FACULTY OF SCIENCE AND TECHNOLOGY

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Mapping ecosystem services in northern Norway

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Introduction

An ecosystem service is a consistent flow of materials, energy, and information from natural capital stocks that are combined with manufactured and human capital services to benefit human welfare.[1] There are four types of ecosystem services, provisioning, regulating, cultural and supporting services. Provisioning services are any type of benefit to humans that can be extracted from nature such as food, oil, timber and water. Regulating services are the benefits given by ecosystem processes that moderate natural phenomena. These services are pollination, erosion and flood control, decomposition and water purification. Cultural services are benefits that are non-material such as tourism, recreation and creative and aesthetic experiences. Finally, there are supporting services which are the services that are necessary for all the other ecosystem services to produce their products. These services are, for example, water cycling, biomass production and production of atmospheric oxygen.[2]

To keep nature in balance, it is important to map the different ecosystems so that people do not ruin the resources for the next generation. The ecosystem services are a crucial part of humans life and wellbeing.[3] Ecosystem services are a big part of the human wellbeing and they are important so that humans can survive. Ecosystems will change naturally with climate change, but humans are affecting the climate change and the way they use ecosystem services. It is important to find a value of the ecosystem services so humans can be mindful on how they use them and what services they have.[4]

Climate change effects on ecosystem services

Changing the climate will affect the ecosystems in a variety of ways. Warming can force species to move to higher altitudes where the temperatures are better for their survival. Another example is if the sea level rises and salt water mixes into a fresh water pond, so that

[1] (nature_paper)
[2] https://www.nwf.org/Educational-Resources/Wildlife-Guide/Understanding-Conservation/Ecosystem-Services , 02.03.23
[3] https://earth.org/what-are-ecosystem-services/, 02.03.23
[4] https://toolkit.climate.gov/topics/ecosystems, 20.03.23

the species have to move or they can end up dying from the change of the environment.[5] Due to ice and snow melting in the Artic the amount of warmth and solar energy absorbed increases because more of the darker surfaces are exposed (albedo effect). The Arctic is warming three times as fast as the global average, which will affect the ecosystem services in the north.[6]

Mapping ecosystem services in northern Norway

The aim of this thesis is to define the ecosystem services of northern Norway because this area is subject to climate change. The main research questions are:

1. What ecosystem services are in Norway?
2. What is the spatial extent of these services?
3. How can these service be valued?
4. By comparing climate class change maps to ecosystem services coverage, where may expected changes occur?

[5] https://19january2017snapshot.epa.gov/climate-impacts/climate-impacts-ecosystems_.html, 23.03.23
[6] https://www.npolar.no/en/themes/climate-change-in-the-arctic/#toggle-id-1, 25.03.23

Map of Norway and northern Norway

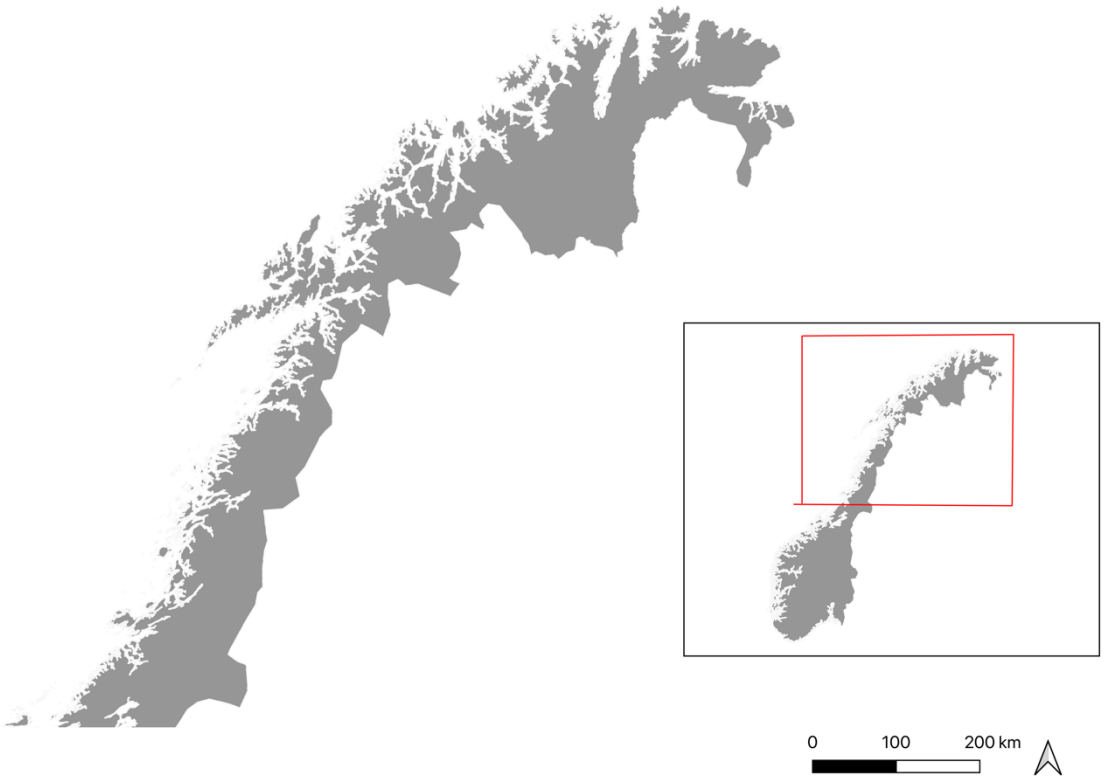

Figure 1: Map of northern Norway, with a small map of Norway showing where northern Norway is located. (https://geodata.lib.utexas.edu/catalog/stanford-jm135gj5367)

Ecosystem services

This thesis examines a subsets of the possible ecosystem services. There are four categories of ecosystem services in Norway. The categories are provisioning, regulating, cultural and supporting which is divided into ecosystem services and then again into subservices. In northern Norway some important ecosystem services in provisioning are fishing and reindeer herding. An important ecosystem service from regulating in northern Norway is cold-water coral which provides animals in the ocean with habitat. Cold-water coral can also help with carbon turnover at the bottom.

This table divides the different categories provisioning, regulating and cultural into ecosystem services which are divided into subservices. The x marks that the subservice is mentioned in the paper 1, 2, 3, 4 or 5. Under the column "this thesis" the x represents the subserves described and used in this thesis with focus on ecosystem services in northern Norway.

Ecosystem services table

Category	Ecosystem service	Subservice	1	2	3	4	5	This thesis
Provisioning services	Food	fish (wild and farmed)	x	x	x	x	x	x
		fresh water fishing	x		x			
		sea plants/vegetable food	x		x	x	x	
		livestock	x	x	x			x
		reindeer herding	x	x	x		x	x
		game (elk, deer, bear, other, water fowl)	x	x	x	x		x
		dairy production (traditional and organic)		x			x	
		crops and cereals (traditional and organic)	x	x	x			
		fruit production (from orchards; traditional and organic)		x				
		berries (non-cultivated)	x	x	x			
		mushrooms	x	x	x			
		non-timber forest product (NTFP)	x	x	x			
		other						
	Water supply	industrial use						

Category	Ecosystem service	Subservice	1	2	3	4	5	This thesis
		drinking water	x	x		x		
		water other	x	x	x	x		
		irrigation water (unnatural)		x				
		water supply (general)	x	x			x	
Provisioning services	Raw materials	non-industrial aggregates (sand, rock, gravel, coral)	x		x	x		x
		biomass fuels		x		x	x	
		algae (non-food)	x			x		
		fertilizers	x	x				
		salt						
		timber and fiber for pulp production	x	x	x	x	x	
		timber production, sustainable	x	x	x			
		energy: fuel wood		x	x	x		
		energy: other bioenergy		x			x	
		fodder and forage: hay		x	x	x		
		fodder and forage: lichens	x	x	x	x		
		fiber: wool		x				
		fiber: leather and fur		x				
		fiber: down from wild birds		x	x			
		other						
	Genetic resources	plant	x	x	x	x		
		animal		x	x			
		general			x			
	Medical resources	biochemicals		x				
		models		x				
		test organisms		x				
		bioprospecting		x				
		medicinal products (natural)	x	x	x	x		
		natural food supplements		x				
		cosmetics		x				
	Ornamental	dyes/colorants		x		x		
		decorative plants		x				
		jewlery		x				
		decorations/handicrafts		x				
		pets/captive animals	x					

Category	Ecosystem service	Subservice	1	2	3	4	5	This thesis
Regulating services	Air quality	capturing fine dust potential						
		air quality regulation		x		x	x	
		UVB protection				x		
	Climate regulation	carbon sequestration		x	x		x	
		gas regulation				x		
		climate regulation general				x	x	
		microclimate regulation		x				
		carbon storage			x		x	
	Moderation of extreme events	storm protection		x		x		
		flood prevention	x	x	x	x	x	
		tsunami						
		fire prevention						
		avalanche prevention/mitigation		x				
		mud flow/floods	x	x				
		general	x					
	Water flow regulation	drainage	x	x				
		river discharge				x		
		natural irrigation						
		drought mitigation	x	x				
		aquifer recharge		x				
		coastal currents	x					
		general	x					
Regulating services	Waste treatment and water purification	water purification		x	x		x	
		soil detoxification		x				
		abatement of noise				x		
		water treatment general		x		x	x	
	Maintenance of soil fertility	maintenance of soil structure		x			x	
		deposition of nutrients	x		x			
		soil formation		x	x	x		
		nutrient cycling		x		x		
		general						
	Pollination	pollination of crops		x			x	
		pollination of wild plants		x	x	x		
		general					x	

Category	Ecosystem service	Subservice	1	2	3	4	5	This thesis
	Erosion prevention	erosion prevention				x	x	
	Biological control	pest control		x	x		x	
		disease control		x			x	
		seed dispersal		x				
		general						
		resilience thru the food web						
		population dynamics		x		x		
Habitat services	Life-cycle maintenance	nursery service	x	x				x
		refugia for migratory and res. species		x				
		gene pool protection		x				
Cultural services	Aesthetic	attractive sea/landscapes	x	x		x		x
	Recreation and tourism	recreation	x	x	x	x	x	x
		tourism		x		x	x	
		ecotourism		x		x	x	
		hunting and fishing	x	x	x	x		
	Inspiration	artistic						
		cultural use						x
		general						
	Spiritual	spiritual/religious		x		x	x	
	Cognitive development	science/research	x	x	x	x		
		education		x	x	x	x	
		general						
	Cultural heritage	social and cultural values		x	x			
	Cultural diversity	diversity		x				
	Mental well-being and health	reduction of stress		x	x		x	

Numbers in the table are referred to these articles.

1. Ref- Håndbok 13 (Dirnat)
2. Ref- Kettunen_etal_2013
3. Ref- The nature index for Norway
4. Ref- Nature paper

5. Ref- Ecosystem services in Norway

Fisheries

Fishing is both an industry and a hobby. Professional fishing is often done in the sea and Norway is the biggest fish producer of the Nordic countries. 50% of Norwegians, respectively, say they have engaged in some sort of fishing the past year(2010).[7] Fishing is a provisioning service providing food and contributes to the economics of the country. Fishing is a part of the provisioning services as it gives humans the benefit of food. Most of the coast line in the north of Norway is used for fishing (figure 2) both professional and hobbyist, although, professional fishermen travel further out to sea. Delimited area where fishing is carried out with active gear such as seine, purse seine, shrimp trawl, or passive gear such as net and line.[8]

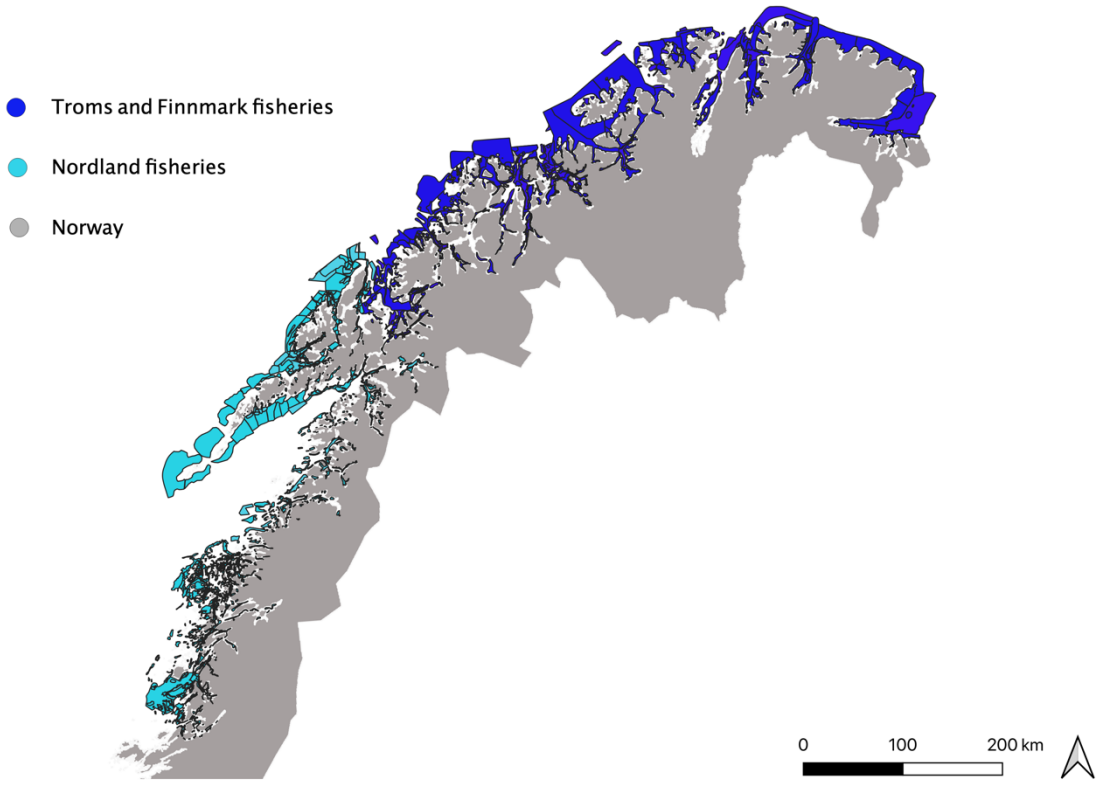

Figure 2: Fisheries in Troms and Finnmark and Norland, Northern Norway (https://kartkatalog.geonorge.no/metadata/fiskeplasser-redskap/09a40026-00e2-4fd8-b390-afd8d6f88c63).

[7] Kettunen_et.al_2013

[8] https://kartkatalog.geonorge.no/metadata/fiskeplasser-redskap/09a40026-00e2-4fd8-b390-afd8d6f88c63, 11.04.23

Reindeer herding

Reindeer herding is a big industry in the Saami population. The most common place for reindeer herding is centered in the mountain pastures in the northern parts of Norway such as Finnmark, Troms, Nordland and Nord-Trøndelag. Over 3000 people herd reindeer and in Finnmark there are 2200 of those 3000, making it the largest reindeer county. The annual number of reindeer vary but as of today there are about 250.000 herd animals in Norway and about 185.000 of them are in Finnmark.[9] Reindeer herding is part of the provisioning service because it gives humans food from the meat, they wear their hide and make tools from their antlers. It is also part of the cultural service as tourists come to see them and people from the north can take the tourists on a sled ride.[10] As seen in Figure 3 large areas of Finnmark are being used for reindeer herding. All the green area in Figure 3 is used for reindeer grazing.

[9] https://www.regjeringen.no/en/topics/food-fisheries-and-agriculture/reindeer-husbandry/reindeer-husbandry/id2339774/, 03.04.23
[10] https://scandinaviafacts.com/what-are-reindeer-used-for-in-norway/, 11.05.23

Figure 3: Reindeer grazing area in northern Norway. (https://kartkatalog.geonorge.no/metadata/reindrift-reinbeiteomraade/d02dc4bd-77d5-4b3b-a316-5a488b6fe811)

Recreation and tourism

In northern Norway there are plenty of tourism activities where nature is a part of it. People can take the Hurtigruten which is a boat to see the nature and islands in the north. There are many different mountains to hike up, like Torghatten, Møysalen and Lyngen Alps. It is possible to go on king crab safari and whale safari or join a rib tour and boat trip to one of the world´s strongest maelstroms Saltstraumen.[11] Dog-sledding is a tourism activity where humans are in a sled being pulled by dogs, often in an Arctic environment.[12] All these activities are a part of the cultural service because it is not a material benefit but tourism which brings benefits to human wellbeing as entertainment and business.

Bird population

In northern Norway there is a large variety of bird populations. People from other countries and different places in Norway travel to the north to watch birds. Varanger is a short distance from other continents, since it is shorter on the top of the planet, and birds from the eastern high Arctic and sometimes North America visit Varanger. There is enough food for migration, overwintering and breeding that comes from birch forests, river deltas, marshes, rich waters and rock slopes.[13] Figure 4 shows northern fulmar, thick-billed murre and black-legged kittiwake. Figure 5 shows razor bill and arctic tern. Figure 6 shows atlantic puffin and lesser black-backed gull. Figure 7 shows common gull, european shag and parasitic jaeger. The dots symbolizes where the species live. The figures are split up so that the symbols of the bird species do not overlap, in order to get a full overview as some of the species live in the same area.

[11] https://www.visitnorway.com/places-to-go/northern-norway/, 18.04.23
[12] https://nordnorge.com/en/tema/dog-sledding-in-northern-norway/, 18.04.23
[13] https://nordnorge.com/en/artikkel/varanger-is-birdwatching-heaven/, 10.05.23

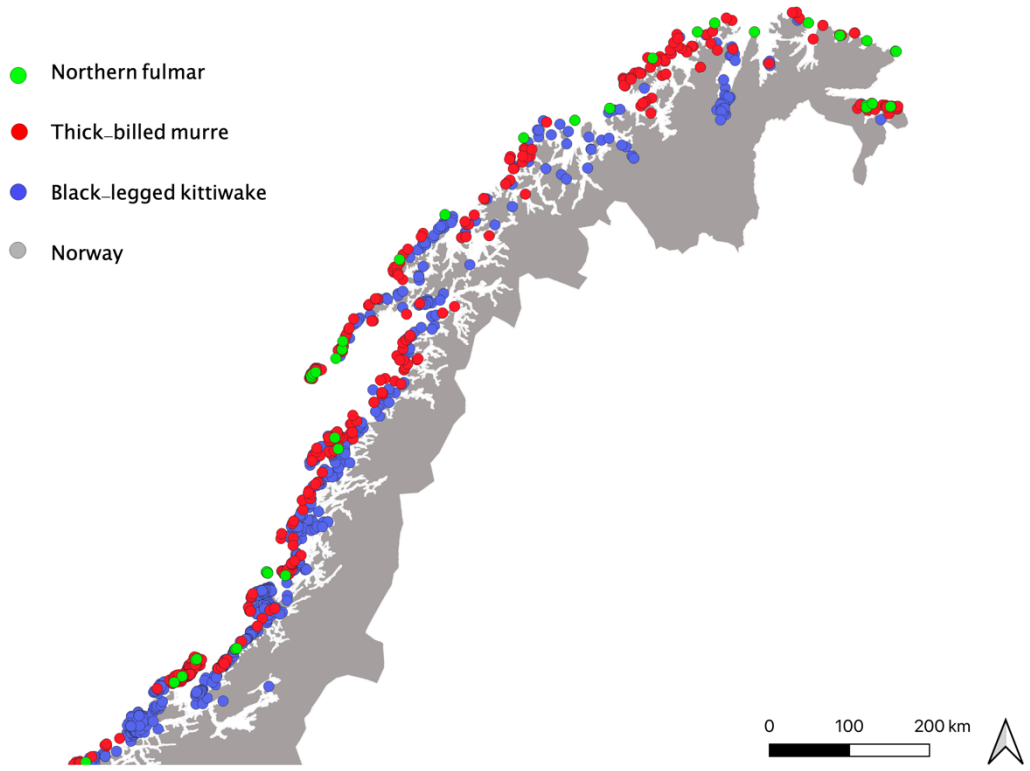

Figure 4: Seabird breeding population in northern Norway. Northern fulmar, Thick-billed murre and Black-legged kittiwake. (https://kartkatalog.geonorge.no/metadata/seapop-estimerte-hekkebestander-for-sjoefugl/ed4f31ed-7497-479d-bc8d-9dfab7d8c37a)

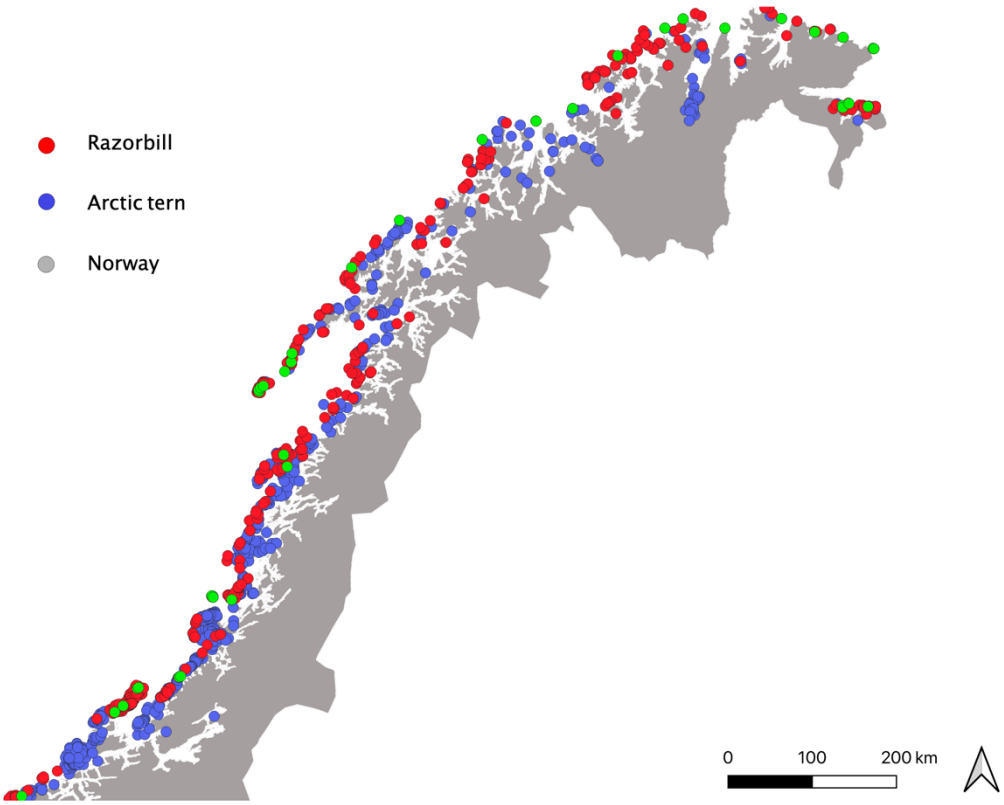

Figure 5: Seabird breeding population in northern Norway. Razorbill and Arctic tern. (https://kartkatalog.geonorge.no/metadata/seapop-estimerte-hekkebestander-for-sjoefugl/ed4f31ed-7497-479d-bc8d-9dfab7d8c37a)

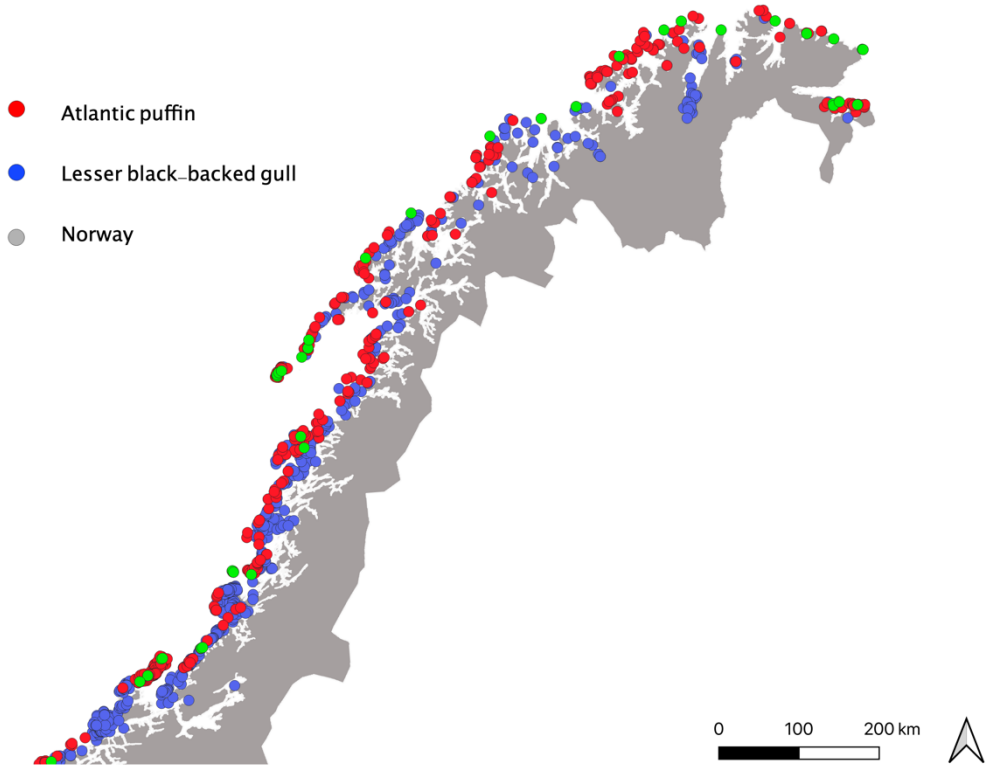

Figure 6: Seabird breeding population in northern Norway. Atlantic puffin and Lesser black-backed gull. (https://kartkatalog.geonorge.no/metadata/seapop-estimerte-hekkebestander-for-sjoefugl/ed4f31ed-7497-479d-bc8d-9dfab7d8c37a)

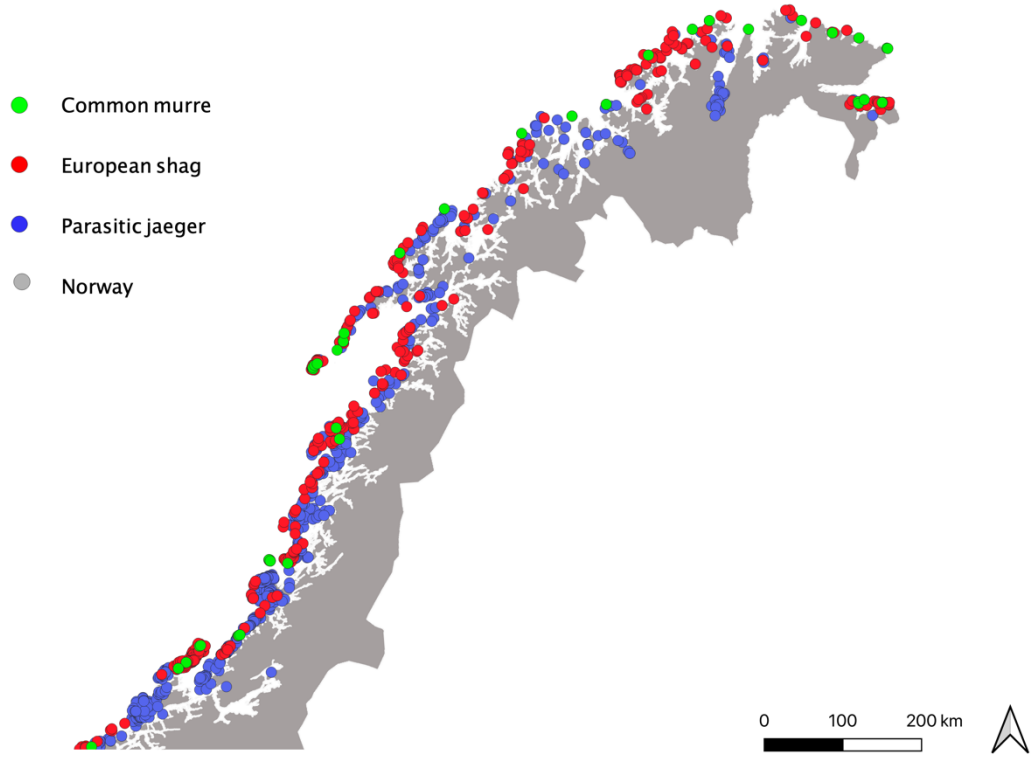

Figure 7: Seabird breeding population in northern Norway. Common murre, European shag and Parasitic jaeger. (https://kartkatalog.geonorge.no/metadata/seapop-estimerte-hekkebestander-for-sjoefugl/ed4f31ed-7497-479d-bc8d-9dfab7d8c37a)

Cold-water coral

Cold-water coral is found in northern Norway and one of the world´s largest known reef complexes is found in waters surrounding Røst in Noerway´s Lofoten Archipelago. The reef is called Røst Reef and is 35 kilometers in length and is three kilometers in width. There are, thus far, 26 different coral species discovered in the Norwegian waters and most of them are well established in waters outside Norway.[14] The cold-water coral is a regulating service as it is a habitat for creatures in the sea such as fish and shrimps. Recent results indicate that the coral reefs are important in the carbon turnover at the bottom in addition to being so-called hot-spots for biodiversity.[15]

[14] https://mareano.no/en/news/news-2015/surrounded-by-corals, 20.04.23
[15] https://www.hi.no/hi/temasider/hav-og-kyst/norske-korallrev, 14.06.23

Ecosystem service valuation

To put a value on the ecosystem services can be difficult since there are different ways to calculate it and the value can be seen from different perspectives.[16] The importance of putting a monetary valuation on ecosystem services is so we can show how economic concepts and tools can help equip society with the means to incorporate ecosystem values into decision making at all levels.[17]

A way to determine the value of an ecosystem service, like clean water in a lake, is to ask the population how much they are willing to pay (WTP) for this service. With recreation and tourism for example the value of the northern Norway, tourist target, is the willingness to pay for the travel to the destination.[18]

An ecosystem service that humans do not need to pay for would have a value of zero, but if humans had to recreate the ecosystem service with the technology humans have today and pay to recreate it this could also be a method to put a value of the natural ecosystem service we have.

"The ecosystem service values contained in the ESVD are Values Estimated in Monetary units (VEM). These values are estimated using a range of approaches, including market prices, cost-based approaches, stated preference methods, revealed preference methods and production function approaches. They generally represent marginal values for a specific ecosystem service provided by an individual ecosystem (they are marginal values in the sense that they represent the change in value for a small change in the overall provision of the specific ecosystem service). To aid direct comparison and aggregation, these values (VEM) have been standardised in the ESVD to common spatial, temporal and currency units, namely International dollars per hectare per year (Int$/ha/year)."[19]

An easy way to calculate the value of an ecosystem service is by finding the international dollar for a service and finding the total area of the service. With this data people can

[16] https://www.ecosystemvaluation.org/1-02.htm, 13.05.23
[17] https://www.sciencedirect.com/science/article/pii/S1470160X14002222, 14.06.23
[18] Schägner-2013-Mapping ecosystem
[19] https://www.sciencedirect.com/science/article/pii/S2212041612000101#bib22, 11.06.23

calculate the value by dividing the total dollar of the service by the area they are looking at, then you get $\frac{\$}{hectare}$.

Dollar divided by area equals value of service

Climate change

Figure 9 and Figure 10 show the worst-case scenario of greenhouse gas emissions in 2005 and 2085. Figure 11 and Figure 12 show the best-case scenario of greenhouse gas emissions in 2005 and 2085. The darker green the less greenhouse gas emission there is and the darker the red the more greenhouse emission there is. Looking on the worst-case scenario 2005 (figure 9) there is a lot of light green over Norway and in northern Norway there is some darker green. Looking on the worst-case scenario 2085 (figure 10) there is less light green and more light red in the south of Norway and the darker green in northern Norway is much less and have turned light green. For the best-case scenario looking at 2005 (figure 11), this is the same as worst-case scenario 2005, there is a lot of light green over Norway and some dark green in the north of Norway. For the best-case scenario 2085 (figure 12) there is a little more light red in south of Norway and less dark green in the north of Norway when looking at best-case scenario 2005 (figure 11). Comparing worst-case scenario 2085 (figure 10) and best-case scenario 2085 (figure 12) there is less light red in the best-case and more darker green in northern Norway.

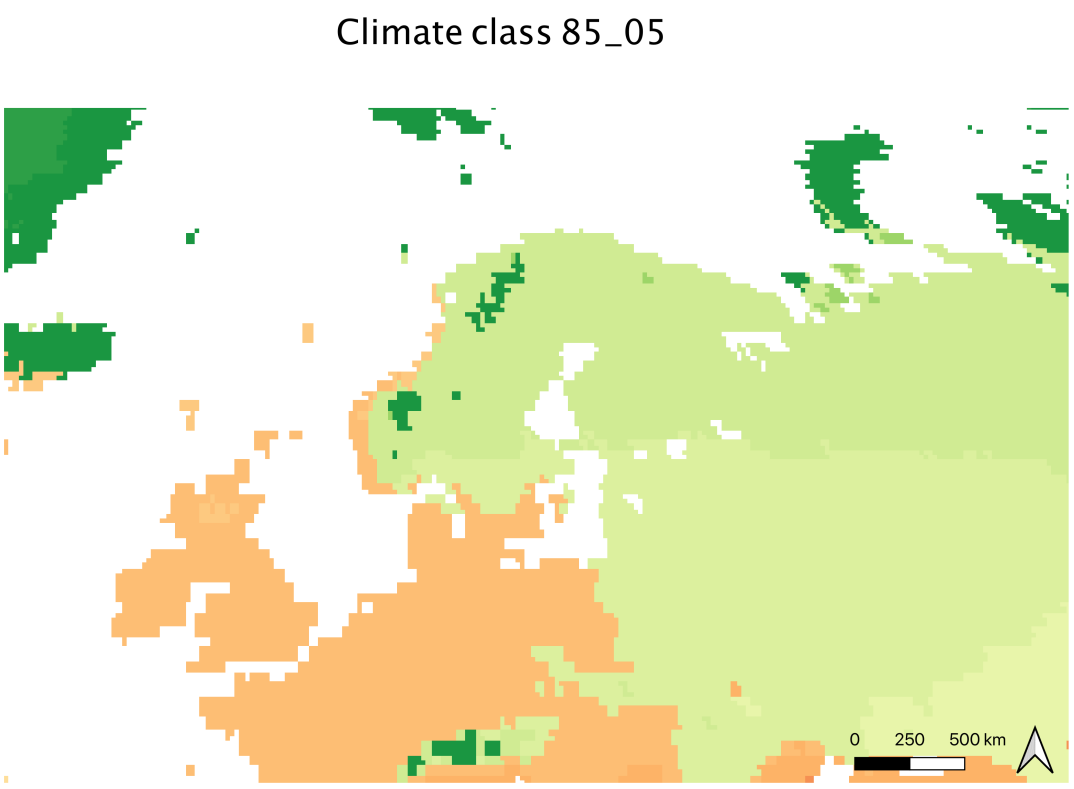

Figure 9: Worst-case scenario of greenhouse gas emissions 2005. (https://www.gfdl.noaa.gov/climate-models/)

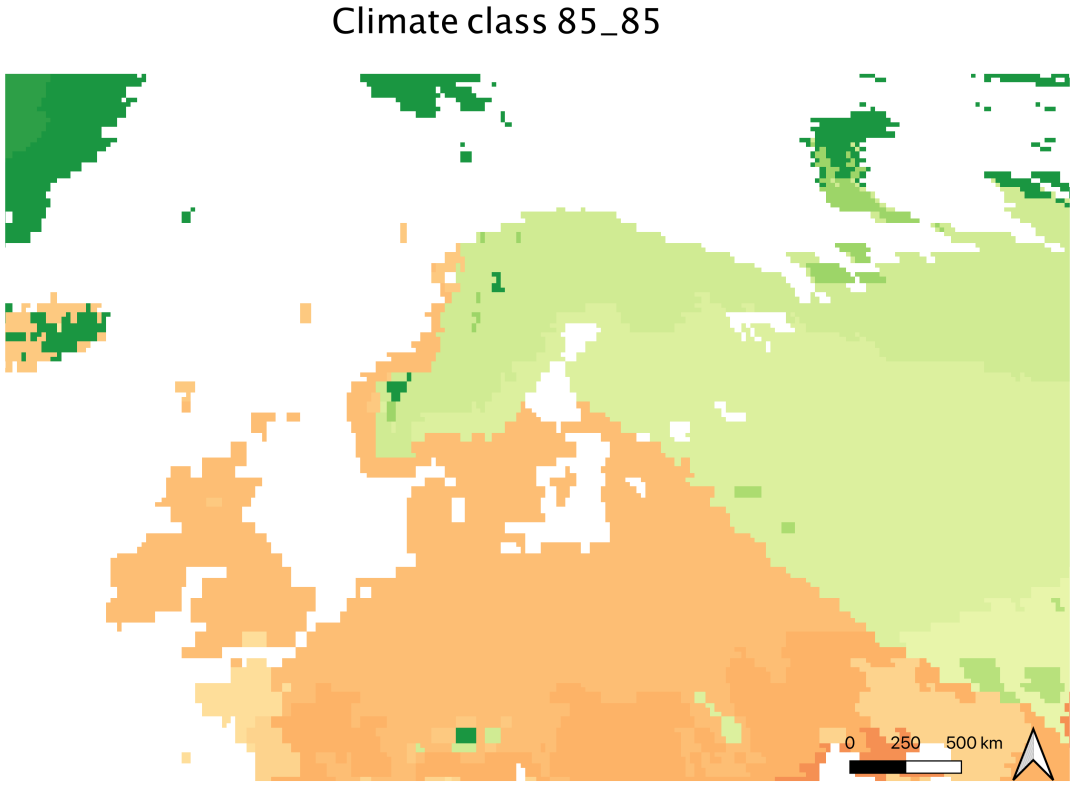

Figure 10: Worst-case scenario of greenhouse gas emissions 2085.
(https://www.gfdl.noaa.gov/climate-models/)

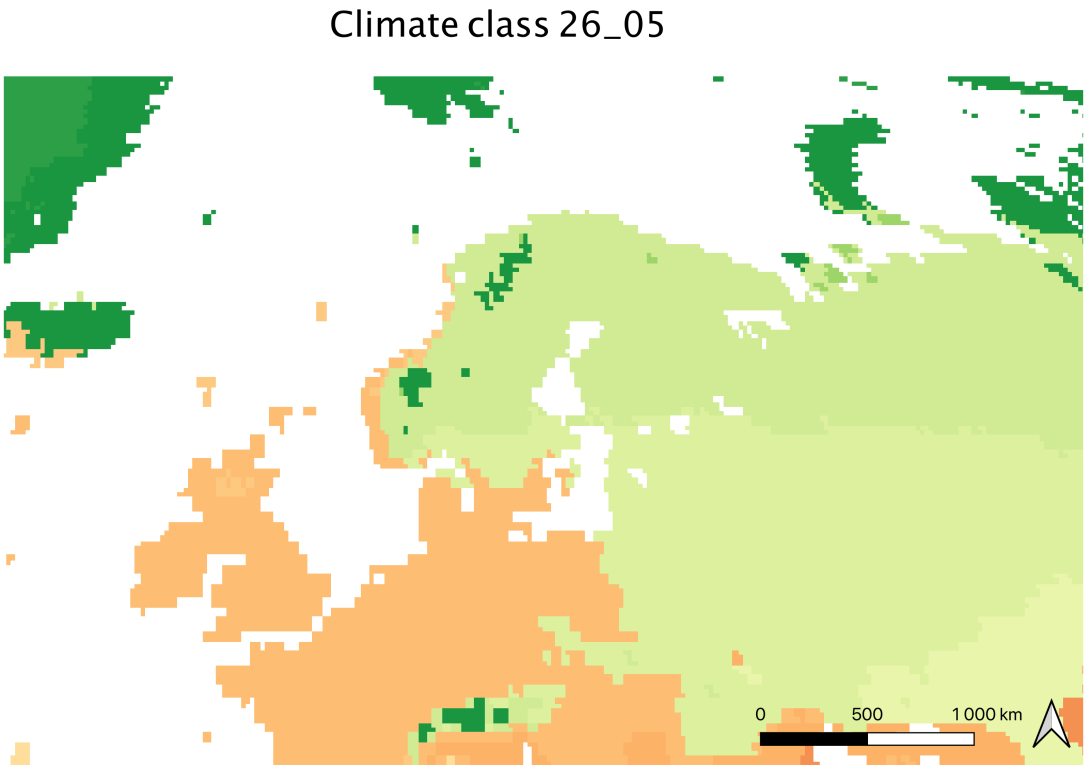

Figure 11: Best-case scenario of greenhouse gas emissions 2005.
(https://www.gfdl.noaa.gov/climate-models/)

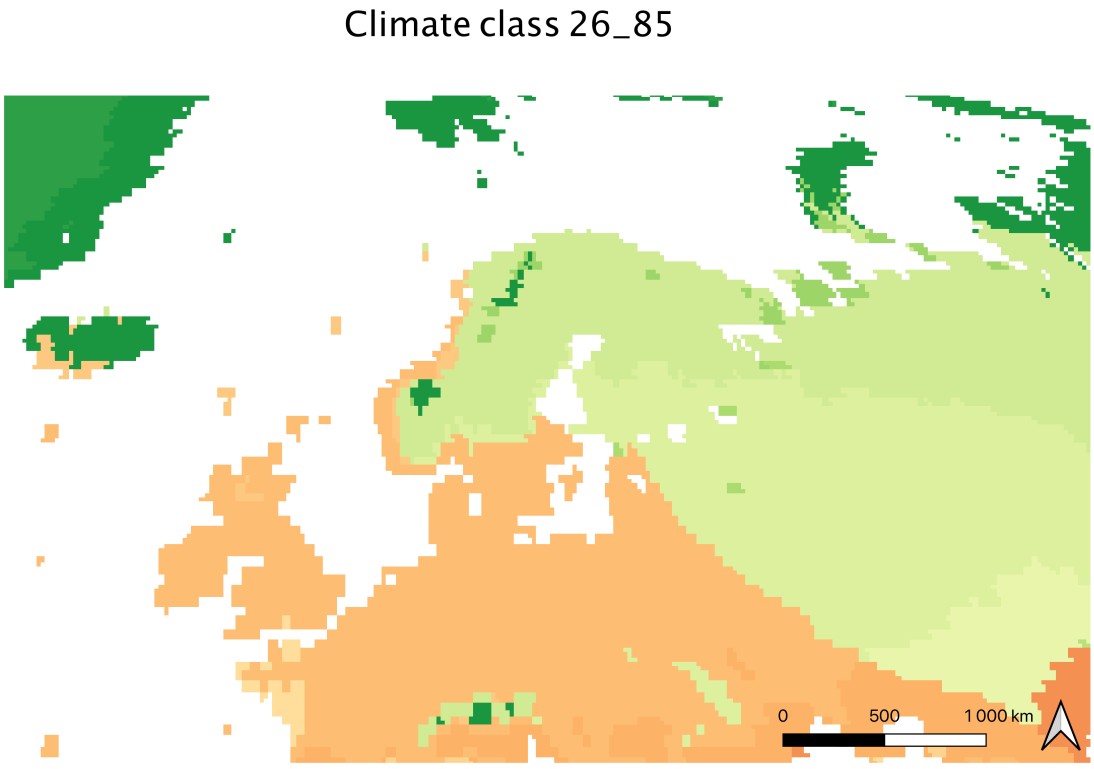

Figure 12: Best-case scenario of greenhouse gas emissions 2085. (https://www.gfdl.noaa.gov/climate-models/)

Discussion

The services mapped in this thesis are both on land and in the sea and the climate change will have an effect on the systems in the water where fish lives, as well as the land and air where reindeer and birds live. By looking at the climate change figures 10 and 12 for worst-case scenario 2085 and best-case scenario 2085 they are both affected by greenhouse emissions and the area in the north of Norway will become warmer with time. Due to temperature rise the cold weather in the north will be affected and the ecosystems will change. The reindeer have a warm hide to protect them from the cold. If it gets warmer they will migrate to colder places and the ecosystem will change. Reindeer herding provides clothes, food and tools so they are an important part of the economic and wellbeing for people living in the north. People doing reindeer herding could have to move with the reindeer to keep up the wellbeing and the economic. To substitute for reindeer herding the people could have to change to farming or other activities to keep making money and get benefits from the nature. In the ocean the fish is used to the temperature, and if the temperature rises they will also possibly migrate to other places in the ocean and the fishermen will have to change profession or travel

with the fish.[20] This change will affect the food supply and the job opportunities that could possibly lead to people having to move more south.

With warmer temperature in the North the snow will not be as much as it was and not for the same period of time so the dog sledding will not be possible as often as before. A substitute for dog sledding on the snow can be dogs dragging a cart on wheels on the bare ground.[21] The lack of snow may interrupt the interest of tourist to travel to the north leading to worse economics and job opportunities.

Conclusion

In this thesis some ecosystem services mapped in northern Norway are reindeer herding, fishing both professional and as a hobby, birdwatching and the cold-water coral. All of these ecosystem services can be found in Troms, Finnmark and Norland and contributes to the economic and wellbeing of humans in the north of Norway. In this thesis there was no mapping or quantifying of the supporting service, because there is not enough data of ecosystem services gathered from the northern Norway.

The value of the ecosystem services can be calculated by finding the total value of a service in dollar and dividing it by the area of interest. The value for the ecosystem services in northern Norway is difficult to calculate since the data gathered from this area are insufficient or the needed data have not been gathered.

Climate change is going to affect all of Norway, but by looking at the climate change figures 9, 10 and 12 we can see a big difference in the greenhouse gas emission. With the warmer weather due to climate change the ecosystems will change and services like reindeer herding and fishing may move to different areas. These differences will again affect the economic and wellbeing of the people living in the north of Norway. They may have to move with the services new location or use the space for a different ecosystem service like farming.

This thesis should be used in the future to understand that there need to be gathered more data of ecosystem services in northern Norway, but also all over the world. It is important to put monetary value on ecosystem services so people can incorporate ecosystem values into

[20] https://19january2017snapshot.epa.gov/climate-impacts/climate-impacts-ecosystems_.html, 23.03.23
[21] https://www.visitnorway.com/listings/dog-sledding-on-wheels/183185/, 11.05.23

decision making at all levels. Ecosystem services are important for humans economic and wellbeing and it is therefore important that we know the vale and can be sustainable with the way we use the services. The services should be used by todays descendants.

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