Marine Litter and Microplastics in the Barents Sea Area

Status of knowledge, monitoring, and management

Report

M-2805 | 2024

Colophon

Title – Norwegian and English: Forsøpling og mikroplast i Barentshavet. Kunnskapsoppsummering. Marine Litter and Microplastics in the Barents Sea Area. Status of knowledge, monitoring and management.

Sammendrag:
This report synthesizes current knowledge on the distribution, sources, pathways and impacts of marine litter and microplastics in the Barents Sea area. In addition, an overview of regulations and management tools relevant for reducing marine litter are presented as well as an overview of the relevant regional and international organisations and stakeholders.

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Front page photo: Beached marine litter in Otervika, Troms, Norge. Photo credits: Ann Kristin Balto.

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List of acronyms and abbreviations

AECO	Association of Arctic Expedition Cruise Operators
ALDFG	Abandoned, lost or otherwise discarded fishing gear
AMAP	Arctic Monitoring and Assessment Programme
ASTD	Arctic Ship traffic Data (PAME database)
CBD	Convention on Biological Diversity
CMS	Convention on Migratory Species of Wild Animals
CP	Chlorinated paraffins
EEA	European Economic Area
EPR	Extended producer responsibility
FAO	Food and Agriculture Organization
EU	European Union
GESAMP	Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection
GIS	Geographic information system
GPA	Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities
GPML	Global Partnership on Marine Litter
ICES	International Council for the Exploration of the Sea
INC	Intergovernmental Negotiating Committee
IMO	International Maritime Organization
IMR	Institute of Marine Research
JRC	Joint Research Centre—the European Commission's science and knowledge service
MAREANO	Norwegian Seabed Mapping Programme
MARPOL	International Convention for the Prevention of Pollution from Ships
ML-RAP	Regional Action Plan on Marine Litter in the Arctic
MIKRONOR	Microplastics in Norwegian coastal areas, rivers, lakes, and air (monitoring program)
MOSJ	Environmental Monitoring of Svalbard and Jan Mayen
NDF	Norwegian Directorate of Fisheries
NEA	Norwegian Environment Agency
NEAS	North-East Atlantic Environment Strategy (OSPAR)
NEA	Norwegian Environment Agency
NIVA	Norwegian Institute for Water Research
NCA	Norwegian Coastal Administration
NMA	Norwegian Maritime Authority
NPI	Norwegian Polar Institute
OSPAR	Oslo/Paris Convention for the Protection of the Marine Environment of the North-East Atlantic
PAME	Protection of the Arctic Marine Environment
PBDEs	Polybrominated diphenyl ethers
PCBs	Polychlorinated biphenyls
POPs	Persistent organic pollutants
PPWD	Packaging and Packaging Waste Directive
PRF	Port reception facilities
SDG	Sustainable Development Goals

SUP	Single-use plastics
TWP	Tyre-wear particles
UN	United Nations
UNCLOS	United Nations Convention on the Law of the Sea
UNEA	United Nations Environment Assembly
UNEP	United Nations Environment Programme
UNFSA	United Nations Fish Stocks Agreement
UV	Ultraviolet
UWWTD	Urban Wastewater Treatment Directive
VMS	Vessel Monitoring System
VNIRO	Russian Federal Institute of Marine Fisheries and Oceanography
WGML	Working Group on Marine Litter (ICES)

Sammendrag

Denne rapporten oppsummerer kunnskap om spredning, kilder, transportveier og påvirkning av marin forsøpling og mikroplast i Barentshavet, med fokus på de norske delene av området. Det gis også en oversikt over regelverk, forvaltningsverktøy og organisasjoner som er relevante i arbeidet mot marin forsøpling.

Marin forsøpling i Barentshavet stammer fra en lang rekke lokale, regionale og globale kilder. Fiskeri og skipsfart er anslått å være største sjøbaserte kilder, mens de største landbaserte bidragsyterne er avfall og avløpsvann. Det er imidlertid behov for mer forskning for å fastslå omfanget av bidraget fra hver enkelt aktivitet.

Elver, havstrømmer, havisdrift, luft og biota transporterer marin forsøpling og/eller mikroplast til og innen Barentshavet. Marin forsøpling og mikroplast forekommer i hele Barentshavområdet. Det er imidlertid usikkerhet knyttet til konsentrasjoner, tilførsel, polymertyper og mengder av kjemikalier og tilsetningsstoffer i plasten.

Vi vet at fugler og andre sjødyr får i seg mikroplast og marint avfall, og at fisk og andre marin dyreliv ofte vikler seg inn i og blir passivt fisket opp av tapte fiskeredskaper. I tillegg fester virvelløse dyr, plankton og bakterier seg på marin forsøpling og flyter over lengre distanser – og bidrar til spredning av potensielt fremmede arter til området. Det fulle omfanget og virkningene av disse prosessene på helsen til havets økosystemer, dødelighet og populasjonsdynamikk er imidlertid dårlig forstått.

Vår kunnskap om marin forsøpling og mikroplast er basert på en rekke studier, inkludert informasjon fra strandrydding, vitenskapelige undersøkelser og miljøovervåking. Mangelen på harmoniserte metoder har imidlertid begrenset vår mulighet til å sammenligne resultater fra ulike studier.

Selv om vi fortsatt trenger informasjon om omfanget av marin forsøpling og mikroplast i Barentshavet for å kunne sette inn mer målrettete tiltak, understreker vår nåværende kunnskap viktigheten av å iverksette føre-var-tilnærminger på området, for å sikre god miljøstatus i Barentshavet også i fremtiden.

Executive Summary

This report synthesizes current knowledge on the distribution, sources, pathways and impacts of marine litter and microplastics in the Barents Sea area, with focus on the areas under the Norwegian jurisdiction. In addition, an overview of regulations and management tools relevant for reducing marine litter are presented as well as an overview of the relevant regional and international organisations and stakeholders.

Marine litter enters the Barents Sea from a wide array of local, regional, and global sources. The primary maritime activities in the Barents Sea are fisheries and shipping, including cruise ship tourism. Offshore resource exploration, and aquaculture activities are also increasing in the region. The major land-based contributors are from waste and wastewater. However, more research is needed to determine the full extent of the contribution from each activity.

Rivers, currents, sea-ice drift, air, and biota are all transport vectors of marine litter and/or microplastics into and within the Barents Sea. Marine litter and microplastics are found throughout the Barents Sea area: in the water column, in sea ice, on the seabed, in sediments and in the coastal zone. There is, however, uncertainty on concentrations, fluxes, polymer types, and abundances of associated chemicals and additives.

We know that birds and other marine animals ingest microplastics and marine litter and that biota often get entangled and passively fished by lost or ‘ghost’ fishing gear. Additionally, biota, including invertebrates, plankton, and bacteria, raft on marine litter and can relocate, potentially introducing invasive species to the area. However, the full extent and impacts of these processes on ocean ecosystem health, mortality rates, and population dynamics are poorly understood.

Our knowledge on marine litter and microplastics is based on numerous studies, including information from beach clean-ups, scientific investigations, and biomonitoring. The lack of harmonized methods has, however, limited our opportunity to compare results from different studies. We need extensive long-term monitoring in multiple areas to better understand 1) the distribution of marine litter and microplastics, 2) the contributions of different plastic types and their associated chemicals, and 3) the effects of local, regional, and international measures to reduce marine litter and microplastics pollution. More

knowledge is also required to properly assess impacts on species and ecosystem, and to be able to conduct realistic risk assessments to broadly support ecosystem health.

Even though we still need information on the full extent of marine litter and microplastics in the Barents Sea for successful targeted actions, our current knowledge emphasizes the importance and urgency of action to address marine litter and microplastics pollution.

1. Objectives and definitions

The aim of this report is to summarise existing knowledge on marine litter and microplastics in the Barents Sea, with focus on the areas under Norwegian jurisdiction. We identify key challenges and recommendations for research, monitoring, and management of marine litter and microplastics in the Arctic region. We also present an overview of the relevant regulations concerning marine litter and microplastics as well as key fora for forming environmental policies with relevance to the Barents Sea area.

This report has three main objectives:

1. Summarize existing knowledge of marine litter and microplastics in the Barents Sea area.
2. Provide a foundation for further international collaboration, research, monitoring, and management.
3. Summarize knowledge on regulations, policies, and international collaboration around reducing marine litter and microplastics.

1.1 Defining marine litter and microplastics

Marine litter has been defined as 'any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment' (Galgani et al., 2010). Marine litter types include items of plastic, paper, machined wood, textiles, metal, glass, ceramics and rubber and any other human-made material that does not degrade within days or months.

In this report we focus on plastics, defined here as synthetic polymers with thermo-plastic or thermo-set properties (synthesized from hydrocarbon or biomass raw materials), elastomers (such as butyl rubber), material fibres, monofilament lines, coating and ropes.

We distinguish between large plastic items (including megaplastics; >1 m, macroplastics; 25 mm-1 m and mesoplastics: 5-25 mm)—hereby referred to as 'marine litter'—and microplastics (< 5 mm), as defined by the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) (GESAMP, 2015). Marine microplastics consist of primary microplastics – particles manufactured <5 mm in diameter (powders, resin pellets, microbeads from cosmetics and cleaning products, fibres from clothes) and secondary microplastics, resulting from the degradation of larger plastic items (bags, bottles, packaging, fishing nets and other) (La Beur et al., 2019).

1.2 Area description

This report covers the Barents Sea area (Figure 1.1). To better understand the occurrence, distribution, and transport of marine litter and microplastics in this region, we provide a brief outline of the climatic, topographic, and oceanographic characteristics of this area.

The Barents Sea is a large continental shelf area located at high latitudes north of northern Norway and the northwestern Russian Federation. This region is characterized by short, cold summers and long, severe winters. The mean depth is approximately 220 m, and the maximum depth is about 500 m (in the western Barents Sea). Two archipelagos (Svalbard and Franz Josef Land) are located in the northern Barents Sea. During the winter months, sea ice mostly covers the waters off Svalbard, Franz Josef Land and Novaya Zemlya. However, the region's climate and the extent of the sea ice are strongly influenced by the inflow of warm Atlantic waters and atmospheric forces.

As shown in Figure 1.1, warm, saline Atlantic waters flow into the southwestern Barents Sea from the Norwegian Sea, creating vast ice-free areas for much of the year. This North Atlantic current (partially a continuation of the Gulf Stream) connects the Barents Sea to a global ocean circulation system. There is also an inflow of Atlantic water from the West Spitsbergen Current to the northern Barents Sea through the deeper parts of the northern shelf. South-westerly winds tend to strengthen the inflow into the Barents Sea, while north-easterly winds tend to slow the inflow and may even reverse it and cause outflow events, particularly in the northern portion of the western entrance to the Barents Sea (Ingvaldsen et al., 2004). Cold and less-saline Arctic water flows into the northern Barents Sea. The boreal and Arctic regimes are separated by a sharp oceanographic polar front in the western part of the Barents Sea. Additionally, the Norwegian Coastal Current flows eastward, following the coastline and bringing less-saline water from the northern Norwegian and Russian coasts into the Barents Sea.

Most of the sea ice in the Barents Sea is moving, first-year pack ice that forms seasonally. Multi-year ice is found in the northern Barents Sea where it is partly advected in from the Arctic Ocean (Vinje, 2001). Ice cover varies seasonally and interannually. Ice coverage in the Barents Sea is at a minimum in September, when an average of 5% of the Sea is covered with ice.

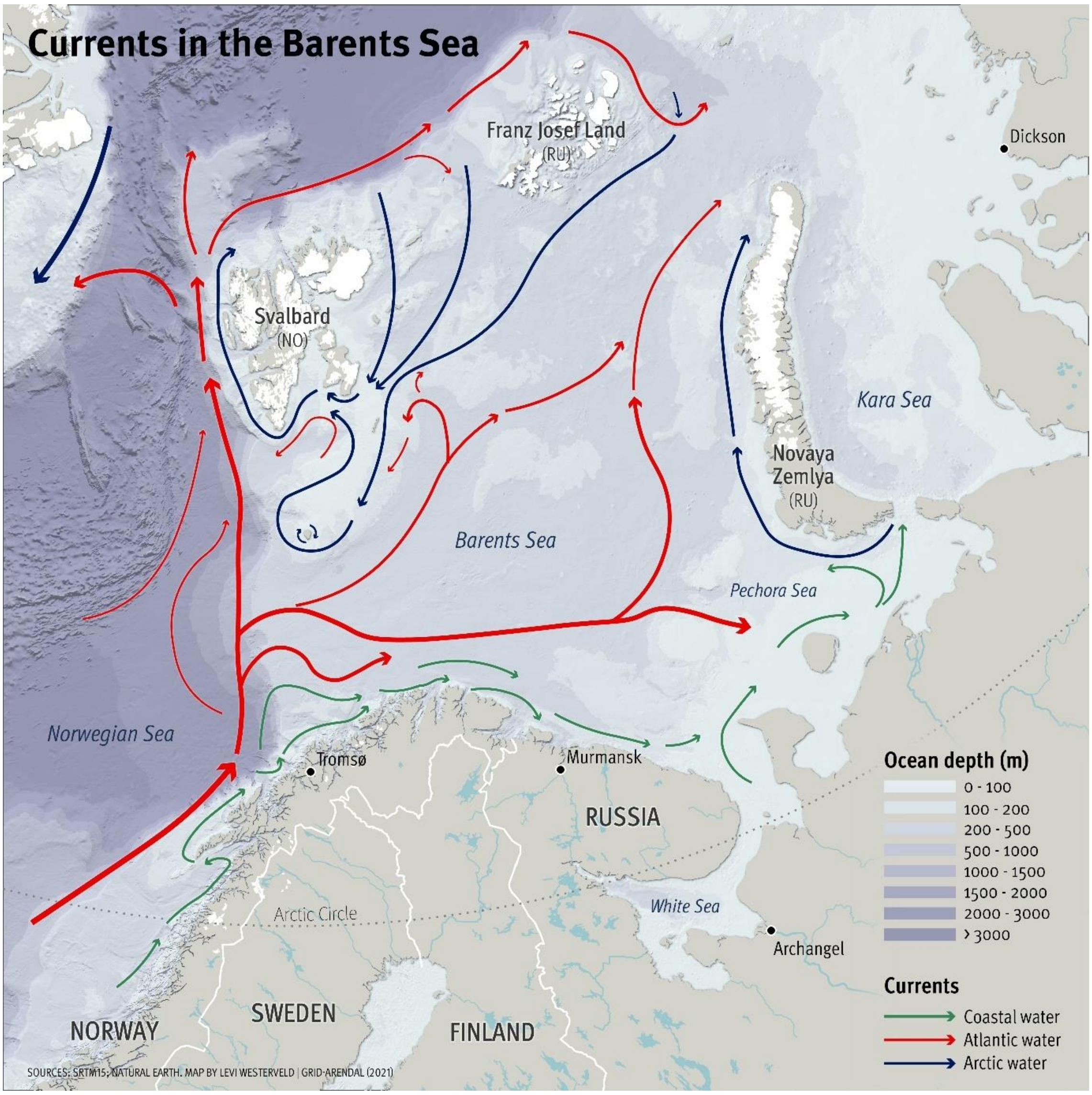


Figure 1.1: Water depth and the direction and movement of large ocean currents to and in the area of interest. Data from above the Arctic Circle are included.

2. Monitoring marine litter and microplastics

Key Findings:

- Norway has monitored beached marine litter on four beaches in the western Barents Sea since 2011.
- Marine litter in the water column and on the seabed has been monitored throughout the Barents Sea since 2010.
- Plastics ingestion in seabirds in the Barents Sea is currently not routinely monitored, even though it is an important indicator of the occurrence and effects of marine litter.
- Norway has an ongoing microplastic monitoring program that started in 2021 - Microplastics in Norwegian coastal areas, rivers, lakes, and air (MIKRONOR)
- There are challenges regarding comparison of results when different analytical methods are used.

Knowledge gaps:

- There is a need for harmonized methods and intercalibration exercises to compare results.
- We need better knowledge on temporal and geographic trends.
- There is a need for better identification of sources to plan and evaluate mitigation measures.

Monitoring is important for understanding trends on the distribution and impact of marine litter in time and space. Monitoring marine litter will aid our understanding of the movement and transport of marine litter, the contribution from sources and geographical regions, and the impact on species and ecosystem. Monitoring will also contribute to document whether actions to address plastic pollution are effective and have the desired outcome.

However, the extent of monitoring programmes for marine litter and microplastic in the Barents Sea are currently limited.

2.1 OSPAR beach litter monitoring

Beach litter in Norway is currently monitored using the OSPAR protocol. Norway reports on beach litter data to OSPAR yearly[1]. The OSPAR protocol is based on registration of litter items on a 100-meter section of a beach, where the litter is divided into 112 different categories (OSPAR, 2010). In 2023, Norway monitored seven OSPAR beaches. Since 2011, two beaches at Svalbard (Brucebukta and Luftskipodden) and two beaches in northern Norway (Rekvika and Åpenvikbukta) have been included in the Barents Sea region, under the so-called OSPAR Maritime Area I. The northernmost beach within the entire OSPAR monitoring area is Luftskipodden. The northern OSPAR beaches provide valuable information on the amount, sources, and origin of litter from this region. For artic beaches, fisheries related litter is often the dominant category.

Nonetheless, to conclude on composition and influxes of beach litter, there are several aspects of the OSPAR-methodology that needs to be addressed and improved for arctic beaches. This work is ongoing in OSPAR. For instance, practice has shown it is difficult to follow all the requirements of the protocol such as the registration frequency of 3-4 registrations per year per beach due to the cold climate (SALT, 2019). Therefore, adjustments of the protocol should be considered for arctic beaches.

A re-evaluation and adjustment of Norwegian OSPAR beaches was started in 2023, to ensure that these beaches meet the criteria needed for monitoring. It has also been decided to increase the number of beaches included in the monitoring, which means that from 2024, 13 (instead of 7) beaches will be monitored. These 13 OSPAR beaches will be evenly distributed along the entire coastline, and monitoring will be conducted three times

[1] Surveyed beach locations | OSPAR Beach Litter Surveys

a year for beaches south of the Arctic Circle and twice a year for beaches north of the Arctic Circle.

Furthermore, when using the OSPAR protocol, litter is only counted and categorised, but beach litter from one beach at Svalbard (Brucebukta) is also weighed as a part of the Environmental Monitoring of Svalbard and Jan Mayen (Miljøovervåking Svalbard og Jan Mayen, MOSJ). Weight is a very useful parameter for evaluating the load of marine litter, since one tiny fragment of plastics and one large fish trawl of many tonnes are counted as "1". Excluding weight as a factor can therefore give misleading information of the most important sources of marine litter abundance.

2.2 Monitoring marine litter and microplastics in the open water and on the seabed

Since 2010, marine litter on the seabed, in the water column and floating on the surface has been registered annually throughout the Barents Sea, as part of the Barents Sea Ecosystem survey (Figure 2.1) (Grøsvik et al. 2018; Eriksen et al., 2018).

On numerous stations covering the entire Barents Sea (Figure 2.1), the survey includes a bottom-trawl haul and a pelagic-trawl haul: this enables the registration of marine litter on the seabed and in the water column. Floating litter is recorded from the bridge when light and wind conditions allow during the cruise. These recordings represent the most substantial time series of marine litter in the Barents Sea. Moreover, data are comparable between vessels and years, as all vessels use standard trawls and trawling operational procedure, and standard sample processing procedures. Categories for registering litter have been according to material type and whether litter is fishery related or not. Since 2023, the protocol for recording marine litter developed by International Council for the Exploration of the Sea's (ICES) Working Group on Marine Litter (WGML) has been implemented. Abandoned, lost, or otherwise discarded fishing gear (ALDFG) has been recorded since 2018, as have microplastics in surface waters as part of Ecosystem surveys.

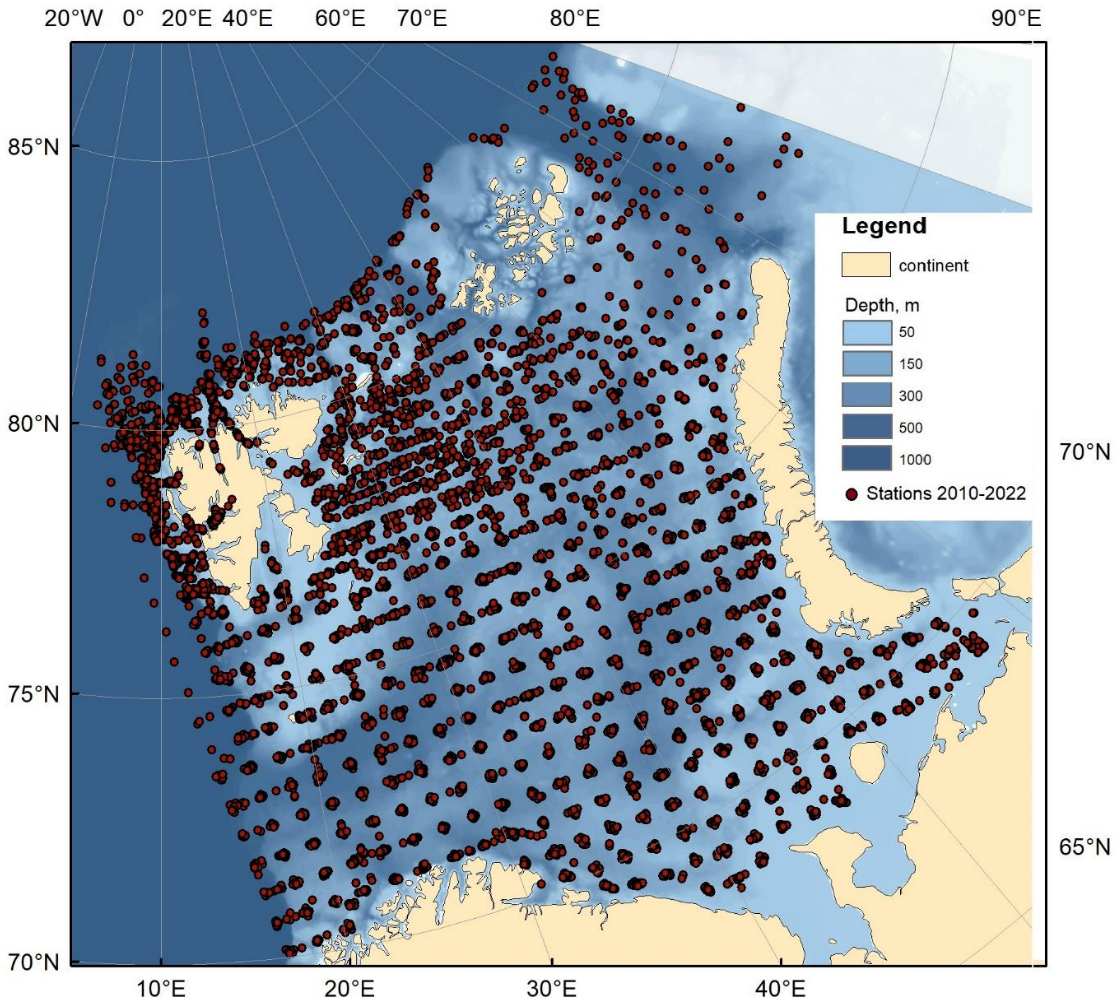


Figure 2.1: Stations for the Barents Sea Ecosystem Surveys from 2010 to 2022 Dots indicate stations from which pelagic and bottom-trawl hauls were taken (35 nautical miles between stations). Station locations varied slightly between years. Map from IMR.

2.3 Mapping of ingested plastics in seabirds

Norway is monitoring ingested plastics (>1 mm) in the stomachs of northern fulmars from the North Sea[2] as an indicator of environmental quality, under the OSPAR Convention. The monitoring programme investigates the stomach content of beached birds. The plastics found represent both ingested and floating plastics. There is a long-term OSPAR goal that not more than 10% of the northern fulmars should have more than of 0.1 g plastic in their stomachs, being set as an ecological Quality Objective (EcoQO) threshold. Of the birds found beached along the Norwegian part of the North Sea, from 2022 until 2023, around 50% did exceed this threshold (Dehnhard et al., unpublished data)

Currently, plastics in seabirds are not being routinely monitored in the Barents Sea area[3]. However, in 2022, northern fulmars collected as bycatch from fisheries in northern Norway

[2] OSPAR Maritime region II: Greater North Sea

[3] OSPAR Maritime region I: Arctic Waters

have been added to the monitoring work under OSPAR. A total of 168 northern fulmars taken as bycatch in 2022 and 2023 were investigated by the Norwegian Institute for Nature Research (NINA). It was found that less birds exceeded the threshold compared to the North Sea region, however still 25% of the birds (42 individuals) did exceed the threshold (Dehnhard et al., unpublished data). Bycatch birds from the east of Greenland were also investigated, however to a much more limited extent with only 36 birds being studied. Out of these birds, 14% exceeded the threshold.

As these results indicate, plastics ingestion by seabirds is widespread also in the circumpolar Arctic. However, considerable gaps that remain in spatial and temporal information, as well as important metrics of plastics ingestion in connection with seabird species' ecology. Thus, it is important to monitor seabirds also in arctic areas as indicators of marine plastics to assess global trends and risks to arctic seabird populations (Baak, 2020). Given the increasing number of studies on plastics ingestion by seabirds, standardized methods are needed to be able to compare studies spatially, temporally and between species (Provencher, 2019; Lusher et al., 2022).

2.4 Microplastics monitoring program (MIKRONOR)

The first national monitoring program on microplastics, Microplastics in Norwegian coastal areas, rivers, lakes, and air (MIKRONOR) , was initiated in 2021 by the Norwegian Environment Agency. Since microplastic monitoring is an immature field when it comes to methodology, it was decided to start the program broadly, both in terms of collection methodology and sample types to gain experience and adapt for the future. The program is currently being evaluated based on both general development in the research field and through experiences gained through the program.

MIKRONOR is designed to provide information on levels and types of microplastics in different parts of the Norwegian environment focusing on water and air. The aim of the program is to contribute to knowledge gaps such as knowledge on existing hot-spots and provide necessary knowledge to assess which measures will have the greatest effect, as well as eventually monitor the effect of measures over time. Sample types analysed in the program so far are several types of marine and freshwater samples from the sea surface, water column, wastewater effluent and urban runoff, as well as both marine and freshwater sediments. In addition, biota represented by bivalves (blue mussels and duck mussels) and marine polychaetas are analysed, as well as air samples.

The sites investigated in the program are spread along the Norwegian mainland coast, in addition to four sites within the Isfjorden- system at Svalbard, more specifically: Sassenfjorden, Isfjorden, Adventfjorden (outside Longyearbyen) and Tempelfjorden. The sites at Svalbard were investigated by two different methodologies: sampling by neuston net (the sea surface) and a water pump (1- 1,5 meters depth). There are also several northern sites included at mainland Norway north of the arctic circle represented by water samples, sediment samples and mussels. For example, sediment samples from Vestfjorden close to the Lofoten archipelago, riverine water samples (using manta trawl) from Målselva south of Tromsø, water and sediment samples in Ullsfjorden north of Tromsø, and several sites in the Barents Sea north from Kirkenes.

Overall low levels of microplastics have so far been detected from these northern sites, with exception of water samples outside of Longyearbyen where relatively high levels were found close to Longyearbyen compared to further away from the city. Relatively high levels have also been found in blue mussels from the Varangerfjord, connected to the Barents Sea, when assessing the results as particles per gram tissue. It is important to note that the blue mussels from the Varangerfjord are smaller than mussels from many other sites, and the size of the mussels itself might therefore influence the levels of microplastics. In addition to general microplastic analysis, specific analysis where also performed on the presence of tire wear particles (TWP) in e.g. blue mussels. Surprisingly high levels of TWPs were detected in mussels from the Varangerfjord with comparable levels to mussels from the Oslofjord, with an average of approximately 27 mg/gram TWP. More research is needed to understand these results and identify the spesific sources.

For sediments, the results published January 2024 illustrated higher levels of microplastics at urban sites such as the Oslofjord and the large lake Mjøsa, compared to more rural sites. Sediments from the Varangerfjord did not show the same trend as for the blue mussels with comparable levels of microplastics as from the Oslofjord. TWP were found at very high concentrations for sites in the Oslofjord and lake Mjøsa, up to 20 mg/g sediment, accounting for 2% of the sediment being TWP. Despite not finding as high levels of TWP as for the Oslofjord, it is still worth nothing that TWP above detection limits were found in most sediment samples from the northern sites, and up to more than 3 mg of TWP per gram sediment were found.[4]

2.5 Towards more harmonised monitoring of the Arctic: new AMAP-guidelines

The technical monitoring guidelines for marine litter and microplastics, developed by the Arctic Council working group Arctic Monitoring and Assessment Programme (AMAP) provide a framework for harmonized monitoring in the Arctic. The guidelines are designed to correspond with data collected under the OSPAR monitoring programme. As such, the AMAP monitoring guidelines provide a useful framework for achieving harmonized monitoring between Arctic states and with existing monitoring in the Northeast Atlantic region (AMAP, 2021). The guidelines are planned to be revisited and updated when needed.

[4] For a full overview of the results, methodology and sites see [Mikronor Data (mikronor-data.no)](mikronor-data.no).

Provencher et al. (2022) have described work done in AMAPs litter and microplastic expert group that has considered the current state of knowledge and methods for litter and microplastics monitoring in eleven environmental compartments representing the marine, freshwater, terrestrial, and atmospheric environments (Figure 1.3.). Based on available harmonized methods, and existing data in the Arctic, the recommendations have been that the implementation of litter and microplastics monitoring should be prioritized in four Priority 1 compartments—water, aquatic sediments, shorelines, and seabirds. These compartments could be monitored to provide benchmark data for litter and microplastics in the Arctic and data on spatial and temporal trends. For the other environmental compartments, the group recommend that methods should be refined for future sources, surveillance monitoring and effects monitoring. While organized as national and regional programs, monitoring of litter and microplastics in the Arctic should be coordinated, with a view to future pan-Arctic assessments (Provencher et al., 2022).

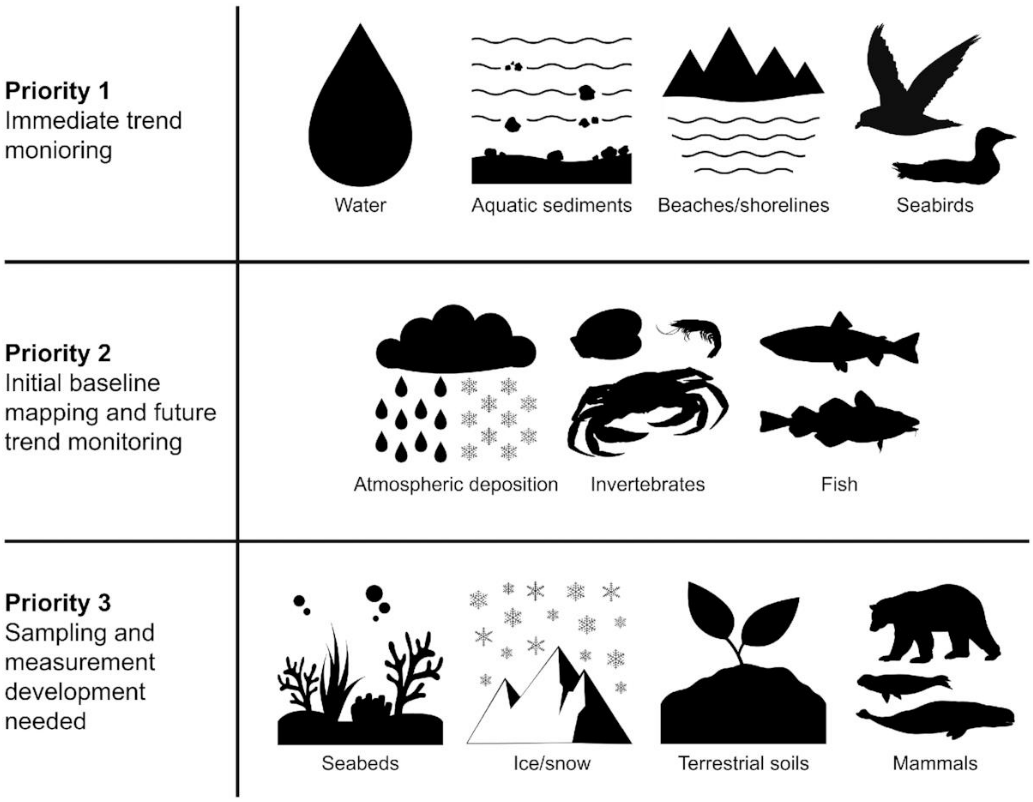


Figure 1.3. Overview of the environmental compartments recommended for monitoring of litter and microplastics in the Arctic as recommended by AMAP (Provencher et al. 2022).

3. Status of knowledge

3.1 Transport of marine litter and microplastics into and within the Barents Sea

Key Findings:

- Marine litter and microplastics are primarily transported into the Barents Sea by the Atlantic current and Norwegian coastal currents.
- Rivers transport microplastics from catchment areas into Arctic Seas.
- Sea ice can temporarily store and transport microplastics.
- Atmospheric transport and deposition are also important pathway for microplastics into the Barents Sea.

Knowledge gaps:

- Observations and analyses of trends of transported marine litter and microplastics into the Barents Sea.
- Define the role and extent of rivers, sea ice and atmospheric transport for microplastics distribution in the Barents Sea.
- Investigate time and portion of transported microplastics sinking to the seabed.

3.1.1 Transport by ocean currents

Surface circulation models and field data show that the Atlantic Current transfers floating marine litter and microplastics from the North Atlantic Ocean to the Barents Sea. These findings emphasize that marine litter and microplastics are a global issue, as ocean currents transport these plastics from distant sources.

Model simulations suggest that a large proportion of microplastics from northern Europe is likely to be distributed along coastlines in Norway and in the Barents Sea within a relatively short period of time (Huserbråten et al., 2022). The model indicates that microplastics released in the southern part of the North Sea will enter the southern Barents Sea within one year (Figure 3.1).

The drift speed of microplastics slows once they reach the northeastern Barents and Kara Seas, but the particles continue their along-shelf advection toward the Laptev Sea. They eventually part with the Arctic shelf seas and start their trans-polar drift (Carmack et al., 2016; Rudels et al., 1999). These findings are corroborated by previous modelling studies on Arctic along-shelf advection (Aksenov et al., 2011) and radioactive tracer analyses (van der Loeff, 2011). However, as an unknown number of particles are incorporated into the ice—in a process known as 'scavenging'—it is not possible to estimate how long it takes for the particles to be transported within the Arctic (van Sebille et al., 2020).

The modelling simulations also concur with infield studies on floating marine litter in the Barents Sea where visual observations of marine litter accumulations have been found to correlate with the hydrophysical and biochemical characteristics of Atlantic surface waters. Monitoring data of floating objects obtained by applying the European Commission Joint Research Council tool for harmonized monitoring (Gonzales-Fernandez et al., 2017) combined with an examination of the physical and chemical characteristics of the inflowing Atlantic water supports prior findings that Atlantic surface waters are transporting floating marine litter to the Arctic (Pogojeva et al., 2021).

It has been hypothesized that the Barents Sea might act as a 'dead end' for plastics originating from the global pool of marine litter and microplastics (van Sebille et al., 2012; Cozar et al., 2017) but this theory is not supported by more recently modelling by Huserbråten et al. (2022). As shown in fig 2.1, this modelling suggests that main drift pattern continues along the Atlantic current along Novaya Zemlya, the Kara Sea and the Laptev Sea before it crosses the Arctic Ocean with several retention zones underway (Huserbråten et al., 2022).

Figure 3.1: Main drift pathway of buoyant microplastics discharged into the North Sea. The model indicates that microplastics released in the southern part of the North Sea will enter the southern Barents Sea within one year based on simulations reported in Huserbråten et al. (2022). The drift study used the Rhine–Ruhr river delta as the source: it is the largest identified point source of microplastics downstream to the Barents Sea in the Northeast Atlantic (Schmidt et al., 2017). Simulation timeline of the drift experiment was 10 years (2007–2017). Figure re-printed (with permission) from Husebråten et al. (2022).

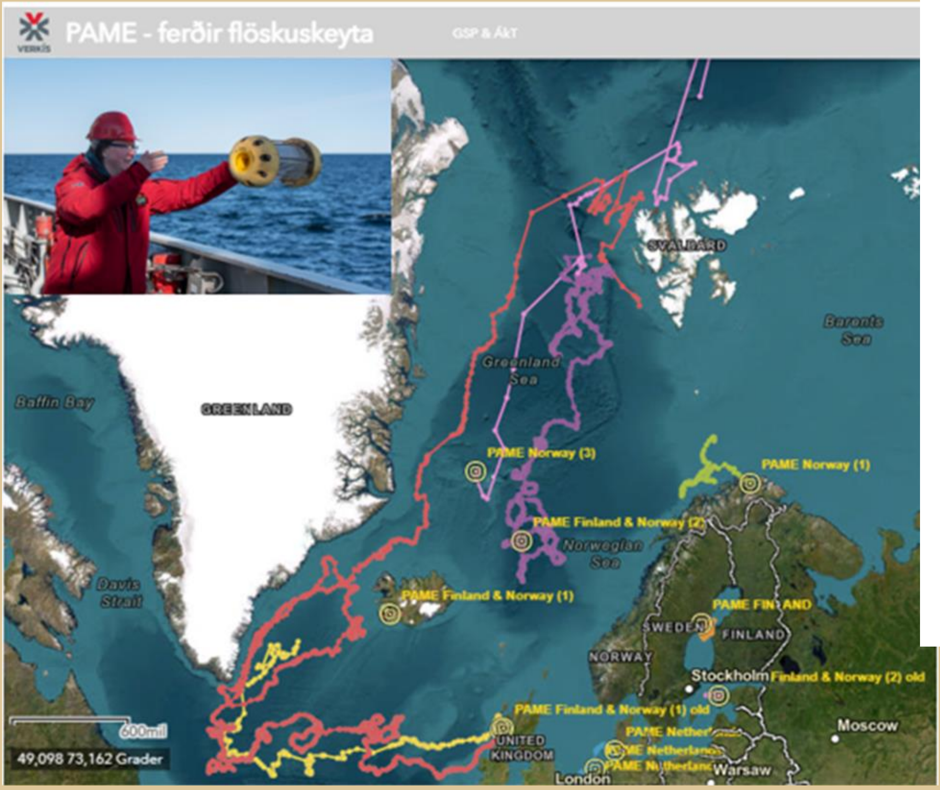
In focus: Plastic in a bottle

The general awareness of marine litter has been raised considerably the last decade and beach litter clean up actions are often facilitated by volunteers.

The working group for Protection of Arctic Marine Environment (PAME) under the Arctic Council currently runs an outreach project, ***Plastic in a Bottle***, to educate the public about the transport of marine litter to and from the Arctic environment. Here, capsules containing GPS trackers are released at different positions at sea and it is possible to follow the journey on a virtual map.

Until now, 6 individual capsules have been released. The one surviving the longest at sea travelled from the west coast of Svalbard to the Island of Tiree on the west coast of Scotland – a journey of more than 18000 km lasting 21 months. Remarkable, the capsule ended up on the same island as a capsule released by PAME southwest of Iceland in 2019. The latest employed capsule was released in the Central Polar Ocean at 84 degrees north in August 2023.

In general, the project has demonstrated that even though the Arctic does receive litter from the European continent, evident from beach litter clean ups, there is also an active transport of surface floating marine litter out of the Arctic. The Arctic is very much connected to its surroundings.



Researcher Ingeborg Hallanger sending a capsule on its journey (photo credit: Olaf Schneider). The map depicts the current capsules and their journeys as per March 2024.

3.1.2 Transport by rivers

The Arctic Ocean receives 11% of the global freshwater discharge (Yakushev et al., 2021). The Barents Sea and White Sea drainage basin encompasses the northern regions of Europe and is divided over Norway, Finland and the Russian Federation (Figure 3.2). Approximately 2.5 million people inhabit these areas (Figure 3.2), and yearly discharge of water is estimated at 463 km3 (Gordeev, 1996). Studies in adjacent Arctic Seas have found that Siberian rivers carry microplastics from river watershed areas; these are mainly polyester fibres that accumulate within the river plumes adjacent to estuaries and deltas (Tošić et al., 2020; Yakushev et al., 2021).

Although the highest weight concentration of microplastics was observed within surface waters of Atlantic origin, Siberian river discharge was identified as the second largest vector for transport of microplastics into the Eurasian Arctic (Yakushev et al., 2021). A study of microplastics collected in the White Sea found high concentrations of microplastics associated with the Severnaya Dvina river (Tošić et al., 2020). Another study recently analysed the discharge from the northern Dvina River, also flowing into the White Sea. The average weight concentration of 18.5 µg/m3 was higher than in the Barents Sea (12.5 µg/m3), indicating that this river may be one of the main sources of microplastic pollution in the White and Barents Seas (Zhdanov et al., 2022). Plastic accumulations in the coastal sediments of the Dvina River were also analysed and found to be 200 particles/120 mg microplastic per kg (Belesov et al., 2022).

These findings suggest that rivers play an important role in the transfer of microplastics into Arctic Seas. However, further examinations are required to identify the extent to which this is occurring in the Barents Sea; here, the strong seasonal cycle must be considered, with frozen lake surfaces and melting activity in the summer, which will have an impact on plastic dynamics.

Figure 3.2: River basins surrounding the Barents Sea and adjacent seas, with estimated population sizes within the catchment areas.

3.1.3 Transport by sea ice

Sea ice plays an important role in the transport of microplastics within the Arctic (Peeken et al., 2018). Levels of microplastics within sea ice have been studied in the Arctic Ocean and the Fram Strait (Obbard et al., 2014; Peeken et al., 2018; Kanhai et al., 2020) but not in the Barents Sea.

Sea ice incorporates high numbers of microplastics, from 2 to 12,000 particles per litre of melted sea ice, depending on the sizes of microplastics analysed. These microplastics are either taken up from the surrounding seas or deposited on the sea surface from atmospheric transport. The Fram Strait is the main gateway for sea ice export out of the

Arctic Ocean (Krumpen et al., 2016). This indicates that sea ice may be an important transport vector of microplastics—both within the Arctic basin and out to the regions where sea ice melts (Obbard et al., 2014; Peeken et al., 2018; Kanhai et al., 2020; von Friesen, 2020).

In addition, sea ice algae, such as *Melosira artica* has been suggested as an important vector for microplastic transport from sea ice to bottom sediments since high levels of microplastics have been found in these algae. Inclusion of microplastic in sea ice algae or algae aggregations give a higher sinking rate than free floating microplastic. It can also render microplastics more available for ingestion by benthic organisms since it is associated with algae (Bergman et al., 2023).

3.1.4 Atmospheric transport

Atmospheric circulation has been shown to provide an efficient pathway for the transport of microfibers and small plastic particles, such as tire dust (Dris et al., 2017; Liqi et al., 2017). While more research is needed on airborne microplastics in the Arctic region, models indicate that atmospheric circulation may efficiently transport microplastics produced by road traffic to remote regions like the Arctic (Evangeliou et al., 2020).

Microplastics have also been detected in all the snow samples taken from drifting sea ice in the Fram Strait and snow on Svalbard, with up to 10,000 microplastic particles per litre of snow (Bergmann et al., 2019). These results indicate that atmospheric transport and dry/wet deposition may be a pathway for microplastics into the Barents Sea.

3.2 Occurrence of marine litter and microplastics in the Barents Sea

3.2.1 Marine litter and microplastics in the open waters of the Barents Sea

Key Findings:

- Marine litter is widely distributed throughout the open waters of the Barents Sea, and current results indicate that levels may be increasing.
- Plastic is the dominant marine litter type.
- Studies show varying but occasionally very high concentrations of microplastics in the upper water masses.

Knowledge Gaps:

- Temporal and geographical trends of marine litter and microplastic densities throughout the open waters of the Barents Sea.
- Relative contributions of observed levels of marine litter and microplastics from local versus distant sources.

The Barents Sea ecosystem surveys show that marine litter is widely distributed throughout the open waters of the Barents Sea (Figure 3.3). The number of litter recordings have increased during the last decade, since these recordings were included in the ecosystem surveys in 2010 (ICES, 2019). The highest volume of floating debris has been observed in the central, eastern and northern areas. (Grøsvik et al., 2018; Novikov et al., 2021).

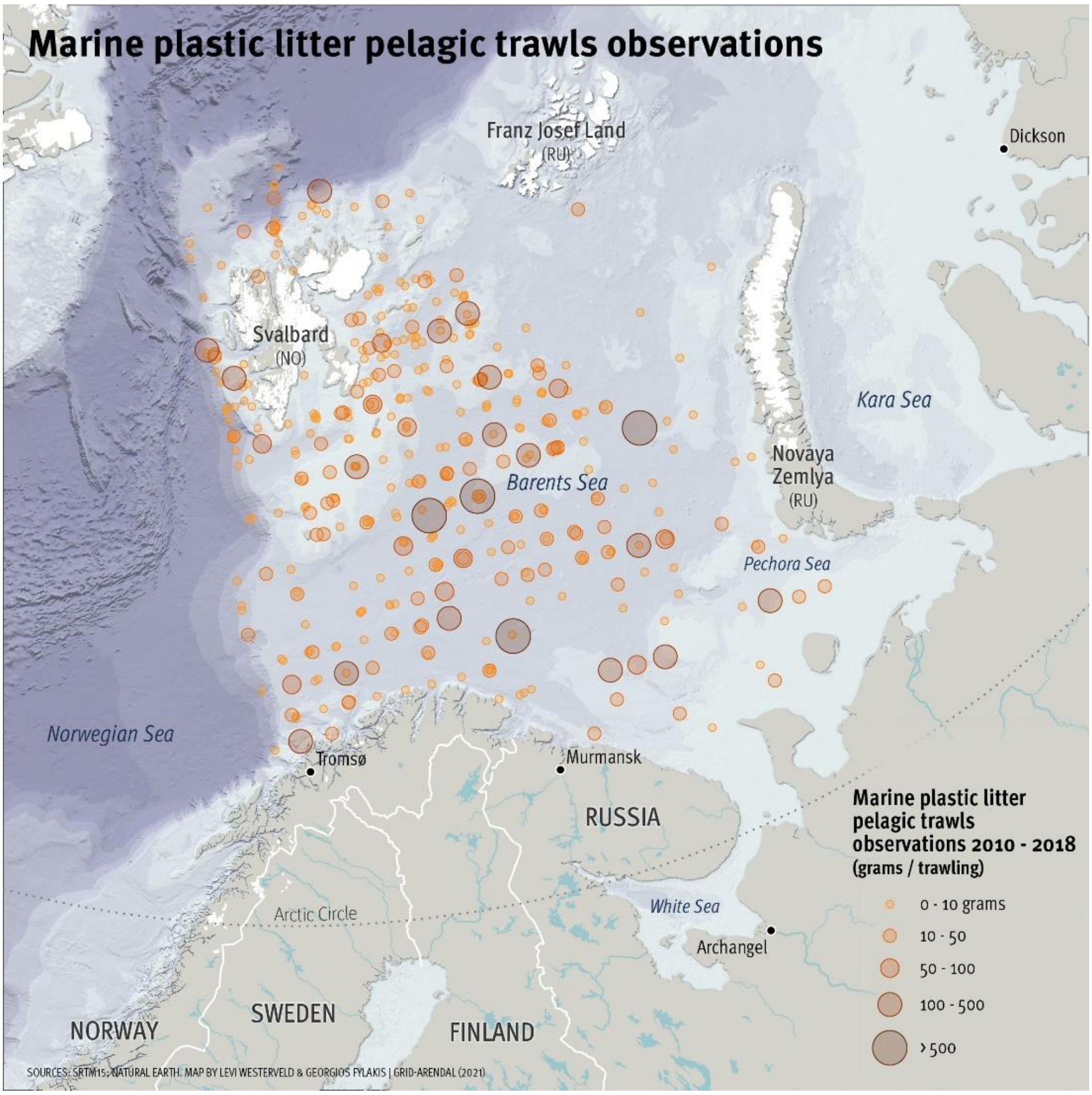


Figure 3.3: Recordings of plastic litter collected in pelagic trawls from the Barents Sea ecosystem surveys between 2010 and 2018 (Grøsvik et al., 2018).

High concentrations of floating marine litter have also been found in open waters in the eastern parts of the Barents Sea and between the northern part of Novaya Zemlya and Franz Josef Land (Novikov et al., 2021; Pogojeva et al., 2021). Large, spatial variations in the concentration of floating marine litter—ranging from an absence of marine litter to areas with significant accumulations—were found in the eastern Barents Sea.

With regard to floating marine litter in Russian Arctic Seas, Pogojeva et al. (2021) only found floating marine litter in water of Atlantic origin inflowing from the Barents Sea. The average density was 0.92 items/km^2. Almost no litter were observed at the more eastern parts of the study as the Kara Sea, Laptev Sea and the East Siberian Sea.

3.2.1.1 Plastics is the most common type of marine litter

Plastics dominate the material observed in surface waters and deeper in the water column. Results from the Barents Sea ecosystem surveys found that plastics accounted for 94% of pelagic-trawl catches and 72% of surface observations. Metal, paper, rubber, glass, and textiles were only observed sporadically (Grøsvik et al., 2018). Novikov et al. (2021) reported similar levels (plastic constituted 71 % of surface observations, 97 % in pelagic trawls) from observations from the Barents Sea ecosystem surveys in the period from 2012 to 2018. Visual ship-based observations during 2016 by citizen scientists also report that plastic constituted 91% of floating plastic in the Arctic and North-East Atlantic (Tekman et al., 2022).

3.2.1.2 High concentrations of microplastics are found in the Barents Sea

Quantifications of microplastics in surface waters from the Barents, Kara and White Seas demonstrated highest levels in the Barents Sea west off the coast of Novaya Zemlya (963*10^3 items per km^2) (Tošić et al., 2020). Studies suggest that some areas have pollution comparable to the most contaminated subtropical zones (Cozar et al., 2017).

The Atlantic current flowing into the Barents Sea may be facilitating this accumulation; however, as this area is also associated with active fishing and shipping activities, further research is needed to establish the relative contribution from various sources (Tošić et al., 2020).

High concentrations of microplastics in surface water have also been found near Svalbard (10,000 particles per square kilometre) (Lusher et al., 2015). This study, which was conducted in areas south and southwest of Svalbard, showed that microplastics were found in 95% of all manta trawl samples collected at the ocean surface (top 16 cm). The occurrence of microplastics in subsurface seawater (6 m depth) was 93%. Three primary types of microplastics were identified: fibres (accounting for 95%), fragments (4.9%) and films (< 0.1%) (Lusher et al., 2015).

Somewhat lower were the microplastic particle concentrations found in samples from around the Kola peninsula (<4800 particles per km2) (Kaliszewicz et al., 2023). The authors reported PET and modified cellulose fibres to dominate the samples and suggest protective clothes, ropes, ship equipment, and fishing nets to be likely sources of them. However, a comparison and interpretation of these studies must be made with caution as the sampling and analysis methods were different.

Microplastic fibres can come from multiple sources, such as the weathering of fishing equipment or input from sewage and wastewater from coastal areas; however, we do not have sufficient knowledge to identify which source is the most important. Microplastics may be transported over large distances by prevailing ocean currents, meaning that source apportionment estimates of these particles is difficult.

Some studies also report in different measurement units. A study investigating microplastics from subsurface waters observed more microplastic in terms of weight in Central Atlantic and Barents Sea (7-7.5 μg/m3) in comparison to the North Atlantic and Siberian Arctic (0.6 μg/m3), while no statistically significant differences in microplastic abundance was observed between areas (Pakhomova et al., 2022). A study from the Fram Straight found on average 7 (0-18.5) microplastic particles per litre (Botterell et al., 2022).

3.2.2 Beached marine litter and microplastics

Key findings:

- Beached marine litter is found across the entire Barents Sea area.
- Plastics comprise the majority of the examined beached marine litter.
- Fisheries and shipping are the dominating source of examined beached marine litter along the northern Barents Sea.

Knowledge gaps:

- Temporal and geographical trends of beached marine litter and microplastics in the Barents Sea.
- Relative contributions of observed levels of marine litter and microplastics from local versus distant sources.
- Methods/protocols for sampling microplastic from stony beaches.

3.2.2.1 Beach litter is found across the Barents Sea coastline and dominated by plastic

Marine litter is arguably most conspicuous when it is washed ashore and becomes 'beach litter'.

There is documented marine litter on beaches across the entire Barents Sea: along the shores of Novaya Zemlya (Vesman et al., 2020), Svalbard (Bergmann et al., 2017; Nashoug et al., 2017; Jaskólski et al., 2018; Weslawksi et al., 2018; Meyer et al., 2023) and northern

Norway (Falk-Andersson et al., 2019; Haarr et al., 2020). Plastics generally constitute the majority of this beach litter (Bergmann et al., 2017; Jaskólski et al., 2018; Weslawksi et al., 2018; Mepex, 2020; Vesman et al., 2020; MOSJ, 2023; Meyer et al., 2023).

Beaches are often not the final destination for marine litter, as litter can be washed out to sea and beached multiple times. Most studies of beach litter will therefore only provide a snapshot image of the current situation and not necessarily represent long-term trends at the studied locations. Although there are several studies of beached marine litter, the lack of standardized methods in these studies makes it difficult to compile knowledge of quantities and sources of marine litter. The lack of harmonized data also hampers our understanding of beached litter development over time.

Modelling beached litter at OSPAR beaches within Norway show that, in general, particles drift northwards. Marine litter and microplastic arriving on Svalbard have regional sources from around Svalbard and the Barents Sea, with additional minor pathways from Iceland and the Norwegian Sea; while the northernmost location in mainland Norway (Troms and Finnmark) receive litter from a larger area from the Barents Sea, Norwegian Sea, Greenland, and Icelandic Sea (Strand et al., 2021).

3.2.2.2 Most beach litter in the northern part of the Barents Sea is associated with fisheries

Beached fishing net on Svalbard. Photo credit: Geir Wing Gabrielsen, NPI.

The amount of beached litter reported from Svalbard vary significantly across studies and is often related to the location of the investigated beach. The amounts of beach litter recorded annually from the 100-meter beach monitored for MOSJ and OSPAR in Svalbard were generally low, with weights well below 50 kg for most years, but these locations are in more sheltered bay areas (MOSJ, 2023). It cannot be excluded that some litter from the site have re-entered the sea, but otherwise this amount represents a yearly load of litter.

Other beaches report higher weight of obtained marine litter, though the age and time since the area was last cleaned is not known (Bergmann et al., 2017; Jaskólski et al., 2018; Meyer et al., 2023; Vesman et al., 2020; Weslawski et al., 2018). Fisheries-related plastics dominated the beach litter especially when mass is considered, and where items can be identified to origin there is a dominance of Norwegian and Russian products (Bergmann et al., 2017; Nashoug, 2017; Falk-Andersson et al., 2019; Falk-Andersson et al., 2021; Meyer et al., 2023).

At Novaya Zemlya higher levels of marine litter was found on the west coast beach (facing the Barents Sea) than the beaches located on the east coast (facing the Kara Sea). This variation might be caused by a higher level of exposure to marine litter - from ocean currents, active fisheries, shipping, and local sources - in the Barents Sea compared to the Kara Sea (Vesman et al., 2020).

3.2.2.3 Beach litter in mainland Norway is more diverse, and half originates from Norway

Mainland northern Norway has more beach litter compared to Svalbard and Novaya Zemlya, both in terms of mass and number of items count. There is also a greater variety of items found, with more costal open beaches having higher portion of heavier items, often related to fisheries, than more sheltered beaches (Salt, 2022). In Lofoten, rope pieces accounted for over 20% of collected beach litter in 2019 by number, followed by polystyrene pieces, fishing net floats, caps and lids, food packaging and beverage bottles (Clean Up Lofoten, 2019).

A 'deep dive' on litter collected from several beaches around Lofoten in 2018 also reported the prevalence of fisheries-related items, rope and rope cut-offs, and industrial and domestic items (Falk-Andersson et al., 2018). Another deep dive—this one on beach litter collected around Tromsø—focused on potential differences in litter composition between exposed and sheltered beaches (Falk-Andersson et al., 2018; Roland et al., 2019). Here, fisheries-related litter dominated on beaches facing the ocean; on sheltered beaches, the litter was largely linked to industry (such as insulation material and detonating cords) and households (such as food packaging).

Further, approximately 50% of the analysed litter was of Norwegian origin. In Varangerfjorden, Norway, ropes, rope cut-offs and other fisheries-related items were the most common types of beach litter (Falk-Andersson et al., 2018). Over 40% of the litter originated from Norway, followed by litter of unknown and foreign origin (Falk-Andersson et al., 2018). Beach cleaning and changing attitudes towards littering have resulted in a decline of beached litter over time in the Lofoten archipelago region. (Haarr et al., 2020).

3.2.3 Marine litter and microplastics on the seabed

Key findings:

- Marine litter on the seabed is found throughout the Barents Sea.
- Higher densities of marine litter have been found close to the coast and in submarine canyons.
- The distribution of litter reflects fishing intensity on a regional scale.
- Harmonized methods are currently implemented to compare results and investigate temporal and geographic trends.

Knowledge gaps:

- Temporal and geographical trends of marine litter and microplastics on the seabed in the Barents Sea.
- Better quantify contribution of local versus distant sources.
- The extent to which microplastics are present in sediments in the Barents Sea.

3.2.3.1 Marine litter is found on the seabed across the Barents Sea

Annual studies of marine litter in bottom trawls from 2010 through 2018 show that plastics are found on the seabed throughout the Barents Sea (Figure 3.4). Plastics dominated the number of marine litter registrations (78-86%), (Grøsvik et al., 2018; Novikov et al., 2021) although the survey found large variations in levels of litter with no identified trends between years and areas (ICES, 2019). However, video recordings of seabed litter in the eastern Fram Strait show that the density has increased over time since the recordings began in 2002 (Martinez et al., 2020).

The Norwegian seabed mapping programme MAREANO has recorded litter by video on the seabed at the continental shelf and slope area from mid-Norway to the Barents Sea—across several years and 23 cruises (Figure 3.5.). The results show that 27% of the transects (each of 700 m) contained marine litter, and – based on video transects – the mean litter density in the offshore Barents Sea was estimated at 154 kg km-2. Most of the litter observed in the video transects originated from the fishing industry (Buhl-Mortensen et al., 2017).

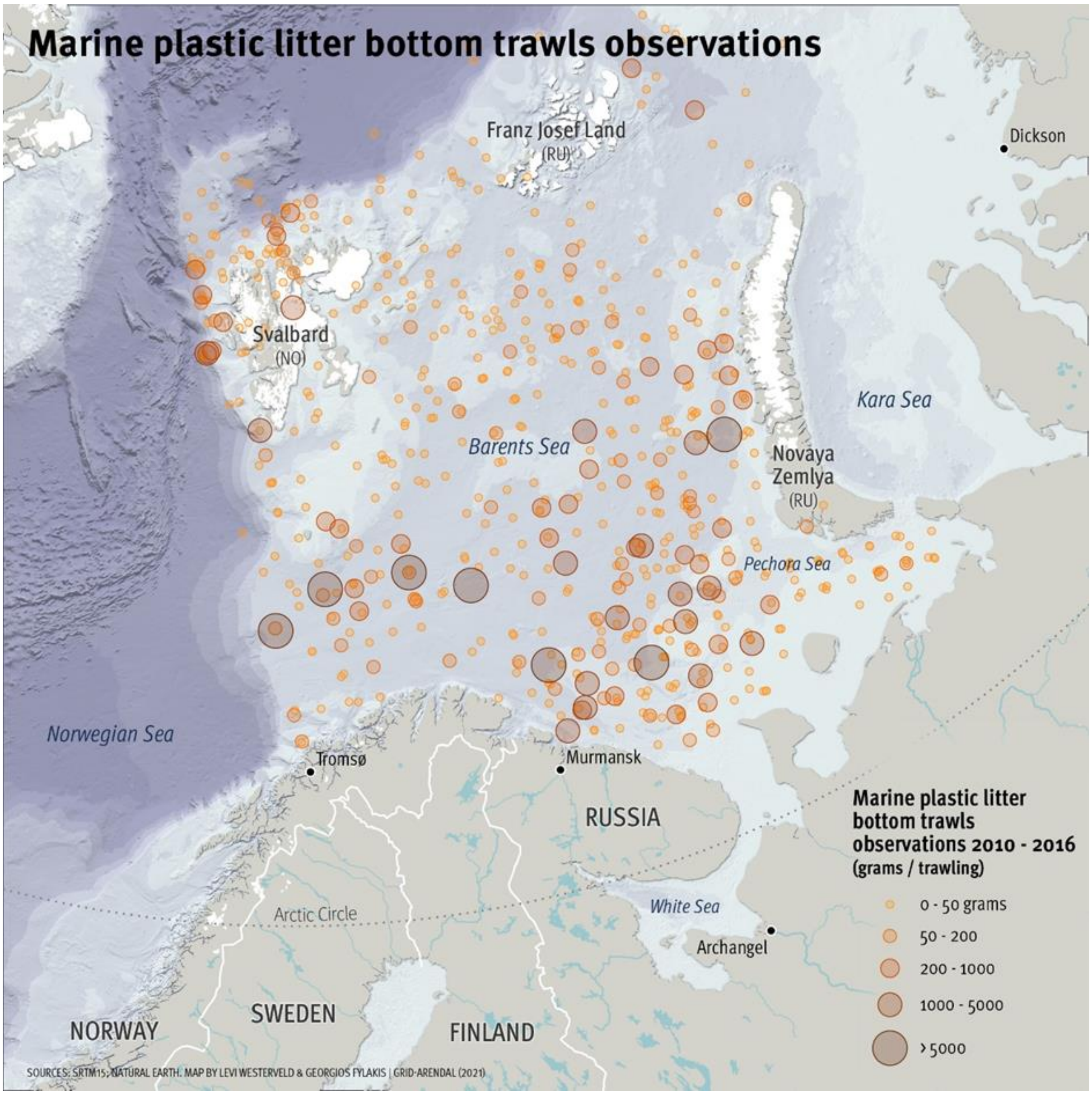


Figure 3.4: Plastics in bottom trawls from 2010 to 2016 (Grøsvik et al., 2018).

The distribution of marine plastic litter observed during bottom trawls showed coastal hotspots around Svalbard (Grøsvik et al., 2018), and at the southern end of Novaya Zemlya and the Northeastern coast of the continent (Novikov et al., 2021), respectively.

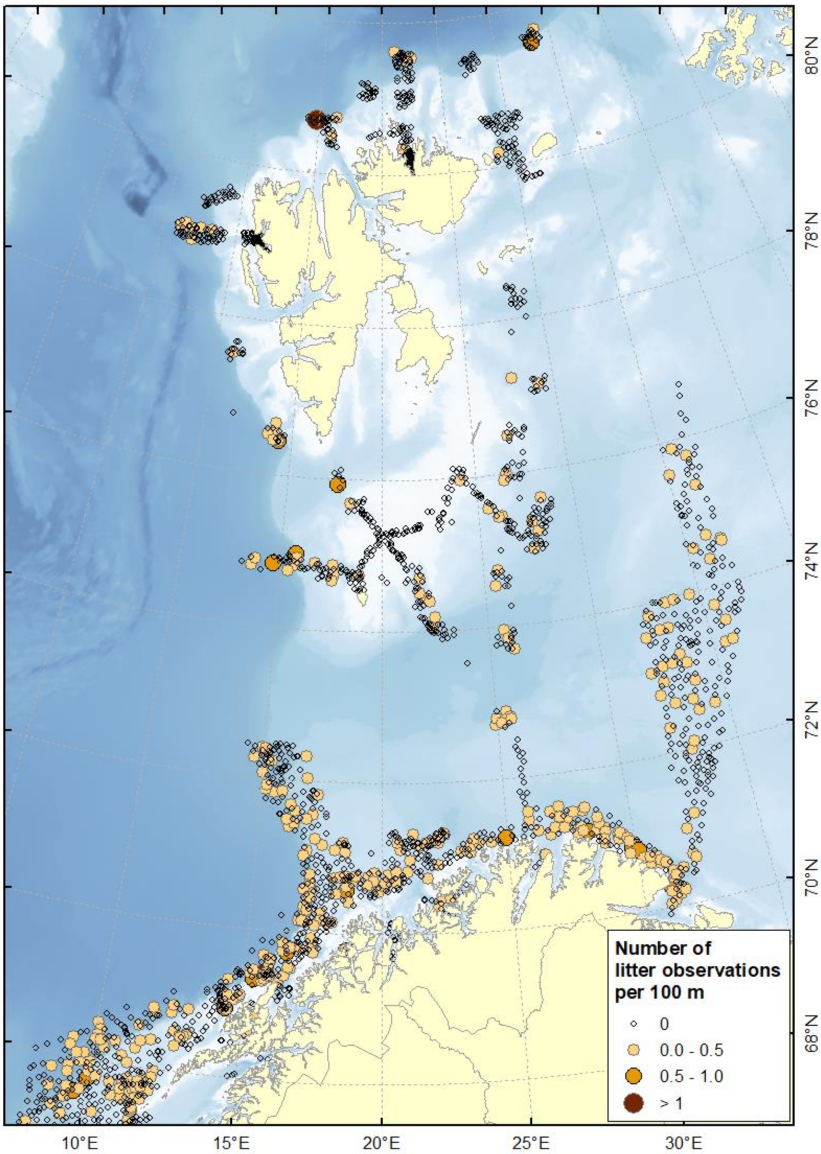


Figure 3.5: Litter densities (observations per 100 m) from video recordings in the Barents Sea region based on data from the MAREANO programme from 2006 to 2022.

3.2.3.2 Marine litter density depends on distance to coastline, fishing intensity and bottom topography

Regional estimates from MAREANO show that the most marine litter was found close to the coast, compared to offshore areas along the continental shelf and slope (Figure 3.5 and 3.6); additionally, the distribution of litter reflected fishing intensity on a regional scale. Several studies also show that higher densities of marine litter may be found in submarine canyons, compared to continental shelves and ocean ridges (Ramirez-Llodra et al., 2011; Pham et al., 2014; Woodall et al., 2015; Buhl-Mortensen et al., 2017; Galgani et al., 2000).

In contrast to regional patterns, results from MAREANO show no clear pattern in the local distribution of marine litter on the seabed (Buhl-Mortensen et al., 2018).

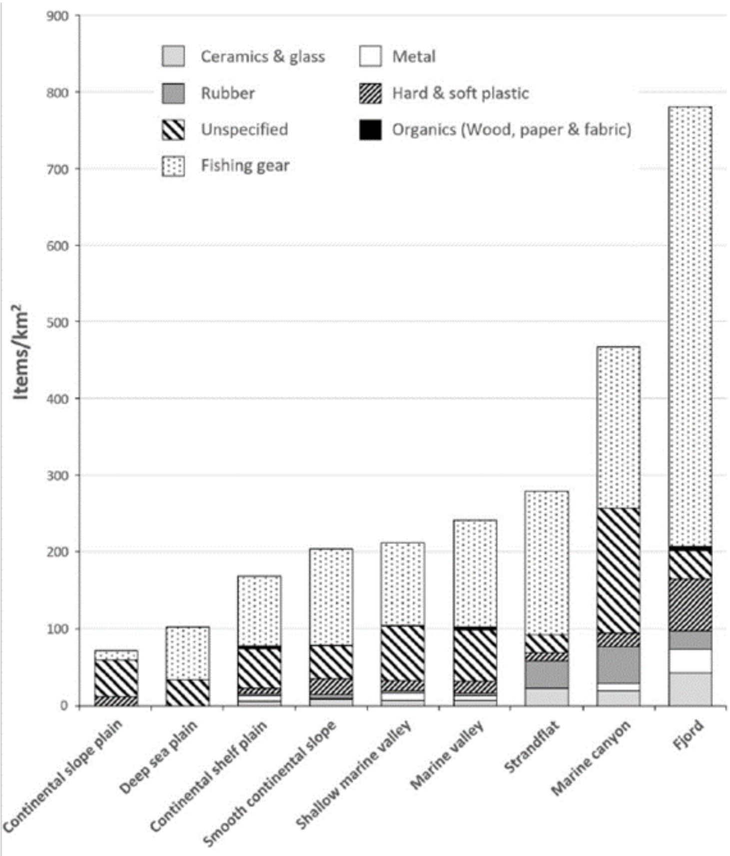


Figure 3.6. Density and composition of litter on the seabed in different marine landscapes from Ålesund and northwards to the Barents Sea. Litter is shown as mean numbers of items/km2 (Buhl-Mortensen et al. 2017).

This may be because litter is transported by currents and accumulates in troughs, canyons and local depressions, rather than directly reflecting fisheries' footprints. Many factors may influence the distribution of marine litter, causing local and regional variations in time and space. Studies report large variation in the occurrence and density of marine litter on the seabed, depending on distance to coastline, population densities, distance to shipping routes, rivers, topography, water currents and circulation. The size, shape, material densities and fouling processes also impact transport distance and sedimentation rates. This emphasizes the importance of regular monitoring to discover trends caused by, for example, changes in human activities and seasonal variations.

3.2.3.3 Occurrence of microplastics in Barents Sea sediments

Few studies have investigated the amount of microplastics in marine sediments within the Barents Sea. Data availability and current knowledge are both rather limited to support robust, spatiotemporal trend analyses, although microplastics have been found in the majority of investigated areas. Microplastics in marine sediments have been recorded in the MAREANO programme since 2018 (Jensen et al., 2018; Jensen and Bellec, 2021; Jensen and Bellec, 2023).

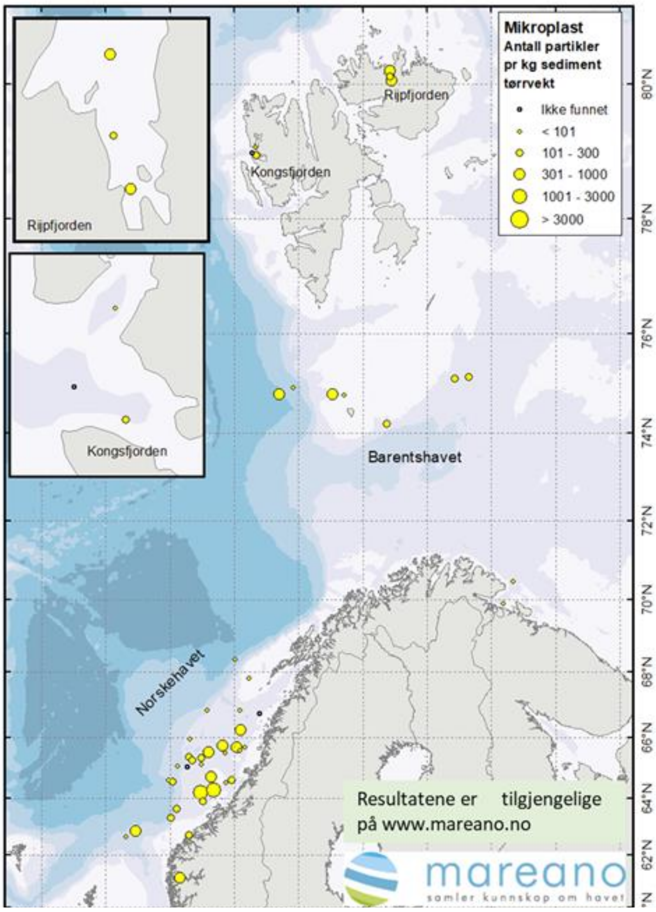


Figure 3.7. Microplastics in marine sediments reported by the MAREANO programme in 2018-2023 (particles per kg sediment dry weight).

The samples were collected at the continental shelf, slope and in the fjords, from Sognefjorden (Western Norway) in the South to Rijpfjorden (Svalbard) in the North (Figure 3.7). Despite three different laboratories analysing the samples with different methods, the results indicate low to moderate amounts of microplastics in all areas with no clear geographical patterns. A study from Kongsfjorden, Svalbard also found microplastics in sediments, although levels were low: On average, 0.33 anthropogenic particles were found per 100 g of surface sediment, dominated by plastic fibres (Collard et al., 2021). Method harmonization and more data are needed to compare levels of microplastics in sediments in different regions.

3.3 Hazards facing marine species and ecosystems in the Barents Sea

Key findings:

- Entanglement in marine litter is occurring within the Barents Sea area and may severely impact local fauna.
- Northern fulmars on Svalbard show increasing burden of ingested plastics with time.
- Arctic species are ingesting microplastics.
- Nest incorporation of marine litter is occurring and can result in entanglement and ingestion of plastics by seabirds.
- Floating marine litter can transport invasive microorganisms and invertebrates into the Barents Sea region.
- Harmonized methods are needed to compare results and investigate temporal and geographic trends.

- There are challenges regarding comparison of results when different analytical methods are used.
- Improved quality assurance and quality control systems are crucial for comparison between studies.

Knowledge gaps:

- The cumulative and interactive effects of marine litter and microplastic pollution on Arctic biota.
- The rate and extent of ghost fishing in the Barents Sea.
- The rate and effects of leaching or the transfer of plastics-associated chemicals into organisms and the environment.
- How efficient marine litter is in transporting and spreading of invasive species.
- There is a lack of a standard reporting system for entanglement of Arctic species to document the extent and possible hot spots for entanglement.

The high concentrations of marine litter and microplastics in the environment are leading to an increasing number of interactions between plastic particles and biota (Figure 3.8). This has a variety of physiological, biochemical, and environmental health consequences for these organisms and marine ecosystem in general.

Globally, the majority of investigated marine species have been shown to be affected by marine litter, through entanglement or ingestion (Kühn et al., 2015; 2020). Most of the documented interactions of marine biota with plastics have impacts at the organism- or sub-organism level; however, the most ecologically relevant effects are predicted at the population level and beyond, including impacts on assemblages, habitats and ecosystems (PAME, 2019). It has also been predicted that plastic pollution may have combined effects with other anthropogenic stressors, making it difficult to quantify the ecological effect of any singular stressor in isolation (PAME, 2019).

Entanglement and ghost fishing are the most conspicuous threats to marine biota: these impacts of marine litter are a serious animal welfare issue, in addition to their potential negative effects on biodiversity. Ingestion is the most common form of interaction between marine biota and microplastics particles and is most likely underestimated due to lack of investigation. Ingestion of marine litter may also result in exposure to harmful chemicals: there are growing concerns about leaching or translocation of chemical additives and other pollutants associated with plastics into organisms and the environment—although, again, there is limited knowledge on the effects of this exposure. Marine litter as a vector for transport of invasive species is also an issue of increasing concern.

When comparing ingestion or frequency of occurrence as a metric, it needs to be kept in mind that the particle size that could be observed due to the method and the extraction method of the plastic from the investigated material, will have a massive influence on the results. Thus, methods are often not sufficiently harmonized to enable reliable comparisons. Also, the lower the size of the plastic particle, the less reliable it is to compare numbers between studies and species.

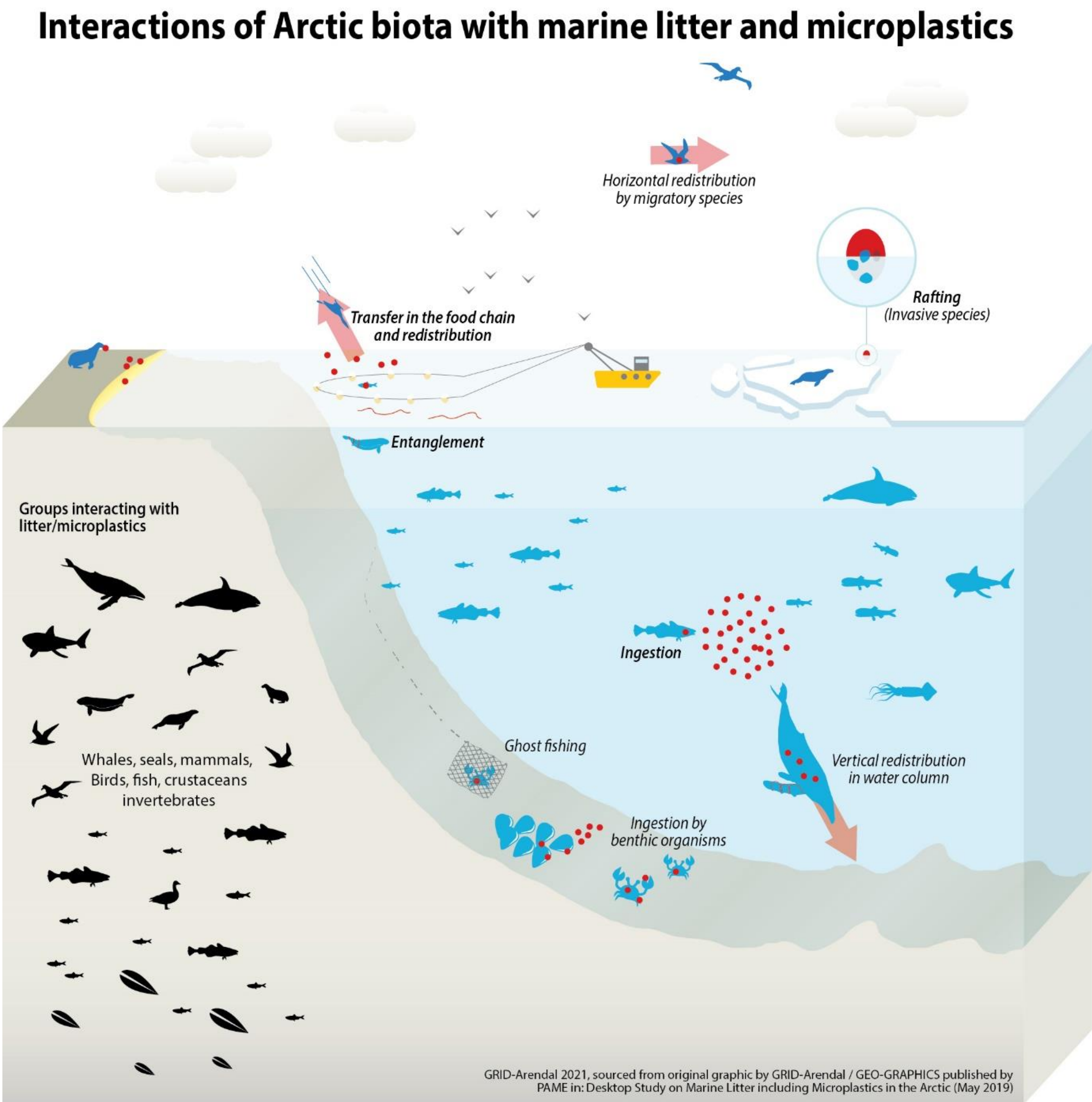


Figure 3.8. A schematic synthesis of marine litter and microplastics in the environment and the different modes of interaction in the Arctic biota.

3.3.1 Entanglement

Entanglement is a growing problem globally, and this issue is also occurring in the Barents Sea region. Marine mammals and seabirds have been observed entangled in marine litter around Svalbard and in the Russian part of the Barents Sea and Kara Seas, however there are no formal data to help identify the extent of the problem. These observations include mammals, such as polar bears, arctic foxes, harbour seals, bearded seals and seabirds, such as arctic tern, red-throated divers, Brünnich's guillemot, kittiwakes and northern gannets (Kovacs et al., 2018; Gavrilo et al., 2019). In addition, entanglement of bowhead whales has been recorded in the North Atlantic (Finley et al., 2021).

Entanglement of terrestrial mammals has also been recorded. Death by entanglement in beached derelict fishing gear and other marine litter, such as wire, was reported as early as 1986 for Svalbard reindeer (Øritsland, 1986). Since then, death by entanglement has been observed regularly for Svalbard reindeer, though no counted or written statement has been published. Also, arctic fox has been reported with derelict fishing gear around its neck (Hallanger et al., 2022).

Reindeer horns entangled in fishing net in Kongsfjoden, Svalbard (Photo credit: Geir Gotaas, NPI), and a dead seal caught in a fishing line (Photo credit: Governor of Svalbard).

3.3.2 Ghost fishing

Abandoned, lost or otherwise discarded fishing gear (ALDFG) will continue catching fish and invertebrates if not removed from the environment. This phenomenon is called ghost fishing. Since the start of 1980s, the Norwegian Directorate of Fisheries (NDF) has conducted annual surveys to retrieve reported ALDFG. Their focus has been pods and gillnets since these have the highest risk for ghost fishing. NDF estimates that since they started, they have retrieved approximately 1000 ton of equipment from the Norwegian Sea, Norwegian coastal areas and the Barent Sea, including 22 000 gillnets with a length of over 600 km (Norwegian Directorate of Fisheries, 2023).

In 2011 retrieved fishing gear had 'ghost fished' 14 metric tonnes of fish and approximately 12,000 crabs, primarily red king crab (McBride et al., 2014). Large et al. (2009) report approximately 2.9 t of fish and crustaceans in 535 retrieved gillnets from Norwegian waters, where 2.5 t was Greenland halibut from Norwegian waters.

ALDFG fishing net cleaned from the sea on Svalbard, Sabineodden 2023. Photo credit: Stian Pedersen.

3.3.3 Ingestion

3.3.3.1 Seabirds

Seabirds are widely recognized as biological indicators of pollution levels, with plastics found in over half of seabird species worldwide (Kühn et al., 2020). Ingestion of plastics by seabirds is an increasing problem, even in remote or isolated areas like the Arctic (Mallory et al., 2006; Provencher et al., 2009). In the Arctic, ingested plastics have been reported in 53% of seabird species (i.e., 27 out of 51) (Baak et al., 2020).

Research on northern fulmars prevails amongst other seabirds due to their recognition as biological indicators of levels of pollution, distribution across the northern hemisphere—enabling standardized comparisons to be made (Trevail et al., 2015; van Franeker et al., 2015; Provencher et al., 2017) — and high vulnerability to plastics ingestion because of their feeding habits (van Franeker et al., 2011).

Northern fulmars are surface feeders, and ingested plastic is used to indicate environmental quality using the OSPAR method (van Franeker et al., 2011). This is primarily monitored through OSPAR in the North Sea, but several studies have been conducted in the Arctic and Barents Sea region using the same or similar methods (Mehlum et al., 1984; Gjertz et al., 1985; Lydersen et al., 1985; van Franeker 1985; Weslawski et al., 1994; Trevail et al., 2015; Herzke et al., 2016; Collard et al., 2022; Tulatz et al., 2023). Studies on northern fulmars in the Svalbard region demonstrate an increase in frequency of ingested plastics, from 29% to 95% within ~40 years (Trevail et al., 2015; Collard et al., 2022). Not only has the frequency of birds with ingested plastic increased, also the amount of ingested plastic has increased with time (Collard et al., 2022). It has also been shown that fulmar chicks get fed plastic by their parents resulting in higher counts of plastic in chicks compared to adults (Tulatz et al., 2023).

Plastic pieces in a northern fulmar stomach. White line in the right-hand corner is 5mm for size comparison. Photo credits: France Collard.

Ingestion of plastics by seabirds has been studied in several other species in northern areas, from eastern Greenland to Franz Josef Land (Table 2). The frequency of plastics ingestion was low in black-legged kittiwakes (Mehlum et al., 1984; Gjertz et al., 1985; Lydersen et al., 1985), little auks (Mehlum et al., 1984; Gjertz et al., 1985; Lydersen et al., 1985), great skua (Knutsen, 2010), glaucous gulls (Mehlum et al., 1984; Lydersen et al., 1985; Weslawski et al., 1994; Benjaminsen et al., 2022) and Brünnich's guillemots (Mehlum et al., 1984; Gjertz et al., 1985; Lydersen et al., 1985).

No plastics were found in sea birds such as common eiders (Mehlum et al., 1984; Lydersen et al., 1985; Weslawski et al., 1994), black guillemots (Mehlum et al., 1984; Gjertz et al., 1985; Lydersen et al., 1985; Weslawski et al., 1994), atlantic puffins (Lydersen et al., 1985), arctic tern (Weslawski et al., 1994), ivory gulls (Mehlum et al., 1984; Gjertz et al., 1985), great cormorant (Benjaminsen et al., 2024), European shag (Benjaminsen et al., 2024), long-tailed skua (Mehlum et al., 1984), and pomarine skua (Gjertz et al., 1985).

Microplastics were also found in the gular pouches of little auks in eastern Greenland—this is a concern, as the pouches hold food for their chicks (Amélineau et al., 2016). Plastics ingestion rates may also vary, due to time of year, morphological differences, foraging range, diet, or retention times of different plastics.

3.3.3.2 Marine fish

Ingestion of plastics has been reported in several species of fish within the Barents Sea and adjacent seas. The amount and frequency of the occurrence of plastics and microplastics are low for all studies. Some studies show higher incidence of ingestion closer to urban areas or areas of higher human activity (Bråte et al., 2017). Moreover, the prevalence of ingested plastics seems to be higher in benthic fish compared to pelagic fish (Morgana et al., 2018).

In Atlantic cod caught in northern Norway no ingested plastics were found (Bråte et al., 2017), though in the Westfjords fishing grounds in Iceland ingested plastic was found in 20.5% of sampled Atlantic cod and 17.4% of the saithe (de Vries et al., 2020). Ingested plastic has also been found in 23% of Atlantic mackerel and in 7.5% of the sampled blue whiting from Icelandic waters (Malinen, 2021). Ingested plastic was found in 34% of bigeye sculpins and 18% of polar cod from the eastern Greenland Sea (Morgana et al., 2018) and in 2.8% of juvenile polar cod from around Svalbard (Kühn et al., 2018). Greenland sharks from Svalbard and southern Greenland ingested plastics with 3% and 8.3% occurrence, respectively. All ingested plastics in the sharks were microplastic particles and associated with pollution from fisheries (Leclerc et al., 2012; Nielsen et al., 2014). No plastic was found in striped snailfish and shorthorn sculpin from Hornsund, Svalbard (Lydersen et al., 1985).

Microplastics are also found in the livers and muscles in fish from other regions (Collard et al., 2017; Akhbarizadeh et al., 2018; Gomiero et al., 2020), and it is assumed that this will also be found when investigated within the Arctic.

3.3.3.3 Marine invertebrates

Ingestion of plastics has been reported in many marine invertebrates within the Barents Sea region (Table 9.1). Ingestion has been observed in species that are filter feeders, deposit feeders, carnivores, omnivores and herbivores. Results suggest that benthic omnivores (including commercially harvested decapods) tend to accumulate more microplastics than species with other feeding habits.

To a varying degree microplastics have been found in blue mussel (Sundet et al., 2016; Lusher et al., 2017; Bråte et al., 2020, Icelandic cockle (Sundet et al., 2016; Gebruk et al., 2022), northern astarte (Gebruk et al., 2022), narrow-hinge astarte (Gebruk et al., 2022), Greenland cockle (Gebruk et al., 2022), chalky macoma (Gebruk et al., 2022), *Hiatella arctica* (Teichert et al., 2021), northern yoldia (Gebruk et al., 2022), great spider crab (Gebruk et al., 2021), hermit crab (Gebruk et al., 2021), red king crab (Fuhrmann et al., 2017) and snow crab (Gebruk et al., 2021). Microplastic has also been reported in the amphipods Gammarus setosus (Iannilli et al., 2019), *Apherusa glacialis, Themisto libellula* and *Themisto abyssorrum* (Botterell et al., 2022) and in the copepods *Calanus hyperboreus* and *Calanus glacialis/finmarchicus* (Botterell et al., 2022) (Table 2).

3.3.3.4 Marine mammals

Information of ingestion of plastics and microplastics is generally lacking within the Barents Sea region. Plastic has been detected in walrus faeces (Carlsson et al., 2021). Stomach content from fin whales western Iceland has also been reported to contain plastic (Garcia-Garin et al., 2021). Though earlier studies of bearded seals and ringed seals did not observe ingested plastic (Lydersen et al., 1985).

3.3.4 Nest incorporation

Nest incorporation, a widespread phenomenon where seabirds use plastic as building material for their nests, can also lead to entanglement of adult birds and offspring. Plastic debris in the nest can also be ingested while adults are raising chicks.

Within the Barent Sea region nest incorporation has been observed to a varying degree depending on species and sites. European shag, common eider, black legged kittiwakes, northern gannets, ivory gulls, herring gull, glaucous gull and Atlantic puffins has all been reported to have incorporated plastic into nests to varying degree (Gavrilo et al., 2019; O'Hanlon et al., 2021). No plastic was observed incorporated into nests of great cormorant, greater black-backed gull, common gull, arctic tern, barnacle goose, and common guillemot (Gavrilo et al., 2019; O'Hanlon et al., 2021). Since there is still little information on nest incorporation in the Barents Sea area and information on many potential species that could incorporate plastic into their nest, it is hard to quantify the extent to which this is taking place. Given species and sites, the frequency of occurrence can range between 0 % to 91 % (O'Hanlon et al., 2021).

Northern gannets with plastics incorporated in their nests at Runde, Norway. Photo credit: Jan Helge Fosså, IMR.

3.3.5 Plastic-associated chemicals

The biological hazards and ecotoxicological effects of digesting plastics for marine biota remain poorly understood. Increased concerns are related to potential adsorption and transport of chemicals within and among food webs and leaching of endocrine-disrupting pollutants (Avio et al., 2017).

A wide variety of chemicals have been found in and on marine litter, such as UV stabilizers, phthalates, brominated flame retardants and polychlorinated biphenyls (PCBs) (Rochman et al., 2013; Gauquie et al., 2015; Rani et al., 2015; Jang et al., 2016). These are collectively referred to as "plastic-associated chemicals". Here, we distinguish between chemicals present in plastics before they enter the marine environment and chemicals that sorb onto the plastics in aquatic ecosystems.

3.3.5.1 What are additives and sorbed contaminants?

Chemicals added intentionally to plastics during manufacture are called additives. Additives are added during plastics production to change the properties of the final product. Examples include flame retardants to decrease flammability, UV stabilizers to strengthen a product's resistance to UV degradation, biocides to protect the product against bacteria, mould and biofouling, and plasticizers to change the ductility of the product (Hansen et al., 2013; Hahladakis et al., 2018). Plastics also commonly contain a number of by-products, unreacted monomers and other impurities (Zimmermann et al., 2019).

Sorbed contaminants are typically hydrophobic organic chemicals that adsorb onto or absorb into plastics drifting in the marine environment (Mato et al., 2001; Rochman et al., 2013). One study also found metals sorbed onto marine plastics (Rochman et al., 2014). Importantly, sorbed contaminants are not purposely added to plastics, but there are overlaps between added and sorbed chemicals. Flame retardants, for example, may be both intentionally added to the polymer and sorb onto plastics later.

Europe alone produces more than 400 different plastic additives in quantities above 100 tonnes per year (ECHA, 2019). As additives are added to polymers to modify a product's appearance and/or physicochemical properties, their amounts and ratios vary, both between different types of polymers and also within the same polymer, depending on the intended usage of the final products (Hansen et al., 2013; Hahladakis et al., 2018). The migration potential and consequent leaching of additives out of plastics depends on several factors; of these, the size of the additive, temperature and the physicochemical properties of the surrounding medium are among the most important (Möller et al., 1994; Reynier et al., 2001; Marcato et al., 2003; Galotto et al., 2011; Beldí et al., 2012; Suhrhoff et al., 2016).

3.3.5.2 Are plastics additives found in Barents Sea biota?

A study on plastics ingested by fulmars from the Faroe Islands found UV stabilizers, flame retardants, and by-products in the plastics (Tanaka et al., 2019). Additives and by-products have been shown to be still present at detectable levels in plastics, even after weathering and fragmentation in the ocean. Indeed, it was found that plastics collected on a beach in the Netherlands leached 15 different additives into stomach oil collected from northern fulmars (Kühn, 2020).

Several chemicals also associated with plastic has been reported in sea birds from the Barents Sea region. Traces of additives were found in the livers of northern fulmars that had ingested plastic. Chlorinated paraffins (CPs; plasticizers), decloranes (flame retardents) and polybrominated diphenyl ethers (PBDEs; flame retardants) have been found in plastic pieces ingested by northern fulmars from Vesterålen (northern Norway) and Rogaland (southern Norway) and Faroes Iceland (Neumann et al., 2021; Collard et al., 2022). However, none of the studies observed a correlation between plastic burden and contaminant concentrations. Nonylphenols and bisphenol A has been measured in Greenland sharks around Greenland (Ademollo et al., 2018).

3.3.5.3 Do we find sorbed contaminants in plastics from the Barents Sea?

Contaminants, such as persistent organic pollutants (POPs), have been shown to sorb onto marine plastics in studies conducted elsewhere (Mato et al., 2001; Teuten et al., 2009; Rochman et al.,2013). Similar processes are likely occurring in the Barents Sea. Indeed, POPs have been found in plastics in the stomachs of fulmars from northern Norway (Herzke et al., 2016).

While there is extensive literature on contaminants in the Barents Sea region (AMAP, 2018), few studies have investigated possible links between contaminant and plastics loads. In fulmars from Svalbard, no difference in contaminant burden was observed between birds with no ingested plastics and birds with ingested plastics (plastics size ≥ 1 mm, OSPAR method) (Trevail et al., 2014; Ask et al., 2016). Regarding POPs, the fulmar's normal diet is the main source of POPs, and the contribution of POPs from plastics is small (Herzke et al., 2016). It has also been suggested that ingested plastics may even decrease the concentration of POPs available for absorption by an organism through diet, due to the sorption of POPs to the plastics particles instead of bioaccumulating (Koelmans et al., 2016).

Environmental contaminants such as CPs, PCBs and PBDEs are frequently measured, and often at high levels within species of wildlife from the Barents Sea region (Muir et al., 2006; Reth et al., 2006; Fuglei et al., 2007; Routti et al., 2009; de Wit et al., 2010). These are chemicals that undergo long range transport (Borga et al., 2001; Ma et al., 2014; de Wit et al., 2010) and cannot be linked to plastics ingestion without additional information regarding stomach plastics content. More research is therefore needed to determine whether additives leach out of ingested plastics and are absorbed by the organism.

In summary, the role of plastics as vectors of sorbed contaminants is highly complex, requiring more research before conclusions can be reached.

3.3.6 Invasive species

Floating litter is responsible for the widespread distribution of many marine species that 'hitch a ride' on the litter (Barnes, 2002; Barnes and Milner, 2005; Weslawski et al., 2018). Floating plastics can also become a new pelagic habitat for microorganisms and invertebrates. Communities that form on the surface of plastic objects are called 'epiplastic': these include a variety of organisms, from cyanobacteria, diatoms and coccolithophoritis, to bryozoans and other invertebrates (Reisser et al., 2014).

The Arctic's low temperature is the most important barrier to invasion by seaborne invasive species. However, this barrier is weakened by the warming of the Arctic Ocean and reduction in sea-ice cover (Barnes, 2002). Of all collected marine litter in 2002 from Kongsfjorden (Svalbard), 7% contained alien organisms (Barnes and Miller, 2005), and in 2017 eight larger plastic items was found colonized with species previously not reported for Svalbard at from Prins Karls Forland (Svalbard) (Weslawski et al., 2018).

3.4 Sources of marine litter and microplastics in the Barents Sea

Key findings:

- The fishing industry is a prominent source of marine litter in the Barents Sea, while the contribution from other marine industries is unclear.
- A Deep-dive informational assessment of marine litter from the region have demonstrated that fishing nets and ropes are being lost or discarded during repairs.
- Post-consumer waste is also recorded on the coast of Svalbard and northern Norway.
- Microplastics are directly discharged into the Barents Sea from communities lacking wastewater treatment plants.
- Microplastics may be directly discharged from routine operations in marine industries.

Knowledge gaps:

- Temporal and geographical trends of the amount of marine litter and microplastics originating from various sources.
- The extent to which marine litter and microplastics originate from local sources and the significance of long-range transport of litter into the region.
- The extent to which marine industries, in particular aquaculture, petroleum, and shipping (including cruise tourism), are contributing to the input of marine litter and microplastics in the Barents Sea.

3.4.1 Marine litter

3.4.1.1 Commercial fishing is a prominent source of marine litter in the Barents Sea

As discussed above, much of the litter found on beaches in Svalbard and in northern Norway has been linked to commercial fishing activities. Fishing-related items registered during beach clean-ups and deep-dives include nets, ropes, trawling equipment, net floats, fish boxes and containers. Most of the nets found in studies of beach litter in Svalbard were trawl nets, used in fisheries for whitefish and shrimp in the Barents Sea (Nashoug et al., 2017; Falk-Andersson et al., 2019). These findings are supported by an analysis of fishing nets washed up on beaches in Svalbard and Jan Mayen (Strietman, 2021).

Monitoring of marine litter on the seabed in the Barents Sea also shows that fishing-related items, such as ropes, strings and cords, pieces of nets, floats/buoys, dominate the litter found on the seabed (Buhl-Mortensen, 2018). Elevated levels of litter on the seabed are found closer to the coast in areas with high fishing intensity (Figure 3.9), suggesting that marine litter on the seabed reflects fishing activity in the region.

Documenting marine litter collected as part of a cleaning action on Svalbard led by Marfo, Norwegian Center Against Marine Litter. Photo credit: Bo Eide.

The nationality of the litter associated with commercial fishing is difficult to identify, as gear from vessels of different nationalities are often produced by the same manufacturers. Many trawl nets found on beaches in Svalbard show a lack of fouling: this suggests that they were not transported long distances by ocean currents and are more likely to originate from vessels operating locally in the Barents Sea (Falk-Andersson, 2019).

Some fishing-related items are likely lost because of equipment wear or insufficient securing of equipment; however, some of the registered items also appear to have been dumped or discarded. Qualitative beach litter analyses from fisheries experts in Svalbard found many nets and ropes to have clean cuts, indicating that they were discarded (Nashoug et al., 2017; Falk-Andersson et al.,2019). It is assumed that parts of trawl nets are lost or dumped when they are clean-cut during repairs.

Indeed, a recent analysis of fishing nets washed up on beaches in Svalbard and Jan Mayen found that the pieces of nets largely came from the mismanagement of net cuttings during on-deck mending (Strietman, 2021). Moreover, many of the nets from Svalbard were less than five years old, suggesting that this is an ongoing practice (Falk-Andersson et al., 2019).

These findings highlight the need to improve the collection and disposal procedures of net-cutting waste on bottom trawling vessels, and to have adequate port reception facilities.

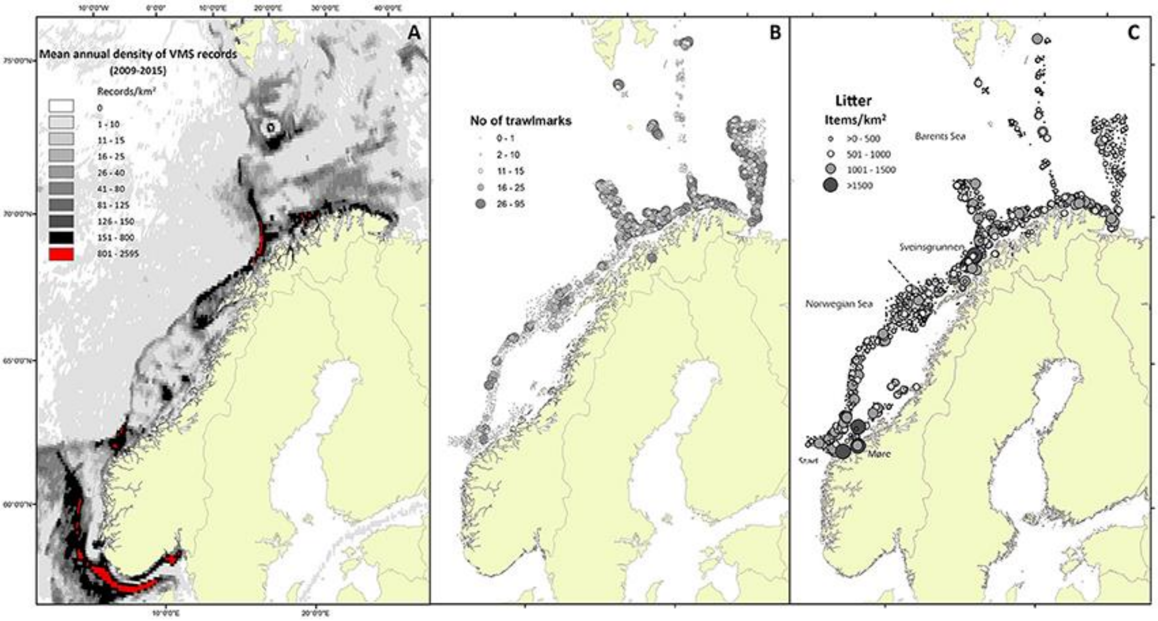


Figure 3.9: Overview of indicators of fishing intensity (a) and impact (b, c) on the seabed in the Norwegian and Barents Sea: a) Annual mean density of Vessel Monitoring System (VMS) records (pings) based on aggregated data for 2009–2015; b) number of trawl marks observed during visual inspections; c) density of seabed litter observed during visual inspections (Buhl-Mortensen 2018).

3.4.1.2 The impact of other marine industries

Although commercial fishing vessels appear to be the most prominent source of litter on beaches and on the seabed in the Barents Sea, marine litter may also come from other marine industries in the region, such as aquaculture, petroleum and shipping (including cruise tourism). Commercial fishing vessels—mainly Norwegian and Russian—account for most of the logged operating hours in the Barents Sea (Silber, 2019), but there is also a high presence of other marine industries, such as cargo ships, ships associated with the petroleum industry, aquaculture and passenger ships (Figure 3.10). However, unlike the fishing industry, there are few direct links between the objects and their source (i.e. aquaculture installations, ships in transit or oil and gas exploration). This makes it difficult to determine the relative contribution of aquaculture, shipping and petroleum to marine litter based on source identification.

Studies of beach litter in Svalbard and northern Norway suggest a link between the nationality of food containers and the nationality of vessels operating in the same area (Falk-Andersson et al., 2018; Falk-Andersson et al., 2019). These findings suggest that marine activities in general could be a source of marine litter in the Barents Sea region. However, the potential discharge of marine litter from these industries remains uncertain and requires further examination.

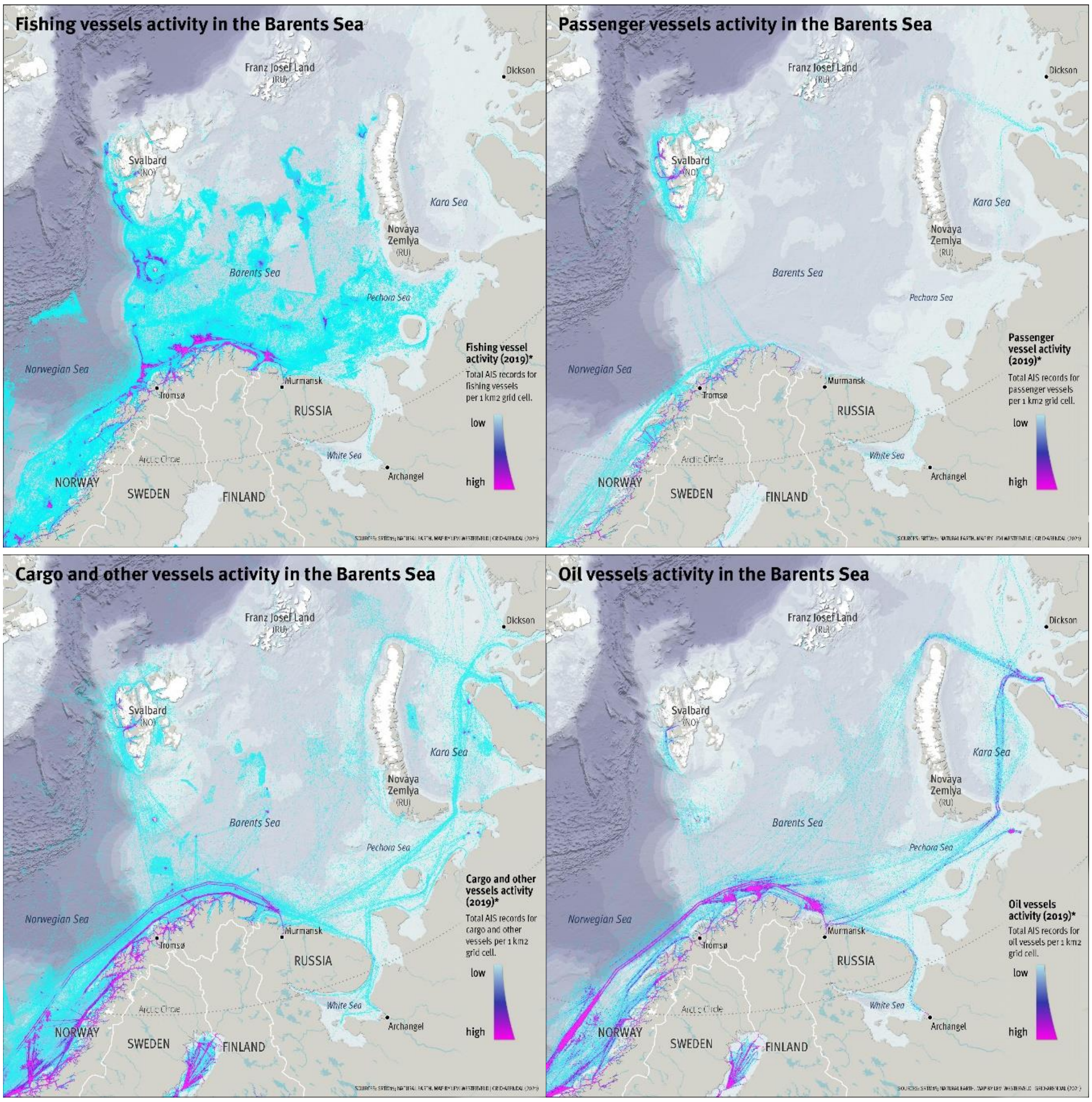


Figure 3.10. Vessel activities in the Barents Sea, based on AIS records from 2019, from 1) fishing vessels, 2) passenger vessels (registered in the AIS records as passenger ships and cruise ships), 3) cargo and other shipping vessels (registered in the AIS records as bulk carriers, general cargo ships, container ships, ro-ro cargo ships, refrigerated cargo ships, offshore supply ships, other service offshore vessels and other activities) and 4) oil vessels (registered in the AIS records as crude oil tankers, oil product tankers, chemical tankers and gas tankers). All the documents have been generated based on the authorized use of data obtained from the Arctic Council Working Group on the Protection of the Arctic Marine Environment's Arctic Ship Traffic Data (ASTD) System. Sources: SRTM12; Natural Earth. Map by Levi Westerveld, Grid-Arendal (2021).

3.4.1.3 Domestic litter is commonly registered along the coast

The presence of domestic litter in the form of household items (mostly estimated to be of local origin) is more prominent on beaches in northern Norway compared to findings in the northern part of the Barents Sea, as described in Section 2. However, beach litter in Svalbard is also comprised of many small, household-related plastic items, such as product packaging and food containers (Nashoug, 2017).

Drinking bottles are some of the most common items registered, and shampoo bottles, cotton buds and various articles of clothing are also often found. However, it is difficult to identify the nationality and origin of these items, as labels on product packaging tend to wear off. More knowledge is needed to establish origin of domestic litter in the Barents Sea to address the appropriate sources.

3.4.2 Microplastics

An analysis of microplastics composition near Svalbard suggests that they may result from three main sources: the breakdown of larger items, transported over large distances by prevailing currents or originating from local vessels; sewage and wastewater inputs from coastal areas; and transport by ocean and atmospheric currents. Additionally, a recent study has shown that the microplastics distribution pattern in the Barents Sea correlates both with oceanic circulation and fishing activities (Tošić et al., 2020).

However, few studies have addressed the inputs of microplastics to the Arctic marine environment, and the relative contribution from local sources or long-range transport from distant sources remains unclear.

3.4.2.1 Wastewater facilities are local sources of microplastics

All human settlements are local sources of microplastics—both fibres and particles. Two studies have shown that microplastic particles and fibres are released from wastewater in Svalbard. In Ny-Ålesund, a treatment plant was installed in 2015, and is the only wastewater treatment plant in Svalbard. This treatment plant reduced the output of microplastics in the size range 0.05-5 mm by 99% (Granberg et al., 2019).

In Longyearbyen, there are currently no wastewater treatment plants. The total yearly emissions of microfibers into the Adventfjorden by wastewater effluent amount to 18 billion non-white microfibers of the size 0.05–5 mm. This means that microplastics emissions from untreated wastewaters of Longyearbyen are similar in scale to emissions from a modern wastewater treatment plant in Vancouver, Canada, serving a much larger city of 1.3 million people. This provides evidence that untreated wastewater from small settlements is important local source for microfiber emissions in the Arctic (Herzke et al., 2021).

3.4.2.2 Microplastics from maritime activities

Fragments of dolly ropes found on Norwegian beaches suggest that bottom-trawl fisheries are a source of microplastics from the wear and tear of such equipment. Most bottom-trawl fisheries in Norway are in the northern parts of the Norwegian Sea and in the Barents Sea, and some use dolly ropes to protect the trawl nets. Dolly ropes are also used extensively in several European fisheries and some of the fragments may have been transported by ocean currents from distant sources. More knowledge is needed to distinguish between the contribution from fisheries within and outside the Barents Sea.

Aquaculture facilities in northern Norway are also potential sources of discharged microplastics, due to wear on equipment like feeding tubes, ropes and netting (SINTEF, 2017). Routine operations in aquaculture facilities have been linked to the fragmentation and release of microplastics: these include the extensive hosing of equipment (to prevent biofouling) (Lusher et al., 2017) and transport of food pellets in feeding tubes.

Shipping may also be a significant source of microplastics discharge. Antifouling paint used on hulls has a relatively high polymer content that can end up in the marine environment, especially during hull cleaning in regions with insufficient regulations and systems for preventing discharge of environmentally harmful substances during routine operations at shipyards (IMO, 2019). Insufficient securing of cargo can also result in significant discharge of plastic pellets (GESAMP, 2015).

4. Policy initiatives and regulations addressing marine litter and microplastics

In this section, we present national Norwegian laws and policies aimed at monitoring and reducing pollution from marine litter and microplastics.

As a member of the European Economic Area (EEA), Norway is also bound by various European Union regulations, and in this section, we will summarise the ones that are relevant for marine litter and microplastics. We also provide a short overview of other relevant international and regional organisations and agreements.

There are several factors that are relevant to addressing the problem of marine litter and microplastics and thus a comprehensive response is required. Accordingly, policies addressing the whole life cycle of plastics are important, as is increasing the circularity of plastics. We therefore outline a range of legislative frameworks of relevance.

A number of initiatives is currently under negotiations; this report gives the status of regulations and policy initiatives as per spring 2024.

4.1 Norwegian and European Union laws and policies

Norway's environmental policies are developed by the government and determined by Parliament (Storting). The Ministry of Climate and Environment has the overall responsibility for administrating the government's environmental policies. However, the policies concerning marine litter and microplastics are addressed by several ministries, with both the Ministry of Trade, Industry and Fisheries and – to a lesser extent – the Ministry of Transport having responsibilities for policies in this area.

Marine plastic pollution is addressed both directly in Norwegian policies and legislation, as well as indirectly through legislation concerning waste management and pollution. The Pollution Control Act[5] includes a general prohibition against pollution and littering—both on land and at sea. It also provides a basic legislative framework for reducing and preventing pollution and for waste management.

In 2021[6] the government presented a cross-sectoral national strategy for a green circular economy and in 2024[7] the new government published an updated action plan on circular economy. These policy documents form the foundation for the governments work to secure economic growth in Norwegian industries and businesses while achieving a more circular economy.

In 2021, Norway also published a dedicated strategy for plastics, which sets out a comprehensive approach to reducing plastic litter and plastic pollution, including in the marine environment. This strategy forms the framework for further national work to increase the amount of recycled plastic and reduce the amount of plastic litter in nature.[8]

Action on plastics is also identified as a priority by the EU in the European Circular Economy Action Plan[9] and a dedicated Plastics strategy[10]. In addition to increasing reuse and recycling, policies that address design and use phase are key to reducing plastic pollution. These policies include, for example, rules on eco-design of products – for example for textiles and tyres – and an outright ban on certain intentionally added microplastics.

4.1.1 The key regulatory authorities

4.1.1.1 Ministries

[5] Pollution Control Act - regjeringen.no
[6] Nasjonal strategi for ein grøn, sirkulær økonomi - regjeringen.no
[7] Handlingsplan for en sirkulær økonomi - regjeringen.no
[8] Norwegian Plastics Strategy - regjeringen.no
[9] Circular economy action plan - European Commission (europa.eu)
[10] Plastics strategy - European Commission (europa.eu)

As the Ministry of Climate and Environment bears the overall responsibility for administrating the Norwegian government's environmental policies, they develop and enforce policies and regulations regarding waste, marine litter and microplastics, amongst others. They also ensure that Norway complies with international agreements.

The Ministry of Trade, Industry and Fisheries develops and enforces policies and regulations involving fisheries and aquaculture.

4.1.1.2 Directorates

The Norwegian Environment Agency (NEA) is responsible for implementing policies of relevance to marine litter and microplastics. The NEA drafts and enforces regulations for waste and pollution and provide guidelines and advice on how the legal framework should be practised.

The Norwegian Polar Institute (NPI) provides professional and strategic advice to the Norwegian authorities on environmental management in the polar regions. It also conducts research in polar regions, including on marine litter and microplastics.

The Norwegian Directorate of Fisheries (NDF) is responsible for implementing policies involving fisheries and aquaculture, and enforces regulations for preventing abandoned, lost or otherwise discarded fishing gear (ALDFG). NDF also organizes an annual retrieval programme for lost fishing gear.

The Norwegian Maritime Authority (NMA) exercises authority and supervises waste handling on ships, including fishing vessels.

The Norwegian Coastal Administration (NCA) exercises authority and initiates clean-up measures when acute pollution or marine litter pose a risk to maritime safety.

4.1.1.3 Local authorities

The County Governors are the state's representatives within geographical regions, and the municipalities are the state's local representatives. The County Governors coordinate regional clean-up initiatives for marine litter. They give permits to local waste management facilities, including waste disposal facilities in Norwegian ports; they also supervise waste management and pollution from industries under the Governors' authority.

The municipalities are responsible for ensuring that there is local infrastructure for handling municipal waste, and they exercise authority in cases of littering.

4.1.2 Addressing marine litter from fisheries and aquaculture

Marine litter collected on Svalbard, stemming from fisheries. Photo credit: Stian Pedersen.

Policies on abandoned, lost, or otherwise discarded fishing gear (ALDFG) are important to addressing marine plastic pollution in the Barents.

Effective waste management of ship-generated waste is dependent on the availability of well-working port reception facilities and is important to preventing marine pollution from ships. Ports are obliged to receive waste from ships such as oily water, garbage, and sewage. Marine litter that is passively fished by the vessel is also considered a waste type that should be disposed of by ships at ports for no additional fee[11].

4.1.2.1 Regulatory incentives for reducing ALDFG

Under the Norwegian Marine Resources Act[12], it is illegal to dump or abandon fishing gear at sea, and fishermen are obliged to search for and retrieve lost fishing gear. If the retrieval is unsuccessful, fishermen must report losses to the authorities. Based on these reports, the Norwegian Directorate of Fisheries (NDF) organizes an annual retrieval programme for lost fishing gear. Retrieved gear is returned to their respective owners if possible.

The EU Directive on the reduction of the impact of certain plastic products on the environment (2019/904) – often called the single-use plastics (SUP) Directive – also addresses ALDFG. The Directive requires that the Member states establish a producer responsibility scheme for fishing gear containing plastics, including from recreational fishing and aquaculture. These schemes should be in place by 2025. National implementation in Norway is ongoing as per spring 2024.

[11] Endringer i regelverk om levering og mottak av avfall og lasterester fra skip - regjeringen.no
[12] The marine resources act (fiskeridir.no)

Norway is party to the MARPOL Convention under the UN International Maritime Organisation (IMO), which provides a legislative framework for regulating ship-generated waste. This includes lost fishing gear. MARPOL Annex V – which is also implemented in Norwegian law – prohibits all discharge of waste into the sea.

In focus: Retrieval surveys for lost fishing gear

Since 1983, the Norwegian Directorate of Fisheries (NDF) has conducted annual retrieval surveys for lost fishing gear along the Norwegian coast. The effort is based on fishermen's reports of lost gear, and the retrieval efforts have concentrated mainly on gill nets, traps, and pots, since these are assumed to have the largest impact in terms of ghost fishing. However, also many other gears such as lines, seines or ropes, are retrieved annually. Retrieved gear that has been marked appropriately is returned to the owner. This incentivizes fishermen to both mark their gear and report lost gear.

4.1.2.2 Port reception facilities – managing ship generated waste

Port reception facilities are regulated under EU Directive (2019/883) that has also been incorporated into Norwegian law.

The Directive is based on the provisions of the above-mentioned MARPOL Convention. The main requirement of the convention is that ports must ensure appropriate reception facilities for waste and cargo residues from ships in the ports and that these must be sufficient to cover the port's normal delivery needs. One of the changes that were introduced when the original Directive was amended in 2019, aims at further incentivising ships to bring waste into the ports by implementing an indirect fee that all ships (with some exceptions) arriving at a port must pay. The fee will cover the costs of managing waste from ships but also include the costs of handling passively fished waste (including ALDFG).

4.1.3 Ensuring effective waste management

Effective solid waste and wastewater management is important to addressing land-based sources of marine litter and microplastics. The Norwegian Pollution Control Act sets the national legislative framework for waste management and for reducing the quantity of waste.

The basic definitions related to waste management and targets for preparing for re-use and recycling of waste materials stem from EU Waste Framework Directive (2008/98/EC).

The Directive also sets rules concerning extended producer responsibility schemes. Additionally, other relevant EU regulations include the Packaging and Packaging Waste Directive (94/62/EC).

4.1.3.1 The regulatory regime for municipal waste

Norwegian legislation distinguishes between household, industrial and hazardous waste. The type of waste determines who is responsible for managing the waste and how the waste is handled (e.g. landfilling, incineration or recycling).

Under the Pollution Control Act, municipalities are responsible for ensuring the appropriate collection and treatment of household waste.

Since 2023, both municipalities and private sector actors that produce municipal waste – such as for example restaurants, cafes, or grocery stores – are obliged to sort out food and plastic waste at source. This new regulation is aimed at increasing re-use and recycling rates of these waste fractions.

Industrial waste includes all waste that occurs in both private and public companies and institutions. Under the Pollution Control Act, private and public companies are responsible for ensuring that their waste is delivered to an approved waste treatment facility.

In 2018, the EU adopted amendments to the Waste Framework Directive, while a review of Packaging and Packaging waste Directive was agreed upon in the EU in 2024. These include increased and long-term goals for the preparing for reuse and recycling of municipal waste and packaging waste from both households and enterprises. As these include plastic products, the amendments are relevant to work on reducing sources to marine litter. When it comes to packaging, the new rules include for example an objective that all packaging placed on the EU market must be recyclable by 2030.

In focus: Norwegian Retailers' Environment Fund

The Norwegian retail industry established the Norwegian Retailers' Environment Fund to comply with the EU Directive on Packaging—this amendment to the PPW Directive is aimed at reducing the consumption of lightweight plastic carrier bags. The Norwegian Retailers' Environment Fund requires a membership fee, either from member retail stores or the plastic bag producers/vendors (on behalf of the members). Through direct allocation of means, the Fund supports initiatives that aim to 1) reduce plastic littering and the consumption of plastic bags, and 2) increase the resource efficiency of plastic, including recycling. It is managed by representatives in the industry and is open to all retailers selling plastic bags.

4.1.3.2 Addressing single-use plastic

The SUP-Directive (2019/904) introduces a ban on certain plastic single-use products, such as cutlery and cotton bud sticks. The ban also includes some packaging items made of expanded polystyrene, such as food containers intended for take-away.

The Directive also focuses on limiting the use and littering of a range of other plastic products through design and labelling requirements, awareness-raising measures, and separate collection schemes. Both the provisions on ban and on labelling are implemented in Norway.

4.1.3.3 Extended producer responsibility

Extended producer responsibility (EPR) is a key regulatory principle that applies to several types of waste. In this approach, manufacturers and importers are responsible for their products throughout the life cycle—even after the product has been discarded as waste. This is implemented in part through membership in various producer responsibility schemes. The producer responsibility schemes ensure that the waste is collected, sorted and recycled, and that the costs are covered by the producers.

In Norway, producers and importers of packaging, electrical and electronic equipment, vehicles, batteries and insulating glass panels containing polychlorinated biphenyls (PCBs) are obliged to be a member of a producer responsibility scheme. An environmental fee is added to the price of goods set on the market. The amount of the fee is determined by the costs associated with collection and end-of-life treatment of the product.

As mentioned here above, the SUP Directive includes provisions on EPR for certain products, including fishing gear and aquaculture equipment containing plastic.

As part of the EU Green Deal and under a targeted revision of the waste framework Directive proposed by the Commission in July 2023, the EU is also proposing a mandatory EPR scheme for textiles. It is estimated that around 65% of textiles produced are made of plastic (Klepp and Tobiassen, 2020), and textiles are estimated to be an important source of microplastics (Periyasamy and Tehrani-Bagha, 2022; European Environment Agency, 2022). As per April 2024, this proposal is still being negotiated in the EU.

4.1.4 Policies targeting microplastics

Regulatory initiatives aimed at addressing pollution from microplastics are relatively new, and action is still partly hampered by the existing knowledge gaps. Even the definition of microplastics is still not globally agreed upon, though the most instances now define microplastics as small plastic particles up to 5mm in diameter[13].

The EU is a regional driving force to regulating microplastics. A proposal to ban certain intentionally added microplastics was adopted in the EU in 2023 ((EU) 2023/2055), and in October 2023, the Commission published a proposal to address microplastics pollution from pellet losses (2023/0373).

Wastewater treatment and laws regulating the use of sludge in agricultural land and landscaping are also of relevance when addressing microplastic pollution.

4.1.4.1 Regulating intentionally added microplastic

The regulation addressing intentionally added microplastics (2023/2055) is part of the EU plastics strategy and expected to prevent the release of 500 000 tonnes of microplastics over 20 years. Under the new rules, intentionally added microplastics are banned from a range of products such as fertilisers, plant protection products, cosmetics, household and industrial detergents, cleaning products, paints and products used in the oil and gas industry.

The ban also includes synthetic infill for artificial turf mostly used in football pitches. This includes the most used infill, synthetic rubber from end-of-life tyres. However, a transition period of eight years is granted before this ban on placing on the market of synthetic infill is in place. Transition periods apply to several other product groups under this regulation as well.

[13] See for example UNEP (Microplastics | UNEP - UN Environment Programme) or EU Commmission (Microplastics (europa.eu))

Design and operation of sport pitches that use synthetic infill has been subject to national regulation in Norway since 2021[14]. Regulation concerns, among others, rules on setting up a physical barrier that stops the spreading of granules outside the pitch, on handling of snow removed from the pitches and information campaigns directed at users of the pitches.

4.1.4.2 Regulating plastic pellet losses

In its strategy on plastics, the EU Commission announced that they will further examine policy options to address unintentional releases of microplastics into the environment. In October 2023, the EU Commission published a proposal (2023/645) for a regulation that addresses microplastic pollution from plastic pellet losses. This proposal still needs to go through the normal legislative process in the EU before it's adopted. Changes to the proposal can thus be expected.

Overall, the current proposal includes provisions aimed at ensuring: Best handling practices for operators; requirement of mandatory certification of larger operators' risk management plans and self-declarations of conformity for smaller companies; and development of a harmonised methodology to estimate pellet losses.

4.1.4.3 Wastewater and sludge – addressing distribution routes for microplastics

It is known that wastewater treatment plants as well as sewage sludge are distribution routes for microplastics into the environment.

Research suggests that the largest wastewater treatment plant in Norway receives more than one billion tiny pieces of plastic every hour[15]. Even with the most advanced treatment plants, a significant amount of microplastics can be assumed to escape to the environment. In case of water overflows or urban runoff, microplastics in water also bypass wastewater treatment. What is more, the microplastics that is filtered out of wastewater, end up in the resulting sewage sludge. This sludge is often used as a fertiliser on agricultural land. There is today a significant knowledge gap when it comes to amounts of microplastics found in soil.

Wastewater treatment is regulated in the EU through Urban Wastewater Treatment Directive (UWWTD), that is also applicable in Norway. The original Directive that stems from 1991 (91/271/EEC) has undergone a review in 2023/24, with one of the changes concerning

[14] Forskrift om begrensning av forurensning (forurensningsforskriften) - Kapittel 23A. Utforming og drift av idrettsbaner der det brukes plastholdig løst fyllmateriale - Lovdata
[15] Norwegian Plastics Strategy - regjeringen.no

microplastics – that in the proposal is treated as "contaminant of emerging concern". Additionally, new monitoring requirements proposed under the Directive include monitoring the presence of microplastics, including in sludge.

There are today no limit values for microplastics in sludge used as a fertiliser. The EU-Commission has indicated a review of the sewage sludge Directive under the Circular Economy Action Plan, but this proposal is still pending.

4.2 International fora relevant to addressing marine litter and microplastics

4.2.1 Legally binding conventions addressing marine litter and microplastics

Norway has ratified a number of key international conventions that contain legally binding provisions for reducing marine litter and microplastics (Figure 4.1.). The signatory states are legally obliged to prevent, reduce and control:

1. pollution of the marine environment from any source, in accordance with the United Nations Convention on the Law of the Sea (UNCLOS); and
2. pollution from ships, in accordance with MARPOL.

Signatory states are also obliged to prohibit the dumping of waste at sea, under the London Convention. Norway has additional commitments to the 1996 London Protocol and is obliged to prevent dumping and pollution from all sources under the OSPAR Convention.

Additional conventions address the harmfulness and transboundary movement of waste (Stockholm and Basel Conventions), and the impact of marine litter on marine species (United Nations Fish Stocks Agreement (UNFSA), Convention on Biological Diversity (CBD) and Convention on Migratory Species of Wild Animals (CMS)).

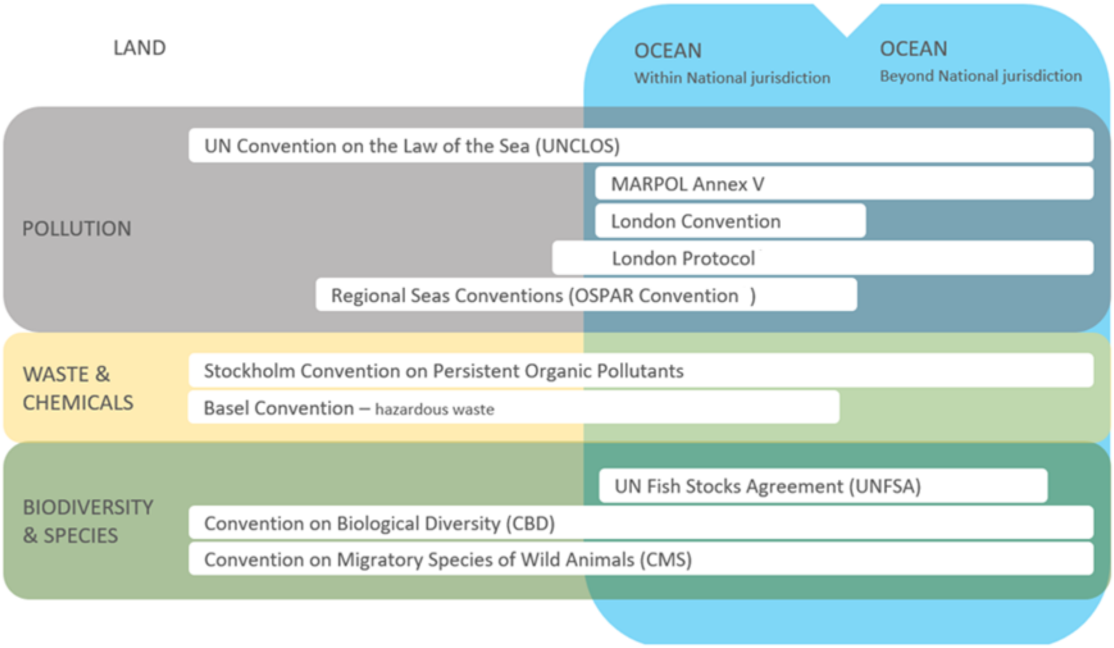


Figure 4.1. International conventions to address marine litter and microplastics. The laws are categorized according to designation (pollution, chemicals and waste, and biodiversity and species) and jurisdictional span (land and ocean within or beyond national jurisdiction). Original image courtesy of United Nations Environment Programme.

4.2.2 Key regional fora addressing marine litter in the Barents Sea

The Arctic Council is the leading intergovernmental forum promoting cooperation, coordination, and interaction among the Arctic States. In 2021, the Arctic Council published a Regional Action Plan on Marine Litter in the Arctic (ML-RAP) (PAME, 2021).

The aim of the plan is to enable Arctic states to implement targeted and collective actions to address both sea- and land-based activities, focusing on Arctic-specific marine litter sources and pathways. The ML-RAP sets out a range of strategic actions organized by the following eight categories:

1. Reducing Marine Litter Inputs from Fisheries and Aquaculture
2. Reducing Marine Litter Inputs from Ships and Offshore Structures
3. Improving Management of Waste and Wastewater
4. Sustainable Materials Management in the Arctic Environment
5. Cleaning Arctic Coasts
6. Strengthening Monitoring and Research
7. Outreach
8. International Cooperation

As the maritime areas covered by the Arctic Council and OSPAR overlap in the Barents Sea, this region is addressed by both fora. Action on marine litter and microplastics is a high priority under the OSPAR Convention, of which Norway is a signature state.

OSPAR revised its Regional Action Plan on Marine Litter in 2022 for the period of 2022-2030 (OSPAR, 2022). The action plan serves as the main instrument to deliver on one of the key objectives under the North-East Atlantic Environment Strategy's (NEAS) (OSPAR, 2021), namely to "prevent inputs of and significantly reduce marine litter, including microplastics, to reach levels that do not cause adverse effects to the marine and coastal environment with the ultimate aim of eliminating inputs of litter".

4.2.3 Key global fora addressing marine litter

4.2.3.1 The United Nations 2030 Agenda for Sustainable Development

The UN 2030 Agenda for Sustainable Development that includes 17 Sustainable Development Goals (SDGs), was adopted by all UN Member States in 2015. Goal 14 (Life Below Water) includes a target to, 'by 2025, prevent and significantly reduce marine pollution of all kinds, particularly from land-based activities, including marine debris and nutrient pollution'[16]. Norway has officially committed to achieving the SDGs[17].

14 LIFE BELOW WATER

Marine litter is also addressed through specific actions and programmes by the United Nations, its associated assembly (UNEA) and programme (UNEP), and its specialized agencies (Table 4.2.).

The following programmes and initiatives under the United Nations aim to preventing and reducing marine litter:

[16] THE 17 GOALS | Sustainable Development (un.org)

[17] Voluntary National Review 2020 of the progress made in the implementation of the 2030 Agenda for Sustainable Development; Voluntary National Review 2016 of initial steps towards the implementation of the 2030 Agenda

The United Nations Environment Programme (UNEP) is responsible for coordinating the UN's environmental activities and assisting developing countries in having environmentally sound policies and practices. UNEP has a number of ongoing initiatives relevant to marine litter in the Arctic, such as the Regional Seas Programme and non-binding Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities (GPA). The UNEP Regional Seas Programme, which engages neighbouring countries to address marine policy issues, has 18 regional seas programmes around the world. Many of these—such as OSPAR, which covers the Northeast Atlantic Ocean, Arctic Ocean and Barents Sea—have developed regional action plans to address marine litter. The GPA, administered by UNEP, addresses eight source categories of pollution, including marine litter, and encourages the development of regional and national programmes of action. UNEP has also established the Global Partnership on Marine Litter (GPML), which is a meeting place for exchanging knowledge on work combatting marine litter. Under the negotiations for the global treaty on plastic pollution, UNEP is in charge of convening and administering the Intergovernmental Negotiating Committee (INC) process.

The United Nations Environment Assembly (UNEA) is the governing body of UNEP. At the bi-annual UNEA meetings, ministers from around the world meet to agree on joint initiatives and declarations related to international environmental issues. In 2017, UNEA stressed the importance of long-term elimination of discharge of litter and microplastics into the oceans. An assessment of the effectiveness of international marine litter governance strategies highlighted key gaps in the existing international frameworks on marine litter and microplastics. In March 2022, a resolution was adopted to develop an international legally binding instrument on plastic pollution, including in the marine environment.

The International Maritime Organization (IMO) is a UN specialized agency with the mandate to promote safe, secure, environmentally sound, efficient and sustainable shipping. The IMO supports the implementation of the International Convention for the Prevention of Pollution from Ships (MARPOL), the 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and other Matter, and the original London Convention 1972. Contracting parties to these treaties are cooperating on an IMO action plan to address marine litter from ships.

The Food and Agriculture Organization (FAO) is a UN specialized agency with the responsibility for food and agriculture, including fisheries. The FAO Code of Conduct for Responsible Fisheries was adopted in 1995 and sets out international standards for responsible practices that ensure the effective conservation, management and development of living aquatic resources, with due respect for the ecosystem and biodiversity. The FAO has developed Voluntary Guidelines on the Marking of Fishing Gear and technical papers on abandoned, lost or otherwise discarded fishing gear (ALDFG).

4.2.3.2 New global agreement to end plastic pollution

In March 2022, at the fifth session of the United Nations Environment Assembly (UNEA-5.2), a resolution was adopted to develop an international, legally binding instrument on plastic pollution, including in the marine environment. UN countries have tasked the UN Environment Programme (UNEP) with managing the negotiations process.

The aim is, by the end of 2024, to create a global, legally binding plastics treaty. The mandate given at UNEA 5.2 includes reference to the need for a comprehensive approach that addresses the full life cycle of plastic and promotes sustainable production and consumption of plastics. Product design, circular economy approaches, and environmentally sound waste management is also emphasized in the mandate.

The global agreement would close the gaps that existing initiatives and agreements do not address, especially at the design and production phases of the plastics life cycle. It could further promote establishing standards and measurable goals and strengthen monitoring of plastic pollution.

Together with Rwanda, Norway is leading a High Ambition Coalition to End Plastic Waste. The coalition is working to develop an ambitious treaty "based on a comprehensive and circular approach that ensures urgent action and effective interventions along the full lifecycle of plastics".[18]

5. Way forward

Despite low population density, marine litter and microplastics are polluting the Barents Sea. Several key sources to marine litter and microplastics have been highlighted in this report, and evidence is emerging on their potential for causing adverse effects in the nature. This all underlines the need for action. On a general basis, knowledge on marine litter in form of macroplastics is more established than knowledge on microplastics.

Identifying sources and prevalence of marine litter by monitoring, mapping or through other investigations such as "deep dives" are key to designing policies and actions that address sources and hot-spot areas for accumulation. Based on our current knowledge, marine litter from fisheries is one of the most important sources: hence, policies and concrete measures targeting these sources are of great importance.

Furthermore, we should continue to gather more knowledge on transport routes of marine litter and microplastics to the Barents Sea, and evidence on the relative contribution of local sources as opposed to long-transported marine litter and microplastics.

[18] HAC Homepage - High Ambition Coalition to End Plastic Pollution : High Ambition Coalition to End Plastic Pollution (hactoendplasticpollution.org)

Guidelines for more harmonised monitoring have recently been published under the Arctic Monitoring and Assessment Programme (AMAP) that will contribute to solving some of the monitoring-related issues highlighted in our report.

The Arctic Council's Regional Action Plan on Marine Litter in the Arctic (ML-RAP) seeks to address the major challenges for the Barents Sea that are also identified in this report. Efforts to deliver on the strategic actions in the ML-RAP will therefore be particularly relevant for the area in the coming years.

Moreover, as the maritime areas covered by the Arctic Council and OSPAR overlap in the Barents Sea, Norway should coordinate the national implementation of the respective regional action plans for this area. OSPAR has published its updated action plan on marine litter in 2022, with several recommendations overlapping and complementing those from Arctic council's ML-RAP.

Additionally, a number of global and regional initiatives and regulations are relevant in addressing marine litter and microplastics, as described in section 4. One of the key developments globally is the push towards a global agreement to end plastic pollution.

Key findings and knowledge gaps identified in this report are summarised in the table below and linked to relevant recommendations from both the Arctic council's marine litter action plan and other relevant international processes, most notably under OSPAR.

Tables

Table 1. Existing knowledge and knowledge gaps in relation to Arctic Council and OSPAR regional action plans for marine litter.

Tema	**Status of Knowledge**		**International action/processes, inkl. OSPAR**	**Recommendations as presented in the Arctic Council Marine Litter Action Plan (ML RAP)**
	Existing knowledge	**Knowledge gaps**		
Monitoring	Norway monitors beached marine litter and marine litter in the water column and seabed. An ongoing microplastic monitoring programme was started in 2021. However, the existing programmes are limited in scope. There are challenges regarding comparison of results when different analytical methods are used.	There is a need for harmonized methods to compare results and investigate temporal and geographic trends.	Arctic Monitoring and Assessment Programme (AMAP): AMAP Litter and Microplastics Monitoring Plan 2021. OSPAR ML-RAP action C4.1: Bridging the policy gap between monitoring and policy.	Set of actions 35 - 39 under heading IV "Strengthening Monitoring and Research".
Transport and occurence	The Atlantic current and Norwegian coastal currents are the primary transport routes for marine litter and microplastics into the Barents Sea.	Time and portion of transported microplastics sinking to the seabed. Observations and analyses of trends of transported marine litter and microplastics into the Barents sea.		Action 38: "Improve understanding and modeling of the sources, sinks, movement, distribution, and temporal trends of marine litter in the Arctic, including pathways into the Arctic, to help identify and prioritize Arctic hot spots and other key geographic areas of concern."

	Rivers transport microplastics from catchment areas into Arctic Seas, as does atmospheric transport. Sea ice can temporarily store and transport microplastics.	Define the role and extent of rivers, sea ice and atmospheric transport for microplastics distribution in the Barents Sea.	OSPAR 2nd ML-RAP, action A3.1. Monitor, prevent and reduce riverine inputs of macro litter to the marine environment and share knowledge on micro litter monitoring.	Action 24: "Identify hot spot source areas of litter in upstream regions of rivers that flow into the Arctic and ways to reduce the input from these potential point and non-point-sources to the Arctic. -- "
Transport and occurence	Beached marine litter is found across the entire area.	Temporal and geographical trends and relative contributions form local versus distant sources of beached marine litter and microplastics in the Barents sea.	OSPAR monitoring: marine litter on beaches.	Actions 31: "Share experiences in implementing --relevant programs for mapping environmentally sound removal, and disposal of marine litter found on shorelines, waterways, and nearshore areas in the Arctic, including opportunities to recover the materials--" Action 32: "Promote best practices for the detection, removal, reuse and recycling of marine litter along Arctic shorelines, waterways, and nearshore areas--" Action 34: "Involve Indigenous Peoples and local communities, youth, and young adults in clean-up actions."
		Better identification of sources to plan and evaluate mitigation measures.		Action 3: "Identify most commonly lost or discarded fishing gear in different areas of the Arctic, as well as where opportunities may exist to develop procedures for ALDFG prevention and reduction within the region."

	Marine litter on the seabed is found throughout the Barents Sea, with higher densities being found close to the coast and in submarine canyons.	Temporal and geographical trends and relative contributions form local versus distant sources of marine litter and microplastics in the seabed.	OSPAR monitoring: marine litter on the sea floor	
		The extent to which microplastics are present in sediments in the Barents Sea.	Work ongoing in OSPAR: monitoring of microplastics in sediments	
Threats to marine species	Marine litter poses threats in form of entangelment and ingestion, both to flora and fauna. Arctic fauna and flora are ingesting microplastics.	Lack of standard reporting system for entangelment.	OSPAR monitoring: plastic particles in stomachs of seabirds (fulmars)	Action 39: " Identify and understand the impacts of marine litter on the environment and wildlife species of ecological, commercial, and cultural importance (e.g., plankton, fish, seabirds, and marine mammals) in the Arctic, including entanglement, ingestion, and potential contaminant transfer from marine litter to wildlife."
	Floating marine litter can transport invasive species to the Barents sea area.	The exact role of marine litter as a vector for invasive species	OSPAR 2nd ML-RAP, action A2.1. Prevent the release of bio-carriers to the marine and riverine environment	
		Lack of harmonised detection limits for microplastics in biota		

Sources	Fishing industry is a prominent source of marine litter.	Role of other marine industries (aquaculture, petroleum, shipping) as sources?	OSPAR 2nd ML-RAP, group of actions under sub-theme Commercial fishing, Recreational fishing and aquaculture. FAO: voluntary guidelines for marking of fishing gear. IMO strategy to address marine plastic litter from ships (2021), e.g. to "Consider extending the reporting requirement in regulation 10.6 of MARPOL Annex V to include reporting data on discharge or accidental loss of fishing gear"; "consider making mandatory the marking of fishing gear".	Action 29. "Promote the development and design of materials for use in fishing gear that minimizes impacts upon ecosystems or the environment from ALDFG." Action 30. "Promote the use of incentives - -to support the reduction of high loss fishing gear used by industry."
	Post-consumer waste is recorded on the coast of Svalbard and Northern Norway		OSPAR 2nd ML-RAP, action A1.1. to prevent and reduce plastic waste by coastal cities and municipalities, A2.2. Reduce macro litter losses in wastewater systems; A4.1-2. to reduce impacts of specific plastic products and plastic packaging.	Set of actions under heading III "Improving onshore waste and wastewater management"
	Microplastics directly discharged from communities lacking wastewater treatment plants.			Set of actions under heading III "Improving onshore waste and wastewater management"

		Relative contribution of marine litter and microplastics from local versus distant sources?		

Table 2: Ingested plastics in marine and terrestrial fauna reported from the Barents Sea area (n is the number of samples analyzed).

Species	**Latin name**	**Norskt navn**	**Location**	**Frequency of occurrence**	**Reference**
Seabirds					
Little auk	*Alle alle*	Alkekonge	Svalbard	0% (n=21)	Mehlum and Gjertz 1984
Little auk	*Alle alle*	Alkekonge	Eastern Svalbard	0% (n=3)	Gjertz et al. 1985
Little auk	*Alle alle*	Alkekonge	Hornsund, Svalbard	45% (n=11)	Lydersen et al. 1985
Black guillemot	*Cepphus grylle*	Teist	Svalbard	0% (n=7)	Mehlum and Gjertz 1984
Black guillemot	*Cepphus grylle*	Teist	Eastern Svalbard	0% (n=2)	Gjertz et al. 1985
Black guillemot	*Cepphus grylle*	Teist	Hornsund, Svalbard	0% (n=20)	Lydersen et al. 1985
Black guillemot	*Cepphus grylle*	Teist	Frans Josef Land	0% (n=5)	Weslawski et al 1994
Brünnich's guillemot	*Uria lomvia*	Polarlomvi	Svalbard	0% (n=1)	Mehlum and Gjertz 1984
Brünnich's guillemot	*Uria lomvia*	Polarlomvi	Eastern Svalbard	0% (n=3)	Gjertz et al. 1985
Brünnich's guillemot	*Uria lomvia*	Polarlomvi	Hornsund, Svalbard	24% (n=21)	Lydersen et al. 1985
Brünnich's guillemot	*Uria lomvia*	Polarlomvi	Entanglement		Gavrilo et al., 2019
Common guillemot	*Uria aalga*	Lomvi	Nest incorporation of plastic	0%	O`Hanlon et al. 2021
Atlantic puffin	*Fratercula arctica*	Lunde	Hornsund, Svalbard	0% (n=14)	Lydersen et al. 1985
Atlantic puffin	*Fratercula arctica*	Lunde	Nest incorporation of plastic	62 – 91%	O`Hanlon et al. 2021

Northern fulmar	*Fulmarus glacialis*	Havhest	Bjørnøya	82% (n=22)	van Franeker 1985
Northern fulmar	*Fulmarus glacialis*	Havhest	Svalbard	43% (n=14)	Mehlum and Gjertz 1984
Northern fulmar	*Fulmarus glacialis*	Havhest	Eastern Svalbard	50% (n=8)	Gjertz et al. 1985
Northern fulmar	*Fulmarus glacialis*	Havhest	Hornsund, Svalbard	15% (n=20)	Lydersen et al. 1985
Northern fulmar	*Fulmarus glacialis*	Havhest	Frans Josef Land	20% (n=5)	Weslawski et al 1994
Northern fulmar	*Fulmarus glacialis*	Havhest	Isfjorden, Svalbard	87.5% (n=40)	Trevail et al. 2015
Northern fulmar	*Fulmarus glacialis*	Havhest	Northern Norway	80.5% (n=72)	Herzke et al. 2016
Northern fulmar	*Fulmarus glacialis*	Havhest	Kongsfjorden, Svalbard	91% (n=43)	Collard et al (2022)
Northern fulmar	*Fulmarus glacialis*	Havhest	Faroe Islands	95% (n=20)	Collard et al. (2022)
Northern fulmar	*Fulmarus glacialis*	Havhest	Kongsfjorden, Svalbard	Fledgelings (n=21)	Tulatz et al. 2023
Northern fulmar	*Fulmarus glacialis*	Havhest	Kongsfjorden, Svalbard	Adults (n=18)	Tulatz et al. 2023
Glaucous gull	*Larus hyperboreus*	Polarmåke	Svalbard	0% (n=2)	Mehlum and Gjertz 1984
Glaucous gull	*Larus hyperboreus*	Polarmåke	Hornsund, Svalbard	0% (n=18)	Lydersen et al. 1985
Glaucous gull	*Larus hyperboreus*	Polarmåke	Frans Josef Land	0% (n=5)	Weslawski et al 1994
Glaucous gull	*Larus hyperboreus*	Polarmåke	Adventfjorden, Svalbard	14% (n=21)	Benjaminsen et al 2022
Glaucous gull	*Larus hyperboreus*	Polarmåke	Nest incorporation of plastic	Observed	Gavrilo et al., 2019
Greater black-backed gull	*Larus marinus*	Svartbak	Nest incorporation of plastic	0%	O`Hanlon et al. 2021
Common gull	*Larus canus*	Fiskemåke	Nest incorporation of plastic	0%	O`Hanlon et al. 2021
Herring gull	*Larus argentatus*	Gråmåke	Nest incorporation of plastic	Observed	Gavrilo et al., 2019
Ivory gull	*Pagophila eburnea*	Ismåke	Svalbard	0% (n=6)	Mehlum and Gjertz 1984
Ivory gull	*Pagophila eburnea*	Ismåke	Eastern Svalbard	0% (n=4)	Gjertz et al. 1985
Ivory gull	*Pagophila eburnea*	Ismåke	Nest incorporation of plastic	Observed	Gavrilo et al., 2019

Black-legged kittiwake	*Rissa tridactyla*	Krykkje	Svalbard	0% (n=27)	Mehlum and Gjertz 1984
Black-legged kittiwake	*Rissa tridactyla*	Krykkje	Eastern Svalbard	0% (n=18)	Gjertz et al. 1985
Black-legged kittiwake	*Rissa tridactyla*	Krykkje	Hornsund, Svalbard	5% (n=20)	Lydersen et al. 1985
Black-legged kittiwake	*Rissa tridactyla*	Krykkje	Nest incorporation of plastic	0 – 13%	O`Hanlon et al. 2021
Black-legged kittiwake	*Rissa tridactyla*	Krykkje	Nest incorporation of plastic	Observed	Gavrilo et al., 2019
Black-legged kittiwake	*Rissa tridactyla*	Krykkje	Entanglement		Gavrilo et al., 2019
Arctic tern	*Sterna paradisaea*	Rødnebbterne	Frans Josef Land	0% (n=5)	Weslawski et al 1994
Arctic tern	*Sterna paradisaea*	Rødnebbterne	Entanglement		
Arctic tern	*Sterna paradisaea*	Rødnebbterne	Nest incorporation of plastic	0%	O`Hanlon et al. 2021
Arctic tern	*Sterna paradisaea*	Rødnebbterne	Nest incorporation of plastic	0%	Gavrilo et al., 2019
Common eider	*Somateria mollissima*	Ærfugl	Svalbard	0% (n=1)	Mehlum and Gjertz 1984
Common eider	*Somateria mollissima*	Ærfugl	Hornsund, Svalbard	0% (n=20)	Lydersen et al. 1985
Common eider	*Somateria mollissima*	Ærfugl	Frans Josef Land	0% (n=5)	Weslawski et al 1994
Common eider	*Somateria mollissima*	Ærfugl	Nest incorporation of plastic	O – 1%	O`Hanlon et al. 2021
Common eider	*Somateria mollissima*	Ærfugl	Nest incorporation of plastic	observed	Gavrilo et al., 2019
Barnacle goose	*Branta leucopsis*	Kvitkinngås	Nest incorporation of plastic	0%	Gavrilo et al., 2019
Long-tailed skua	*Stercorarius longicaudus*	Fjelljo	Svalbard	0% (n=1)	Mehlum and Gjertz 1984
Pomarine skua	*Stercorarius pomarinus*	Polarjo	Eastern Svalbard	0% (n=2)	Gjertz et al. 1985
Great skua	*Stercorarics skua*	Storjo	Bjørnøya	6% (n=128)	Knutsen 2010
Red-throated diver	*Gavia stellata*	Smålom	Entanglement		Gavrilo et al., 2019
Northern gannet	*Morus bassanus*	Havsule	Entanglement		Gavrilo et al .,2019
Northern gannet	*Morus bassanus*	Havsule	Nest incorporation of plastic	Observed	Gavrilo et al., 2019

European shag	*Gulosus aristotelis*	Toppskarv	North Cape, Norway	0% (n=9)	Benjaminsen et al. 2024
European shag	*Gulosus aristotelis*	Toppskarv	Nest incorporation of plastic	4 – 14%|	O`Hanlon et al. 2021
European shag	*Gulosus aristotelis*	Toppskarv	Nest incorporation of plastic	Observed	Gavrilo et al., 2019
Great cormorant	*Phalacrocorax carbo*	Storskarv	North Cape, Norway	0% (n=8)	Benjaminsen et al. 2024
Great cormorant	*Phalacrocorax carbo*	Storskarv	Nest incorporation of plastic	0%	O`Hanlon et al. 2021
Marine Mammals					
Bearded seal	*Erignathus barbatus*	Storkobbe	Hornsund, Svalbard	0% (n=1)	Lydersen et al. 1985
Bearded seal	*Erignathus barbatus*	Storkobbe	Entanglement		
Ringed seal	*Phoca hispida*	Ringsel	Hornsund, Svalbard	0% (n=5)	Lydersen et al. 1985
Harbour seal	*Phoca vitulina*	Steinkobbe	Entanglement		
Walrus	*Odobenus rosmarus*	Hvalross	Poolepynten, Prins Karls Forland, Svalbard	34 particles/kg 87.5% (n=5)	Carlsson et al. 2021
Polar bear	*Ursus maritimus*	Isbjørn	Entanglement		
Bowhead whale	*Balaena mysticetus*	Grønlandshval	Entanglement		Finley et al. 2021
Fin whale	*Balaenoptera physalus*	Finnhval	Western Iceland	0.057 particles per gram in krill in stomach of whale	Garcia-Garin et al., 2021
Terrestrial mammals					
Arctic fox	*Vulpes lagopus*	Fjellrev	Svalbard	10% (n=20)	Hallanger et al. 2022
			Entanglement		Hallanger et al. 2022
Arctic fox	*Vulpes lagopus*	Fjellrev	Entanglement		Gavrilo et al., 2019
Svalbard reindeer	*Rangifer tarandus platyrhynchus*	Svalbardrein	Entanglement		Øritsland 1986
Marine fish					
Polar cod	*Boreogadus saida*	Polartorsk	Central Arctic Ocean and Svalbard	2.8% (n=72)	Kühn et al. 2018
Polar cod	*Boreogadus saida*	Polartorsk	Northeast Greenland	18% (n=85)	Morgana et al. 2018
Big eye sculpin	*Triglops nybelini*	Grønlandsknurrulke	Northeast Greenland	34% (n=71)	Morgana et al. 2018
Atlantic cod	*Gadus morhua*	Torsk	Lofoten, Norway	0% (n=56)	Bråte et al. 2017

Atlantic cod	*Gadus morhua*	Torsk	Varangerfjorden, Norway	0% (n=58)	Bråte et al. 2017
Atlantic cod	*Gadus morhua*	Torsk	Western Iceland	20.5% (n=39)	De Vries et al 2020
Saithe	*Pollachius virens*	Sei	Western Iceland	17.4% (n=46)	De Vries et al 2020
Blue whiting	*Micromesistius poutassou*	Kolmule	Iceland	7.5% (n=40)	Malinen 2021
Atlantic mackerel	*Scomber scombrus*	Makrell	Southeast Icleand	12% (n=50)	Malinen 2021
Striped snailfish	*Liparis liparis*	Vanlig ringbuk	Hornsund, Svalbard	0% (n=3)	Lydersen et al. 1985
Shorthorn sculpin	*Myoxocephalus scorpius*	Vanlig ulke	Hornsund, Svalbard	0% (n=17)	Lydersen et al. 1985
Greenland halibut	*Reinhardtius hippoglossoides*	Blåkveite	Bycatch in ghost fishing		Large et al. 2009
Greenland shark	*Somniosus microcephalus*	Brugde	Western Svalbard	3% (n=45)	Leclerc et al. 2012
Greenland shark	*Somniosus microcephalus*	Brugde		8.3%	Nielsen et al 2014
Marine invertebrates					
Northern astarte	*Astarte borealis*	-	Pechora Sea	10%	Gebruk et al. 2022
Narrow-hinge astarte	*Astarte montagui*	-	Pechora Sea	18.2%	Gebruk et al. 2022
Iceland cockle	*Ciliatocardium ciliatum*	Hjerteskjell	Pechora Sea	12.5%	Gebruk et al. 2022
Iceland cockle	*Ciliatocardium ciliatum*	Hjerteskjell	Isfjorden, Svalbard	0% (n=10)	Sundet et al. 2016
Chalky macoma	*Macoma calcarea*	-	Pechora Sea	20%	Gebruk et al. 2022
Greenland cockle	*Serripes groenlandicus*	-	Pechora Sea	30%	Gebruk et al. 2022
Hiatella artica	*Hiatella artica*	Steinboreskjell	Mosselbukta, Svalbard	100%	Teichert et al. 2021
Northern yoldia	*Yoldia hyperborea*	-	Pechora Sea	13.3%	Gebruk et al. 2022
Blue mussel	*Mytilus edulis*	Blåskjell	Longyearbyen, Svalbard	FO not given. 9.5 fibres/mussel (n=10)	Sundet et al. 2016
Blue mussel	*Mytilus edulis*	Blåskjell	Skallneset, Norway	95% (n=20)	Lusher et al. 2017
Blue mussel	*Mytilus edulis*	Blåskjell	Skallneset, Norway	80 % (n=20)	Bråte et al. 2018
Hermit crab	*Pagurus pubescens*	Eremittkreps	Pechora Sea	26% (n=43)	Gebruk et al. 2021
Great spider crab	*Hyas araneus*	Pyntekrabbe	Pechora Sea	22% (n=9)	Gebruk et al. 2021
Snow crab	*Chionoecetes opilio*	Snøkrabbe	Pechora Sea	35 % (n=23)	Gebruk et al.2021
Red king crab	*Paralithodes camtschaticus*	Kongekrabbe	Porsangerfjord, Norway	37.9% (n=139)	Fuhrmann et al. 2017

Gammarus setosus	*Gammarus setosus*		Kongsfjorden, Svalbard, Norway	100% (n=20)	Iannilli et al., 2019
Themisto libellula	*Themisto libellula*		Fram Strait	100% (n=2)	Boterell et al 2022
Themisto abyssorrum	*Themisto abyssorrum*		Fram Strait	100% (n=1)	Boterell et al 2022
Apherusa glacialis	*Apherusa glacialis*		Fram Strait	100% (n=1)	Boterell et al 2022
Calanus hyperboreus	*Calanus hyperboreus*	Feitåte	Fram Strait	21% (n=5)	Boterell et al 2022
Calanus glacialis/finmarchicus	*Calanus glacialis/finmarchicus*	Ishavsåte/Raudåte	Fram Strait	1% (n=102)	Boterell et al 2022

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