kelp forests.

However, the review by Carranza et al. (2024) identified more studies that reported negative responses of kelp (tangle) harvesting on fish assemblages than positive or non-significant responses. Carranza et al. (2024) also identified a lack of studies that investigated effects of kelp harvesting on fish assemblages over consecutive years, and consecutive harvest events. Thus, there is a knowledge gap on the long-term effects of kelp harvest on fish assemblages.

Besides shags and great cormorants, a number of other seabird species are known to make use of kelp forests as foraging grounds. This is particularly the case for black guillemots (Dehnhard et al. 2023; see also case study) as well as common eiders (Bustnes & Lønne 1997). Black guillemots feed on smaller size fish and invertebrates than the shags and great cormorants, while common eiders particularly target green sea urchins (*Strongylocentrotus droebachiensis)* when feeding in kelp forests (Bustnes et al. 2013, Bustnes & Lønne 1997). As sea urchins feed on the kelp plants and have the potential to graze down kelp forests (as happened in Northern Norway; Christie et al. 2019), foraging common eiders are beneficial for the kelp forest ecosystem. It remains open how kelp harvesting is affecting the food sources of these two species, and how long it takes until possible negative effects have reversed. This is mirrored by the conclusions of Carranza et al. (2024) and highlights the need for especially more long-term studies, that assess impacts of harvesting over many years, and whether the fallow period of ~3-4 years is long enough to guarantee recovery not only of kelp biomass but also of the associated communities.

Finally, Carranza et al. (2024) highlighted the need to evaluate how climate change, e.g. through heatwaves or increased storm activity, may amplify negative impacts of harvesting on kelp forests, and reduce the kelp forests' capacity recover after harvesting and to store carbon. A recent estimate suggested that kelp forests in Norway store about 2.6 million tonnnes carbon, equivalent to 9.5 million tonnes CO^2 (Gundersen et al. 2021). This corresponds to 18.9 % of the total CO^2 emissions of Norway in 2019 (50.3 million tonnes; Norwegian Ministry of Climate and Environment 2021) and reflects the importance of kelp forests as a carbon storage.

Our literature review identified only two studies that investigated effects of knotted wrack harvest on birds. One study found a negative effect of harvest on the densities of brood-rearing common eider females during summer, especially in areas with a steep coastline, and hence little available intertidal area (Blinn et al. 2008). The second study by Johnston et al. (2024) found a small reduction in bird numbers from pre-harvest to the year during which harvest happened, and an increase in the year post harvest. The latter was interpreted as a possible positive effect of disturbance and re-growth on the birds, and hence a positive bottom-up effect. However, effect sizes were small, and the study concluded that the overall effects of knotted wrack harvest on birds were likely rather small. Notably, the studies by Blinn et al. (2008) and Johnston et al. (2024) were conducted Canada and Maine, respectively, where regulations required a minimum cutting height above the holdfast of 25 cm and 40.6 cm, respectively (Blinn et al. 2008; Johnston et al. 2024). In addition, harvest is performed manually from small boats with a specially designed cutting rake (Monagail et al. 2017; Lauzon-Guay et al. 2021). On a small scale, the harvest as performed in Canada in the 2000s was found not to reduce invertebrate abundance (Hamilton and Nudds 2003). These factors are important, as they differ substantially from the harvest practice in Norway, and hence make transferability of results difficult. Harvest in Norway is practiced by sucking up the plants and cutting simultaneously, a practice that was abandoned by Canada and the USA in the 1990s to protect the seaweed habitat from over-exploitation. It is likely that suction harvest removes not only the plant material but also attached and mobile invertebrates and hence – although not scientifically investigated – that harvest leads to a reduction of the invertebrate community in the intertidal seaweed belt. There is further no regulation in Norway regarding the minimum cutting height above the holdfast. If only few cm above the holdfasts remains after harvest, this means slower regrowth of the plants (Printz 1959, Ugarte et al. 2006) and reduced shelter for invertebrates.

If harvest indeed leads to a reduction of invertebrates in the intertidal seaweed zone, one would expect a reduction in food availability for common eider ducklings, especially if harvesting occurred in spring or early summer, hence prior to or during the breeding period. Common eider ducklings during their first few weeks of life can hardly dive and thus feed almost exclusively on small gastropods, young blue mussels, small crustaceans and insects in the seaweed belt of the intertidal zone (Cantin et al. 1974, Soot-Ryen 1941). Hence, it is especially the abundance of invertebrates that is of importance for the birds. This was also a concern of locals at Hysvær, a common Eider colony located within the Vega UNESCO area and the Hysvær/Søla landscape and animal protection area, when commercial harvesting of knotted wrack was stopped during June 2023 (Budalen & Kristoffersen 2023). However, it remains unclear to which degree the harvesting regime in Norway is affecting the invertebrate biomass in the intertidal zone, and ultimately the birds' food availability. Besides common eiders, the rocky intertidal zone is also an important foraging habitat for numerous wader species, e.g. ruddy turnstones (*Arenaria interpres*), golden plovers (*Pluvialis apricaria*) and purple sandpipers (*Calidris maritima*) (Summers et al; 1988; 2002, Burton 2012). The highest numbers of waders in the intertidal zone in Norway are registered during spring and autumn (Heggøy et al. 2023), when waders need to fatten up to gain energy reserves for their migration to/from wintering areas (Evans & Davidson 1990). Purple sandpipers, however, are an exception, with large numbers of the European population overwintering in Norway (Heggøy et al. 2023).

How harvest of knotted wrack is affecting food availability of these wader species and potentially their chances to survive migration or the wintering period, is another knowledge gap. Timing of harvest relative to when waders are using the areas (during migration, breeding season or winter) may be a critical aspect considering the impact on the birds but information is completely lacking. Independently of harvest, a previous study found that presence of knotted wrack was positively associated with the number of shorebirds (Johnston et al. 2021). The recovery potential and speed of recovery of the plants, but also how fast invertebrates associated to the intertidal seaweed belt may recover after harvest is thus of high importance, yet poorly investigated, especially in Norway. Furthermore, it is unclear which effect repeated harvesting has on both the plants and invertebrates, in addition to the question if fallow periods are sufficiently long. This is important as knotted wrack in Norway can be harvested annually in the same areas due to a lack of regulations. These knowledge gaps, in combination with the outdated biomass estimate of knotted wrack in Norway, reflect the high demand for more knowledge. These and similar knowledge gaps are also recognized by researchers from the Institute of Marine Research, who also see the need for effect studies and to develop regulations for harvest of knotted wrack in Norway (Steen et al. 2024).

One of the identified studies that assessed habitat modification effects (Dugan et al. 2003) found a negative effect of removing beach-cast seaweeds on the presence of shorebirds. This type of seaweed removal is very different from the commercial harvesting performed in Norway, and removal of beach-cast seaweed clearly has no effect on the underwater/intertidal habitat and hence any species that forage in the subtidal or intertidal. Nevertheless, the study is interesting and relevant, as it is likely that commercial harvesting of kelp and knotted wrack from their subtidal and intertidal habitats also can lead to a reduction of beach-cast seaweed biomass along the shore. Commercial harvesting may thus reduce the availability of beach-cast seaweed biomass and impact food availability for shorebirds in a different habitat than where the harvesting occurs. However, one can expect that this is a regionally and temporally restricted process, possibly with a quite limited effect size. This is also a process that so far – to the best of our knowledge – has not been studied, and thus forms another knowledge gap.

4.3 Case study – to which extent do seabirds use harvested areas and protected areas?

In our case study that focused on the area north of Vikna, we found extensive overlap of foraging locations of shags and black guillemots from Sklinna with kelp-harvested areas. For shags, our results are in line with a previous study that investigated the overlap of foraging locations and harvested areas (Christensen-Dalsgaard et al. 2020). This is not surprising as the data used by Christensen-Dalsgaard et al. (2020) was also included in this current assessment. Previous research has also highlighted the importance of kelp forests as foraging habitat for both shags and black guillemots (Christensen-Dalsgaard et al. 2017; Dehnhard et al. 2022, 2023), and since central Norway is a core area for kelp harvesting, it is thus not very surprising that birds also use areas that are being harvested. It is, however, worth noting that black guillemots from Sklinna are using harvested areas to a higher degree (56% of foraging locations / 53% of all GPS locations) than protected areas. Multiple protected areas are located north of Vikna, including both Sklinna and Muddvær nature reserves, which are where the colonies are located. Nevertheless, the majority of foraging locations of seabirds in the region were outside of the boundaries of nature reserves, except for shags during the early breeding season, where 51% of foraging locations were located within nature reserves. For black guillemots at Muddvær and common guillemots at Sklinna, well under 10% of the foraging locations were located within protected areas, showing that protected areas do not effectively safeguard foraging areas of these populations during the breeding season. Of the protected areas used by the birds, it is further worth noting that commercial harvest of kelp and knotted wrack was forbidden only in four out of the ten protected areas used for foraging by the seabirds investigated in our case study. Regulations explicitly allowed the harvesting of tangle in three out of the ten protected areas used, and of knotted wrack in six out of ten protected areas during at least part of the year. However, harvesting of kelp did not occur in any of the protected areas during the study period, also not those where it was permitted.

Our case study was limited to GPS tracking data that was mostly collected during the breeding season, predominantly the chick-rearing period, with the exception of shags in 2020-2022, where also the post-breeding season was covered. Use of protected areas during the late breeding and post-breeding season decreased by shags, while the overlap with harvested areas remained similar. Outside of the breeding season, common guillemots that are breeding at Sklinna migrate away from their breeding grounds, and typically spend their winters in deeper waters either in the Barents Sea or Northern North Sea (Fauchald et al. 2021; Amélineau 2021). Shags and black guillemots are coastal year-round and often, but not necessarily remain at their breeding sites (Baak et al. 2020, Moe et al. 2021; Bråthen et al. in prep). Shags and black guillemots may thus utilize harvested areas year-round, while the overlap with the studied protected areas may be lower if birds move away from their colonies.

The chick-rearing period is an important period in the annual cycle of seabirds, and foraging areas used during this period and the food availability in these areas determine the breeding success on the colony level (Regular et al. 2014, Sandvik et al. 2016). For example, previous research on shags from Sklinna has shown that in years with poor food availability chick survival was lower, while shag parents extended their foraging range and travelled further to find food (Lorentsen et al. 2019). Shags show a clear preference to forage as close to colonies as possible (Dehnhard et al. 2022) – a preference also present in black guillemots (Dehnhard et al. 2023).

Thus, food availability in kelp forests near colonies and during the breeding season is of high importance to guarantee high breeding success. If kelp harvesting is impacting food availability – something that is still not evaluated for most species (see knowledge gaps highlighted in section 4.2), seabirds may thus be particularly sensitive to harvesting of kelp forests close to their colonies, especially right before or during the breeding season. As seabirds are long-lived, adult survival is typically high and is the main driver of population changes in seabird species (Gaillard et al. 1998; Layton-Matthews et al. 2024). However, a recent report identified that long-term poor breeding success was a major driver of population decline in 20 out 32 declining seabird populations in Norway (Layton-Matthews et al. 2024). The report also concluded with highlighting the need for appropriate management actions, which in the case of reduced breeding success include the reduction of impacts on food availability and the designation of marine protected areas to safeguard important foraging areas (Layton-Matthews et al. 2024). These management actions are also in agreement with global commitments by the UN to stop the biodiversity crisis and protect 30% of the marine environment, including coastal zones, by 2030 (Maestro et al. 2019). This agreement was ratified by Norway, but as of spring 2024 only 4.5 % of mainland Norway's marine areas are protected (Statistics Norway 2024).

4.4 Attitudes of interest groups towards harvesting of tangle and knotted wrack

As the commercial interest in wild seaweed harvesting grows, concerns about its potential impact on biodiversity are becoming more pronounced. In Norway, balancing economic interests with conservation is critical, as coastal habitats support numerous marine species which are vulnerable to disturbance and climate change. This survey aimed to capture the attitudes of various interest groups on harvesting tangle and knotted wrack. The focus was on critical ecological concerns, such as seasonal impacts on wildlife and harvesting within protected areas and harvesting during sensitive periods for wildlife (e.g. migration, breeding season and moult).

During the study preparation, a search for existing scientific literature on attitudes of interest groups toward wild seaweed harvesting revealed only limited research on this topic. Apart from Maack (2019), who examined sustainability criteria and ecosystem-based management practices for seaweed harvesting and conducted qualitative interviews with relevant interest groups and experts, not much is known about the view of the public or specific interest groups. This lack of information highlights the importance of the present study in delivering insights for sustainable management. Also, by analysing shifts in attitudes after providing ecological information, we aimed to understand how awareness might influence policy support.

Research shows that factual information can impact attitudes towards resource management, often leading to more sustainable preferences (Ajzen 1991; Tabi et al. 2014). For example, the HydroCen Nea report demonstrated that awareness of the environmental benefits of mitigating measures (e.g., on fish populations) strengthened support for conservation measures (Sundt-Hansen et al. 2021). Similarly, Maack (2019) noted that regulatory frameworks with sustainability criteria influence industry practices towards ecosystem-based management. Together, these findings suggest that informed respondents may adopt more cautious views about seaweed harvesting.

Across all interest groups, a generally cautious stance on seaweed harvesting emerged, reflecting concern for ecological vulnerabilities in coastal ecosystems. This was true for tangle harvesting and only to a somewhat smaller degree for knotted wrack harvesting. Many respondents favoured restrictions during sensitive periods, like seabird breeding and migration, and were generally opposed to harvesting within protected areas. Concerns about tangle harvesting were pronounced across nearly all interest groups, showing a strong preference for regulating both the timing and locations of harvesting activities. Responses to open questions also revealed that respondents are particularly concerned about the use of trawling as a method to harvest seaweed, due to its destructive effects on seaweed habitats. For knotted wrack, there was also a concern that harvest may conflict with interests of local landowners. However, commercial harvest of knotted wrack (and all other intertidal seaweed) on private property requires the approval of the landowners according to the Norwegian regulations in Friluftsloven. Friluftsloven only allows the public to harvest seaweed for own use, as long as the harvest is sustainable and of small or no value to the landowner.

Although responses varied across interest groups, a common theme was the preference for a management approach that combines conservation and resource use. Interestingly, when additional information on the ecological impacts of tangle and knotted wrack harvesting was provided, responses showed only moderate changes. This could be the result of the fact that initial attitudes were already cautious. Overall, respondents changed their opinion to be in favour of better protection, however with two exceptions: Onto the questions *if there should be protection against tangle harvesting during breeding and migration periods for seabirds* and *if there should be protection against knotted wrack harvesting during the breeding and migratory periods in areas, where it is known that seabirds or migratory birds are vulnerable*, respondents across all interest groups showed a decrease in willingness for such protection after information was provided. Viewing once more how questions and options to answer these were phrased (**Supplementary Materials 6.5**), we noticed that inadvertently the options to answer these two questions were phrased slightly different before information was provided than after, where the options after information was provided were somewhat ambiguous ("I am strongly for/against protection in the breeding [and migration] period" before; "I am strongly in favour/against this" after information was provided). While we cannot rule out with certainty that the change in opinion reflected a real wish against better protection, it appears more likely that the ambiguous phrasing made some people tick "I am (strongly) against this" when they in fact were against harvesting, and hence in favour of better protection, and should thus have ticked "I am (strongly) in favour of this".

Apart from the species case of these two questions, the observed changes in our survey align with studies showing that factual information can enhance conservation support but may not strongly shift established views (Tabi et al. 2014). Furthermore, the nature of the survey (relatively long with detailed information) could have led to a higher response rate from people who already have a bigger interest in and more established opinion on the subject matter. This could have further limited the potential that the given information had to shift the views of survey respondents.

Since the survey responses reflected mostly views of tourism-related and other industry actors, rather than direct seaweed harvesters, there was an overall preference for ecosystem preservation over harvesting expansion. The attitudes towards tangle and knotted wrack harvesting showed some variation among the groups. For tangle harvesting, we found that tourism and other industry respondents especially supported regulated harvesting, particularly with seasonal restrictions, aligning with principles of sustainable resource management (Maack 2019; Ostrom 1990). Many advocated for stricter regulations, particularly emphasizing seasonal limitations to protect sensitive periods for seabirds and shorebirds.

Environmental advocates in NGOs and researchers underscored the negative impact of knotted wrack harvesting on intertidal ecosystems, particularly for bird species dependent on these habitats. Many respondents in this group recommended limiting or banning harvesting in sensitive coastal areas. Although seaweed harvesters did not respond, other industry respondents generally showed moderate support for responsible practices. Information provision led to increased acceptance of seasonal and spatial limitations, indicating a growing recognition of the need to balance harvesting with ecological concerns.

The survey findings indicate that most interest groups — especially the tourism sector and NGOs — favoured a cautious approach, advocating for protective regulations. Across all groups, there was a consensus on limiting harvesting in protected areas and adopting seasonal restrictions. The observed attitude shifts following information provision suggest that educational efforts may play an important role in strengthening support for environmentally sound harvesting practices. The lack of responses from active seaweed harvesters presents a limitation, underscoring the need for more inclusive engagement in future research to ensure that both economic and ecological perspectives are represented in policy development.

With regards to limitations of our study, we have to acknowledge that this survey sample may be slightly skewed, as respondents primarily represented outdoor-interested and environmentally concerned individuals. While this subset of the population does reflect relevant interest group concerns, it may underrepresent pro-harvesting voices. Additionally, many respondents voiced concerns about other environmental issues, particularly those affecting fish populations, which suggests a broader ecological perspective. We also did not investigate whether attitudes toward seaweed harvesting differ across demographic groups, such as urban versus rural residents or younger versus older populations.

While this study captured general attitudes across interest groups, there is limited insight into the underlying motivations and values that drive these attitudes. Future research could explore the specific concerns, values, and socio-economic factors that influence different stakeholders' perspectives on seaweed harvesting. Such understanding could help tailor communication and policy approaches to address the different priorities of each group.

4.5 Conclusions

We summed up existing knowledge about kelp and seaweed harvesting with a focus on seabirds and shorebirds. Although harvesting of kelp and knotted wrack in Norway have been going on for hundreds of years, and gradually got industrialized during the 1970s, there is still insufficient knowledge about the effects of harvesting on birds. Despite a small proportion of the nationwide standing stock being taken for tangle per year, concerns are relevant as the overlap between birds and harvested areas can regionally be considerable, as shown in our case study, and in addition the period when most kelp is harvested coincides with the seabirds' breeding period. For knotted wrack, where the last estimate for the standing stock was published in 1970, it is not even known how much of the nationwide standing stock is harvested every year, let alone how the harvest affects food availability for shorebirds or seabirds that use these habitats to feed.

Our report identified a number of knowledge gaps associated with the effects of seaweed harvest in Norway on sea- and shorebirds, and the literature review revealed that this was overall a poorly studied topic. Severe knowledge gaps on the harvest of knotted wrack and the need for better regulations have also been identified by The Marine Research Institute (Steen et al. 2024), but with so little knowledge available, it is difficult to provide recommendations towards what a sustainable harvest of knotted wrack would look like. We do highlight that by sucking up the knotted wrack together with attached invertebrates, as it is common practice now by commercial trawlers, a large proportion of invertebrate biomass is removed from the environment, which also means a loss of potential food for shorebirds and eider ducklings. It is worth noting that such an approach has been abandoned in for instance Canada and Maine, USA.

The survey results reveal a negative attitude and cautious stance towards seaweed harvesting among all interest groups targeted in the survey, with broad support for protective measures like seasonal restrictions to safeguard seabird breeding and migration periods. Although additional ecological information led some respondents to shift from "don't know" responses to defined stances, the overall changes were visible but moderate, indicating that initial attitudes were already conservation-oriented. However, the survey's low response rate, especially from commercial harvesters, limits the diversity of perspectives represented. Thus, while the findings reflect the views of environmentally engaged interest groups, they may not fully encompass all interest groups.

Our results provide valuable insights for decision-makers at both regional and national levels. Regionally, they can inform management strategies and regulatory considerations for existing and prospective protected areas, while nationally, they can support the development of policies governing seaweed harvesting practices. This report may also be useful internationally as the results from the literature review are internationally valid, and results from the case study and survey may be transferable to other countries where harvesting is allowed or considered.

Many seabird and shorebird populations are experiencing severe declines. In order to stop this negative development, we need a shift towards an ecosystem-based management and hence reduce human impacts in areas that are important for wildlife. Closing the knowledge gaps identified in this report and managing seaweed harvest according to the best knowledge available will contribute to reduce impacts on seabirds and shorebirds and help reverse the currently negative development.

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6 Supplementary materials

6.1 Supplementary materials 1: Benchmark articles for effects of kelp and seaweed harvest on birds

Christensen-Dalsgaard, S., Mattisson, J., Norderhaug, K.M. & Lorentsen, S.-H. 2020. Sharing the neighbourhood: assessing the impact of kelp harvest on foraging behaviour of the European shag. Marine Biology, 167: 136. doi: https://doi.org/10.1007/s00227-020-03739-1

Johnston, E.M., Klemmer, A.J., Braun, L.A., Mittelstaedt, H.N., Muhlin, J.F., Webber, H.M. & Olsen, B.J. 2024. Evaluating bottom-up forcing of a rocky intertidal resource harvest on a high trophic level consumer group. Estuarine, Coastal and Shelf Science, 298: 108627. doi: https://doi.org/10.1016/j.ecss.2024.108627

Lorentsen, S.-H., Sjotun, K. & Grémillet, D. 2010. Multi-trophic consequences of kelp harvest. Biological Conservation, 143: 2054-2062. doi: https://doi.org/10.1016/j.biocon.2010.05.013

6.2 Supplementary materials 2: Results from systematic literature search and filtering for relevance

140 articles found and screened for relevance, where we include only those that specifically address the impact of kelp and seaweed harvest on birds. After screening, the seven articles listed below were found to fit the criteria (see **Table 2** in the main text).

Relevant articles in search

Blinn, B.M., Diamond, A.W. & Hamilton, D.J. 2008. Factors Affecting Selection of Brood-rearing Habitat by Common Eiders (*Somateria mollissima*) in the Bay of Fundy, New Brunswick, Canada. Waterbirds, 31: 520-529. doi: https://doi.org/10.1675/1524-4695-31.4.520

Carranza, D.M., Wieters, E.A., Vásquez, J.A. & Stotz, W.B. 2024. Exploring the consequences of kelp removal: a review shows we are missing a broader perspective. Biodiversity and Conservation, 33: 401-437. doi: https://doi.org/10.1007/s10531-023-02769-7

Christensen-Dalsgaard, S., Mattisson, J., Norderhaug, K.M. & Lorentsen, S.-H. 2020. Sharing the neighbourhood: assessing the impact of kelp harvest on foraging behaviour of the European shag. Marine Biology, 167: 136. doi: https://doi.org/10.1007/s00227-020-03739-1

Dugan, J.E., Hubbard, D.M., McCrary, M.D. & Pierson, M.O. 2003. The response of macrofauna communities and shorebirds to macrophyte wrack subsidies on exposed sandy beaches of southern California. Estuarine Coastal and Shelf Science, 58: 25-40. doi: https://doi.org/10.1016/s0272-7714(03)00045-3

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Lorentsen, S.-H., Sjotun, K. & Grémillet, D. 2010. Multi-trophic consequences of kelp harvest. Biological Conservation, 143: 2054-2062. doi: https://doi.org/10.1016/j.biocon.2010.05.013

Navedo, J.G., Verdugo, C., Rodríguez-Jorquera, I.A., Abad-Gómez, J.M., Suazoid, C.G., Castañeda, L.E., Araya, V., Ruiz, J. & Gutiérrez, J.S. 2019. Assessing the effects of human activities on the foraging opportunities of migratory shorebirds in Austral high-latitude bays. PLoS One, 14: e0212441. doi: https://doi.org/10.1371/journal.pone.0212441

6.3 Supplementary materials 3: Additional figures showing survey responses

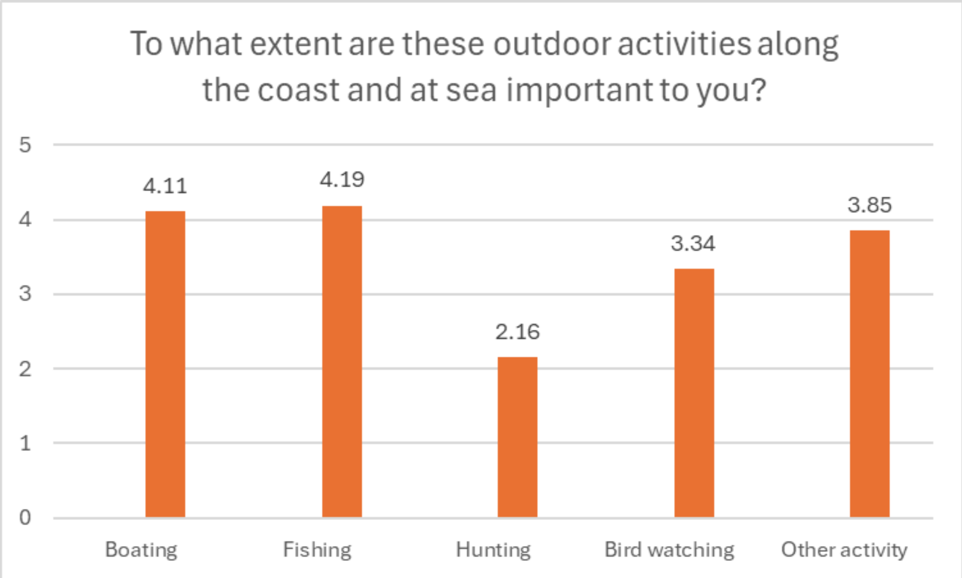

Figure 6.3.1. *Mean values for responses to the question on the importance of different outdoor activities: On a scale from: 0 (not important) to 5 (very important).*

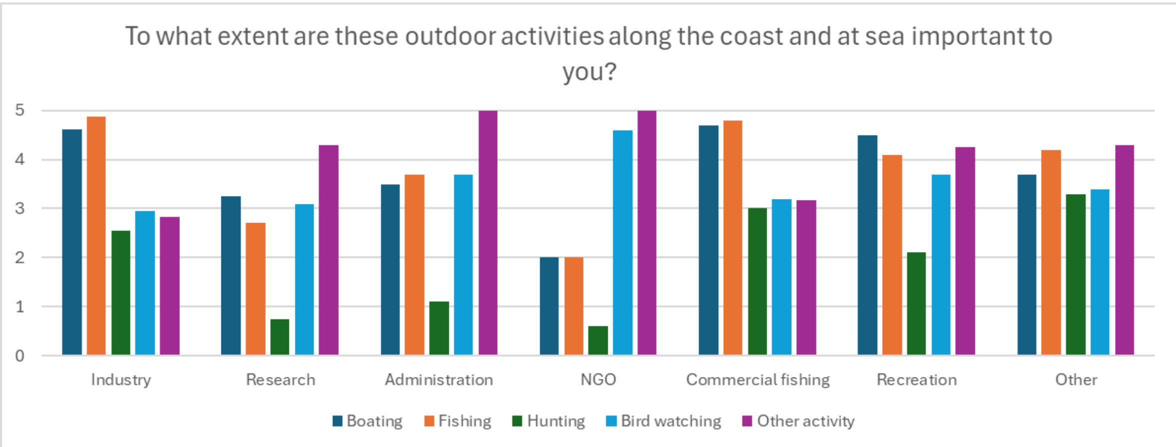

Figure 6.3.2. *Mean values for responses to the question on the importance of different outdoor activities, per interest group. On a scale from: 0 (not important) to 5 (very important).*

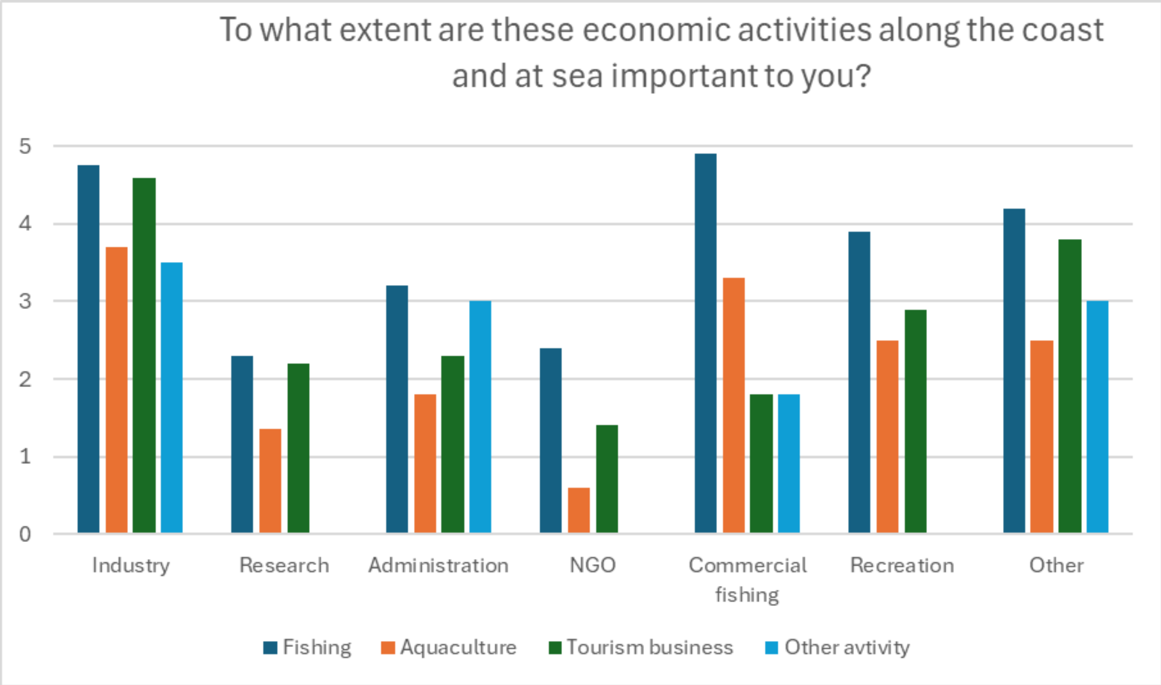

Figure 6.3.3. *Mean values for responses to the question on the importance of different economic activities, per interest group. On a scale from: 0 (not important) to 5 (very important).*

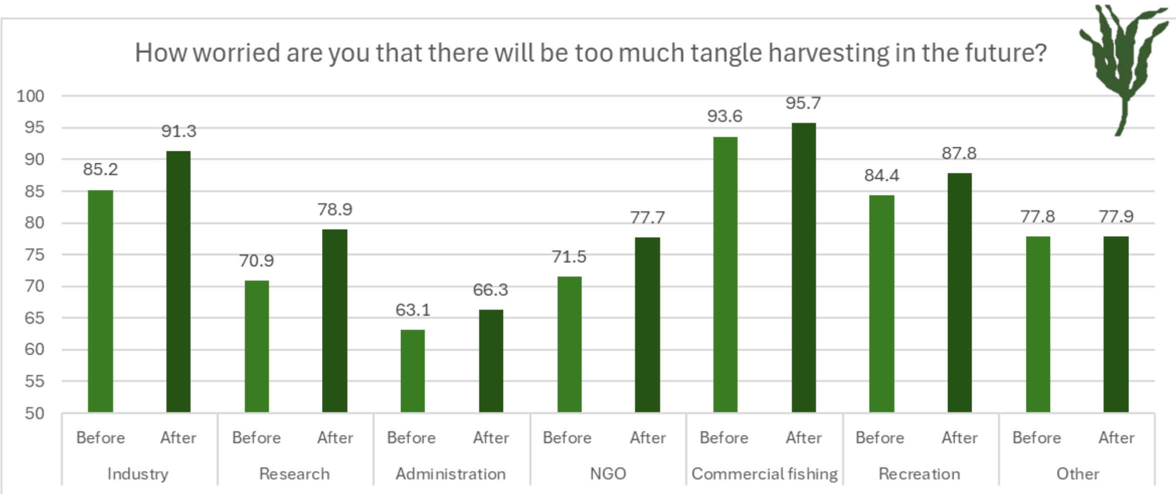

Figure 6.3.4. *Average percentage level of concern about tangle harvesting in the future, per interest group, before and after information about tangle harvesting was given, where 0% is not worried and 100% is extremely worried. N = 71 respondents.*

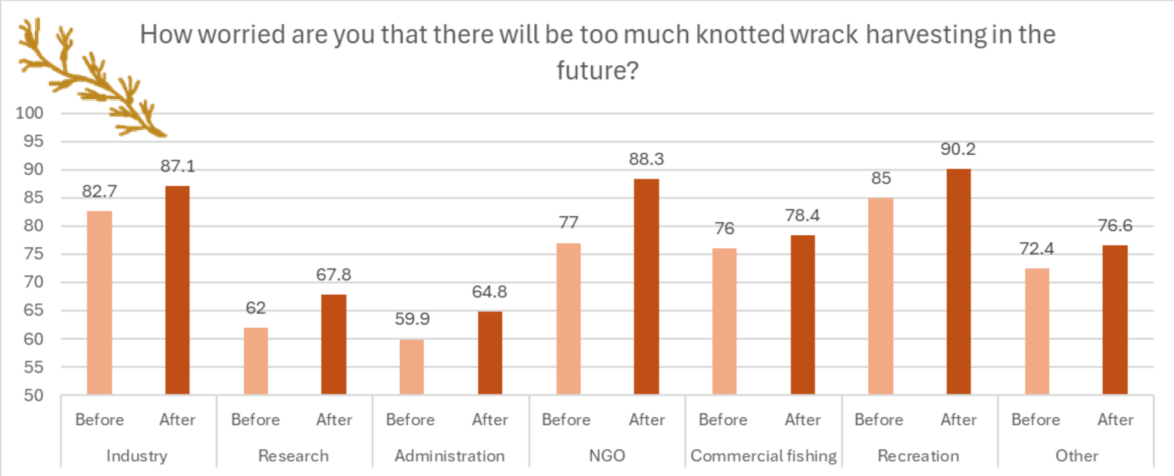

Figure 6.3.5. *Average percentage level of concern about harvesting of knotted wrack in the future, per interest group, before and after information about tangle harvesting was given, where 0% is not worried and 100% is extremely worried. N = 71 respondents.*

6.4 Supplementary materials 7: Email invitation to the web-based survey

The invitation to participate in the survey was sent out in Norwegian. We present here the text in the original language.

Hei!

Her har du en mulighet til å komme med dine meninger om tang- og tare-høsting!

Norsk institutt for naturforskning (NINA) har et prosjekt på oppdrag av Statsforvalteren i Trøndelag for å finne ut mer om holdninger til høsting av tare og tang.

Både tang- og tarehøsting øker i utbredelse og intensitet, og det er mange aktører som kan bli påvirket av denne aktiviteten. I denne spørreundersøkelsen ønsker vi derfor å kartlegge hvordan forskjellige interessenter og aktører stiller seg til høsting av tang og tare, både innenfor og utenfor verneområder.

*Utfyllingen tar ca. 30 minutter. Du kan ta en pause undervegs og fortsette utfyllingen senere. All informasjon blir lagret fortløpende. Vi vil understreke at informasjonen du gir blir behandlet konfidensielt. Vennligst fyll ut undersøkelsen **innen 29. september**.*

Stortare (Laminaria hyperborea) og grisetang (Ascophyllum nodosum) er de eneste algeartene som høstes kommersielt i Norge i dag. Tang ligger øverst i fjæra og er dermed lett å få øye på, mens tare vokser på stilker lengre ned i sjøen. Både tang og tare høstes med spesielle typer båter på kyststrekningen Rogaland-Nordland. Taren blir trålt opp med en tindetrål som trekkes med en kabel bak skipet langs havbunnen og river løs tareplantene. Alginat, som utvinnes fra stortare, er en viktig ingrediens i forskjellige produkter innenfor medisin, kosmetikk og som tilsetningsstoffer i matvarer. Tangmel, som utvinnes fra grisetang, er rik på mineraler og vitaminer og brukes som tilskuddsfôr til husdyr.

Her finner du lenken til spørreundersøkelsen: Take the Survey

Som takk for deltakelsen kan alle deltakere bli med i en loddtrekning, og vinnere kan *velge blant fem forskjellige naturbøker eller en t-skjørte.*

Tror du at du ikke er rett person til å svare på denne spørreundersøkelsen, eller kjenner du til noen andre som du synes skal være med? Vennligst svar på denne e-posten og send oss kontaktinformasjonen til personen(e) du mener vi bør kontakte.

På forhånd takk for din medvirkning!

Med vennlig hilsen, Nina Dehnhard, Berit Köhler, Tessa Bargmann

6.5 Supplementary materials 8: Survey questions and provided information

Below are the survey questions as well as all information presented as part of the survey. We present also this part in the original language (Norwegian).

Norsk

Velkommen til spørreundersøkelsen "Holdninger til høsting av tang og tare"!

Først har vi noen spørsmål om din bakgrunn:

Hvilken av følgende interessegrupper identifiserer du deg mest som?

- Næring
- Forskning
- Forvaltning
- NGO
- Yrkesfisker
- Rekreasjon. Hvilken?
- Annen. Hvilken?

I hvilken grad er disse friluftslivsaktiviteter langs kysten og på havet viktig for deg?

	Svært viktig	Viktig	Litt viktig	Nøytralt	Lite viktig	Ikke viktig
Båtliv	○	○	○	○	○	○
Fiske	○	○	○	○	○	○
Jakt	○	○	○	○	○	○
Fuglekikking	○	○	○	○	○	○
Annet aktivitet. Hvilken?	○	○	○	○	○	○

I hvilken grad er disse friluftslivsaktiviteter langs kysten og på havet viktig for deg?

	Svært viktig	Viktig	Litt viktig	Nøytralt	Lite viktig	Ikke viktig
Båtliv	○	○	○	○	○	○
Fiske	○	○	○	○	○	○
Jakt	○	○	○	○	○	○
Fuglekikking	○	○	○	○	○	○
Annet aktivitet. Hvilken?	○	○	○	○	○	○

I hvilken grad er disse næringsaktiviteter langs kysten og på havet viktig for deg?

	Svært viktig	Viktig	Litt viktig	Nøytralt	Lite viktig	Ikke viktig
Fiske	○	○	○	○	○	○
Akvakultur	○	○	○	○	○	○
Turistnæring	○	○	○	○	○	○
Annen aktivitet. Hvilken	○	○	○	○	○	○

Kjønn

○ Mann
○ Kvinne
○ Ikke binær
○ Ønsker ikke å oppgi

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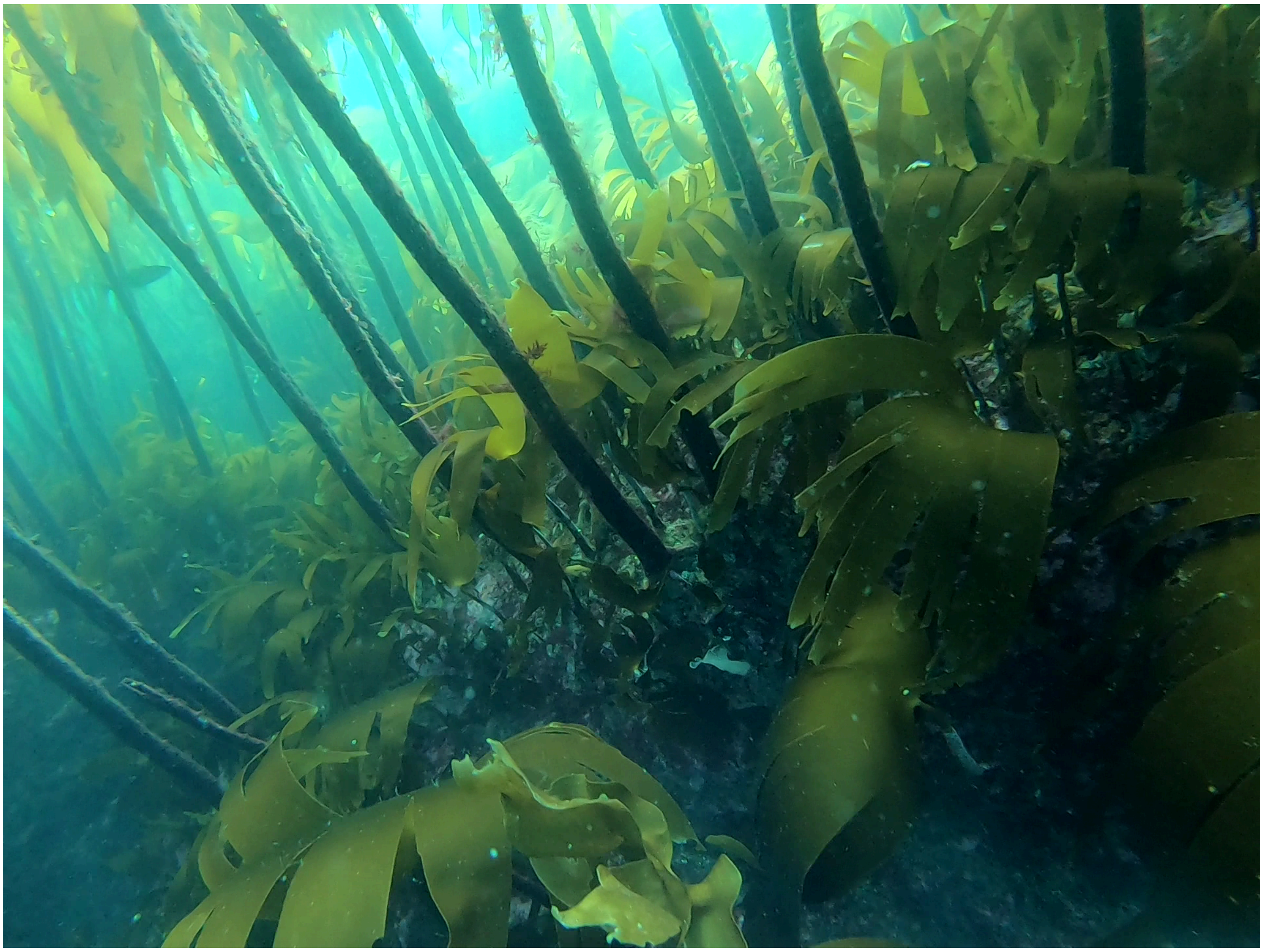
Nå skal vi se nærmere på tare- og tanghøsting. Først om TARE:



Hva er din generelle holdning til høsting av tare?

- ◯ Sterkt for – Jeg mener at tarehøsting er svært viktig og bør fremmes.
- ◯ For – Jeg støtter tarehøsting, men det kan være noen utfordringer knyttet til tarehøsting.
- ◯ Nøytral – Jeg har ingen sterke meninger om tarehøsting.
- ◯ Mot – Jeg er generelt mot tarehøsting, men det kan være noen unntak.

- ◯ Sterkt mot – Jeg mener at tarehøsting er skadelig for naturen og bør unngås.
- ◯ Har ingen mening
- ◯ Vet ikke nok om temaet

I dag rulleres tarehøsting slik at hvert område høstes hvert femte år og ligger urørt de andre fire årene i det samme området. Synes du at tare bør høstes:

- ◯ Mye hyppigere
- ◯ Hyppigere
- ◯ Like mye som nå
- ◯ Sjeldnere
- ◯ Mye sjeldnere
- ◯ Aldri
- ◯ Har ingen mening
- ◯ Vet ikke nok om temaet

Verneforskriften til noen verneområder tillater høsting av tare, mens det er forbud mot høsting i andre verneområder. Hva tenker du om høsting av tare i verneområder?

- ◯ Det burde være tillatt i alle områder, inkl. verneområder.
- ◯ Det er bra at det er forbudt i noen og tillatt andre verneområder.
- ◯ Det burde være forbudt i alle verneområder å høste tare.
- ◯ Vet ikke

- [ ] Andre synspunkter

Burde det være fredning i hekkeperioden mot høsting av tare hvor vi vet at sjøfugl er sårbare?

- Jeg er sterkt for fredning i hekkeperioden.
- Jeg er noe for fredning i hekkeperioden.
- Jeg er nøytralt til fredning i hekkeperioden.
- Jeg er noe imot fredning i hekkeperioden.
- Jeg er sterkt imot fredning i hekkeperioden.
- Jeg har ingen mening.
- Jeg vet ikke nok om temaet.

Hva tror du er påvirkningen av høsting av tare på følgende ...?

	Svært positiv	Middels positiv	Nøytral	Noe negativ	Middels negativ	Svært negativ
Forekomst av fisk	○	○	○	○	○	○
Mattilgang for fugl (f.eks. ærfugl eller skarv)	○	○	○	○	○	○
Fugl pga. forstyrrelser (f.eks. pga. støy eller båten som kommer veldig nærme)	○	○	○	○	○	○
Forekomst av sjøpattedyr (sel og hval)	○	○	○	○	○	○

	Svært positiv	Middels positiv	Nøytral	Noe negativ	Middels negativ	Svært negativ
Forekomst av andre marine dyr (f.eks. strandsnegler, krepsdyr)	○	○	○	○	○	○
Annet	○	○	○	○	○	○

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Er du bekymret at det blir for mye tarehøsting i framtida?

Veldig lite bekymret	Litt bekymret	Middels bekymret	Veldig bekymret	Har ingen mening

0 10 20 30 40 50 60 70 80 90 100

Hvorfor?

Har du andre synspunkter om forhold som man bør ta hensyn til med tanke på tarehøsting, eller har du noen andre innspill og kommentarer om høsting av tare?

Hvor mye kunnskap vurderer du at du har om tarehøsting?

- Svært mye
- Mye
- Passe
- Lite
- Veldig lite

side 3 av 9

Nå skal vi se nærmere på høsting av TANG.

Hva er din generelle holdning til høsting av tang?

- ◯ Sterkt for – Jeg mener at tanghøsting er svært viktig og bør fremmes.
- ◯ For – Jeg støtter tanghøsting, men det kan være noen bekymringer.
- ◯ Nøytral – Jeg har ingen sterke meninger om tanghøsting.
- ◯ Mot – Jeg er generelt mot tanghøsting, men det kan være noen unntak.
- ◯ Sterkt mot – Jeg mener at tanghøsting er skadelig for naturen og bør unngås.
- ◯ Har ingen mening
- ◯ Vet ikke nok om temaet

I dag høstes tang slik at aktørene selv bestemmer når hvert område høstes. Typisk kan det gå 4-6 år mellom hver gang et område høstes, men høstingen kan være hyppigere der veksten er god. Synes du at tang bør høstes:

- ○ Hyppigere
- ○ Like mye som nå
- ○ Sjeldnere
- ○ Aldri
- ○ Har ingen mening
- ○ Vet ikke nok om temaet

I dag blir tang høstet fra skip som kutter tang rett over steinen og suger opp tang samt alt som vokser/lever på plantene samt vann opp i båten. Vannet blir spylt ut igjen. Tenker du at denne høstemetodikken med båt kan være et problem for fugl, fisk eller andre marine dyr?

- ○ Veldig stor grad
- ○ Stor grad
- ○ Nøytral
- ○ Liten grad
- ○ Veldig liten grad
- ○ Har ingen mening
- ○ Vet ikke nok om temaet

Verneforskriften til noen verneområder tillater høsting av tang, mens det er forbud mot høsting i andre verneområder. Hva tenker du om høsting av tang i verneområder?

- ◯ Det burde være tillatt i alle områder, inkl. verneområder.
- ◯ Det er bra at det er forbudt i noen og tillatt andre verneområder.
- ◯ Det burde være forbudt i alle verneområder å høste tang.
- ◯ Vet ikke
- ◯ [ ] Andre synspunkter

Burde det være fredning i hekkeperioden (vår, sommer) og i trekkperioden (vår og høst) mot høsting av tang hvor vi vet at sjøfugl eller trekkfugl er sårbare?

- ◯ Jeg er sterkt for fredning i hekke- og trekkperioden.
- ◯ Jeg er noe for fredning i hekke- og trekkperioden.
- ◯ Jeg er nøytral til fredning i hekke- og trekkperioden.
- ◯ Jeg er noe imot fredning i hekke- og trekkperioden.
- ◯ Jeg er sterkt imot fredning i hekke- og trekkperioden.
- ◯ Jeg har ingen mening.
- ◯ Jeg vet ikke nok om temaet.

Hva tror du er påvirkningen av høsting av tang på følgende ...?

	Svært positiv	Middels positiv	Nøytral	Noe negativ	Middels negativ	Svært negativ
Forekomst av fisk	○	○	○	○	○	○
Mattilgang for fugl (f.eks. ærfugl eller skarv)	○	○	○	○	○	○
Fugl pga. forstyrrelser (f.eks. pga. støy eller båten som kommer veldig nærme)	○	○	○	○	○	○
Forekomst av sjøpattedyr (sel og hval)	○	○	○	○	○	○
Forekomst av andre marine dyr (f.eks. strandsnegler, krepsdyr)	○	○	○	○	○	○
Annet	○	○	○	○	○	○

side 4 av 9

Er du bekymret at det blir for mye tanghøsting i framtida?

Veldig lite bekymret | Litt bekymret | Middels bekymret | Veldig bekymret | Har ingen mening

0 10 20 30 40 50 60 70 80 90 100

Hvorfor?

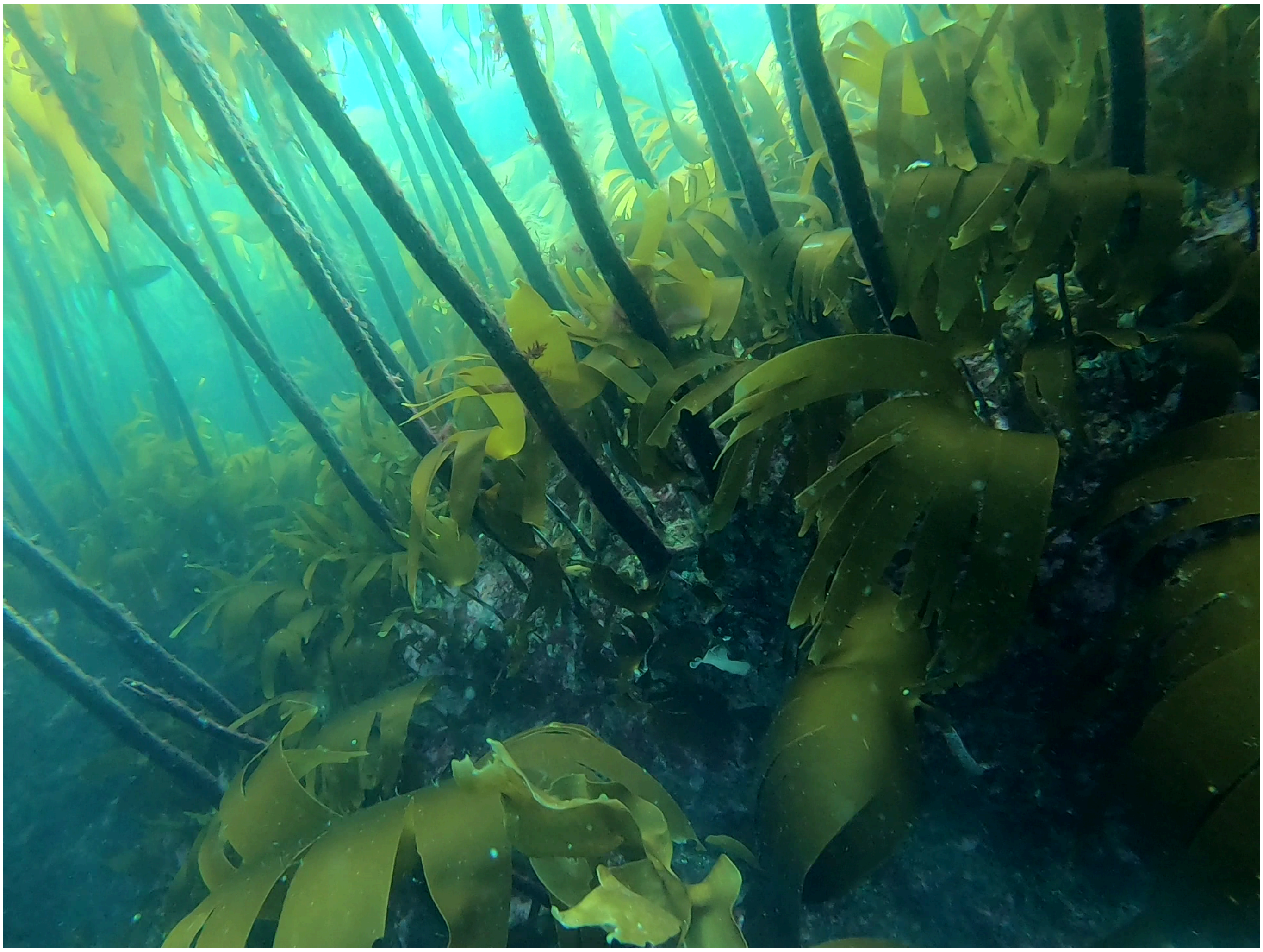
Har du andre synspunkter om forhold som man bør ta hensyn til med tanke på tanghøsting, eller har du noen andre innspill og kommentarer om høsting av tang?

Hvor mye kunnskap vurderer du at du har om tanghøsting?

- ◯ Svært mye
- ◯ Mye
- ◯ Passe
- ◯ Lite
- ◯ Veldig lite

side 5 av 9

Nå har vi noe informasjon for deg og vi vil be deg om å lese gjennom. Først om TARE:



Forskningen viser at:

- Stortare bruker rundt fire år på å vokse til sin opprinnelige størrelse etter høsting. Denne gjenveksten kommer i stor grad fra vekst i underskogen av nylig etablert stortare som unngikk å bli høstet, og underskogen er betydelig mindre fire år etter høsting (1). Dette fører til lite variasjon i størrelsen til taren som er igjen etter høsting. Tareskogen er et viktig område for næringssøk for sjøfugler. Hos toppskarv og teist er det dokumentert at næringssøk rundt hekkekolonier kan være tett koblet til utbredelsen av tareskog (2,3,4).

- Effekten av taretråling på fiskesamfunn har blitt undersøkt i eksperimentelt trålte områder. I trålsporene hvor tare er høstet er det funnet lavere antall av fisk over havbunnen enn ved lokaliteter som ikke er høstet. I trålsporene trakk fisken ned på havbunnen, mens i tareskogen var flere fisk høyere opp i vannmassene. Denne effekten er imidlertid funnet å være lokal og kontrollområder nært høstede trålspor kan ha like mye fisk som områder lengre unna (5). Effekten av høsting kan også variere mellom arter med ulik levemåte. Artssammensetningen og adferden i trålsporene og i kontrollområder kan derfor være ulik. Høyere opp i vannmassene (over tareskogen) ble det ikke påvist endring i forekomsten av fisk i studiet av Norderhaug et al (6).
- Studier har funnet at det er betydelig reduksjon av invertebrater, slik som snegler og muslinger, i områder der tare er høstet (6).

Referanser:

1 Steen et al. 2016, ICES Journal of Marine Science,
2 Christensen-Dalsgaard et al. 2017, Marine Biology.
3 Dehnhard et al. 2022, Frontiers in Marine Science.
4 Dehnhard et al. 2023, Marine Biology.
5 Steen et al. 2012, Fisken og Havet Rapport.
6 Norderhaug et al. 2020, Marine Ecology Progress

Series.

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Og nå for TANG

YouTube video tanghøsting:

Forskningen viser at:

- Grisetang vokser raskere enn tare. Etter høsting går det rundt ett år før mengden og høyden på tangen er i nærheten av sin opprinnelige høyde (7). Ved mer intensiv høsting kan det ta lengre tid før tangen når opprinnelig størrelse.
- Høyvokst grisetang har vist seg å være svært viktig for blant annet ærfuglunger tidlig etter klekking. I denne perioden holder ungene seg på toppen av tangen som flyter i overflaten og søker næring der fram til de blir store nok til å kunne dykke etter mat (8).
- Med sine lange forgreininger og høyde ved høyvann former grisetang komplekse habitater. Den skaper slik viktige leveområder for en rekke arter, for eksempel som gjemmesteder for fisk (9) og næringssøk for små krepsdyr (10).
- Kystområder som har rike tangforekomster og tangvoller med død tang som har skylt på land er viktige leveområder for en rekke vannfugler, slik som ulike vadefugler og ærfugl (11).

- I perioden etter tanghøsting har det blitt funnet en reduksjon i antall fugler i høstede områder når det er lavvann, denne effekten avtar med tid og går tilbake mot opprinnelig forekomst ett år etter (12).

I dag er tanghøstingen relativt lite regulert og utbygget i Norge. Det er bare ett amerikansk selskap (DuPont) som produserer alginat fra taretrålingen, som dermed har et monopol i Norge. Det er vurdert å være et stort potensial for videre utvikling av tang- og tarehøsting om en kun ser på hvor stor veksten av tang og tare er i forhold til hvor mye som høstes. Nye områder lenger nord ble åpnet for taretråling i 2022, og flere firmaer har utrykt en interesse for økt høsting.

Referanser:
7 Johnston et al. 2023, Journal of Experimental Marine Biology and Ecology.
8 Hamilton 2001, Waterbirds.
9 Rangeley and Kramer 1998, Ecology.
10 Pavia et al. 1999, Journal of Experimental Marine Biology and Ecology.
11 Johnston et al. 2021, Marine Ecology Progress Series.
12 Johnston et al 2024, Estuarine, Coastal and Shelf Science.

Du vil nå få noen av de samme spørsmålene som i første del av spørreundersøkelsen, for å se om informasjonen du nettopp har fått har endret holdningene dine til tang- og tarehøsting.

TARE

TANG

Hva er din generell holdning til høsting av tare/tang nå?

	Sterkt for - Jeg mener at høsting er svært viktig og bør fremmes.	For - Jeg støtter høsting, men det kan være noen bekymringer.	Nøytral - Jeg har ingen sterke meninger om høsting.	Mot - Jeg er generelt mot høsting, men det kan være noen unntak.	Sterkt mot - Jeg mener at høsting er skadelig for naturen og bør unngås.
Høsting av tang	○	○	○	○	○

	Sterkt for - Jeg mener at høsting er svært viktig og bør fremmes.	For - Jeg støtter høsting, men det kan være noen bekymringer.	Nøytral - Jeg har ingen sterke meninger om høsting.	Mot - Jeg er generelt mot høsting, men det kan være noen unntak.	Sterkt mot - Jeg mener at høsting er skadelig for naturen og bør unngås.
Høsting av tare	○	○	○	○	○

Verneforskriften til noen verneområder tillater høsting av tare/tang, mens det er forbud mot høsting i andre verneområder. Hva tenker du om høsting av tare/tang i verneområder?

	Det burde være tillatt i alle områder, inkl. verneområder	Det er bra at det er forbudt i noen og tillatt andre verneområder	Det burde være forbudt i alle verneområder å høste tare	Vet ikke	Andre synspunkter
Høsting av tare	○	○	○	○	○
Høsting av tang	○	○	○	○	○

Hvis du har andre synspunker - forklar:

Burde det være fredning i hekkeperioden (vår, sommer) og i trekkperioden (vår og høst) mot høsting av tang hvor vi vet at sjøfugl eller trekkfugl er sårbare?

	Ja, jeg er sterkt for dette	Jeg er noe for dette	jeg er nøytralt til dette	jeg er noe mot dette	Jeg er sterkt mot dette	Jeg har ingen mening
Høsting av tare						
Høsting av tang						

Hva tror du er påvirkningen av TAREhøsting på følgende ...?

	Svært positiv	Middels positiv	Noe positiv	Nøytral	Noe negativ	Middels negativ
Forekomst av fisk						
Mattilgang for fugl (f.eks ærfugl eller skarv)						
Fugl pga. forstyrrelser (f.eks. pga. støy eller båten som kommer veldig nærme)						
Forekomst av sjøpattedyr (sel, hval eller oter)						
Forekomst av andre marine dyr (f.eks. strandsnegler, krepsdyr)						

	Svært positiv	Middels positiv	Noe positiv	Nøytral	Noe negativ	Middels negativ
Annet. Hva?	○	○	○	○	○	○

Hva tror du er påvirkningen av TANGhøsting på følgende ...?

	Svært positiv	Middels positiv	Noe positiv	Nøytral	Noe negativ	Middels negativ
Forekomst av fisk	○	○	○	○	○	○
Mattilgang for fugl (f.eks ærfugl eller skarv)	○	○	○	○	○	○
Fugl pga. forstyrrelser (f.eks. pga. støy eller båten som kommer veldig nærme)	○	○	○	○	○	○
Forekomst av sjøpattedyr (sel, hval eller oter)	○	○	○	○	○	○
Forekomst av andre marine dyr (f.eks. strandsnegler, krepsdyr)	○	○	○	○	○	○
Annet. Hva?	○	○	○	○	○	○

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Er du bekymret at det blir for mye TAREhøsting i framtida?

Veldig lite bekymret	Litt bekymret	Middels bekymret	Veldig bekymret	Har ingen mening

0 10 20 30 40 50 60 70 80 90 100

Hvorfor?

Er du bekymret at det blir for mye TANGhøsting i framtida?

Veldig lite bekymret	Litt bekymret	Middels bekymret	Veldig bekymret	Har ingen mening

0 10 20 30 40 50 60 70 80 90 100

Hvorfor?

Har du andre synspunkter om forhold som man bør ta hensyn til med tanke på tare/tanghøsting, eller har du noen andre innspill og kommentarer om høsting av tare/tang?

Har du noen kommentarer til oss?

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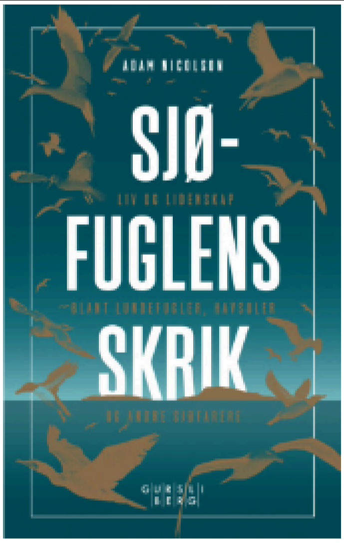
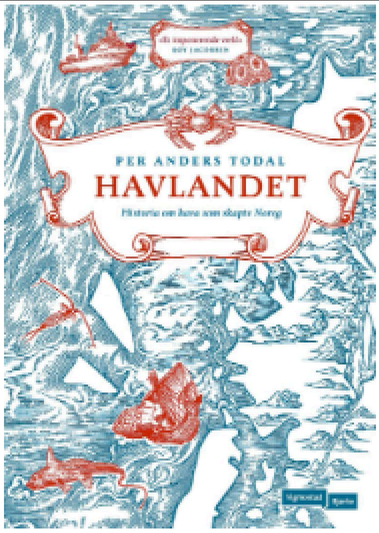
Vi takker for at du tok deg tid til å besvare denne undersøkelsen! Ditt svar er blitt registrert.

Vil du bli med i loddtrekningen?

- ◯ Ja
- ◯ Nei





Hvis ja: Hvilken premie vil du vinne?

- ○ Bok: Uten fugler blir ikke livet det samme – av Martin Eggen
- ○ Bok: Midt i flokken – av Olav Strand
- ○ Bok: Havlandet: Historien om hava som skapte Noreg – av Per Anders Todal
- ○ Bok: Sjøfuglens Skrik – av Adam Nicolson
- ○ Bok: Skogen: Om trær, folk og 25 000 andre arter – av Anne Sverdrup-Thygeson
- ○ T-skjorte: designet i anledning verdens fiskevandringsdag (motiv: Vederbuk/ Gudbrandsdalslågen)

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NINA Report

The Norwegian Institute for Nature Research, NINA,
is as an independent foundation focusing on environmental research, emphasizing the interaction between human society, natural resources and biodiversity.

NINA was established in 1988. The headquarters are located in Trondheim, with branches in Tromsø, Lillehammer, Bergen and Oslo. In addition, NINA owns and runs the aquatic research station for wild fish at Ims in Rogaland and the arctic fox breeding center at Oppdal.

NINA's activities include research, environmental impact assessments, environmental monitoring, counselling and evaluation. NINA's scientists come from a wide range of disciplinary backgrounds that include biologists, geographers, geneticists, social scientists, sociologists and more. We have a broad-based expertise on the genetic, population, species, ecosystem and landscape level, in terrestrial, freshwater and coastal marine ecosystems.

ISSN: 1504-3312
ISBN: 978-82-426-5316-1

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