Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Natural Sciences
Department of Biology

Gabriella Nicole Giannone

Gap analysis in the effectiveness of the current Marine Protected Area network design framework with respect to biodiversity conservation in coastal Norway

Master's thesis in Biology
Supervisor: Glenn Dunshea
Co-supervisor: Torkild Bakken
June 2024

NTNU
Norwegian University of
Science and Technology

Gabriella Nicole Giannone

Gap analysis in the effectiveness of the current Marine Protected Area network design framework with respect to biodiversity conservation in coastal Norway

Master's thesis in Biology
Supervisor: Glenn Dunshea
Co-supervisor: Torkild Bakken
June 2024

Norwegian University of Science and Technology
Faculty of Natural Sciences
Department of Biology

NTNU
Norwegian University of
Science and Technology

ABSTRACT

Marine protected areas (MPA) have become cornerstones for biodiversity conservation in recent years. They are characterized by regulating anthropogenic activity in order to decrease negative impacts from climate change and human activity on particular marine habitats and organisms. This study reviewed the current habitat data, species occurrence data, and conservation area data for territorial (12 nautical miles from the coast) coastal areas in Norway, by county, to find weaknesses in the Norwegian MPA network design framework. It is found that there is really no existing network, as MPAs designated by OSPAR are few and far between with low connectivity. The 24 current MPAs are widely disconnected and not nearly as ecologically-coherent as they could be due to gaps in species occurrence records and little habitat data when compared to the size of the marine area reviewed. There are many conservation areas designated by the Norwegian state, but the regulations in these areas are weak and/or not enforced. Dredging and fishing activity are still permitted in MPAs found along the southern coast of Norway, and in other conservation areas. Recommendations are given for how Norway can move forward from the current state of the MPA network. Principles for the MPA network design framework, such as the use of spatial prioritization, comprehensiveness, surrogates, and representativity are suggested as tools for more effective biodiversity conservation in the future. Norway is a country with a large coastal area and variable habitats, such Røstrevet, the world's largest and deepest cold-water reef, so the creation of a strong, well-managed, and ecologically-coherent MPA network would strengthen the resilience of marine ecosystems and organisms in other areas.

SAMMENDRAG

De siste årene har marine verneområder har blitt hjørnesteiner for bevaring av biologisk mangfold. De er karakterisert ved regulering av menneskelig aktivitet, med formål om å redusere negativ påvirkning på marine habitater og organismer. Denne undersøkelsen vil gjennomgå gjeldende habitatdata, artsforekomstdata og verneområdedata for territoriale (12 nautiske mil fra kysten) kystområder i Norge etter fylke, for å finne svakheter i det norske MPA-nettverkets designrammeverk. Undersøkelsen viser at det ikke er noe eksisterende nettverk, ettersom MPAer utpekt av OSPAR er få og med lav tilkobling. De 24 nåværende MPAene er vidt frakoblet og ikke på langt nær så økologisk sammenhengende som de kunne vært, på grunn av hull i artsforekomstregistreringer og lite habitatdata sammenlignet med størrelsen på det marine området som er gjennomgått. Det er mange verneområder utpekt av den norske stat, men regelverket i de gjeldende områdene er svakt og/eller ikke håndhevet. Mudring og fiske er fortsatt tillatt i MPAer langs sørkysten av Norge, og i andre verneområder. Det gis anbefalinger for hvordan Norge kan gå videre fra dagens tilstand i MPA-nettverket. Prinsipper for MPA-nettverksdesignrammeverket, som bruk av romlig prioritering, helhet, surrogater og representativitet, foreslås som verktøy for mer effektiv bevaring av biologisk mangfold i fremtiden. Norge er et land med et stort kystområde og varierende habitater, slik som Røstrevet; verdens største og dypeste kaldtvannskorallrev. Etableringen av et sterkt, godt administrert og økologisk sammenhengende MPA-nettverk vil styrke motstandskraften til marine økosystemer og organismer i andre områder.

ACKNOWLEDGEMENTS

Completing this master's thesis has been a demanding and rewarding journey. Facing steep learning curves along the way, like learning how to code in R (and ultimately coming to like it), and reacquainting myself with GIS applications like ArcGIS Pro, has had its peaks and valleys. As I near the other side, I recognize I have become a better scientist. Marine biodiversity conservation is one of my greatest interests in this life and I am irrevocably grateful for the opportunity to delve farther into this topic.

My foremost gratitude and love goes to my family, friends, and and roommates who have been patient both with my frustrations and my excitement during this project. They supported me through days when code would not run and solutions were far off in the distance and days where my code would run and worked better than I could have hoped.

My deepest thanks go to my thesis supervisors Glenn Dunnshea and Torkild Bakken for taking the time and care to give constructive feedback on my work and being open to new solutions when sticking points got the better of me.

Lastly, I would like to acknowledge the lovely people at the Thawra ثورة encampment for their dedication to stand in solidarity with the people of Palestine. They sat with me on sunny days and rainy days, talking through ideas and becoming friends. Whether they know it or not, they helped keep me grounded.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

List of all abbreviations in alphabetical order:

- **BBNJ** Marine Biological diversity of areas Beyond National Jurisdicion
- **CBD** Convention on Biological Diversity
- **COP15** 15th meeting of the Convention of Parties to the UN CBD
- **EBSA** Ecologically or Biologically Significant Area
- **EMODnet** European Marine Observation and Data Network
- **EPSG** European Petroleum Survey Group Geodetic Parameter Dataset
- **GBF** Kunming-Montreal Global Biodiversity Framework
- **GCS** Geographic Coordinate System
- **GD-PAME** Global Database on Protected Area Management Effectiveness
- **GIS** Geographic Information System
- **HI** Havforskningsintituttet
- **HIC** High-Income Country
- **ICZM** Integrated Coastal Zone Management
- **IUCN/IUCN WCPA** International Union for Conservation of Nature/World Commission on Protected Areas
- **LIC** Low-Income Country
- **MAREANO** Marine Areal database for Norwegian waters
- **MPA** Marine Protected Area
- **NGO** Non-governmental organization Newly Merging Economy
- **NEE** Newly Merging Economy
- **NOAA** National Oceanic and Atmospheric Administration

- **NTNU** Norges tekniske-naturvitenskapelige universitet (Norwegian University of Science and Technology)
- **OBIS** Ocean Biodiversity Information System
- **ODIMS** OSPAR Data & Information Management System
- **OECM** Other Effective Area-Based Conservation Measure
- **OSPAR** Oslo/Paris Convention for the Protection of the Marine Environment of the North-East Atlantic
- **SAI** Species Accumulation Index
- **SHP** Shapefile
- **SDG** UN Sustainable Development Goal
- **SOSI** Samordnet Opplegg for Stedfestet Informasjon (Norwegian file format)
- **SVO** Særlig verdifulle områder i havområder (SVO)/Particularly valuable areas in the sea
- **UNCLOS** UN Convention on the Law of the Sea
- **UN/EP** United Nations/Environment Program
- **UTM** Universal Transverse Mercator coordinate system
- **WDPA** World Database on Protected Areas
- **WGS** World Geodetic System

CHAPTER
ONE

INTRODUCTION

1.1 Background

The creation and regulation of marine protected areas (MPAs) and other effective area-based conservation measures (OECMs) are integral in conservation. They are created with the aim to stimulate sustainable usage of marine resources and to support the longevity of biodiversity conservation outcomes [**35**].

1.1.1 The Anthropocene and the biodiversity crisis

The Anthropocene epoch describes the current geological age, named as the period in which human activity has been the dominating force acting on the climate, the environment, and abiotic/biotic factors. While we are still officially within the Holocene, the Anthropocene is a more specific and detailed way to describe this current interval of geologic time - although the start date is difficult to delimit [**22**]. While the Anthropocene is marked by previously inconceivable innovation and human ingenuity (marked by a pattern of changing the environment around us (Figure 1.1.1)), it has also been a time of great biodiversity and habitat loss, putting the modern day into the ‘Sixth Mass Extinction’ [**40**].

Mass extinctions are characterized by intervals where extinction rates greatly outpace those during neighboring geological intervals [**40**]. Rate-determination of prehistoric extinctions are hard to define because extinction rates within the fossil record are irregular, even in times without mass extinctions. Extinctions are shown to occur in pulses and not uniformly throughout the entirety of stages, meaning that a background extinction rate poorly grasps the magnitude of biodiversity loss [**40**]. Spalding & Hull (2021) attribute this difficulty to ‘extinction debt’, or the concept that even if anthropogenic activity ceased absolutely and immediately, there is still a lag time after the fact in which populations decline and lead to extinctions.

Johnson *et al.* 2017 discuss how recent extinction events and biodiversity decline can be explained by over-exploitation, land use conversions, urban development, disease, and the spread of invasive species. They pinpoint four interconnected reasons for the failures in the reversal/mitigation of global biodiversity loss. The first is the ever-increasing human population size and per capita consumption; the second is the amplification effect

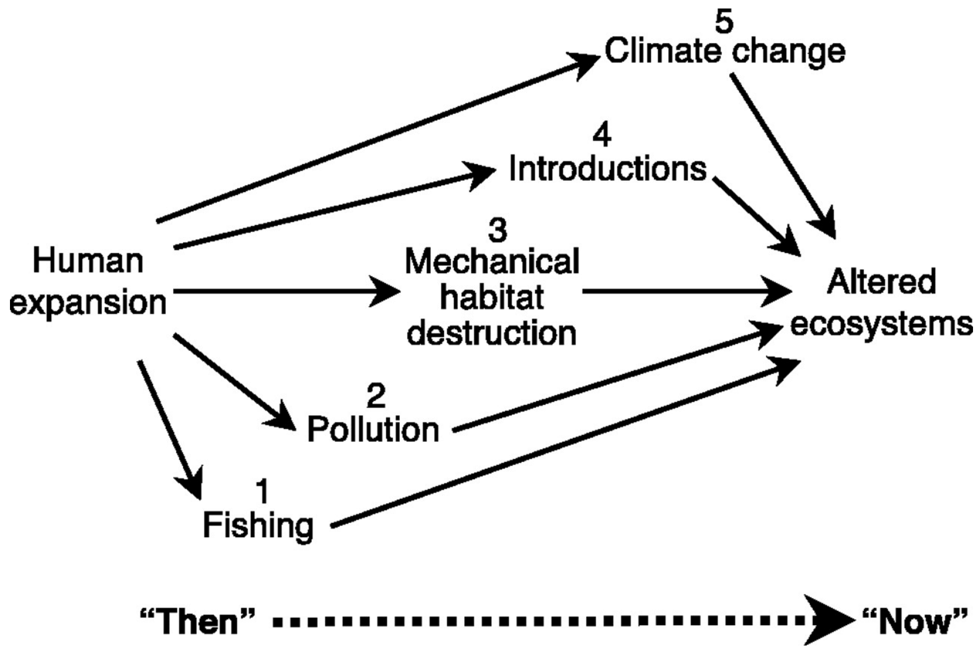


Figure 1.1.1: Generalization of the historical sequence of disturbances by humans. Source: Jackson *et al.* 2001.

(e.g. climate change and rising global water temperatures causing coral bleaching which leads to reduced growth and survival rates of affected corals which leads to decreased function of a previously highly productive and diverse community [**32**]; the third is that funding for conservation is lacking globally; the fourth is that conservation still stands on its own, generally not being considered in economic and social decisions and planning [**18**]. They also discuss effective conservation action with a note on how MPAs are most effective when no-take policies are effectively enforced and if the protected areas are large, isolated, and long-lived [**18**].

1.1.2 The idea that protected areas are central to the sustainable use of ecosystems

Protected areas are essential to the conservation of biodiversity and habitat because they a) guard the biological and cultural significance of natural areas; b) protect biodiversity, species richness, genetic variability, ecological processes, and ecosystem services; and c) serve communities both intrinsically and extrinsically [**25**]. Services to human societies provided by protected areas include nature-watching, wild harvesting, environmental resilience, and benefits to aquaculture and fisheries [**9**]. Increasing demands by humans on our environment (urban sprawl, population growth, agriculture, etc.) make natural areas less resilient against the force of negative anthropogenic impacts. Protected areas are the main tool for the conservation of biodiversity across the planet [**39**]. The global call to action regarding environmental degradation and human effects on the marine environment has led to demands to increase global MPA coverage [**30**], with MPAs experiencing rapid growth, globally, in the previous two decades [**35**]. Figure 1.1.2 visually represents of biodiversity loss without protection, and at different levels of marine protection. The MPA Guide by the Marine Protection Atlas states that currently 2.9% of the ocean is highly or fully protected, with Protected Planet stating that 8% of global ocean is protected

(Marine Protection Atlas - https://mpatlas.org/).

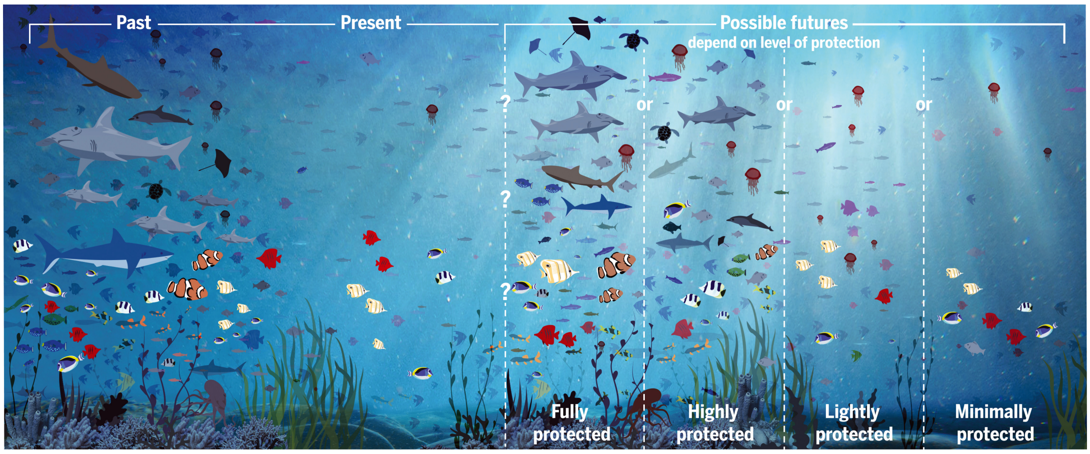


Figure 1.1.2: Visual depiction of the need for MPAs. Source:Grorud-Colvert *et al.* 2021.

1.2 Global & Regional Coastal MPA Initiatives and Existing Networks

1.2.1 Global Initiatives

1.2.1.1 UN Convention on Biological Diversity (CBD)

The 30by30 Initiative. Target 3 of the 2022 Kunming-Montreal Global Biodiversity Framework (GBF) is to conserve 30% of land, waters, and seas. One effort of this target is the '30by30' initiative, finalized in 2022 at the 15th meeting of the Conference of Parties to the UN Convention on Biological Diversity (CBD COP 15). Joint global efforts for marine conservation are underpinned by the '30by30' initiative, wherein signatory governments work to create a network of MPAs and OECMs that cover at least 30% of the global ocean by 2030 [**13**]. Currently there are 73 member countries working with this initiative, including Norway, Sweden, Denmark, and Finland. The network of MPAs and OECMs would extend across both national and international marine areas [**13**]. Since some marine areas fall outside national jurisdictions, the Areas Beyond National Jurisdiction (BBNJ) Agreement was adopted on 19 June 2023 by the Intergovernmental Conference on Marine Biodiversity of Areas Beyond National Jurisdiction under the United Nations Convention on the Law of the Sea (UNCLOS)[**16**]. The overarching issues this agreement considers are:

1. Marine genetic resources, including the fair and equitable sharing of benefits

2. Measures such as area-based management tools, including marine protected areas

3. Environmental impact assessments

4. Capacity-building and the transfer of marine technology

1.2.1.2 UN Sustainable Development Goals

The Sustainable Development Goals (SDGs) were adopted by the UN in 2015. They outline 17 overarching goals for a prosperous world. The creation and effective maintenance of coastal MPAs deals mainly with Goal 13:'Take urgent action to combat climate change and its impacts' and Goal 14: 'Conserve and sustainably use the oceans, seas and marine resources for sustainable development'.

1.2.1.3 International Union for Conservation of Nature (IUCN)

The IUCN World Commission on Protected Areas (WCPA) is a grid of 2500+ members across 140 countries that contribute strategic input to policymakers on the creation and maintenance of protected areas. The goals of this commission are to support global initiatives, guide MPA design, and advocate for the management of marine and terrestrial areas.

1.2.1.4 Protected Planet

Protected Planet is a collaboration between IUCN and the United Nations Environment Program (UNEP). This initiative provides data through the World Database on Protected Areas (WDPA), World Database on OECMs, Global Database on Protected Area Management Effectiveness (GD-PAME), and other corresponding information. Protected Planet focuses on GBF Target 3. Reported by Protected Planet are the number of protected areas per IUCN management classification (Figure 1.2.1), the type of governance of protected areas (Figure 1.2.2), and the international, national, and regional designations for the protected areas (Figure 1.2.3) in Norway.

1.2.1.5 OSPAR Network

In October 2022, the Oslo/Paris Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Commission) reported in a press release that its network of MPAs reached 11 percent coverage of the North-Eastern Atlantic Ocean, comprising 583 MPAs and encompassing 1.5 million km^2 [**31**]. Figure 1.2.4 shows the network as of October 2022.

Most existing MPAs within the OSPAR network are unprotected to some degree, with only 0.03 percent being highly to fully protected in 2022 [**37**]. Among the OSPAR Contracting Parties, highly protected areas were found only in Portugal, Germany, and France, with fully protected OSPAR MPAs only being found in Portugal and the UK [**37**]. Additionally, marine zones at higher latitudes, including the arctic waters around Norway, seem to have much less OSPAR MPA coverage and lower protection levels than OSPAR zones at lower latitudes (although the areas surrounding the Norwegian Trench and Oslofjorden have substantial coverage) (Figure 1.2.5)[**37**]. Considering 551 MPAs associated with the OSPAR network, 80 percent had no regulation data available on the OSPAR MPA database [**37**]. Still, Wright *et al.* (2021) considers the OSPAR Commission

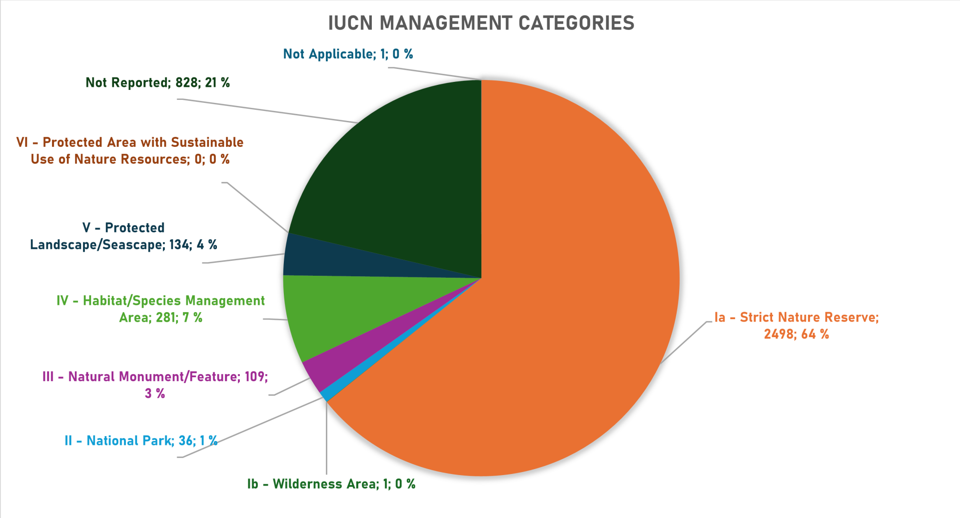


Figure 1.2.1: IUCN Management Category - name of classification; number of protected areas in Norway per classification; percentage of each category out of 3888 protected areas. Includes marine, aquatic, and terrestrial protected areas. Adapted from Protected Planet.

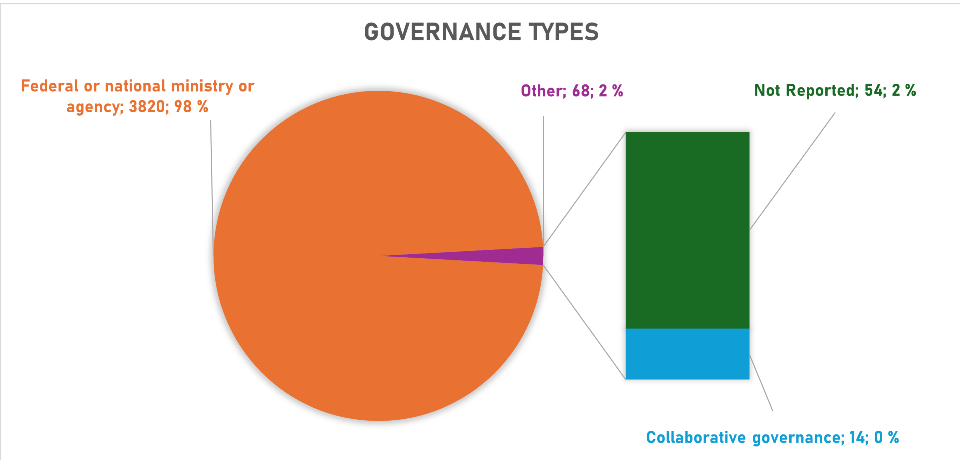


Figure 1.2.2: Governance Type; number of protected areas per type in Norway; percentage of each category out of 3888 protected areas. Protected Planet does not detail in which way governance is collaborative. Adapted from Protected Planet.

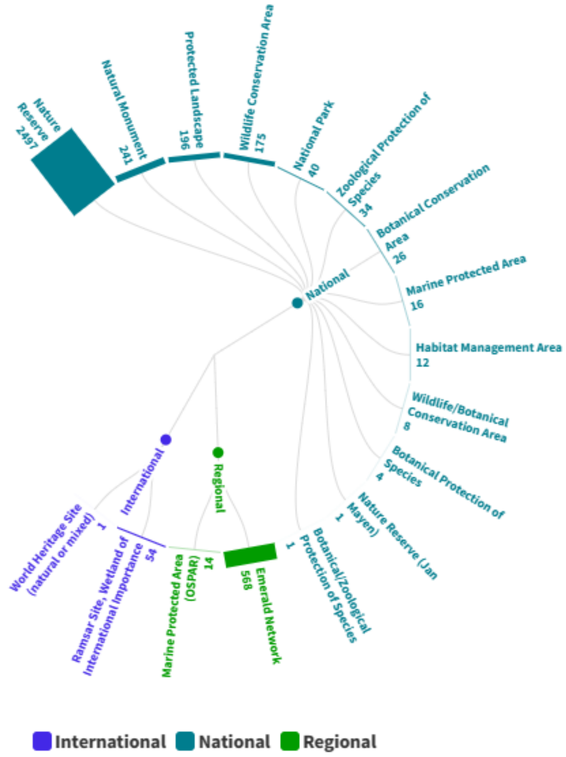


Figure 1.2.3: Combined designations of protected areas at the regional, national, and international levels. Adapted from Protected Planet.

the "best-known example of a regional organization attempting to engage in broad-based cross-sectoral cooperation for the conservation and sustainable use of BBNJ" [**46**].

1.2.2 Coastal Environments and MPAs

1.2.2.1 Characteristics of the coastal zone

Coastal zones are extremely unique ecosystems housing a great deal of biodiversity [**45**]. Nutrient exchange, riverine inputs, tidal flow, carbon sequestration, storm/flood protection, biodiversity support, and ecosystems services are all key characteristics of coastal zones [**45**], including housing unique flora and fauna and maintenance of habitat for commercial fish spawning [**34**]. Species utilize these zones for breeding, foraging, migrations, nesting, and safety [**45**]. However, the proximity to anthropogenic activity has led to coastal degradation [**45**]. This is amplified with climate change impacting coastal systems, including rising sea levels that expedite coastal erosion, which consequently leads to more instances of inundation, storm flooding, seawater intrusion into fresh groundwater, and more occurrences of tidal water breach into estuaries and lotic ecosystems [**24**]. A noteworthy amount of known global coverage of coastal ecosystems are under pressure, with 50% of marshes, 35% of mangroves, 30% of coral reefs, and 29% of seagrasses being lost or degraded [**27**].

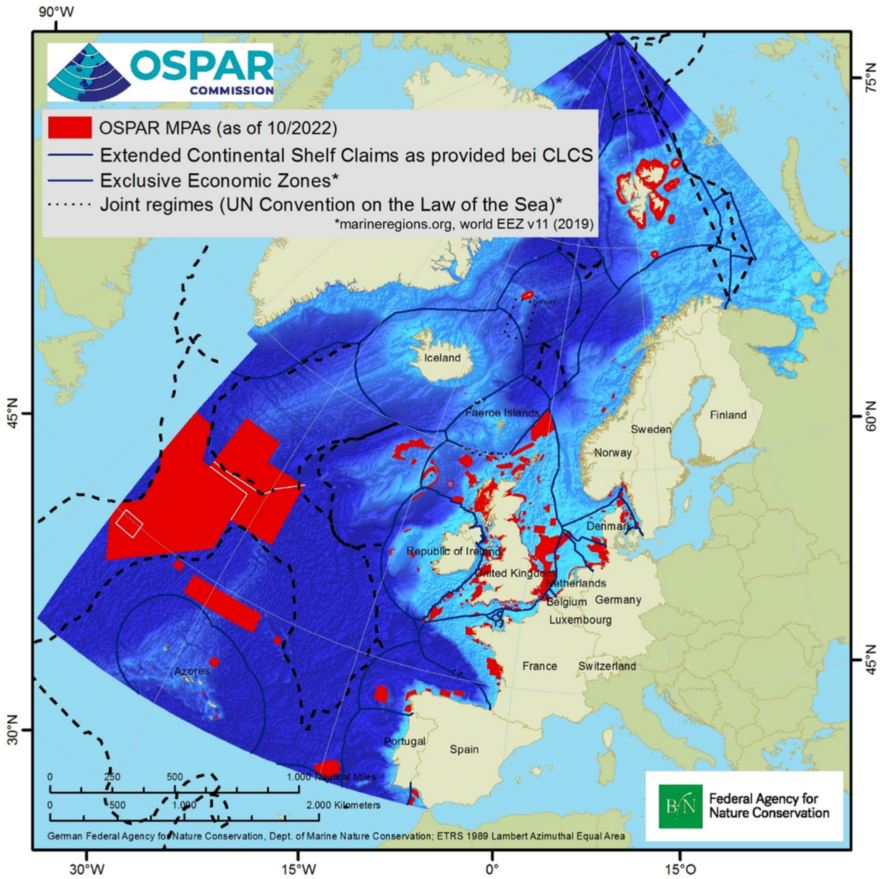


Figure 1.2.4: OSPAR MPA network as of 10/2022. Source: OSPAR Assessment Portal.

1.2.3 The Norwegian Coastal Environment & MPAs

According to Environment Norway, 80% of Norway's population lives <10 km from the sea. The coast of Norway is extremely long and varied, at 25,148 km [**6**], characterized by fjords, islands, and the world's largest cold-water coral reefs [**15**]. Important habitats include kelp forests, seagrass beds, cold water coral reefs, soft-bottom, and hard-bottom communities. The state expects integrated coastal zone management (ICZM) initiatives to be realized by the municipalities [**43**]. Norway has large oil, gas, aquaculture, shipping, and commercial fishing industries, so there is lots of anthropogenic pressure on the marine environment [**15**]. The expansion of aquaculture in Norway drives the reallocation of shared resources (i.e. coastal and sea areas) to the private sector [**43**] (i.e. a 'tragedy of the commons' situation).

According to Protected Planet, Norway has 3888 total protected areas, be that MPAs, terrestrial, or inland protected areas. Norway has not reported any OECMs, although Fiskeridirektoratet claims in a 2015 article that there are more than 150 areas where local area-based management measures have been introduced [**23**]. These numbers differ from the latest national report from Norway under the CBD Sixth National Report, last updated 21 December 2018 [**29**]. Protected Planet states any discrepancies can be explained by "difference[s] in methodologies and datasets used to assess protected area coverage and differences in the base maps used to measure terrestrial and marine area of a country or territory". While Protected Planet has been updated since 2018 when the

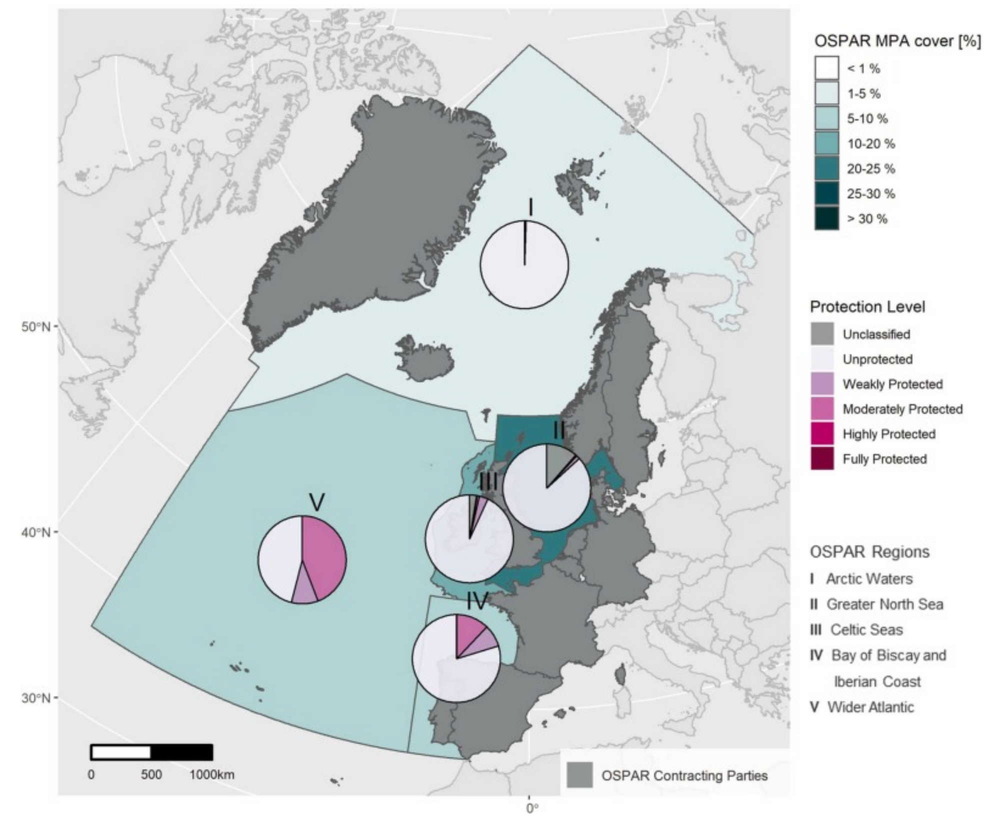


Figure 1.2.5: MPA coverage and their protection levels in OSPAR regions. Percentage of OSPAR MPA coverage for each region in turquoise. The percentage of protection levels of the MPA covered area for each region in the pink color scale. Contracting Parties in dark grey. Source: Roessger, Claudet, & Horta e Costa 2022.

Sixth National Report was updated, Protected Planet posits that 1.35% of marine and coastal areas have been given protection, while the the report states that by 2017, 3.1% of territorial waters were cross-sectorally protected under the Nature Diversity Act, along with the protection of 18 coral reefs from dredging [**29**].

1.3 Principles of MPA Design/MPA Networks

1.3.1 Definitions, Different Algorithms, and Different Approaches

MPAs are zones wherein human activity has been restricted in some way in order to decrease anthropogenic impacts on particular marine ecosystems [**30**]. They are enforced as areas for conservation, such as to maintain biodiversity, mitigate negative human impacts, facilitate fish stock and resource recovery, and to prevent further deterioration of marine environments, with focus on those that are “ecologically representative” [**30**]. Additionally, they are traditionally designed with multiple objectives in mind (such as to protect biodiversity; to ensure connectivity; to avoid population collapse and support population resiliency; to avoid adverse evolutionary effects from selective fishing; to optimize the value, efficacy, and yield of fisheries; and to placate stakeholders [**30**].

Some classic proxies for biodiversity representation globally to implement protected areas have included species richness or environmental variables analyses [**1**, **36**]. In recent decades, diversity patterns have typically used the species richness surrogates [**1**]. Potential sites for protection would then be those with the highest number of species or threatened/vulnerable species in a designated study area that would altogether represent close to all or all the species [**1**]. Species richness may be the most widely-applied approach to prioritizing sites for conservation and this approach is appropriate when measuring ecosystem function [**1**]. Astudillo-Scalia & Albuquerque (2020) used the Species Accumulation Index (SAI) to determine the efficacy of species richness for marine mammal groups. They found that there seems to be a positive correlation between species richness and ecosystem function [**1**]. Species richness may not be an appropriate benchmark in terms of trying to represent the greatest number of species in a key area. This is because species richness can ignore endemism and rarity in species found in an area, thus possibly resulting in a reduced number of protected species [**44**]. Furthermore, species richness does not consider complementarity (i.e. how well sites in a network work together for conservation objectives [**21**]). Complementarity can be assessed using algorithms such as Zonation, which considers the rarity of species and evaluates all potential scenarios of site-selection and can assign a higher priority to those sites which house those species with limited ranges [**1**, **41**].

1.3.2 Spatial Conservation Prioritization

What is spatial prioritization? Biodiversity conservation is constrained by limited resources [**41**], therefore prioritization is required. Spatial prioritization is the mapping and analysis of areas for the purpose of conservation action. Priority areas can be identified for the establishment of protected areas and the investment of conservation action (i.e. invasive species management, habitat restoration, species distribution analyses, etc.) using spatial analysis of quantitative data [**41**].

Integrate planning products with a strategy for implementation. There are many factors when prioritizing area for conservation. Considering connectivity, adequate representation of biodiversity surrogates, portraying spatial patterns, the influence of climate change, metapopulation dynamics, and habitat quality and diversity are all key when creating a management plan for target species/areas [**41**, **4**]. Adaptive management strategies should be used to fulfill species and habitat persistence goals and to monitor them over time [**41**]. There is a clear 'knowing-doing gap' in the implementation of conservation action when moving from research on/using spatial prioritization and processes and the actual creation of protected areas [**41**]. The specific objective of conservation prioritization is to identify effective and beneficial actions that will produce the best possible conservation outcome given limited resources and information [**41**] for a point in time.

1.3.3 What makes a successful and coherent MPA network?

Effective MPAs are ones that were created with size, placement, level of protection, existing biodiversity, and specific biodiversity threats in mind [**35**], but there are innumerable gaps in global biodiversity data. MPAs should be formed to function as a network for biodiversity protection [**35**], with supervised indicators for successful MPA management [**11**]. Ecological and biological diversity should be carefully considered when planning conservation action and conservation action sites [**3**]. Havforskningsinstituttet (HI) acknowledges the use of ecologically or biologically significant area (EBSA) criteria as a metric for where biological production and biodiversity is the most critical [**20**].

While there exists social and political pressures on the 30by30 target, it is not recommended to achieve this by designating MPAs in zones of:

1. low biodiversity,
2. low production, or
3. with low anthropogenic activity

The creation of MPAs and MPA networks that serve as 'paper parks' wherein management is nonexistent is also not supported [**30**].

The proportions of MPAs under-performing and exceeding the threshold for effective MPA management of MPAs globally and by continent in 2017 are explored in Figure 1.3.1 [**11**]. As seen in the figure, Africa, the Americas, Europe, and Oceania are generally missing the mark of successful management, with Asia leading in efficient management.

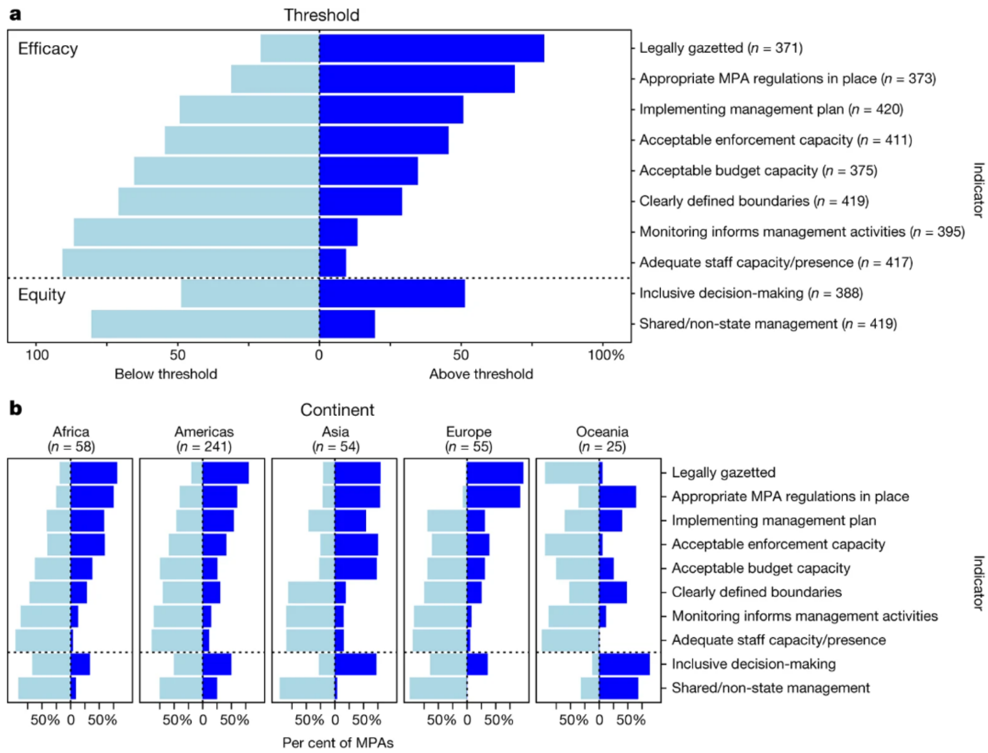


Figure 1.3.1: Percent of global MPAs exceeding, meeting, or missing threshold values for indicators of effective MPA management; (a) values shown for all MPAs (n = 433); (b) values shown by continent. Dark blue bars (R) indicate proportions above the threshold, light blue bars (L) indicate proportions below the threshold. Source: Gill *et al.* 2017.

Principle of Complementarity. Complementarity considers how well sites in a network work together and approaches coverage for all biodiversity features [**21**]. It is especially important because the conservation of planning units is dynamic over time (i.e. it changes as the network of priority areas is delimited and expanded and as the distribution of features in an area changes with that). When designing an MPA network it is important that the planning units being prioritized for conservation complement existing protected areas and those planned for future investment [**41**]. This principle supports existing ecosystem function; that is, each species in a community has its own characteristics and functions that already exist in a community, regardless of human interaction. Through protected area networks, the coexistence of multiple species who each have their own function in a community is advantageous to the stability of that ecosystem [**41**].

Representativity, Replication, and Comprehensiveness. When establishing an MPA, comprehensiveness should be a big consideration. Following this principle, a portion of the full range of biodiversity features is considered, taking into account composition (species & genetic diversity), habitat types, and function (i.e. recruitment and dispersal) [**41**]. Each biodiversity feature protected should be representative of that area in question. Comprehensiveness is defined by the thoroughness with which planning unit characteristics are represented and the amount of each feature is present (replication) in the MPA [**42**]. Representing surrogates, like well-known biodiversity features such as genetic diversity, habitat variety, community composition, and functional roles [**41**] are important in an effective MPA. McLeod *et al.* 2008 suggest diminishing risk spreading by protecting at least 20-30% of each habitat type (representation), at least 3 examples of each habitat type (replication), and ensuring the replicates are spatially diverse enough to reduce the probability of them being adversely impacted by the same disturbance [**24**].

Connectivity. It is extremely important to recognize and incorporate ecological spatial connectivity in MPA design, use, and management due to the large range of movement of organisms and materials in the ocean [**4**]. Acknowledging the needs of connectivity must include knowledge on reproductive output, dispersal, settlement, and post-settlement survival (recruitment) of species in an area [**2**], as well as species-specific requirements such as dispersal capacity, sensitivity to edge effects, and home range size [**41**]. Species and organisms inhabiting adjacent or overlapping communities (metapopulations) are linked by the exchange of genes, resources, and energy, [**2**] which further demonstrates the necessity for MPA networks. Lack of connectivity is disadvantageous to the persistence and resilience of target species in a patch network [**41**], although only 11% of the 746 MPAs examined by Balbar & Metaxas 2019 considered connectivity as an ecological criterion in MPA design (Figure 1.3.2).

Ecological spatial connectivity is achieved through the protection of multiple interconnected, spatially distinct ecosystems within an MPA or within an MPA network [**4**]. MPAs can benefit ecological processes both inside and outside the administrative boundaries of the MPA. They contribute to the sustainability of exploited populations and fisheries outside their boundaries by providing safety for larval production, through adult 'spill-over', and through the protection of juvenile habitat [**4**]. Improving management outside the administrative boundaries of MPAs will also "ease the performance burden for MPAs and lower the eventual target coverage to be attained" [**30**].

Ecological coherence of MPA networks. Representativity, connectivity, adequacy, and replication, when combined, inform on the ecological coherence of MPA networks [**42**]. Well-established principles that underpin habitat suitability and reserve connectivity [**41**]

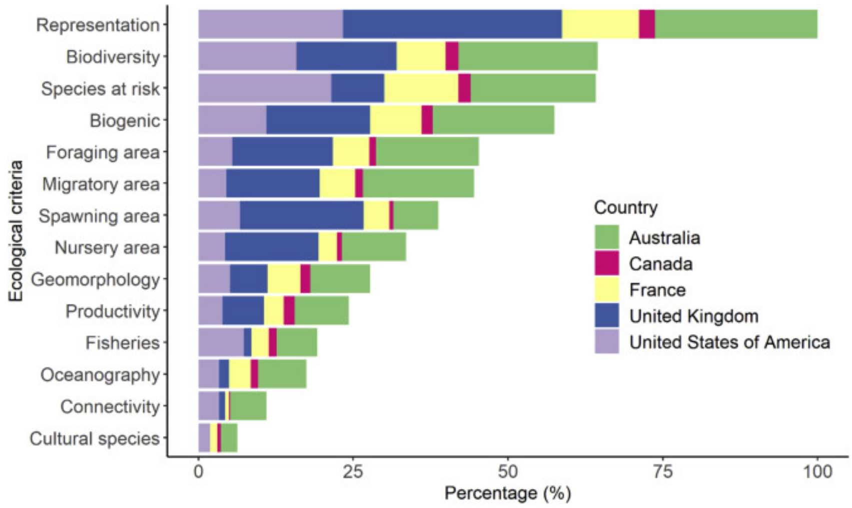


Figure 1.3.2: Use of 14 ecological criteria in the design of 746 MPAs across Australia, Canada, France, the UK, and the U.S. (Hawai'i and California only). Source: Balbar & Metaxas, 2019.

are:

- Species are more likely to persist in suitable habitat rather than unsuitable habitat
  - The relationship between suitability, availability of resources, carrying capacity, and abundance is considered
- Large, compact, and better connected conservation areas are better for species persistence than smaller, scattered areas
  - The effects of area, isolation, and edge effects are considered
  - Generalizations from island biogeography, observations, and metapopulation attributes supports this

Vulnerability & Resilience. Vulnerability is encompassed by three determinants [**41**]:

- Exposure: the possibility of a threat affecting an area over time or the time expected until the area is affected
- Intensity: the magnitude, frequency, and duration of a threat or pressure
- Impact: the response of a species or ecosystem to the threat or pressure

Resilience is the ability of an ecosystem to maintain key functions and processes and remain stable by resisting or adapting to changes in the environment despite pressures [**25**]. Critical areas that are biologically and/or ecologically important (e.g. nursery grounds, spawning areas, areas of high biodiversity) should be prioritized for protection [**25**]. Long-lived protection (20-40 years, with preference for permanent MPA accreditation) allows for recovery of species and the improvement of ecosystem health [**7**]. Shorter-lived MPAs (i.e. MPAs that are seasonal, rotational, periodically harvested), while less relevant for building ecosystem resilience, can be vital in protecting areas at critical times (e.g. nursery areas in spawning seasons). For these MPAs, an additional 15% of key habitats should

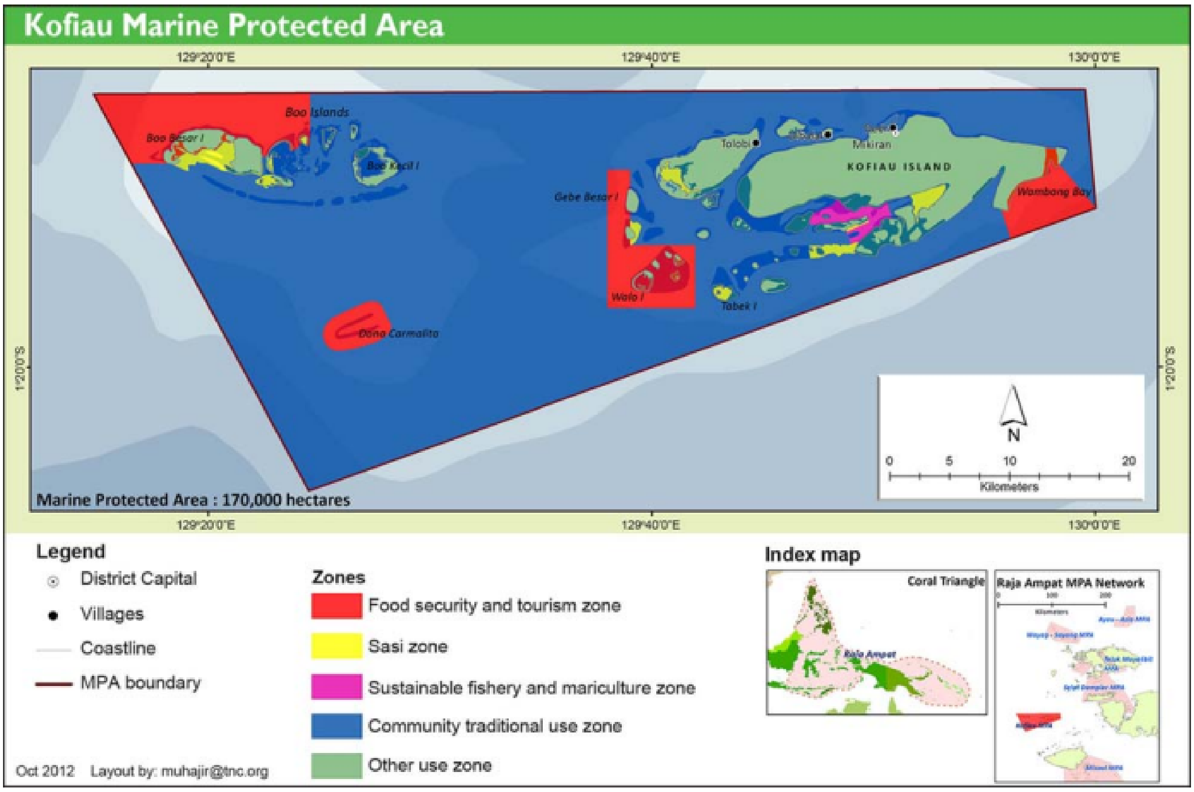


Figure 1.3.3: Example of a multiple use MPA, Kofiau MPA, Raja Ampat, 2012. Source: Green, White, & Kilarski, 2013.

be included in the MPA design [**7**].

Shape and Size of MPAs. Small, well-enforced MPAs properly managed may ultimately be more important for maintaining biodiversity than large protected areas without management [**11**]. The size of the MPA should be based upon the movement patterns of the species found within the MPA, including the use of multiple habitats and depth zones [**38**] throughout a target species life cycle (i.e. be familiar with the life history characteristics of the species for proposed protection). MPA networks designed for resilience should include MPAs of 10-20 km across to be large enough to support the full range of marine habitat, and utilize simple shapes (i.e. rectangles, squares) as opposed to elongated ones to minimize edge effects and maximize the area of interior protection [**25**]. To reduce risk spreading, but build resilience, separating marine reserves by 1 to 20 km is suggested as this will still accommodate the larval dispersal patterns of most species and ensure spatial variation [**7**].

A multi-use MPA is one wherein different zones work in collaboration to produce results they could not obtain as singular MPAs. They are typically as large as possible and can work to a) maximize fisheries benefits, b) protect a larger range of habitats, and c) mitigate risk [**7**]. An example is shown in Figure 1.3.3.

Surrogacy. You will never have a complete list of species let alone adequate spatial info on the distribution of all species, so using surrogates and the 'best available science' [**38**] is a good way to combat uncertainty and incomplete information. Species-level surrogates employ distributions of individual species from well-studied groups as indicators of spatial patterns/the distribution of biodiversity in an area [**41**]. Community-level surrogates utilize spatial descriptors or correlations of patterns in the distribution of entire ecological communities/ecosystems (e.g.mapped vegetation types, abiotic environmental classifications, richess, etc.) [**41**]. These two levels can be interdependent and work in complement.

Overview. In a 2013 guide to MPA design in tropical ecosystems, the National Oceanic and Atmospheric Administration (NOAA) provides 15 principles for MPA network design that take biodiversity, climate change, and fisheries into account (some of which are aforementioned). These principles each can apply to other ecoregions, and should be referenced within the Norwegian MPA network design framework. The principles target 5 overarching categories that underpin the creation of a resilient MPA network: risk spreading, protecting critical areas, incorporating connectivity, threat reduction, and sustainable use [**7**]. The 15 principles are as follows:

1. Prohibit destructive activities throughout the management area.
2. Represent 20-40% of each habitat within marine reserves.
3. Replicate protection of habitats within marine reserves.
4. Ensure marine reserves include critical habitats.
5. Ensure MPAs are in place for the long term (20-40 years), preferably permanently.
6. Create a multiple use MPA that is as large as possible.
7. Apply minimum and variable sizes to MPAs.
8. Separate marine reserves by 1 to 20 km.
9. Include an additional 15% of key habitats in shorter term marine reserves.
10. Locate MPA boundaries both within habitats and at habitat edges.
11. Have MPAs in more square or circular shapes.
12. Minimize and avoid local threats.
13. Include resilient sites in marine reserves.
14. Include special or unique sites in marine reserves.
15. Locate more protection upstream.

1.4 Study Objectives

Conservation progress is generally measured by the total marine area under protection [**35**] but when large MPAs are created that do not house much biodiversity, the conservation potential is undermined by the size of the MPA. This research aims to explore gaps in knowledge with the current Marine Protected Area network design framework in coastal, contiguous Norway with focus on how this framework is impacting biodiversity conservation. Due to the size of this study area, this study was focused at the county level. To reach this objective, the following questions are addressed:

1. What habitat and biological data is available for MPA design in territorial coastal waters of contiguous Norway?

2. Are there inconsistencies in reported MPAs?

3. Is there spatial, taxonomic, or methodological bias in the available data?

4. Is the existing data effective for MPA network planning given MPA design criteria?

5. Is the current network design framework ecologically coherent and how can it be improved with biodiversity conservation in mind?

CHAPTER

TWO

METHODS

2.1 Spatial tools and Databases

ArcGIS Pro 3.2 and R version 4.4.0 ”Puppy Cup” were used in this analysis. Unless otherwise stated, all shapefiles and data in R were converted to EPSG:4326 (WGS84) using `sf`; all GIS shapefiles (SHP) were converted to EPSG:4326 (WGS84) using the Project geoprocessing tool. The full R script, list of R packages and citations, GIS layer data/citations, etc. will be found in the GitHub repository (see Appendix). To focus this analysis, only the marine areas within the territorial border (within 12 nautical miles of the coast) of Norway were considered. Analyses were based at the county level due to the large amount of data, following the 14 counties in Norway that have marine area (Figure 2.1.1).

2.1.1 Analysis of MPA, habitat, and dredge data

In ArcGIS Pro, a map layer was created of the intersection of a shapefile of municipalities boundaries and a shapefile with counties boundaries, clipped to a file of the territorial waters of Norway adapted as SOSI files from Geonorge and converted to SHP file format with the Sosicon online application. The intersection of the administrative data created an output with county and municipality data merged. The Clip geoprocessing tool was used to merge the administrative output layer with the Norwegian maritime border shapefile of the territorial waters of Norway (12 nm from the coast, outward). Figure 2.1.2 shows the model built in ArcGIS Pro to create this shapefile. This layer was used in the analysis of MPA and habitat coverage.

The Protected Area data used in this analysis was downloaded as SHP files from Protected Planet’s World Database on Protected Areas (WDPA). The April 2024 data was used. MPA shapefiles came from the OSPAR Data and Information Management System (ODIMS), and the OSPAR Commissions map tool under République Français and their Office Français de la Biodiversité. There are two OSPAR MPA Network datasets on the ODIMS website - one from 16 July 2021, and one from 1 January 2023. The 2021 dataset is downloadable as as a shapefile and was used in this analysis, while the 2023 dataset is only downloadable as an image (the image does not download properly).

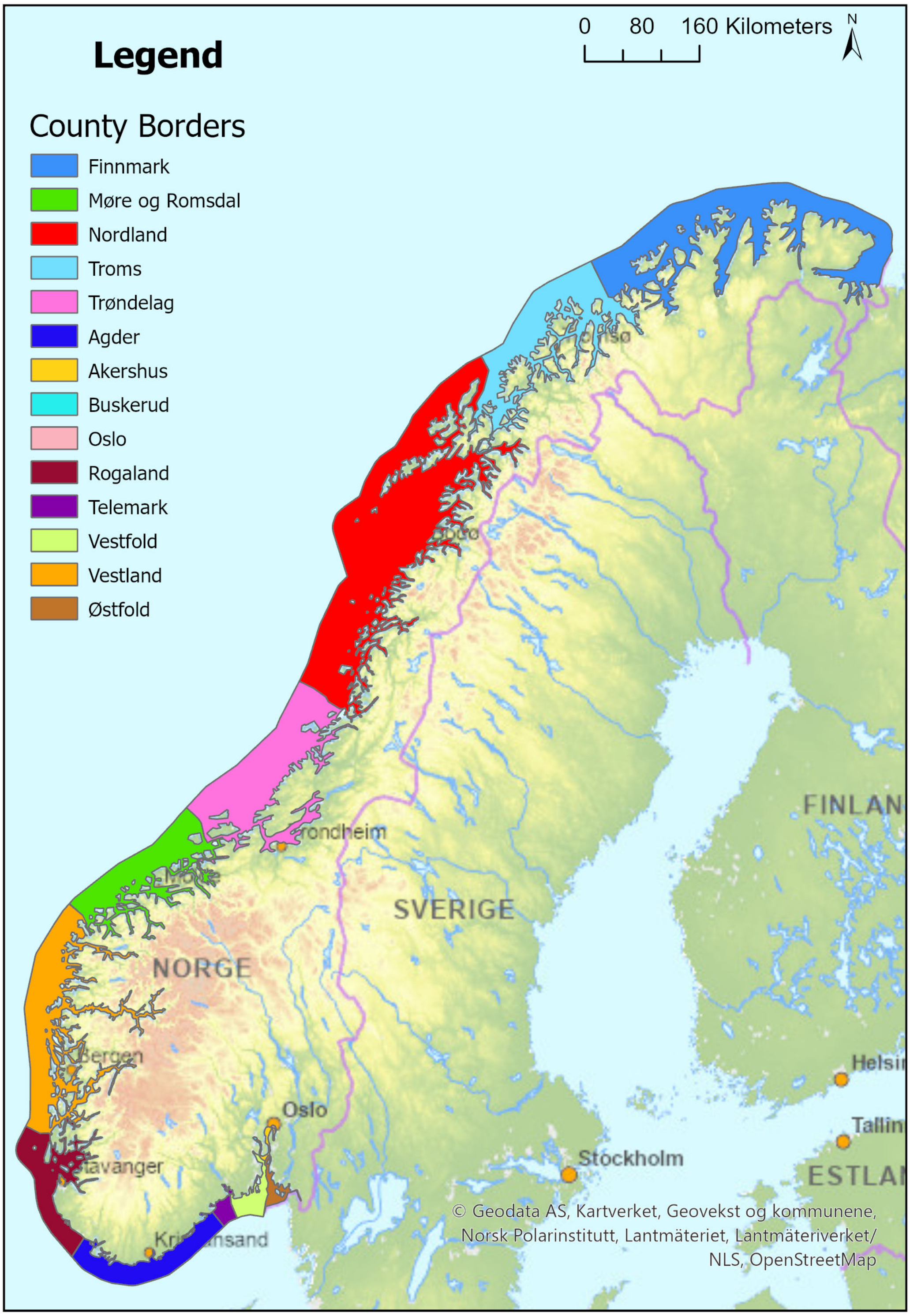


Figure 2.1.1: Study Area: territorial waters of Norway shaded by county.

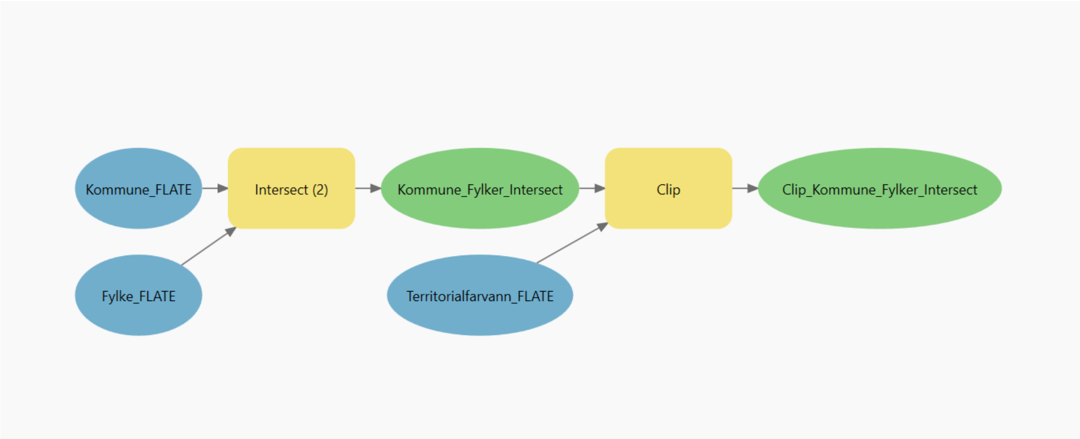


Figure 2.1.2: Model showing creation of administrative shapefiles: input features (blue), geoprocessing tools (yellow), and output feature classes (green). The rightmost output feature became the base input layer for intersections in ArcGIS Pro.

To find the distance to the closest MPA, the Measure tool in ArcGIS Pro was used manually to find geodesic distance in kilometers from the closest point of each MPA to its nearest MPA. A conservative approach was employed and distance was found following one point in a straight line to the next nearest point. MPA and its Habitat data, biotype data, and particularly valuable areas in the sea (SVO) data was downloaded as shapefiles from the HI/Marine Areal database for Norwegian waters (MAREANO) program and Miljødirektoratet. Lobster conservation area polygons were downloaded from Fiskeridirektoratet as SHP files. Trawling and dredge data was downloaded as SHP files from the European Marine Observation and Data Network (EMODnet). Shapefiles and sources are shown in Table 2.1.1.

Using the Intersect geoprocessing tool, the aforementioned shapefiles were individually intersected with the clipped administrative/territorial waters map layer. A field was added to each attribute table. Using the Calculate Geometry tool, geodesic area in square kilometers and in GCS WGS84 was calculated in this added field. Kelp reference area, identified coral reef, coral conservation areas, coral reef prohibited areas, WDPA, SVO, OSPAR MPAs, nature conservation area, and lobster conservation area shapefiles were exported to RStudio. Using `sf`, the shapefiles were changed to data frames and the coordinate reference system was set to EPSG:4236. Proportions were calculated by summing the area of each data layer's area per county and dividing by each county's territorial water area.

Habitat and biotype polygons and points were intersected with the administrative data shapefile in ArcGIS Pro and geodesic area was calculated in WGS84 using the previously stated method. Using the Select by Attributes tool an expression was created to filter by county in each map layer with polygon geometry. This filtered the data table by county and the area calculated by the Calculate Geometry tool was summed using the sum function in Microsoft Excel.

Barents Sea biotype data and dredge data were intersected with the administrative map layer in ArcGIS Pro. This clipped the data to the territorial waters of Norway.

Coastline was calculated using the Measure tool in ArcGIS Pro by manually following the coast and indentations to find approximate coastline by county in kilometers.

Table 2.1.1: GIS shapefiles and sources.

Shapefile	Source
Norges Maritime Grenser/ Norwegian Maritime Borders	Geonorge/Kartverket
Administrative enheter fylker/ Administrative units - County	Geonorge/Kartverket
Administrative enheter kommuner/ Adminitrative units - Municipality	Geonorge/Kartverket
World Database of Protected Areas, Norway, April 2024	Protected Planet
Beam trawls	EMODnet
Bottom otter trawls	EMODnet
Bottom seines	EMODnet
Static gears	EMODnet
Pelagic trawls and seines	EMODnet
OSPAR MPA (2021)	ODIMS
OSPAR MPA	OSPAR Commission Map Tool
Naturtyper	Mijødirektoratet
Naturvernområder/Nature conservation areas	Mijødirektoratet
(SVO)	Mijødirektoratet
Soft-bottom coral gardens	HI/MAREANO
Soft-bottom sponge gardens	HI/MAREANO
Deep water seapen fields	HI/MAREANO
Hard-bottom coral gardens	HI/MAREANO
Hard-bottom sponge gardens	HI/MAREANO
Neptheidae fields	HI/MAREANO
Barents Sea biotype points	HI/MAREANO
Lobster conservation areas	Fiskeridirektoratet
Kelp reference area	Fiskeridirektoratet
Seapen fields	HI/MAREANO
Identified coral reefs	HI/MAREANO
Observed coral reefs	HI/MAREANO
Coral reef conservation areas	HI/MAREANO
Coral reef prohibited areas	HI/MAREANO

2.1.2 Analysis of species occurrence records

The Ocean Biodiversity Information System (OBIS) was used as the main database for species occurrence data. Using the Mapper tool (https://mapper.obis.org/), a polygon was drawn roughly following 12nm outside the coast of Norway, and excluding terrestrial contiguous Norway, Svalbard, and Jan Mayen (Figure 2.1.3). This preliminary shape captured species occurrence data within the polygon and decreased the processing time for `robis` to connect to the OBIS API in R. This data was then filtered using `dplyr` based on the condition that the occurrences must be contained within Animalia, Chromista, and Plantae kingdoms. This excluded Bacteria, Protozoa, Fungi, and Biota incertae sedis. After reviewing the make-up of the data, class Aves was then filtered out using `dplyr` due to an overwhelmingly large amount of bird occurrence data to make the following results and recommendations more relevant.

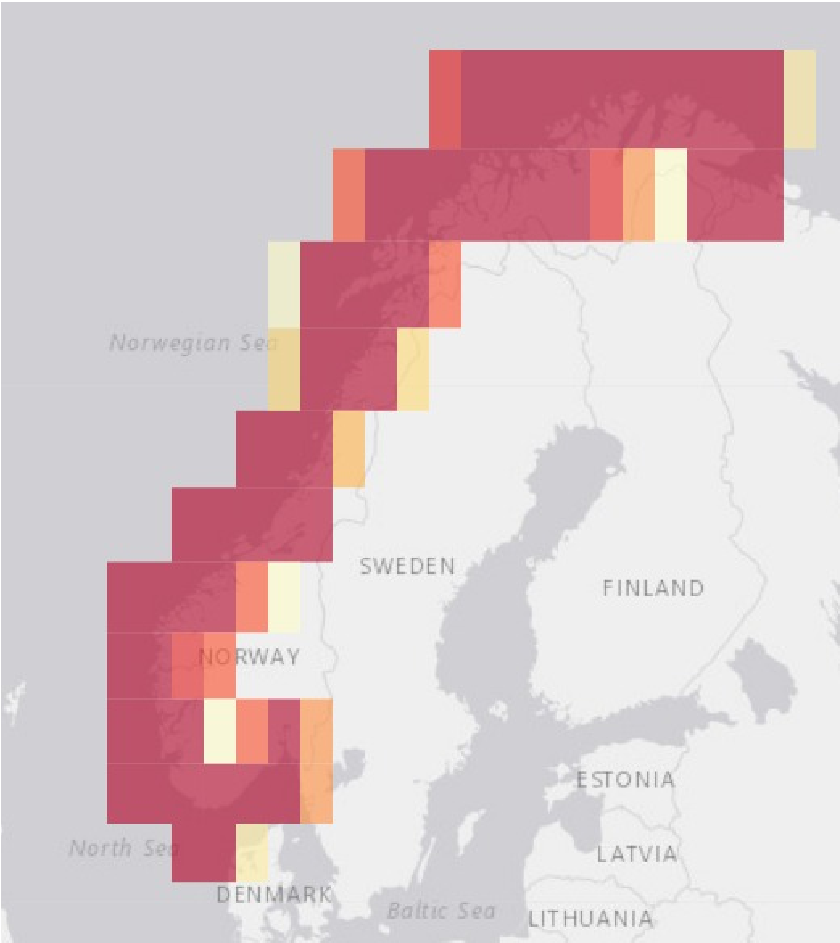


Figure 2.1.3: Preliminary polygon drawn in OBIS Mapper to filter marine species occurrence data.

In ArcGIS Pro, a map layer was created through the intersection of the SHP file with counties data and the SHP file of the territorial waters of Norway - downloaded from Geonorge. Using the same method as above, geodesic area in square kilometers was calculated in ArcGIS Pro using the Calculate Geometry tool. This layer was exported to R using `sf` was converted to a sf object and the coordinate reference system was set to EPSG:4326. The OBIS occurrence data was joined with this layer and then intersected using `sf` to give only the species occurrences found within 12 nautical miles of the contiguous Norwegian coast, forming the Norwegian territorial marine area.

County maps with species occurrence records were made using `dplyr` and `ggplot2`. As species occurrence data had point geometry, to quantify how much data is present and how much data is absent, the intersected shapefile in R and the shapefile in ArcGIS Pro were transformed using `sf` to EPSG 25833 (UTM zone 32N), and using the fishnet function from `sp`, a grid was created for each county map. The county and territorial waters intersected layer was rasterized in ArcGIS Pro using the Polygon to Raster geoprocessing tool. The count of raster cells was generated per county in ArcGIS Pro was used as the base for the number of cells. Cells in R were manually counted to represent areas in which species occurrence data is present versus absent. In both R and ArcGIS Pro, counties with administrative coastal areas of less than 1000km^2 were gridded with 2km^2 cells, and those with areas greater than 1000km^2 were gridded with 5km^2 cells. Species occurrences were normalized by area per county using `sf` and `ggplot2` by calculating density of species occurrences records to area of each county's territorial waters and then log-transforming the species density.

Distribution of time intervals was run in R using a function to create intervals based on year values in the data table. Ten-year intervals from 1970-2024 were created and all data recorded prior to 1970 was aggregated. A barchart was created using `ggplot` The analysis of depth by phylum was created by combining recorded depth values and phylum into a data frame and plotting using `ggplot`. Since there were over 3000 species and/or identifiers in this dataset (not all species occurrences had species name and only went to a higher taxonomic rank), phylum was used to make the depth data more visually comprehensive. Table 2.1.2 gives the full use of R packages and functions used in the R script.

Table 2.1.2: R packages and functions used.

R Package	**Function**
`robis`	Connect to the OBIS API
`dplyr`	filter, mutate, summarize, group_by
`ggplot2`	ggplot
`sf`	st_as_sf, st_set_crs, st_read, st_transform, st_join, st_intersection, st_make_grid
`sp`	fishnet
`cowplot`	plot_grid
`scales`	percent

CHAPTER

THREE

RESULTS

3.1 The current MPA situation in Norway

3.1.1 Summary of Results of conservation areas

There are discrepancies between available MPA data. Protected Planet WDPA marine data do not align with the 2021 OSPAR MPA data from ODIMS or the OSPAR MPA data from the OSPAR Commission web map application, which also do not align with each other (Figures 3.1.7 - 3.1.13). It can be assumed that part of the explanation as to why these two OSPAR MPA datasets do not match is because the 2021 data on the ODIMS website has since been updated in the OSPAR Commission web map tool. We can expect that this data is a closer match to the inaccessible 2023 ODIMS data. The ODIMS MPA data, which is reported as a live feed from the MPA Web Feature Service, but is only downloadable for the data up until July 2021, shows that there are 14 OSPAR MPAs: Breisunddjupet, Framvaren, Færder, Gaulosen, Jomfruland, Jærkysten, Korallen, Raet, Rødberg, Saltstraumen, Selligrunnen, Sularevet, Tauterryggen, and Ytre Hvaler within the Norwegian coastal area. The official OSPAR Commissions website map tool finds additional OSPAR MPAs within the Norwegian coastal zone, including the previously listed 14 plus Innervisten, Kaldvågfjorden og Innhavet, Karlsøyfjorden, Lopphavet, Lurefjorden og Lindåsosane, Nordfjorden, Rossfjordstraumen, Rystraumen, Skarnsundet, and Ytre Karlsøy (Figure 3.1.1). On their website, Protected Planet identifies 11 MPA zones within the Norwegian Coast: Breisunddjupet, Korallen, Saltstraumen, Tauterryggen, Framvaren, Gaulosen, Jærkysten, Rødberg, Røstrevet, Selligrunnen, Sularevet, and Ytre Hvaler. Only Ytre Hvaler and Raet show up in the list of Protected Areas in the SHP file from WDPA. They are both listed as national parks. OSPAR MPAs with their areas, year of designation/proposal, and the county they fall within is listed in Table 3.1.1. These 24 MPAs found in coastal Norway are not well connected. A conservative approach was taken to measuring the distance between MPAs, and it was found that there are up to 190km of distance between MPAs (Table 3.1.2).

The coral reef conservation data and the coral reef prohibited area GIS data (i.e. human activity is restricted) is exactly the same. The only difference is the description of each polygon. Coral reef conservation areas are described as ”Coral MPAs” in the HI/MAREANO data, although several of these conservation areas are not geographically defined as part of any existing MPA. Coral reef prohibited areas have information regarding re-

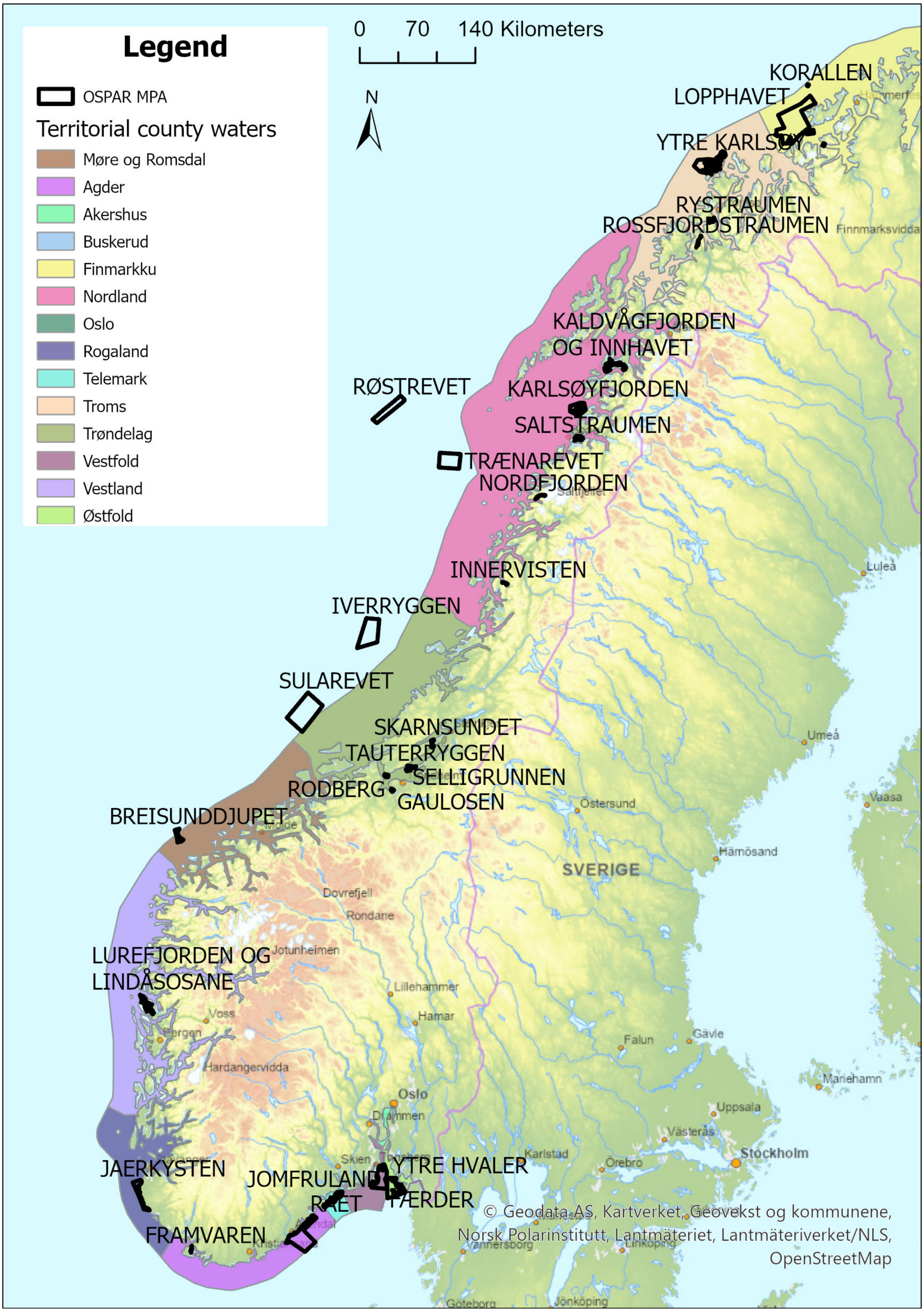


Figure 3.1.1: OSPAR MPAs around contingous Norway. Those that fall within the territorial waters (12 nautical miles from the coast) are shaded with the county waters they fall into. Map extent 1:7 500 00.

Table 3.1.1: List of OSPAR MPAs in coastal Norway. Reported marine areas and status year come from the OSPAR MPA Datasheets for each MPA. D = designated, P = proposed. ∗Full area of Sularevet is 989km^2 and 13.2km^2 fall within 12 nm of the coast.

Name	**Area (km^2)**	**Status Year**	**County**
Korallen	3.80	D.2012	Finnmark
Lopphavet	1317.99	P.2023	Finnmark
Saltstraumen	25.00	D.2015	Nordland
Tauterryggen	44.00	D.2015	Trøndelag
Gaulosen	10.86	D.2017	Trøndelag
Rødberg	14.13	D.2017	Trøndelag
Jomfruland	115.00	D.2018	Agder/Telemark
Raet	599.00	D.2018	Agder
Jaerkysten	142.56	D.2017	Rogaland
Framvaren	6.00	D.2015	Agder
Færder	340.00	D.2018	Vestfold/Østfold
Ytre Hvaler	340.00	D.2010	Østfold
Kaldvågfjorden og Innhavet	92.30	D.2020	Nordland
Karlsøyfjorden	162.38	D.2020	Nordland
Nordfjorden	11.61	D.2020	Nordland
Innervisten	5.05	D.2020	Nordland
Ytre Karlsøy	409.48	D.2020	Troms
Rystraumen	17.51	D.2020	Troms
Rossfjordstraumen	11.38	D.2020	Troms
Skarnsundet	18.48	D.2020	Trøndelag
Lurefjorden og Lindåsosane	69.13	D.2020	Vestland
Breisunddjupet	60.80	D.2012	Møre og Romsdal
Sularevet	13.20*	D.2005	Trøndelag
Selligrunnen	0.66	D.2005	Trøndelag

Table 3.1.2: List of OSPAR MPAs in coastal Norway with the distance the closest point of the nearest MPA.∗Selligrunnen is within Tauterryggen.

Name	**Distance to closest MPA (km)**
Korallen to Lopphavet	11.67
Ytre Karlsøy to Rystraumen	54.90
Rystraumen to Rossfjordstraumen	17.53
Kaldvågfjorden og Innhavet to Karlsøyfjorden	45.38
Saltstraumen to Karlsøyfjorden	24.5
Nordfjorden to Saltstraumen	77.87
Innervisten to Nordfjorden	108
Sularevet to Rødberg	110.23
Skarnsundet to Tauterryggen	30
Rødberg to Gaulosen	14.50
Selligrunnen to Tauterryggen	0*
Breisunddjupet to Lurefjorden og Lindåsosane	190
Jaerkusten to Framvaren	66.90
Raet to Jomfruland	15.8
Færder to Ytre Hvaler	0.2

strictions on fishing and fishing gear permitted in these areas, and do not identify these areas as Coral MPAs. Of the 12 coral areas listed in these datasets, only 6 fall within OSPAR designated MPAs. There are many HI observed coral reefs within 12 nautical miles of the Norwegian coast. Some fall within OSPAR MPAs (Figures 3.1.3 and 3.1.5) and some dense coral reef areas do not fall within an MPA, but within nature conservation areas (Figure 3.1.4), while there are also designated coral conservation areas that do not have observed coral reef data within (Figure 3.1.4). Nature conservation areas defined by Mijødirektoratet are designated with IUCN protected area categories. Of the 837 nature conservation area polygons found in coastal Norway, 542 are defined as Strict Nature Reserve (IUCN Category Ia), 169 as Habitat or Species Management Area (IUCN Category IV), 33 as Protected Landscape or Seascape (IUCN Category V), 10 as Natural Monument (IUCN Category III), 7 as National Park (IUCN Category II), and 76 as not rated. 51/76 polygons of the unrated protected areas are polygons overlapping or making up 19 OSPAR MPAs (Table 3.1.3 lists nature conservation areas that are also OSPAR MPAs).

Additionally, dredge activity is found in national park and MPA areas (3.1.2), which have coral reef conservation zones (Figure 3.1.5) and lobster conservation zones (Figure 3.1.6).

For the following summaries for each county OSPAR MPA data from the OSPAR Commission was used instead of the 2021 ODIMS MPA data as the OSPAR Commission data seems to have been updated since 2021.

Agder. Agder has 6749km^2 of territorial coastal marine waters. Of roughly 215km of coastline, there is ∼82 km of coastline under WDPA protection, ∼47km of that which is designated as ”National Park” (Raet Nasjonalpark). This national park is also partly an OSPAR MPA (598.7km^2). There are 1510km^2 of designated SVO, about 22% of the

Table 3.1.3: Nature conservation areas which are also geographically defined as OSPAR MPAs.

Overlap	**County**
Lopphavet	Finnmark
Saltstraumen	Nordland
Tauterryggen/Selligrunnen	Trøndelag
Gaulosen	Trøndelag
Rødberg	Trøndelag
Jomfruland	Agder/Telemark
Raet	Agder
Jaerkysten	Rogaland
Framvaren	Agder
Færder	Vestfold/Østfold
Ytre Hvaler	Østfold
Kaldvågfjorden og Innhavet	Nordland
Karlsøy	Nordland
Nordfjorden	Nordland
Innervisten	Nordland
Ytre Karlsøy	Troms
Rystraumen	Troms
Rossfjordstraumen	Troms
Skarnsundet	Trøndelag
Lurefjorden og Lindåsosane	Vestland

Table 3.1.4: Coastal conservation areas in percent coverage of county territorial water area. When cell is marked with a dash, assume there is <0.001% coverage or no coverage at all.

County Name	**Coral Reef Conservation Areas**	**WDPAs**	**OSPAR Commission MPAs**	**ODMIS MPAs 2021**	**Nature Conservation Areas**	**Lobster Conservation Areas**
Agder	-	10.77 %	8.84 %	8.84 %	10.95 %	0.08 %
Akershus	-	2.58 %	-	-	1.01 %	3.09 %
Buskerud	-	6.12 %	-	-	6.12 %	-
Finnmark	0.01 %	0.48 %	4.97 %	0.01 %	5.57	-
Møre og Romsdal	0.37 %	4.7 %	0.37 %	0.37 %	4.72	-
Nordland	0.27 %	2.59 %	0.65 %	0.05 %	3.5 %	0.01 %
Oslo	-	7.82 %	-	-	6.81 %	28.68 %
Rogaland	<0.01 %	2.16 %	1.85 %	1.85 %	5.43 %	0.5 %
Telemark	-	0.21 %	12.43 %	12.43 %	12.58 %	0.35 %
Troms	0.28 %	2.29 %	2.58 %	-	5.01 %	-
Trøndelag	0.05 %	2.38 %	0.51 %	0.41 %	6.08 %	-
Vestfold	-	0.37 %	17.5 %	17.5 %	18.16 %	1.38 %
Vestland	<0.01 %	0.93 %	0.35 %	-	1.63 %	0.08 %
Østfold	1.21 %	37.52 %	35.98 %	35.98 %	43.95 %	2.22 %

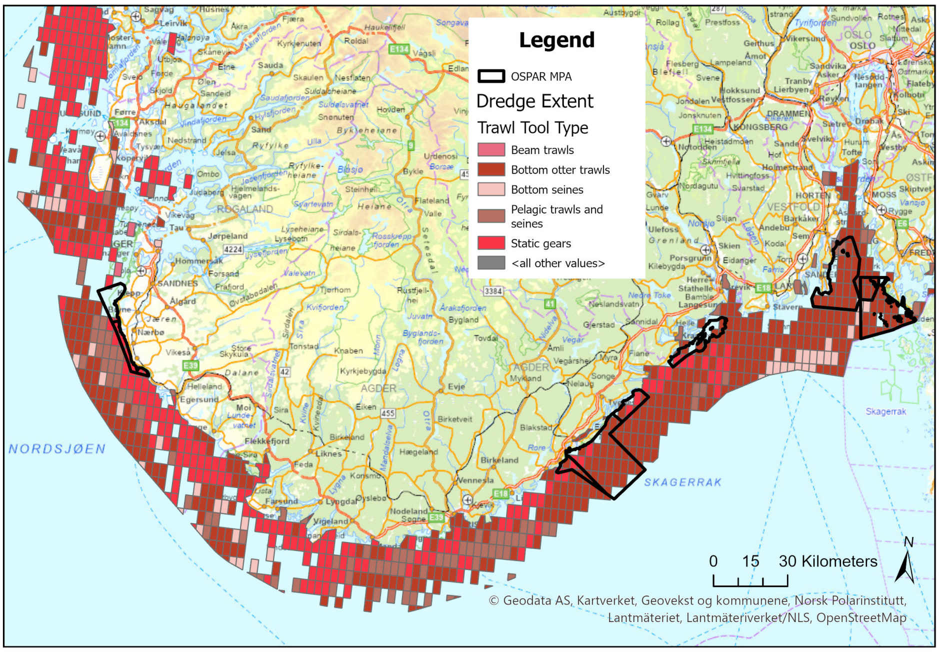


Figure 3.1.2: Dredging in southern coastal Norway (red) and OSPAR MPAs (black outline).

total sea area. There are 7 zones of lobster conservation areas, equalling 5.23km^2.

Akershus. Akershus is found within Oslofjorden, in the southeast of the country. It has 314km^2 of territorial coastal marine waters. The coastline measures ~162.5km with 9 lobster conservation zones, equalling 9.7km^2. There are 3.2km^2 of nature conservation zone. Most of these 50 nature conservation zones ares considered nature reserves, with some being bird conservation areas under Appendix 49 of Regulations relating to the Protection plan for Oslofjorden. There is 8.11km^2 under WDPA protection of wildlife or botanical conservation, or nature reserves - none of which overlap OSPAR MPAs.

Buskerud. Buskerud has only 43km^2 of territorial marine area and around 37km of coastline. 2.6km^2 are defined as nature reserve by Protected Planet.

Finnmark. Finnmark has 26430km^2 of territorial coastal marine waters, ~2200km of coastline, and contains 18 WDPAs, equalling 126.1km^2; 1319.66km^2 of OSPAR designated MPAs; 14193.69km^2 of SVO; 3.79^2 of lobster reserve; and 3.79km^2 of coral reef conservation area (completely overlaps Korallen MPA).

Møre og Romsdal. Møre og Romsdal has 11950km^2 of territorial coastal marine waters and roughly 1181km of coastline. It contains 563.85km^2 of WDPAs, 44.6km^2 of OSPAR designated MPA, 8811.72km^2 of SVOs, 20.55km^2 of kelp reference area, and 44.62km^2 of coral reef conservation area (completely overlaps Breisunddjupet MPA).

Nordland. Nordland has 44251km^2 of territorial coastal marine waters and roughly 1475.6km of coastline. It has 1146.67km^2 of WDPAs; 285.77km^2 of OSPAR designated MPA; 26896km^2 of SVO; 139.05km^2 of kelp reference area; 1 lobster conservation area of 3.82km^2; and 118.07km^2 of coral reef conservation area (not within a designated MPA).

Oslo. Oslo has ∼13.5km of coastline with 1.94km^2 of WDPAs; 7.11km^2 of lobster conservation zone.

Rogaland. Rogaland has 7537km^2 of territorial coastal marine waters and approximately 657km of coastline, with many indentations. There are 163.28km^2 of WDPAs; 140.28km^2 of OSPAR designated MPA; 2288.53km^2 of SVO; 37.72km^2 of lobster conservation zone; and 0.09km^2 of coral reef conservation area (not within a designated MPA).

Telemark. Telemark has 937km^2 of territorial coastal marine waters and 120km of coastline, containing 1.97km^2 of WDPAs; 116.76km^2 of OSPAR designated MPA; 1.80km^2 of SVO; and 3.31km^2 of lobster conservation zone within its area.

Troms. Troms has territorial water area of 16360km^2, with a coastline of approximately 1380km. Within the county marine area there are 421.96km^2 of WDPAs; 9530km^2 of SVO; and 46.06km^2 of coral reef conservation area (not within an MPA).

Trøndelag. Trøndelag has 18662.50km^2 of territorial coastal marine waters, and roughly 918km of coastline in Trøndelag. There are 443.78km^2 of WDPAs; 94.89km^2 of OSPAR designated MPA; 7761.67km^2 of SVO; 137km^2 of kelp reference area; 49.75km^2 of coral reef conservation area (13.2^2 overlaps with Sularevet MPA).

Vestfold. Vestfold has 1922.30km^2 of territorial coastal marine waters with 231km of coastline. This county contains 7.08km^2 of WDPAs; 336.60km^2 of OSPAR designated MPA; 1032.37km^2 of SVO; and 26.51km^2 of lobster reserve.

Vestland. Vestland has 17348km^2 of territorial coastal marine waters. There is roughly 1526km of coastline due to the many fjords. It has 160.27km^2 of WDPAs; 59.84km^2 of OSPAR MPA; 3163.43km^2 of SVO; 166km^2 of kelp reference area; 13.57km^2 of lobster conservation zone; 0.66km^2 of coral reef conservation area (not within an MPA).

Østfold. This county has 930.30km^2 of territorial coastal marine waters. Østfold has about 167km of coastline. The territorial water area contains 349.24km^2 of WDPAs; 334.96km^2 of OSPAR designated MPA; 590km^2 of SVO; 20.68km^2 of lobster reserve; 3 coral reef conservation areas making up 4.27km^2 and falling within Ytre Hvaler MPA, and one coral reef conservation zone of 7.04km^2 not falling within an MPA.

3.2 Habitats

Agder. Agder is characterized by soft bottom areas (1.01km^2), fjord with naturally low oxygen content, littoral basin, shoals (0.62km^2), shell sand deposits (25.01km^2), strong tidal currents, large kelp forest areas (63.2km^2), eelgrass beds (7.2km^2), oyster areas (0.30km^2), and soft-bottom sponge garden habitat.

Akershus. There seems to be fairly little habitat data for Akershus. Habitat data includes soft bottom areas (1.99km^2) and eelgrass beds (1.07km^2).

Buskerud. There is little habitat data for Buskerud. Habitat data includes soft bottom areas (2.05km^2) and eelgrass beds (0.99km^2).

Finnmark. The GIS data shows that Finnmark contains soft bottom areas (84.4km^2), fjord areas with naturally low oxygen content, sand shell deposits, strong tidal currents, large scallop deposits (33.9km^2), large kelp forest areas (157.3km^2), and eelgrass beds (0.64km^2). According to HI/MAREANO, several biotypes in the Barents Sea are present (Figure 3.2.1), including mixed sandy substrates housing sea urchins, sea cucumbers, and tunicates; gravelly/sandy substrates with lace corals; soft-bottom sponge gardens; mixed muddy substrates housing polychaetes and small sponges; coarser substrates housing sea pen fields and Nephtheid corals; sandy substrates with sponges; hard substrates encrusted by red algae; sea pen populations, soft-bottom coral garden, and cup coral areas.

Møre og Romsdal. Møre og Romsdal is characterized by several habitat types: soft bottom areas (95.8km^2), shoals (2.75km^2), shell sand deposits, strong tidal currents, large kelp forest areas (956.4km^2), eelgrass beds (2.17km^2), sea pen fields, soft-bottom coral gardens, soft-bottom sponge gardens, and Neptheidae meadow.

Nordland. Nordland contains soft bottom areas (129.5km^2), fjord areas with naturally low oxygen content (22.7km^2), littoral basin, loose calcareous algae, shoals (4.25km^2), shell sand deposits, especially deep fjord areas (22.3km^2), strong tidal currents, scallop deposits (325.03km^2), large kelp forest zones (1282.9km^2), other important marine habitats, sea pen areas, soft-bottom coral gardens, soft-bottom sponge gardens, Neptheidae meadow, and deep water sea pens.

Oslo. Oslo has gaps in habitat data. Habitat data includes soft bottom areas (0.79km^2), eelgrass beds (0.05km^2), and oyster deposits (0.21km^2).

Rogaland. Rogaland contains fjord with naturally low oxygen content, soft bottom areas (6.7km^2), littoral basin, shoals, shell sand deposits, strong tidal currents, large kelp forest (209.9km^2), eelgrass beds (4.69km^2), soft-bottom coral area, and soft-bottom sponge area.

Telemark. Data shows Telemark has soft bottom areas (8.36km^2), shoals, shell sand deposits, kelp forest (12.12km^2), eelgrass beds (3.03km^2), and soft-bottom sponge gardens.

Troms. Troms contains soft bottom areas (58.9km^2), fjord areas with naturally low oxygen content, shoals, shell sand deposits, strong tidal currents, large scallop deposits (10.75km^2), kelp forest areas (196.2km^2), and eelgrass beds. According to the IMR and MAREANO, several biotypes in the Barents Sea are present (Figure 3.2.1), including mixed sediment sponge gardens; Lophelia reef or sponge; sea pen fields and coral areas in coarse substrate; and red algae encrusting harder substrates. MAREANO data also shows that Troms administrative waters also contain Neptheidae areas, soft-bottom coral areas, and soft-bottom sponge areas.

Trøndelag. Contains soft bottom areas (70.5km^2), fjords with naturally low oxygen content, littoral basin, shoals, shell sand deposits, strong tidal currents, large scallop deposits

(299.4km^2), large kelp forests (886.7km^2), eelgrass beds (6.07km^2) and other important marine habitat. Trøndelag also contains sea pen fields, soft-bottom coral/Neptheidae and soft-bottom sponge areas.

Vestfold. Vestfold has soft bottom areas (16.5km^2), shell sand deposits, kelp forest (6.2km^2), eelgrass beds (7.59km^2), and soft-bottom sponge areas.

Vestland. Vestland has soft bottom areas (6.8km^2), fjord with naturally low oxygen content, coral zones (2.65km^2), littoral basin, shoals, shell sand deposits, strong tidal currents, large scallop areas (143.3km^2), large kelp forest (582km^2), eelgrass beds (1.4km^2), oyster deposits (0.02km^2), and other important marine habitat. The county waters also contain soft-bottom sponge gardens and Neptheidae areas.

Østfold. Østfold has soft bottom areas (19.9km^2), littoral basin, shoals, shell sand deposits, kelp forest areas (7.79km^2), eelgrass beds (3.66km^2), and other important marine habitat.

3.3 Species Occurrences

This analysis used the 136,942 species occurrences recorded within 12nm of the Norwegian coast (Figures 3.3.1 - 3.3.7). These occurrences are found within 3737 unique identifiers (mostly species names but some records do not include species and instead go as detailed as class, for example) (full list of species included in the repository linked in the Appendix). A summary of occurrences and territorial water area per county is found in Table 3.3.1. In order to compare the occurrence records and available across counties, the species occurrence records were normalized as density by county (Figure 3.3.8).

Agder. Agder had 33761 species occurrence records across 1293 unique species. ~208 of 270 cells in the 5km^2 grid had occurrence data.

Akershus. Akershus had 1314 species occurrence records across 72 unique species identifiers. ~47 of 80 cells in the 2km^2 grid had occurrence data.

Buskerud. Buskerud had 1 species occurrence record across 1 unique species. 1 of 11 cells in the 2km^2 grid had occurrence data.

Finnmark. Finnmark had 13247 species occurrence records across 1398 unique species identifiers. ~981 of 1062 cells in the 5km^2 grid had occurrence data.

Møre og Romsdal. Møre og Romsdal had 9839 species occurrence records across 850 unique species identifiers. ~383 of 479 cells in the 5km^2 grid had occurrence data.

Nordland. Nordland had 9695 species occurrence records across 927 unique species identifiers. ~1240 of 1750 cells in the 5km^2 grid had occurrence data.

Oslo. Oslo had 96 species occurrence records across 11 unique species identifiers. ~3.5

Table 3.3.1: OBIS species occurrences and territorial sea area in square kilometers per county.

County Name	Total Occurrences	County Area (sq.km)
Agder	33761	6749.62
Akershus	1314	314.67
Buskerud	1	43.12
Finnmark	13247	26430.87
Møre og Romsdal	9839	11950.07
Nordland	9695	44251.01
Oslo	96	24.81
Rogaland	11707	7537.35
Telemark	472	937.67
Troms	12192	16360.65
Trøndelag	18979	18662.50
Vestfold	5813	1922.30
Vestland	18290	17348.37
Østfold	1536	930.30

of 6 cells in the $2km^2$ grid had occurrence data.

Rogaland. Rogaland had 11707 species occurrence records across 635 unique species identifiers. ~226 of 300 cells in the $5km^2$ grid had occurrence data.

Telemark. Telemark had 472 species occurrence records across 120 unique species identifiers. ~48 of 238 cells in the $2km^2$ grid had occurrence data.

Troms. Troms had 12192 species occurrence records across 1292 unique species identifiers. ~524 of 652 cells in the $5km^2$ grid had occurrence data.

Trøndelag. Trøndelag had 18979 species occurrence records across 867 unique species identifiers. ~279 of 751 cells in the $5km^2$ grid had occurrence data.

Vestfold. Vestfold had 5813 species occurrence records across 289 unique identifiers. ~51 of 75 cells in the $5km^2$ grid had occurrence data.

Vestland. Vestland had 18290 species occurrence records across 698 unique species identifiers. ~572 of 698 cells in the $5km^2$ grid had occurrence data.

Østfold. Østfold had 1536 species occurrence records across 188 unique species identifiers. ~78.5 of 236 cells in the $2km^2$ grid had occurrence data.

For records in the dataset with the year included the occurrence record, the distribution of records by time interval are shown in Figure 3.3.9. Most data was recorded between the years 2000 and 2020. Depth added to the occurrence data ranged from 0 to ∼6000 meters, with most species being recorded within 1000m of the surface. This is likely due to it being easier to record and collect data on organisms found closer to the surface. The phyla Nematoda, Rhodophyta, Rotifera, and Tracheophyta did not have depth recorded with their species occurrence data. The distribution of depth data recorded, by phylum, is displayed in Figure 3.3.10. The basis for records for the occurrence data includes human observation being 46.7% of the data collection type, machine observation being 0.02%, living specimen being 0.001%, preserved specimens being 16.6%, material sample being 0.004%, and 'occurrence' (which is an undefined category) being 36.7%.

3.3.1 Interesting species, and species indicative of habitat

Running the list of species occurring in this dataset against the 2021 Norwegian Red List returns several vulnerable or endangered species that should be considered when MPA planning (Table 3.3.2).

Additionally, macroalgae, like *Laminaria* kelp are known to be key habitat for high levels of biodiversity (Christie *et al.* 2003). The Norwegian coast has large areas of kelp forest along the coasts of Rogaland, Vestland, and Møre og Romsdal.

MAREANO has defined eight biotypes in Norway that are especially vulnerable: soft-bottom sponge communities, hard-bottom sponge communitites, deep arctic sponge aggregations, sublittoral seapen communities, bathyal seapen communities, soft-bottom coral gardens, hard-bottom coral gardens, and cold-water coral reefs. Cross-referencing the list of species they define as ecologically significant and vulnerable (Vulnerable Biotypes) against the list of species in the OBIS occurrence data, the following is found:

Soft-bottom sponge communities. Species indicative of this habitat are *Geodia* (found in Vestland, Rogaland, Østfold, Agder, Troms, Trøndelag, Møre og Romsdal), *Aplysilla sulfurea* (found in Rogaland, Agder, and Finnmark, and *Stryphnus ponderosus* (found in Troms).

Hard-bottom sponge communities. Species indicative of this habitat are *Axinella* (found in Vestland, Telemark, Rogaland, Agder, Trøndelag, Møre og Romsdal, Finnmark), *Phakellia* (found in Vestland, Rogaland, Akershys, Agder, Troms,Østfold, Nordland, Finnmark, Trøndelag, Møre og Romsdal), and *Antho dichotoma* (found in Nordland, Finnmark).

Deep arctic sponge communitites. A class indicative of this habitat is class Hexactinellida, which is found in Trøndelag as preserved specimen.

Sublittoral seapen communities. Species indicative of this habitat are *Funiculina quadrangularis* (found in Vestland, Rogaland, Agder, Trøndelag), *Virgularia mirabilis* (found in Vestland, Rogaland, Agder, Østfold, Nordland), *Pennatula phosforea* (found in Agder), and *Kophobelemnon stelliferum* (found in Møre og Romsdal, Rogaland, Agder, Troms, Nordland, Trøndelag). *Nephrops norvegicus* (found in Telemark, Møre og Romsdal, Vestfold, Agder, Trøndelag), *Parastichopus tremulus* (found in Møre og Romsdal, Vestland, Rogaland, Finnmark, Troms, Trøndelag, Nordland) are megafauna associated with this habitat type.

Bathyal seapen communities. A genus associated with this habitat is *Neohela*, found in Vestland, Finnmark, Troms, Nordland, and Trøndelag.

Soft-bottom coral gardens. *Isidella lofotensis*, found in Troms, is commonly associated with this habitat.

Hard-bottom coral gardens. Species indicative of this habitat are *Paragorgia arborea* (found in Nordland), *Primnoa resedaeformis* (found in Trøndelag and Agder), and *Swiftia* spp. (found in Agder).

Cold-water coral reefs. Species indicative of this habitat are *Lophelia pertusa* (found in Møre og Romsdal, Vestland, Vestfold, Rogaland, Østfold, Finnmark, Troms, Trøndelag, Nordland) and *Madrepora oculata* (found in Vestland, Troms, Trøndelag).

The Norwegian coast is home to many species of cetaceans. Interesting species include *Balaenoptera acutorostrata*, the minke whale (found in Møre og Romsdal, Buskerud, Vestland, Rogaland, Finnmark, Troms, Trøndelag, Nordland); *Balaena mysticetus*, the bowhead whale (found in Finnmark); *Balaenoptera borealis*, the sei whale (found in Møre og Romsdal, Vestland, Finnmark, Troms, Trøndelag, Nordland); *Balaenoptera musculus*, the blue whale (observed in Møre og Romsdal, Vestland, Finnmark); *Balaenoptera physalus*, the fin whale (observed in Møre og Romsdal, Telemark, Vestland, Agder, Finnmark, Troms, Trøndelag, Nordland); *Eubalaena glacialis*, the North Atlantic right whale (recorded observation in Finnmark in 1999); *Globicephala melas*, the pilot whale (observed in Møre og Romsdal, Vestland, Rogaland, Agder, Akershus, Finnmark, Troms, Trøndelag, Nordland); *Physeter catodon/Physeter macrocephalus*, the sperm whale (found in Nordland, Troms, Finnmark, Møre og Romsdal, Vestland, Trøndelag); *Orcinus orca*, the orca (observed in Møre og Romsdal, Telemark, Vestland, Rogaland, Agder, Oslo, Østfold, Akershus, Finnmark); and *Megaptera novaeanglie*, the humpback whale (recorded seen in Møre og Romsdal, Vestland, Rogaland, Østfold, Akershus, Finnmark, Troms, Nordland).

Table 3.3.2: IUCN Redlist species found in this dataset. EN = endangered; VU = vulnerable; RE = regionally extinct; NT = near threatened.

Name	**Redlist Category**	**Found**
Anguilla anguilla	EN	Rogaland, Vestland
Balaena mysticetus	EN	Finnmark
Balaenoptera musculus	VU	Møre og Romsdal, Vestland, Finnmark
Eubalaena glacialis	RE	Finnmark
Halichoerus grypus	VU	Finnmark, Nordland, Rogaland, Troms, Trøndelag, Vestland, Østfold
Homarus gammarus	VU	Akershus, Møre og Romsdal, Nordland, Rogaland
Salmo salar	NT	Vestland
Sebastes norvegicus	EN	Finnmark, Møre og Romsdal, Nordland, Telemark, Troms, Trøndelag, Vestland
Swiftia pallida	VU	Agder

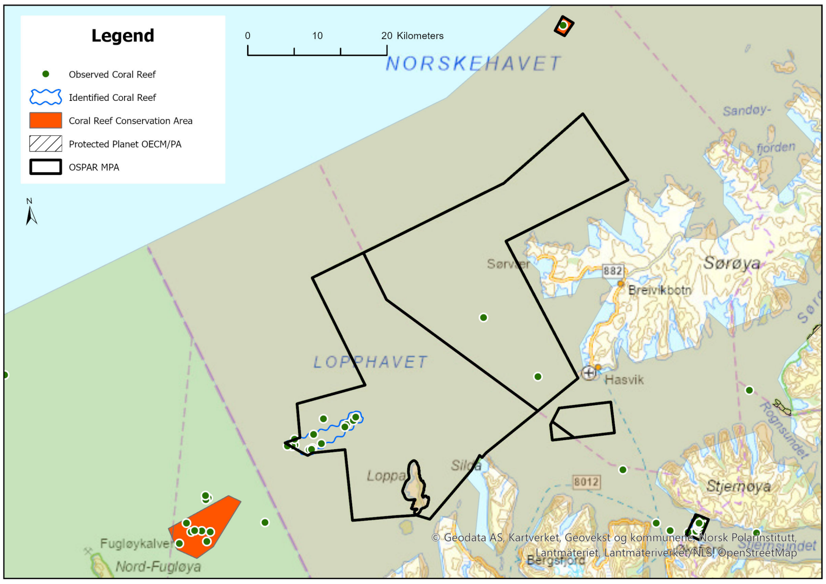


Figure 3.1.3: Coral reef conservation area in Troms (green area) outside of a recognized MPA, and coral reef within OSPAR designated MPAs in Finnmark (light beige area).

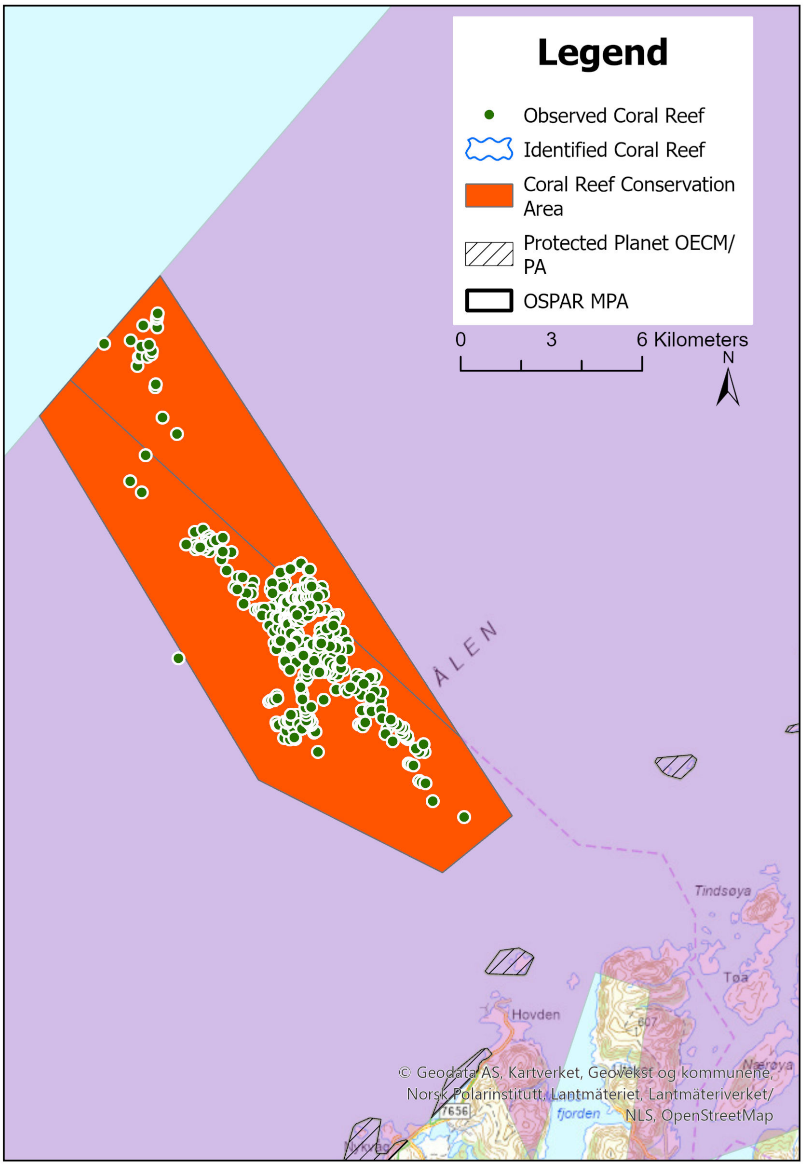


Figure 3.1.4: High density of coral reef without real protections (i.e. not within an MPA) in Vesterålen, Nordland.

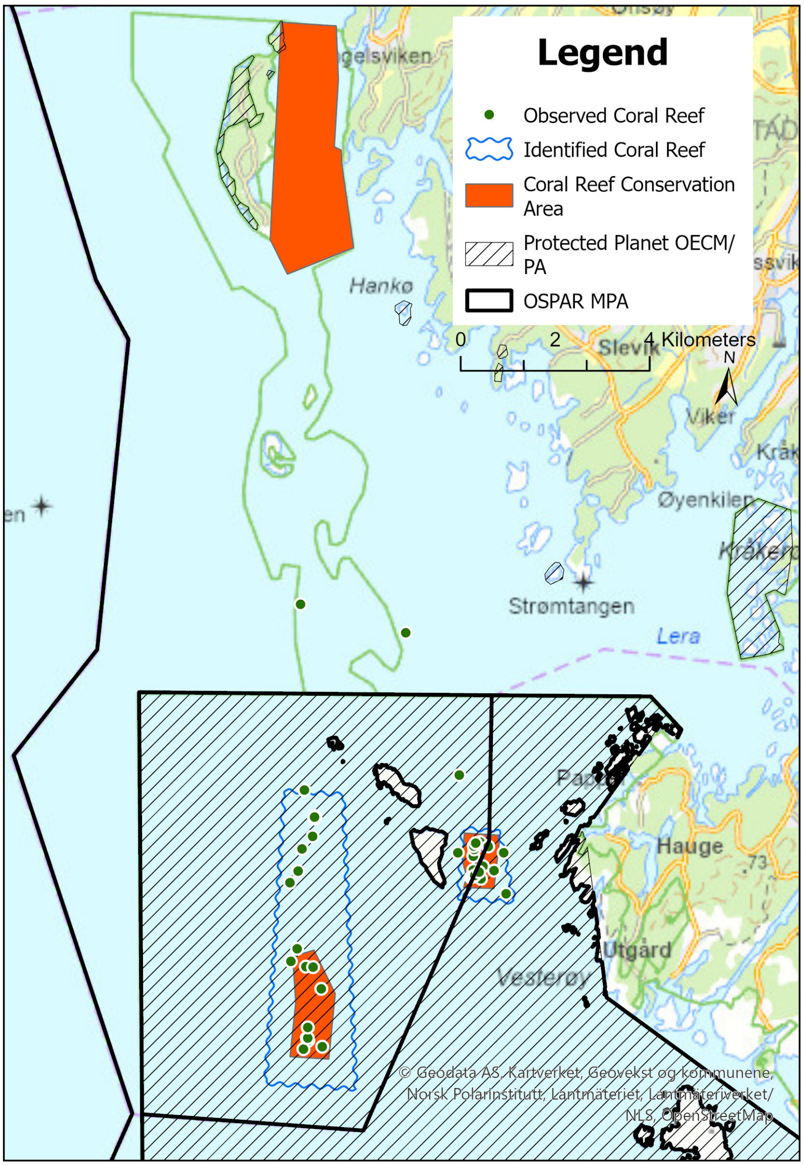


Figure 3.1.5: Observed and identified coral reefs overlapping Protected Planet designated Protected Areas and OSPAR designated MPAs in Østfold.

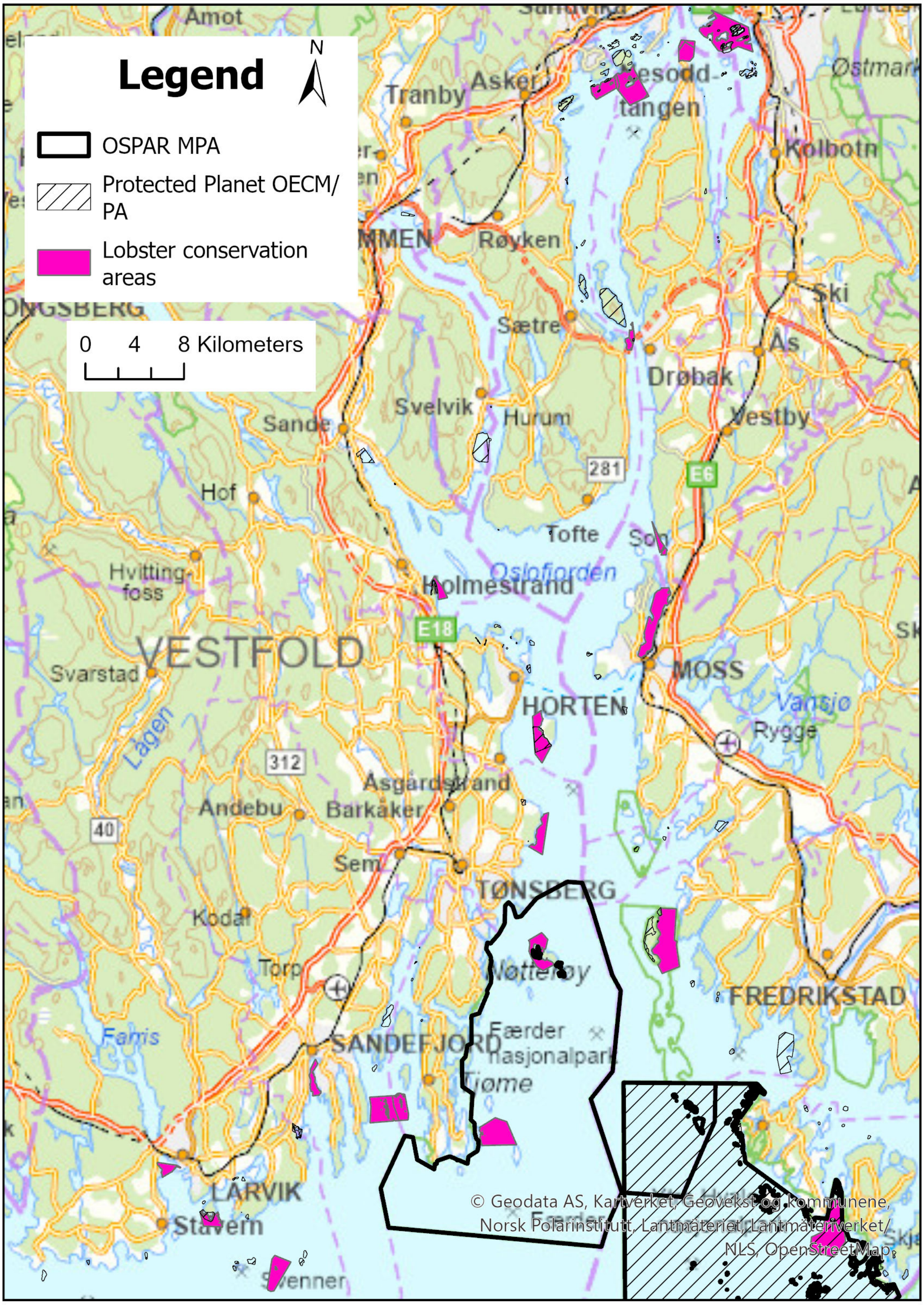
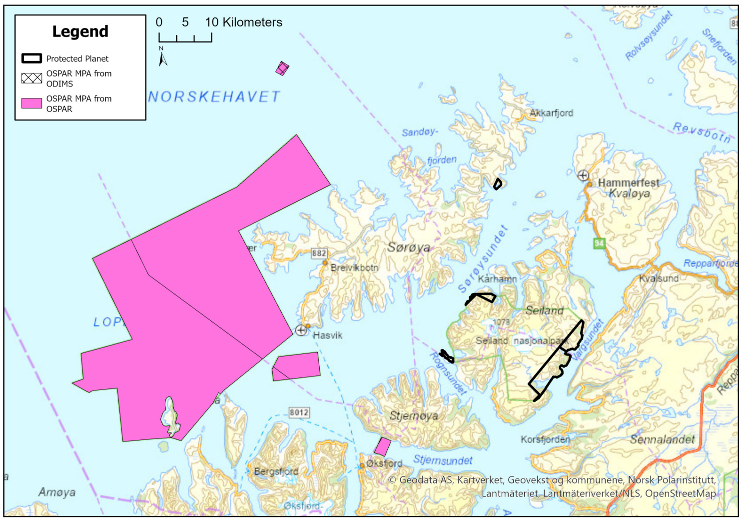


Figure 3.1.6: Lobster conservation areas around Vestfold, Østfold, and Akershus. This is the most dense congregation of lobster conservation areas in Norway.



(a)

(b)

Figure 3.1.7: MPA discrepancies: Finnmark. The black outline represents Protected Planet Protected Areas, the crosshatch represents 2021 ODIMS MPAS, and the pink represents OSPAR MPAs from the OSPAR Commission Interactive Map Tool.

Figure 3.1.8: MPA discrepancies: Troms. The black outline represents Protected Planet Protected Areas, the crosshatch represents 2021 ODIMS MPAS, and the pink represents OSPAR MPAs from the OSPAR Commission Interactive Map Tool.

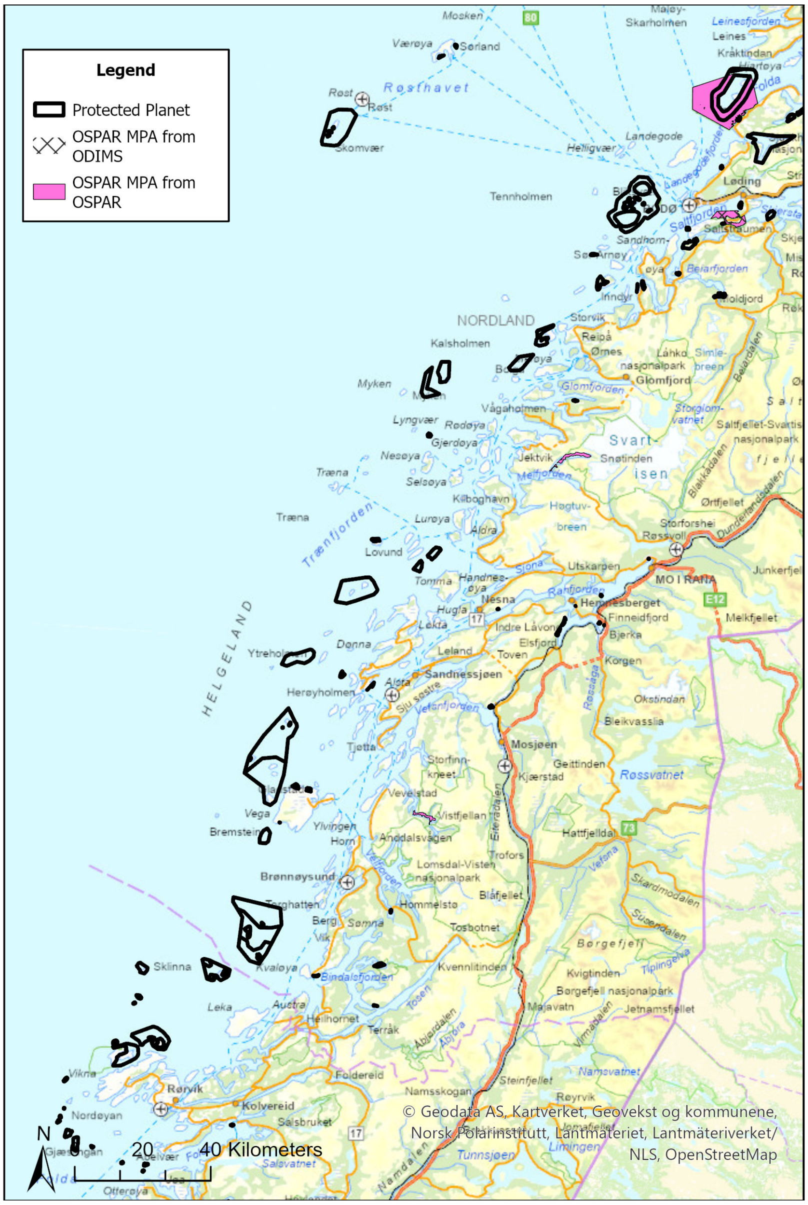


Figure 3.1.9: MPA discrepancies: Nordland. The black outline represents Protected Planet Protected Areas, the crosshatch represents 2021 ODIMS MPAS, and the pink represents OSPAR MPAs from the OSPAR Commission Interactive Map Tool.

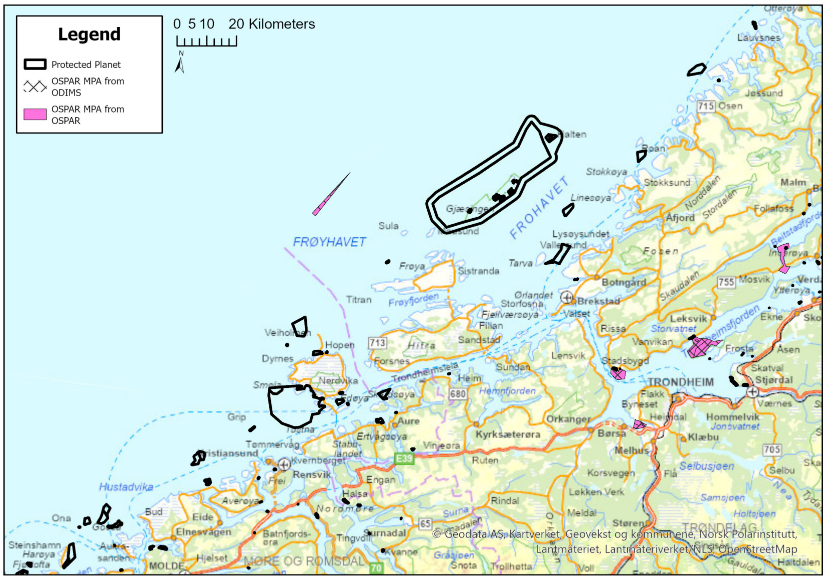


Figure 3.1.10: MPA discrepancies: Møre og Romsdal and Trøndelag. The black outline represents Protected Planet Protected Areas, the crosshatch represents 2021 ODIMS MPAS, and the pink represents OSPAR MPAs from the OSPAR Commission Interactive Map Tool.

Figure 3.1.11: MPA discrepancies: Vestland. The black outline represents Protected Planet Protected Areas, the crosshatch represents 2021 ODIMS MPAS, and the pink represents OSPAR MPAs from the OSPAR Commission Interactive Map Tool.

Figure 3.1.12: MPA discrepancies: Agder and Rogaland. The black outline represents Protected Planet Protected Areas, the crosshatch represents 2021 ODIMS MPAS, and the pink represents OSPAR MPAs from the OSPAR Commission Interactive Map Tool.

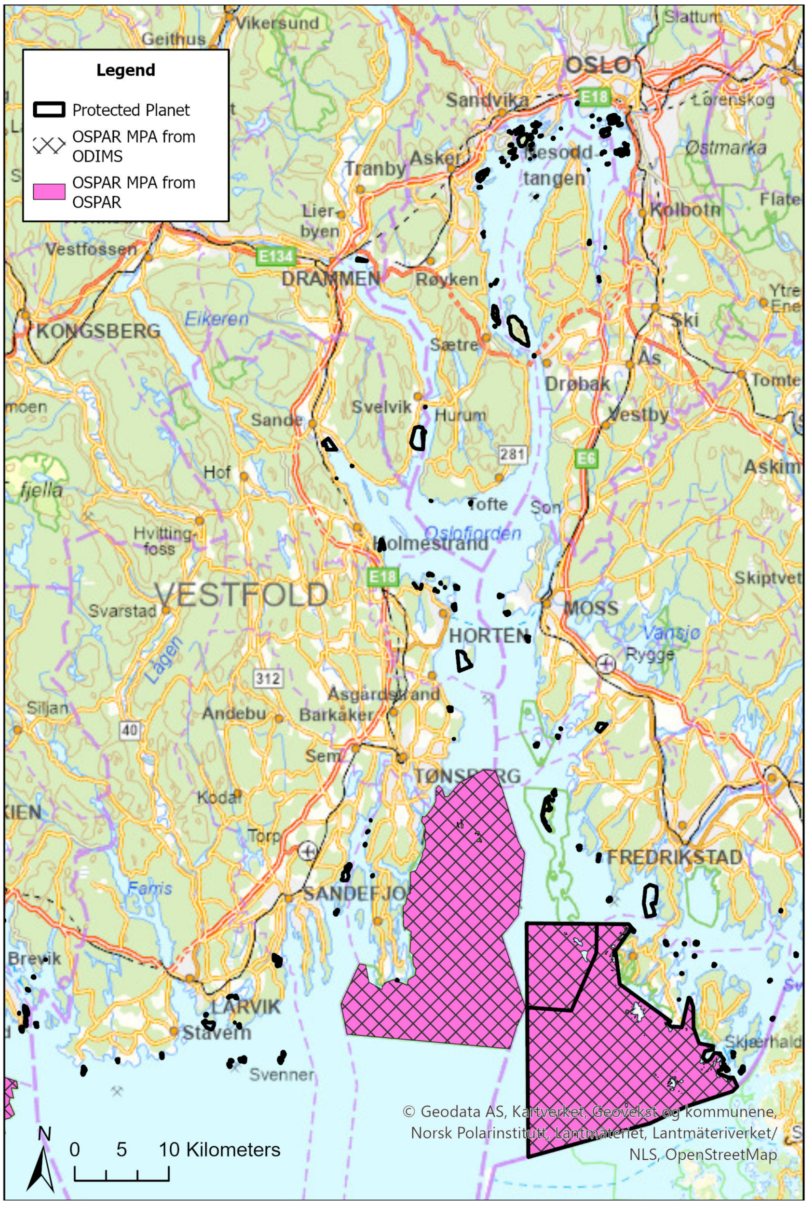


Figure 3.1.13: MPA discrepancies: Oslo, Akershus, Vestfold, and Østfold. The black outline represents Protected Planet Protected Areas, the crosshatch represents 2021 ODIMS MPAS, and the pink represents OSPAR MPAs from the OSPAR Commission Interactive Map Tool.

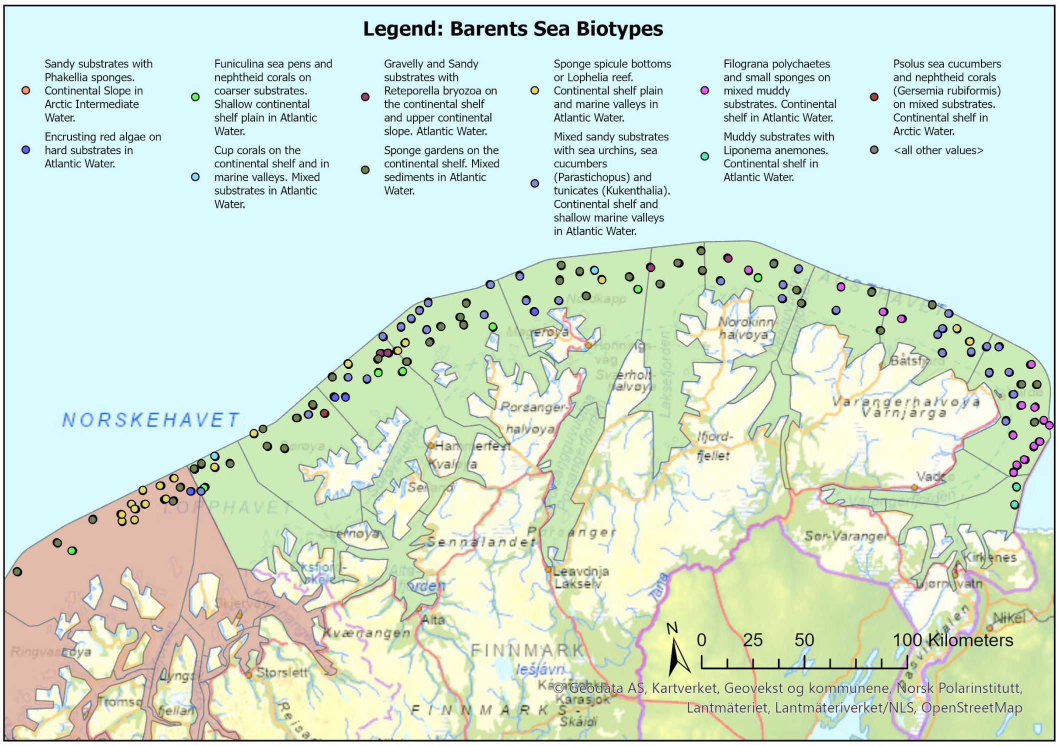


Figure 3.2.1: Barents Sea biotypes, in Troms (red coastal area) and Finnmark (green coastal area). Adapted from MAREANO.

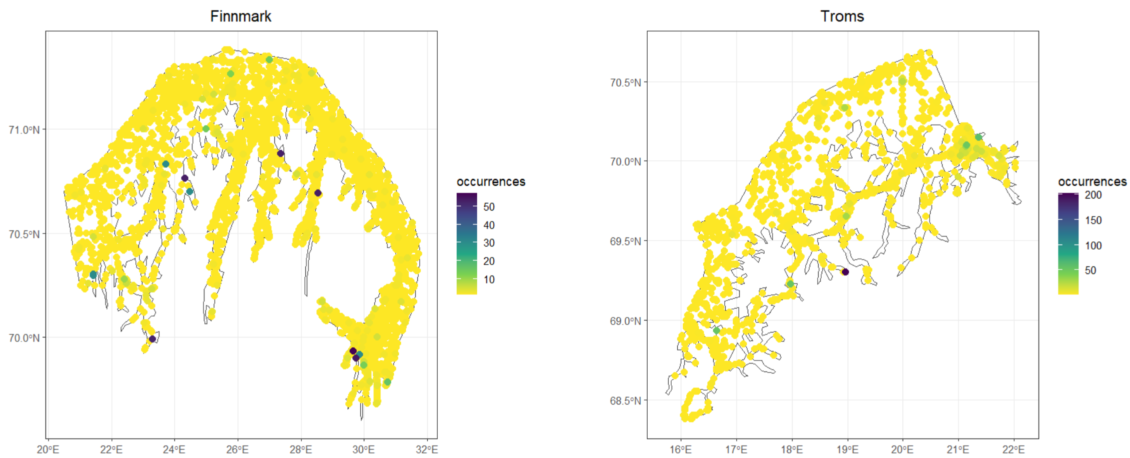


Figure 3.3.1: Species occurrence records: Finnmark and Troms. The color scale shows low (yellow) to high (purple) species occurrence records with point geometry.

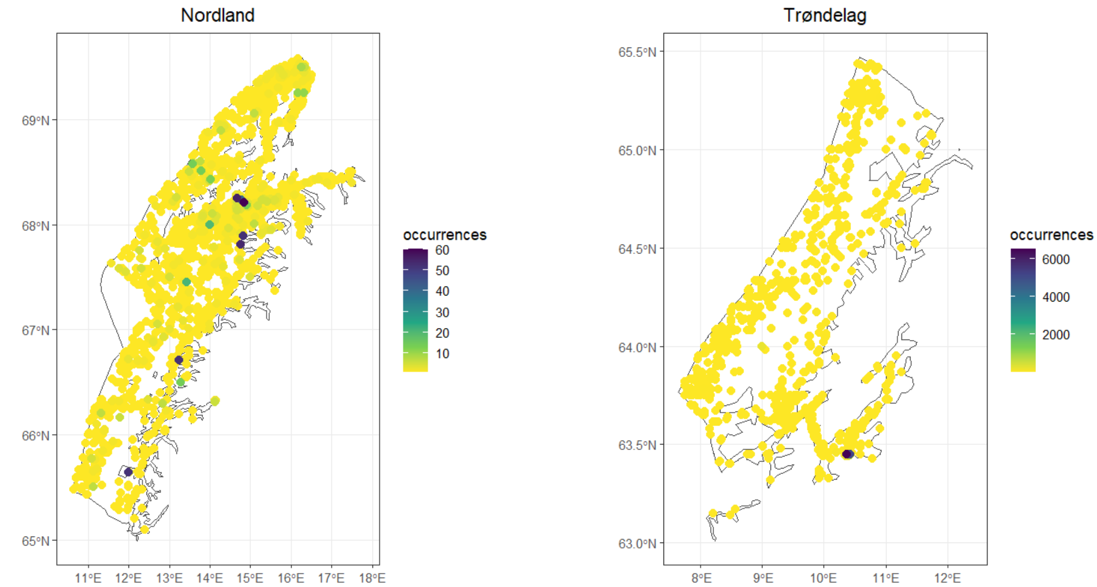


Figure 3.3.2: Species occurrences records: Nordland and Trøndelag. The color scale shows low (yellow) to high (purple) species occurrence records with point geometry.

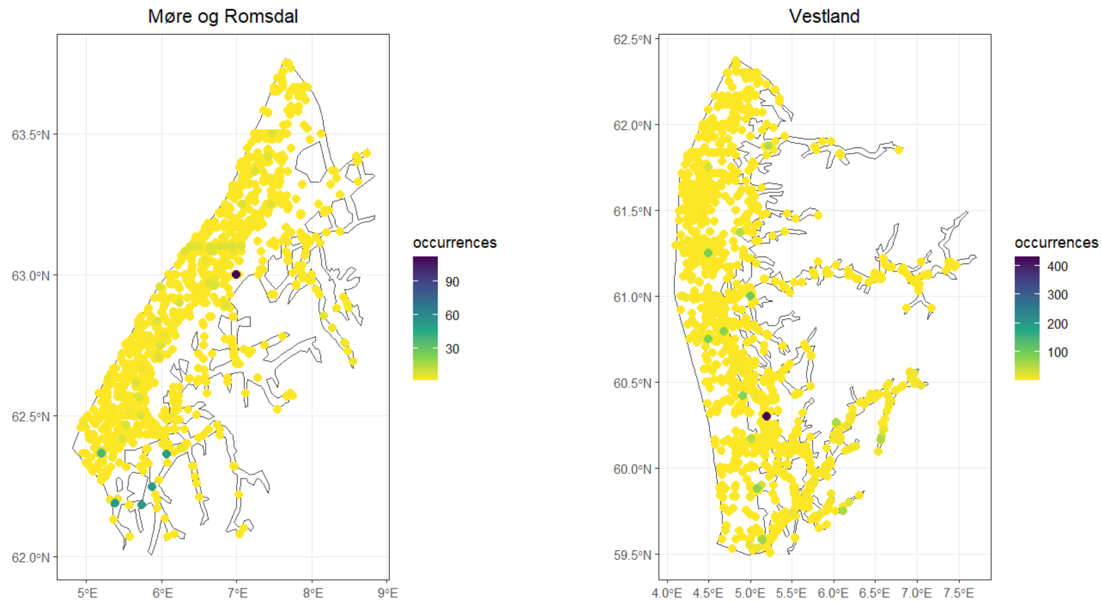


Figure 3.3.3: Species occurrences records: Møre og Romsdal and Vestland. The color scale shows low (yellow) to high (purple) species occurrence records with point geometry.

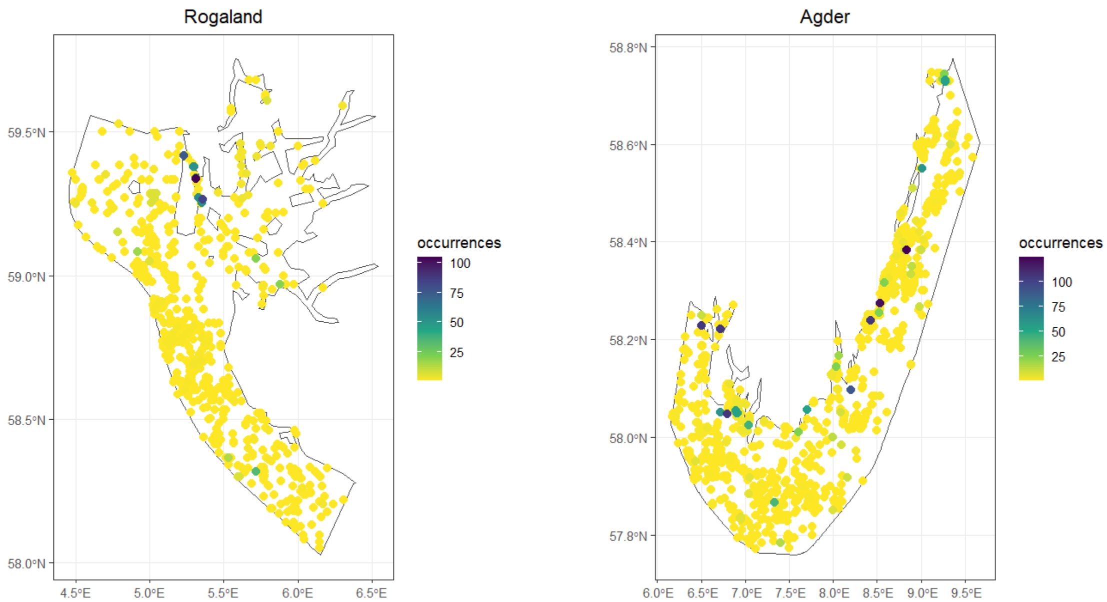


Figure 3.3.4: Species occurrences records: Rogaland and Agder. The color scale shows low (yellow) to high (purple) species occurrence records with point geometry.

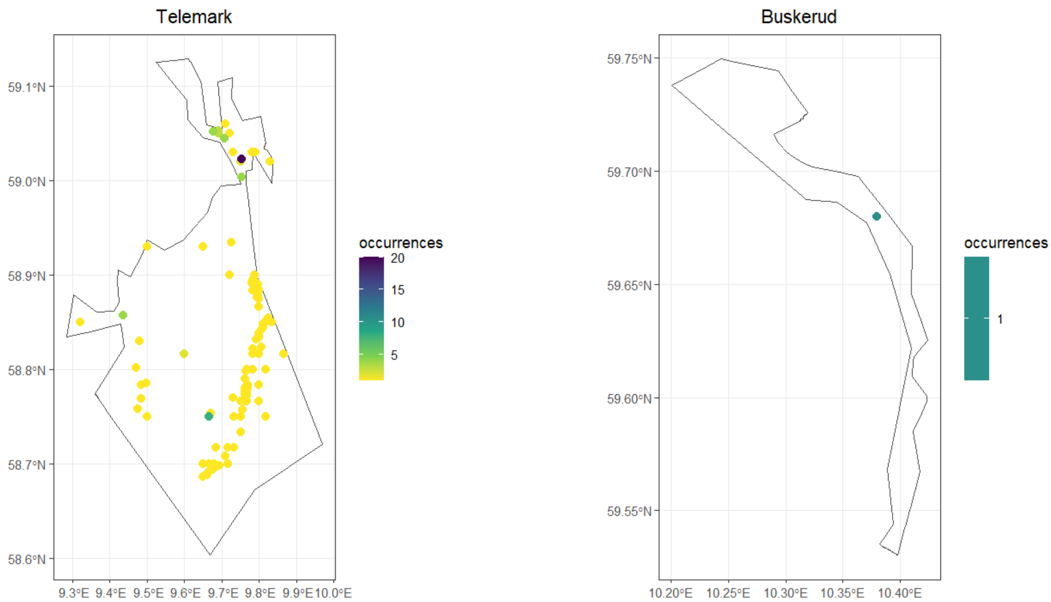


Figure 3.3.5: Species occurrences records: Telemark and Buskerud. The color scale shows low (yellow) to high (purple) species occurrence records with point geometry.

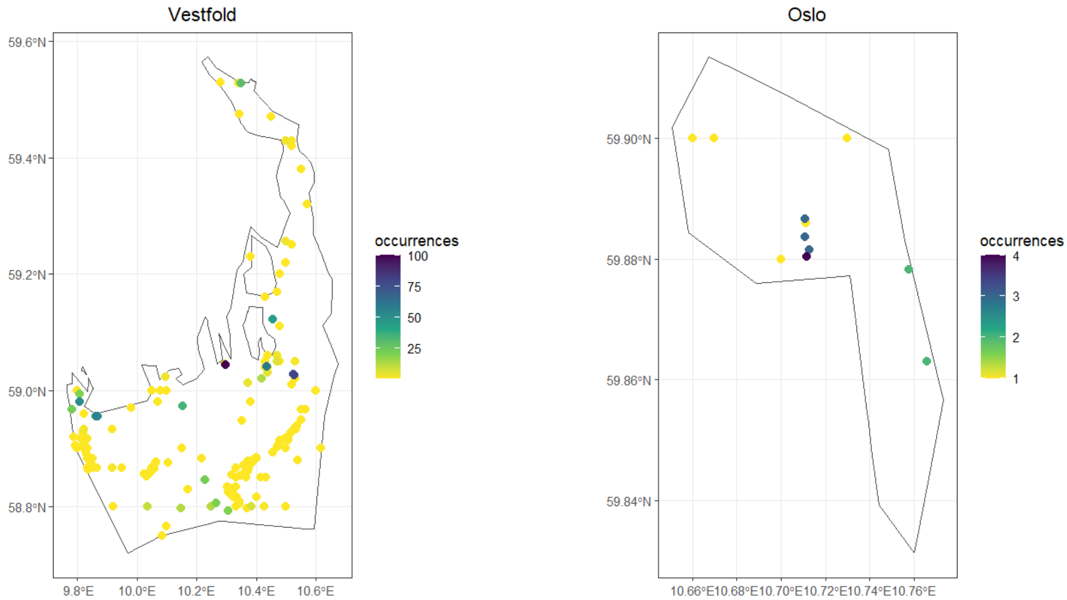


Figure 3.3.6: Species occurrences records: Vestfold and Oslo. The color scale shows low (yellow) to high (purple) species occurrence records with point geometry.

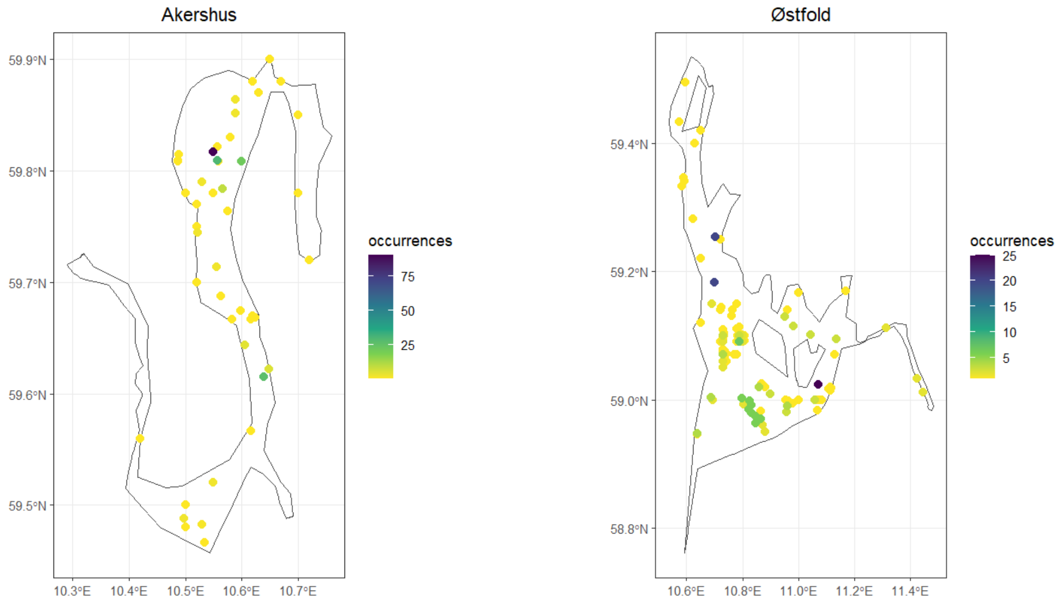


Figure 3.3.7: Species occurrences records: Akershus and Østfold. The color scale shows low (yellow) to high (purple) species occurrence records with point geometry.

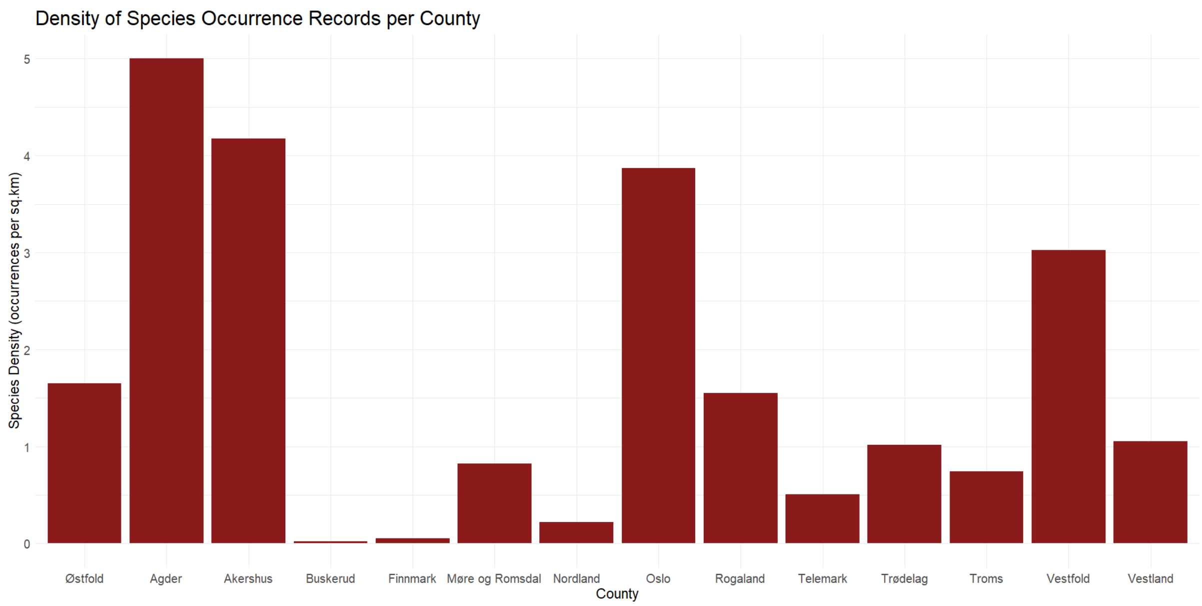


Figure 3.3.8: Normalized species occurrence records by county to show relative amount of occurrences.

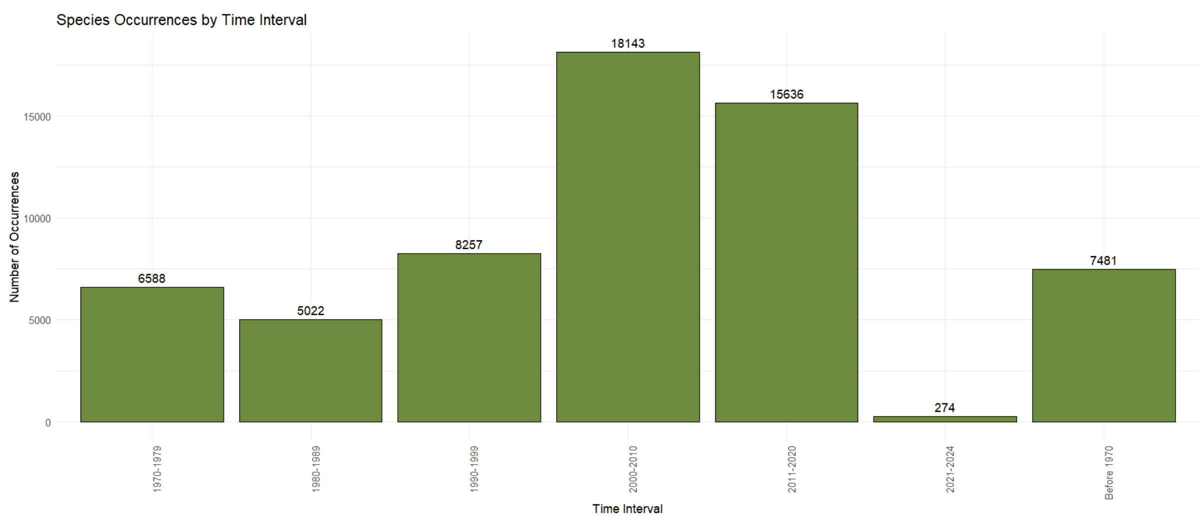


Figure 3.3.9: Distribution of time records in OBIS with count of occurrence records.

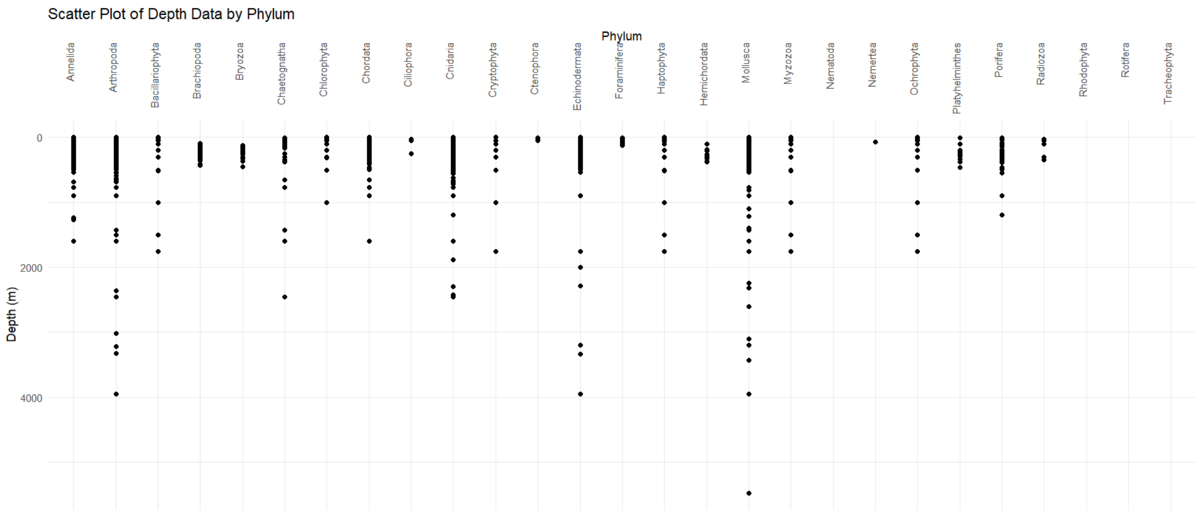


Figure 3.3.10: Scatter plot showing distribution of depth at which the OBIS records were collected. Due to the large amount of data, this was run at the phylum level. Depth data was not recorded for Nematoda, Rhodophyta, Rotifera, and Tracheophyta.

CHAPTER

FOUR

DISCUSSION

4.1 The current data situation

Because the creation of MPAs is multidisciplinary and needs data to be effective, accessible and up-to-date data is required. Data-sharing in Norway is acceptable, but incomplete. Using some time, habitat, administrative, and occurrence data can be found from HI/MAREANO, Miljødirektoratet, Fiskeridirektoratet, Geonorge/Kartverket, Artsdatabanken, and OBIS. Problems occur with data reporting. One glaring example is coral reef conservation area in Østfold that does not have any observed coral reef data within it (Figure 3.1.4). Both GIS data layers came from the MAREANO database. This discrepancy could be due to data not existing or being reported, but inconsistencies like this make planning effective MPA networks with sound bases more difficult.

4.1.1 The current scope of conservation areas and habitat data

For the nature conservation areas designated with IUCN categories, 542 are defined as Category Ia (which should have the strictest protections), 169 as Category IV, 33 as Category V, 10 as Category III, 7 as Category II, and 76 as not rated. Since there is no correlation between the reported IUCN category and the expectations for regulation within the category from IUCN [**20**], there are likely discrepancies between what a category actually allows and how the area is being used in practice. Fisheries are considered to be the most important influencing factor on marine life in Norway. Because Norway has large aquaculture and commercial fishing industries [**15**], marine protected areas in Norway are weak against fisheries (IPBES 2019). An example is that dredging continues in OSPAR MPA areas around Agder, Vestfold, and Østfold (Figure 3.1.2). This means that if fishing continues to occur in these protected areas and nature conservation areas, the maximum category that could be achieved by the current regulations/management would be Category IV [**20**]. If bottom trawling is to be used for commercial fishing, then there is reason for why the marine national parks in Norway continue to not meet the criteria to register those sea areas to the CBD [**20**].

Lobster conservation areas have the strictest protections in Norway, having complete protection and gear use restrictions [**20**]. The GIS data from Fiskeridirektoratet includes the restrictions on fishing. They list the following 5 different restriction notes for the lobster conservation areas:

1. It is forbidden to fish with tools other than hand-lines, fishing rods, lures, fishing nets or purse seines in the area.

2. It is forbidden to fish with tools other than hand-lines, fishing rods, lures, seines or purse seines in the area. Anglers [registered on a certain list (referred to as Sheet B in the data] can fish with wrasse rods during the wrasse season.

3. It is prohibited to fish with other tools than hand-lines, fishing rods, lures, seines or purse seines along the entire sea line down to a depth of 50 meters counted from the lowest water level.

4. It is forbidden to fish with lobster cages along the entire sea line down to a depth of 50 meters counted from the lowest water level. All lobster caught in the conservation area must immediately be returned to the sea at the catch site.

5. It is forbidden to fish with lines and rods along the entire sea line down to a depth of 50 meters counted from the lowest water level.

Considering these restrictions note that purse seines are allowed and that dredge activity in southern Norway overlap the same MPAs, Færder and Ytre Hvaler (Figure 3.1.2), that lobster conservation areas are within (Figure 3.1.6), it does not give much confidence to the extent to which OSAPR MPAs are being managed in Norway.

Since representativity, replication, and comprehensiveness principles are key to building an ecologically coherent MPA network [**41**], thorough and well-documented habitat descriptions and seafloor mapping should be executed. With this in mind, there is very little thorough habitat type data within the territorial waters of coastal Norway, and while habitat data is available, it is more sparse and less comprehensive than expected, with imprecise biotype data and data concentrated in mid-northern coastal Norway, with little data in southern-mid coastal Norway. In general, data seems to be lacking in the Skagerrak area, which is unfavorable as the Integrated Management of the Marine Environment of the North Sea and Skagerrak (Management Plan) white paper states that the "North Sea-Skagerrak area is Norway's most intensively used sea area and one of the most heavily trafficked in the world" (Meld. St. 37 (2012–2013) [**28**]. The MAREANO program is in place to collect ecological data from the seabed to then describe and map habitat distribution in benthic areas [**12**]. MAREANO/HI combat lack of GIS data by performing seafloor mapping and other research, but there is a lot of room for the improvement of habitat datasets, especially since current habitat data more or less hugs the coast and the mouths of fjords.

One way in which this seems to be approached is through the creation of SVOs. These areas have been recognized through pre-defined EBSA criteria [**20**] as having significant importance to biodiversity and biological production [8]. SVOs cover extremely large areas of the Norwegian coast and do not have any formal correlation to the management of the area since designating an area as an SVO does not effect the regulation of the area [20]. Covering large swaths of map area with the designation that it needs to be better protected due to vulnerable species or habitat does nothing for biodiversity conservation outcomes unless action is actually taken. For example, defining coral conservation areas as Coral MPAs when they do not in fact fall within an explicitly existent MPA undermines the goals of MPA creation.

Another approach to data-gathering seems to be the creation of kelp reference areas. Reference areas are created for monitoring and research purposes to study how conservation measures effect populations [20]. Kelp reference areas are found along the coast in Møre og Romsdal, Nordland, Trøndelag, and Vestland counties. Because Norway seems to employ a ”bottom-up” approach to coastal conservation (i.e. both lobster reserves and ICZM [43] are set at the municipality level), this method to data-gathering can be well-suited to smaller-scale conservation efforts.

4.1.2 The current scope of species occurrence data

Species occurrence records were severely lacking in some counties, and habitat data was sparse in many counties, with Buskerud, Finnmark, and Nordland having the least amount of species occurrence data relative to the size of the coastal marine area (Figure 3.3.8). Species occurrence records span many decades (Figure 3.3.9), and as time goes on, data recorded in the past becomes less relevant for making management decisions for the present and the future. Thoroughly updating species distribution datasets at least every several years is key to maintaining a effective MPA management plan considering comprehensiveness and representativity principles.

Additionally, depth data on observations, whether human or machine, should be recorded and precise. When creating MPAs it is important to know as much as possible about the species inhabiting a proposed MPA. The depths at which they dwell is a good example of traits that define species behavior and life history characteristics. Considering 4 of 27 phyla existing in the OBIS dataset had no depth data at all (Figure 3.3.10), attention should be paid to all collection metrics when recording an observation of a species occurrence, being as exact as possible when identifying species. Many species occurrence records reviewed did not include a species name, but was defined by a higher taxonomic rank (e.g. many in class Gastropoda, Polychaeta, and Bivalvia did not go farther than class rank; many within genera Cerastoderma, Melanella, and Craniella did not go farther than genus). Knowing what lives within a marine area is important when management planning.

4.2 Review of the current Norwegian MPA Network and Network Design Framework

A network of MPAs describes several MPAs working in conjunction through connectivity to increase the efficacy of biodiversity conservation, including a range of protection levels from 'no-take' MPAs (prohibiting extraction of organisms) to 'partial protection' (sustainable use of resources and non-destructive activities) [**10**] to multi-use MPAs. The results from reviewing the available data show that there is a lot of room for improvement with regards to biodiversity conservation in coastal Norway. In order to create a comprehensive and ecologically coherent MPA network, thorough species distribution analyses and description of habitats should be executed.

The MPA network in coastal contiguous Norway is almost nonexistent. Based on the currently available data, a MPA network planned using this information would not be based upon thorough knowledge. In general, MPA coverage is low along the west coast (Figures 3.1.8 - 3.1.11), with unknown to low levels of protection in MPA covered area (Figure 1.2.5). There is connectivity of MPAs around Vestfold and Østfold (connectivity can be seen in Figure 3.1.13), but in other areas of Norway, MPAs have no connectivity. Of the approximately 153463km^2 of territorial coastal marine area in contiguous Norway, $\sim$3930km^2, or 0.025% are designated as OSPAR MPAs.

MPA networks that are cost-efficient are those that exercise priority and comprehensiveness, representative of the vulnerable species and habitats for the least possible cost [**41**]). A simple conceptual framework for creating a MPA network (Figure 4.2.1) first includes identifying vulnerable habitats and species. SVOs are were recognized for that very reason. MAREANO and HI are in place to expand the knowledge on Norway's waters. The monitoring of populations, habitat health, seafloor mapping and species distribution models lead to a more effective management planning process. Limitations, restrictions, and goals should be set within biodiversity conservation outcomes in mind. A proposed, planned, or in-place MPA should continue to be monitored and data gathering should be extensive in conjunction with adaptive management practices in order to create the most effective MPA as possible. Networks should be planned with representativity, connectivity, replication, comprehensiveness, size, shape, and spatial prioritization in mind.

MPA networks work well to connect breeding and foraging grounds, and to work as corridors for migratory routes of megafauna (e.g. for cetaceans) [**33**] and to cover the full range of habitats. Marine life generally tends to have wider ranges than terrestrial wildlife does [**4**], able to cover entire coasts (Figure 4.2.2), so connectivity of protected areas that cover the full range of habitat is beneficial to the conservation of the species. Marine reserves should be separated by 1 to 20km in order to accommodate adult, juvenile, and larval movement [**7**]. Obstacles with this are that a) is is difficult to manage the extent of negative human activity within all territorial coastal waters [**33**] of Norway, b) migratory routes often traverse commercial human activity [**33**] (i.e. commercial shipping, commercial fishing, wind, wave, and oil energy structures/activity, and c) migratory marine life do not keep within one country's borders [**33**] (hence regional and international MPA collaboration such as the OSPAR network). One way to combat this is to keep the distances between marine reserves on the higher end of the range (i.e. around 20km), both to minimize risk spreading, and to capture spatial variation within habitats [**7**]. MPAs in coastal Norway are more often farther than 20km from the next nearest MPA, with closest disconnected MPAs being up to $\sim$190km apart (Table 3.1.2).

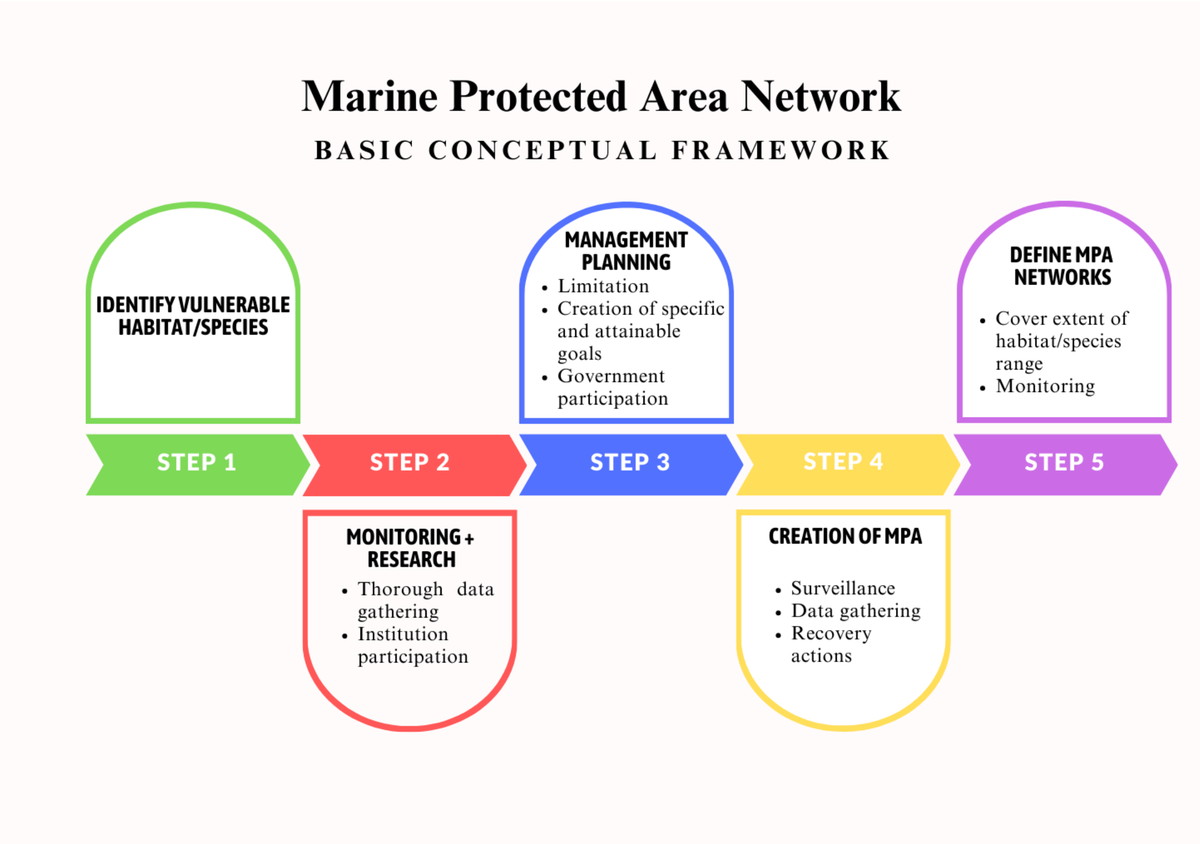


Figure 4.2.1: Simple conceptual framework. Step 5 can circle back to Step 1 to improve MPA networks.

4.2.1 Recommendations for future work

A fully comprehensive network of priority areas is not achievable as it would be impossible to obtain spatial data on all aspects of biodiversity [**41**]. Because comprehensive data would be expensive and time-consuming, utilizing surrogates and prioritization would help to balance the protection:cost ratio [**10**]. Representing certain well-known biodiversity features (i.e. genetic diversity, habitat diversity, community composition, functional roles) could help fill in some of the gaps in data.

OSPAR MPAs and nationals that already exist are not being managed with strict regulation (i.e. dredge activity overlapping lobster conservation areas, OSPAR MPAs, and national parks in southern Norway (Figure 3.1.2)). Strengthening restrictions in these areas may be more cost-effective than starting by building an entirely new MPA. Already defined nature conservation areas and coral reef conservation areas could be a wise next step to be considered for OECM and MPA regulations, as some habitat mapping has already been done. The highly dense area of coral reef observed by HI (Figure 3.1.4) is recommended as a new area to be managed to fit OSPAR MPA criteria. Since the area has been combed for data and geographically defined as a conservation area, the subsequent action would be to limit human and commercial activity in this area. Areas marked as SVO should be re-evaluated for and examined for priority based on MAREANO data (i.e. the eight vulnerable biotypes already determined by MAREANO) and with Redlist species (Table 3.3.2) in mind.

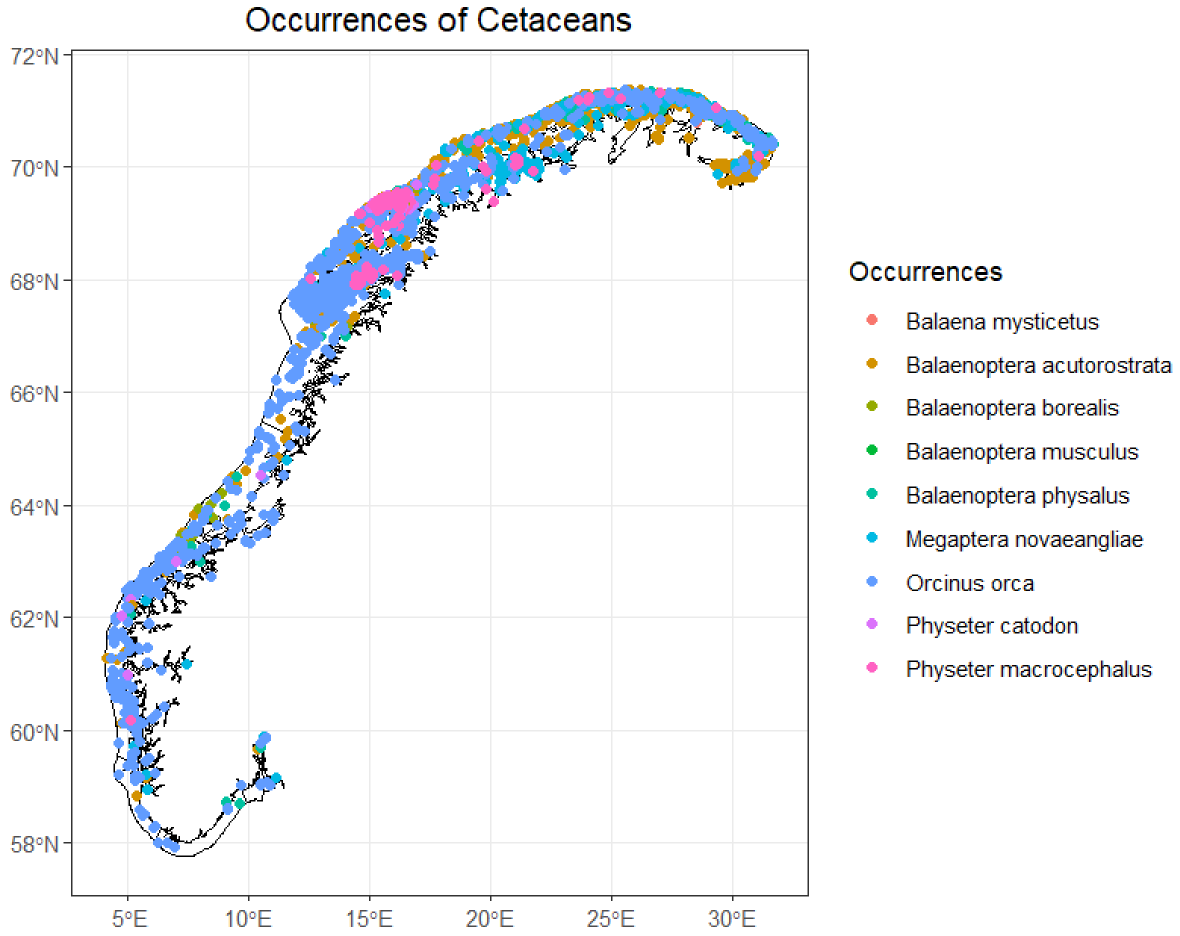


Figure 4.2.2: Occurrences of several cetacean species showing range of migration patterns along the coast of Norway.

More thorough habitat type data should be collected. MPA networks design is framed on the basis that there is enough good and recent data that decisions are made purposefully and with regards to conserving biodiversity. Using replication, representativity, comprehesivenesss and complementartity as principles for an ecologically-coherent MPA network means that data following these principles should exist. This has not been seen in the view of the current MPA network design action Norway has employed in its territorial marine areas, thus far. A solution for the lack of data is not to create large "paper parks". MPAs are meant to be areas of protection that have decreased anthropogenic activity and commercial use. The way to use MPAs as efficient tools to combat habitat degradation and species loss is to be specific with the goals for protection in a geographically defined area.

As mentioned previously, Norway has large commercial energy, fishing, and shipping industries. Creating MPA networks can be challenging when strict regulation traverses stakeholder interests (Figure 1.3.3). Creating multi-use MPAs are recommended as a potential solution. Multiple use MPAs are large and have zones of weaker and stronger regulations [**7**], making them useful in the face of human recreation and economic influences.

CHAPTER
FIVE

CONCLUSIONS

This thesis explores the current MPA situation within 12 nautical miles of the Norwegian coast. The objective was to analyze gaps in available data and detail what types of data is needed to create an ecologically-coherent MPA network that effectively supports biodiversity conservation goals.
Many discrepancies are found in conservation area data. Reporting of data was not always consistent (e.g. Figures 3.1.5 and 3.1.7 - 3.1.13) and should be rectified during future research.

It was found that the species occurrence records and distribution of habitat types were missing comprehensive data. Of the analyzed spatial areas, habitat data is severely lacking in some areas. After normalizing species occurrence data, it was found that species occurrence data was deficient in several counties, namely in Buskerud, Finnmark, and Nordland.

Data is always being updated. In this gap analysis, only open source and publicly available data was accessed. There are museum collections, universities, and research institutes with their own collections of data that may not report to OBIS, Miljødirektoratet, or Fiskeridirektoratet. Additionally, in systematics, species get split up, redefined, renamed, and given synonyms, so some degree of uncertainty exists when reviewing large species occurrence datasets like the one in this analysis. Scientific papers with new information that are not yet published may also lead to deeper understanding of the species occurring in the coastal waters of Norway.

When occurrence records do not provide a species information and only give higher rank classification it is possible that the organism has not yet been identified, or it was unable to be identified as a certain species due to condition or other factors. Defining species based only on morphology (as could be the case with human observation records) accuracy can be uncertain.

Effective MPA network design is only achievable if management decisions are made based on well-informed decisions.

REFERENCES

[1] Astudillo-Scalia, Y., & Albuquerque, F. (2020). Why should we reconsider using species richness in spatial conservation prioritization?. *Biodiversity and Conservation*, *29*, 2055-2067. https://doi.org/10.1007/s10531-020-01960-4 .

[2] Balbar, A.C. and Metaxas, A. (2019). The current application of ecological connectivity in the design of marine protected areas. *Global Ecology and Conservation*, 17, p.e00569. https://doi.org/10.1016/j.gecco.2019.e00569.

[3] Belote, R. T., Barnett, K., Dietz, M. S., Burkle, L., Jenkins, C. N., Dreiss, L., ... & Aplet, G. H. (2021). Options for prioritizing sites for biodiversity conservation with implications for "30 by 30". *Biological Conservation*, *264*, 109378. https://-doi.org/10.1016/j.biocon.2021.109378.

[4] Carr, M.H., Robinson, S.P., Wahle, C., Davis, G., Kroll, S., Murray, S., Schumacker, E.J. and Williams, M. (2017). The central importance of ecological spatial connectivity to effective coastal marine protected areas and to meeting the challenges of climate change in the marine environment. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *27*, 6-29. https://doi.org/10.1002/aqc.2800.

[5] Christie, H., Jørgensen, N. M., Norderhaug, K. M., & Waage-Nielsen, E. (2003). Species distribution and habitat exploitation of fauna associated with kelp (Laminaria hyperborea) along the Norwegian coast. *Journal of the Marine Biological Association of the United Kingdom*, *83*(4), 687-699. https://doi.org/10.1016/j.ocecoaman.2010.10.013.

[6] CIA. The World Factbook, Norway;2024. http://www.cia.gov/library/publications/the-world-factbook/geos/no.html. Accessed 30.04.2024.

[7] DESIGNING MARINE PROTECTED AREA NETWORKS TO ACHIEVE FISHERIES, BIODIVERSITY, AND CLIMATE CHANGE OBJECTIVES IN TROPICAL ECOSYSTEMS: A practitioner guide». Edited and Compiled by: Alison Green, Alan White and Stacey Kilarski. https://repository.library.noaa.gov/view/noaa/16939.

[8] Eriksen, E., van der Meeren, G. I., Nilsen , B. M., & von Quillfeldt, C. H. (2021). Særlig Verdifulle og sårbare områder (SVO) I Norske Havområder. Havforskningsinstituttet. https://www.hi.no/en/hi/nettrapporter/rapport-fra-havforskningen-2021-26. Accessed 30.05.2024.

[9] Fletcher, S., Saunders, J., & Herbert, R. J. H. (2011). A review of the ecosystem services provided by broad-scale marine habitats in England's MPA network. Journal of Coastal Research, 378-383.

[10] Geange, S. W., Leathwick, J., Linwood, M., Curtis, H., Duffy, C., Funnell, G., & Cooper, S. (2017). Integrating conservation and economic objectives in MPA network planning: A case study from New Zealand. *Biological Conservation*, *210*, 136-144. https://doi.org/10.1016/j.biocon.2017.04.011.

[11] Gill, D., Mascia, M., Ahmadia, G. *et al.*(2017). Capacity shortfalls hinder the performance of marine protected areas globally. *Nature*, *543*, 665–669. https://-doi.org/10.1038/nature21708.

[12] Gonzalez-Mirelis, G., & Buhl-Mortensen, P. (2015). Modelling benthic habitats and biotopes off the coast of Norway to support spatial management. *Ecological Informatics*, *30*, 284-292. https://doi.org/10.1016/j.ecoinf.2015.06.005.

[13] Gov.UK. (2022). Global Ocean Alliance: 30by30 initiative. GOV.UK. Retrieved November 24, 2022, from https://www.gov.uk/government/topical-events/global-ocean-alliance-30by30-initiative/about. Accessed 2.03.2024.

[14] Grorud-Colvert, K., Sullivan-Stack, J., Roberts, C., Constant, V., Horta e Costa, B., Pike, E. P., ... & Lubchenco, J. (2021). The MPA Guide: A framework to achieve global goals for the ocean. *Science*, *373*(6560), eabf0861.

[15] Harman, C., Bekkby, T., Calabrese, S., Trannum, H., Oug, E., Hagen, A. G., ... & Frigstad, H. (2019). The environmental status of norwegian coastal waters. *World Seas: An Environmental Evaluation*(pp. 69-84). Academic Press. https://-doi.org/10.1016/B978-0-12-805068-2.00003-6.

[16] Intergovernmental Conference on Marine Biodiversity of Areas Beyond National Jurisdiction. (Updated 2024, May 29). Agreement under the United Nations Convention on the Law of the Sea on the Conservation and Sustainable Use of Marine Biological Diversity of Areas Beyond National Jurisdiction. United Nations Convention on the Law of the Sea. https://www.un.org/Depts/los/bbnj.htm. Accessed 31.05.2024.

[17] IPBES 2019. Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. E. S. Brondizio, J. Settele, S. Díaz, and H. T. Ngo (editors). IPBES secretariat, Bonn, Germany. Accessed 29.05.2024.

[18] Jackson, J. B., Kirby, M. X., Berger, W. H., Bjorndal, K. A., Botsford, L. W., Bourque, B. J., ... & Warner, R. R. (2001). Historical overfishing and the recent collapse of coastal ecosystems. *Science*, *293*(5530), 629-637. DOI: 10.1126/science.1059199.

[19] Johnson, C. N., Balmford, A., Brook, B. W., Buettel, J. C., Galetti, M., Guangchun, L., & Wilmshurst, J. M. (2017). TBiodiversity losses and conservation responses in the Anthropocene. *Science*, *356*(6335), 270-275. DOI: 10.1126/science.aam9317.

[20] Jørgensen, L. L., Moland, E., Husa, V., Kutti, T., Kleiven, A. R., & van der Meeren, G. (2021). Marint Vern: The Institute of Marine Research's expert assessment of the challenges and status of work on marine protection and protection in Norway.Havforskningsinstituttet. https://www.hi.no/hi/nettrapporter/rapport-fra-havforskningen-2021-9.

[21] Kullberg P, Toivonen T, Montesino Pouzols F, Lehtomäki J, Di Minin E, Moilanen A (2015) Complementarity and Area-Efficiency in the Prioritization of the Global Protected Area Network. *PLoS ONE. 10*(12): e0145231. https://doi.org/10.1371/journal.pone.0145231.

[22] Lewis, S. L., & Maslin, M. A. (2015). Defining the anthropocene. *Nature*, *519*(7542), 171-180. https://doi.org/10.1038/nature14258.

[23] Marine Protected Areas. Fiskeridirektoratet. (2015, March 19). https://www.fiskeridir.no/English/Coastal-management/Marine-protected-areas. https://doi.org/10.6084/m9.figshare.24943371. Accessed 30.05.2024.

[24] McLean, R. F., Tsyban, A., Burkett, V., Codignotto, J. O., Forbes, D. L., Mimura, N., ... & Ittekkot, V. (20201). Coastal zones and marine ecosystems. *Climate change*, 343-379.

[25] McLeod, E., Salm, R., R. Green & Almany, J. (2008). Designing marine protected area networks to address the impacts of climate change. *Frontiers in Ecology and the Environment*, *7*362-370. https://esajournals.onlinelibrary.wiley.com/doi/-full/10.1890/070211.

[26] McNeely, J.A. (1994). Protected areas for the 21st century: working to provide benefits to society. *Biodiversity Conservation*, *3*, 390–405. https://-doi.org/10.1007/BF00057797.

[27] Mehvar, S., Filatova, T., Dastgheib, A., De Ruyter van Steveninck, E., & Ranasinghe, R. (2018). Quantifying economic value of coastal ecosystem services: a review. *Journal of marine science and engineering*, *6*(1), 5. DOI 10.3390/jmse6010005.

[28] Ministry of the Environment. (2013, April). Integrated Management of the Marine Environment of the North Sea and Skagerrak (Management Plan). Meld. St. 37 (2012–2013) Helhetlig forvaltning av det marine miljø i Nordsjøen og Skagerrak (forvaltningsplan). https://www.regjeringen.no/. Accessed 27.05.2024.

[29] Norway | Sixth National Report. (21 December 2018). Convention on Biological Diversity. https://chm.cbd.int/database/record/D874F120-974C-0CFE-32C4-6BCBE13146B5. Accessed 25.04.2024.

[30] O'Leary, B. C., Winther-Janson, M., Bainbridge, J. M., Aitken, J., Hawkins, J. P., & Roberts, C. M. (2016). Effective coverage targets for ocean protection. *Conservation Letters*, *9*(6), 398-404. https://doi.org/10.1111/conl.12247.

[31] Oslo/Paris Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Commission). (2022, October 5). 11% of the North-East Atlantic is Now Protected [Press release]. https://www.ospar.org/news/mpareport. Accessed 30.05.2024.

[32] Ostrander, G. K., Armstrong, K. M., Knobbe, E. T., Gerace, D., & Scully, E. P. (2000). Rapid transition in the structure of a coral reef community: the effects of coral bleaching and physical disturbance. *Proceedings of the National Academy of Sciences*, *97*(10), 5297-5302. https://doi.org/10.1073/pnas.090104897.

[33] Pendoley, K. L., Schofield, G., Whittock, P. A., Ierodiaconou, D., & Hays, G. C. (2014). Protected species use of a coastal marine migratory corridor connecting marine protected areas. *Marine biology*, *161*, 1455-1466. https://doi.org/10.1007/s00227-014-2433-7.

[34] Portman, M. E., Esteves, L. S., Le, X. Q., & Khan, A. Z. (2012). Improving integration for integrated coastal zone management: An eight country study. *Science of the total environment*, *439*, 194-201. https://doi.org/10.1016/j.scitotenv.2012.09.016.

[35] Roberts, K. E., Valkan, R. S., & Cook, C. N. (2018). Measuring progress in marine protection: A new set of metrics to evaluate the strength of marine protected area networks. *Biological Conservation*, *219*, 20-27. https://doi.org/10.1016/j.biocon.2018.01.004.

[36] Rodrigues, A. S., & Brooks, T. M. (2007). Shortcuts for biodiversity conservation planning: the effectiveness of surrogates. *Annual Review of Ecology, Evolution, and Systematics*, *38*, 713-737. https://doi.org/10.1146/annurev.ecolsys.38.091206.095737.

[37] Roessger, J., Claudet, J., & e Costa, B. H. (2022). Turning the tide on protection illusions: The underprotected MPAs of the 'OSPAR Regional Sea Convention'. *Marine Policy*, *142*, 105109. https://doi.org/10.1016/j.marpol.2022.105109.

[38] Saarman, E., Gleason, M., Ugoretz, J., Airamé, S., Carr, M., Fox, E., Frimodig, A., Mason, T. and Vasques, J. (2013). The role of science in supporting marine protected area network planning and design in California. *Ocean & Coastal Management*, *74*, 45-56. https://doi.org/10.1016/j.ocecoaman.2012.08.021.

[39] Saura, S., Bastin, L., Battistella, L., Mandrici, A., & Dubois, G. (2017).Protected areas in the world's ecoregions: How well connected are they?. *Ecological indicators*, *75*, 144-158. https://doi.org/10.1016/j.ecolind.2016.12.047.

[40] Spalding, C., & Hull, P. M. (2021). Towards quantifying the mass extinction debt of the Anthropocene. Proceedings of the Royal Society B, 288(1949), 20202332. https://doi.org/10.1098/rspb.2020.2332.

[41] Spatial Conservation Prioritization: Quantitative Methods and Computational Tools. (2009). Editors: Atte Moilanen, Kerrie A. Wilson, Hugh Possingham.

[42] Sundblad, G., Bergström, U., & Sandström, A. (2011). Ecological coherence of marine protected area networks: a spatial assessment using species distribution models. *Journal of Applied Ecology*, *48*(1), 112-120. https://doi.org/10.1111/j.1365-2664.2010.01892.x.

[43] Tiller, R., Brekken, T., & Bailey, J. (2012). Norwegian aquaculture expansion and Integrated Coastal Zone Management (ICZM): Simmering conflicts and competing claims. *Marine Policy*, *36*(5), 1086-1095. https://doi.org/10.1016/j.marpol.2012.02.023.

[44] Veach, V., Di Minin, E., Pouzols, F. M., & Moilanen, A. (2017). Species richness as criterion for global conservation area placement leads to large losses in coverage of biodiversity. *Diversity and Distributions*, *23*(7), 715-726. https://-doi.org/10.1111/ddi.12571.

[45] Williams, B. A., Watson, J. E., Beyer, H. L., Klein, C. J., Montgomery, J., Runting, R. K., ... & Wenger, A. (2022). Global rarity of intact coastal regions. *Conservation Biology*, *36*(4), e13874. https://doi.org/10.1111/cobi.13874.

[46] Wright, G., Gjerde, K. M., Johnson, D. E., Finkelstein, A., Ferreira, M. A., Dunn, D. C., ... & Grehan, A. (2021). Marine spatial planning in areas beyond national jurisdiction. *Marine Policy*, *132*, 103384. https://doi.org/10.1016/j.marpol.2018.12.003.

APPENDICES

A - Github repository link

All code, R packages and citations, GIS layer citations, and latex-files used in this document are included in the Github repository linked below. Further explanations are given in the readme-file.

- `https://github.com/gn-gia/master-thesis.git`

B - Additional Figures

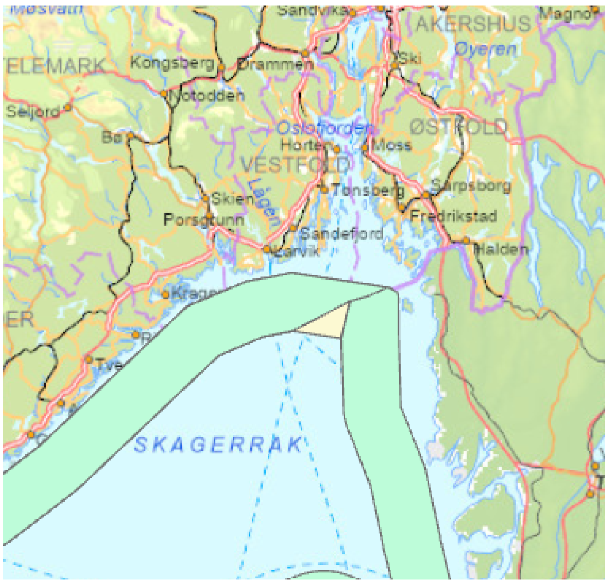


Figure .0.1: Territorial waters discrepancy: Maritime Boundaries Geodatabase and the Geonorge database reported from Kartverket agreement in boundary (green); Border portion included by Geonorge and not the Maritime Boundaries Geodatabase (yellow).

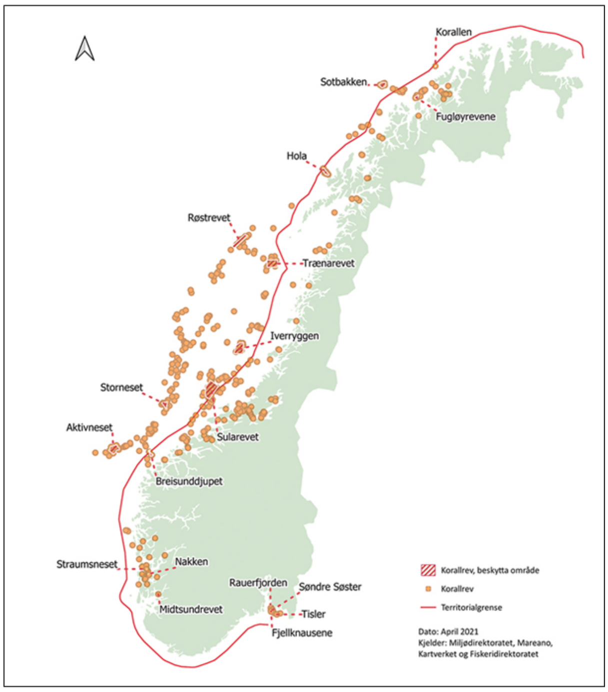


Figure .0.2: Protection of coral reefs against fishing activity. Source: Norwegian Environment Agency, Mapping Authority, Norwegian Fisheries Directorate (Meld. St. 29 (2020-2021))[**8**].

.

NTNU

Norwegian University of
Science and Technology