Fishing nets on the coastline of the Arctic and North-East Atlantic: a source analysis

Findings and recommendations based on an in-depth analysis of the sources, origin, and pathways of fishing nets collected on beaches in Greenland, Iceland, Jan Mayen, Svalbard, the Netherlands, Norway, and Scotland

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This study was Commissioned by Rijkswaterstaat Water, Verkeer en Leefomgeving and prepared for OSPAR as input for OSPAR Action 36: 'To develop best practices in the fishing industry'

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This report presents the findings and recommendations of the first comparative study into the sources, origin and pathways by which fishing nets end up on beaches spread over the Arctic and North-East Atlantic region: Greenland, Iceland, Jan Mayen, Svalbard, the Netherlands, Norway, and Scotland. The conclusion of this report is that improved waste management of net cuttings on board bottom trawling vessels and in ports is the most effective mitigation measure to prevent most fishing net litter on beaches.

Dit rapport beschrijft de resultaten van het eerste vergelijkende onderzoek naar de bronnen en herkomst van visnetten die verzameld zijn op stranden, verspreid gelegen over het Arctische en Noordoostelijke gedeelte van de Atlantische Oceaan: Groenland, IJsland, Jan Mayen, Spitsbergen, Noorwegen, Nederland en Schotland, evenals de oorzaken van het in zee terechtkomen van die visnetten. De belangrijkste conclusie van dit rapport is dat een beter afvalbeheer van afgesneden netdelen aan boord van bodemtrawlschepen en in havens de meest effectieve maatregel is om het aanspoelen van visnetten op stranden te voorkomen.

Key words: fishing nets, marine litter, beach litter, fishing gear, beach litter monitoring, ALDFG, ghost gear, fisheries waste, Litter-ID.

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Preface

Marine plastic pollution is a worldwide phenomenon, including in the Arctic and North-East region of the Atlantic Ocean. This causes a variety of risks for marine species, coastal communities and sea-based activities. Recent research efforts giving an insight into the overall composition and general sources of beach litter, are currently being used to better understand and address the issue. However, due to a lack of detail in the available data, many questions as to the sources and pathways of beach litter still remain, making it more challenging to effectively target the root causes. Fishing nets are an example of marine litter where such information is lacking.

At Wageningen University & Research we believe that a better understanding of the root causes of marine litter paves the way for taking more effective action at local, national and international levels. To achieve this goal, we have developed several marine litter analysis tools. One of these tools specifically addresses beached fishing nets. Since 2017, the tool is being applied to gain a more detailed characterisation of the sources and pathways of fishing nets collected on beaches throughout the Arctic and North-East Atlantic region. This is the first time such a large-scale systematic effort is taking place in this region.

In this report, the current results and findings of this ongoing research are presented. The key message of this report is that improved waste management of net cuttings on board bottom trawling vessels and in ports is the most effective mitigation measure to prevent most fishing net litter on beaches. We hope that the recommendations can be used to further refine and improve OSPAR's Regional Action Plan on marine litter and other ongoing initiatives by the fishing industry, individual governments and NGOs, international organisations such as the International Maritime Organization, the EU, and the Arctic Council among others, thereby providing inspiration for new initiatives.

This report was commissioned and funded by Rijkswaterstaat Water, Verkeer en Leefomgeving. The data presented in this report was obtained during several beach litter analysis sessions throughout the Arctic and North-East Atlantic region. Financial support to carry out these analyses was also provided by the Dutch Ministry of Foreign Affairs, the Dutch Ministry of Infrastructure and Water, Rijkswaterstaat Noord-Nederland, Rijkswaterstaat Water, Verkeer en Leefomgeving, Wageningen University & Research, World Wide Fund for Nature (WWF), the Circumpolar Conservation Union, the North Sea Foundation, Svalbard Environmental Fund and the Dolfinarium, for which we are very grateful.

In addition, we gratefully acknowledge the help and support of many other people and organisations. There are too many to name here but there are some people we would especially like to thank for their help and support in analysing the fishing nets: Klaas-Jelle Koffeman, Dagfinn Lilleng, Roger Larsen, Lars Thomassen, Georg Haney and Ben Wensink. We also would like to thank Michael Kingston, Thomais Vlachogianni, Arabelle Bentley, and Ryan d'Arcy Metcalfe for their feedback on the draft version of this report.

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Summary

S.1 Key Findings

- Of the study areas analysed, all fishing net litter that washes up on beaches are *pieces* rather than complete nets, otherwise known as 'lost gear' (that may also include attached ropes, buoys, steel wire and other materials). Most of these pieces are relatively small in size and originate from nets used in bottom trawl fisheries. The pieces found on beaches are the result of damage during trawling, and, predominantly, the mismanagement of net cuttings during mending on deck. Net cuttings reach the sea due to not having effective waste management systems in place for the collection and disposal of such waste material and are either being unintentionally washed overboard or deliberately discarded.
- This report shows that, in the opinion of the fishing experts engaged, most pieces of fishing net >50cm originate from vessels operating in fishing areas relatively close to where these pieces were collected, both inside States' 12-mile territorial limit, and in international waters outside the 12-mile zone, involving national and internationally registered vessels.
- Based on the report's findings, the key recommendation is to further improve the collection and disposal procedures of net cutting waste on board bottom trawling vessels in combination with having adequate waste reception facilities in (fishing) ports and to address this issue on a national, regional, and international level. This would not only significantly improve marine environmental conditions, and safety of navigation for ships and fishing vessels in the Arctic and North-East Atlantic region, but also assist with the existing obligations under MARPOL ANNEX V regulations for the prevention of pollution by marine litter from ships and fishing vessels. Additionally, it is argued that, current and proposed mitigation measures such as the marking of gear, reporting of lost gear, or setting collection targets for used fishing gear are inadequate to target most fishing net litter on beaches. Accordingly, the conclusion of this report is that improved waste management of net cuttings on board bottom trawling vessels and in ports is the most effective mitigation measure to prevent most fishing net litter on beaches. In Chapter 5.2, these recommendations are further elaborated upon.
- This report acknowledges that important progress has been made and much work is currently being carried out to address the issue of abandoned, lost or otherwise discarded fishing gear (ALDFG) throughout the Arctic and North-East Atlantic region. The report's findings and recommendations made in Chapter 5.2 will contribute to on-going initiatives which include, but are not limited to, those by the fishing industry, NGOs, individual States, OSPAR's Intersessional Correspondence Group on Marine Litter, IMO's Marine Litter Action plan, IMO's efforts to implement the Cape Town Agreement for the Safety of Fishing Vessels, the Arctic Council's Protection of the Arctic Marine Environment Working Group's Regional Action Plan on Marine Litter, the Nordic Council of Minister's work, FAO's Regional Fisheries Agreement work, the EU's Single-Use Plastics Directive - 2019/904/EU, and the EU's Plastics Strategy, the EU's Marine Strategy Framework Directive (2008/56/EC), the EU's Green Deal, and the EU's Zero Pollution Action Plan.

S.2 Other results

- For trawl net pieces of >50 cm, measured at their longest dimension, it was determined that 79% of the pieces were found to be deliberate off-cuts from trawl nets, the result of mending work, while 21% were found to have been accidentally lost due to wear and tear during trawling. While some of the larger pieces reached almost 200 m^2 in size, most of the pieces were relatively small: 62% of the nets were in the 0.5 - 5 m^2 category.
- For trawl net pieces of <50 cm, measured at their shortest dimension, it was determined that most were cut-off mesh ends and a small amount were twine cord. Both are used in trawl fisheries. Due to the small size of pieces in this size category the fishing sector and the geographical origin could not be determined.

- The analysis in this report is the first time that such a systematic large-scale examination of stranded fishing nets has taken place in this region, which involved the development of the Fishing Net Assessment Protocol. This method has proven to be a successful tool in helping to determine the sources and pathways of stranded fishing net litter. In light of this, it is also clear from this report that further field work should be carried out to enhance the understanding of these issues, not only in the Arctic and North-East region of the Atlantic Ocean, but also in other areas, using the same analysis method.
- Whilst (pieces of) bottom trawl nets may or may not represent the main category of fishing net litter in the marine environment, they do represent the most common source of fishing net litter *on beaches*. To gain a more holistic view of the sources and pathways of all (pieces of) fishing nets ending up in the marine environment, it is recommended to combine in-depth analyses of fishing nets collected from beaches, which is the focus of this report, with analyses of fishing nets collected from the seabed which could be the focus of future work.

S.3 Methodology

Due to the general characterisation of fishing net litter in OSPAR beach litter monitoring data, much is still unknown about the sources and pathways (the manner in which the piece of net entered the sea and how from that occurrence it ended up stranded on a beach) of fishing nets found on beaches in the Arctic and North-East region of the Atlantic Ocean. This lack of knowledge makes it more challenging to effectively target the root causes and was the motivation behind the development of the Fishing Net Assessment Protocol by Wageningen Economic Research in 2017. Since then, the protocol has been applied at various locations throughout the Arctic and North-East Atlantic region:

- In total, 211 pieces of trawl net of 50 cm and over, at their longest dimension, were examined. These had been collected during beach clean-ups in Greenland, Iceland, Jan Mayen, Svalbard, the Netherlands, Norway, and Scotland. With the help of national fishing gear experts, as much quantitative and qualitative information as feasibly possible was collected on the origin, type of net, fishing sector and pathways. The material used, characteristics such as mesh size, level of wear and tear, and cut or tear marks on each side of the net was analysed.
- In total, 2,908 pieces of fishing net 50 cm and under, at their longest dimension, collected from beaches in the Netherlands, Svalbard, Scotland, Iceland and Greenland were examined. Because of the small size and lack of sufficient clues in smaller pieces of fishing net, less information could be obtained so not all criteria of the Fishing Net Assessment Protocol could be applied. As a result, the fishing sector and origin could not be determined. What could be determined was the general source as well as the most probable cause (where such an assessment was feasible).

In several of the study areas, gillnets were also examined. Gillnets are mostly used on the seabed and have a low buoyancy, so they tend to sink, whereas most trawl nets have a high buoyancy and float. Therefore, this reduces the probability of finding large quantities of gillnets on beaches. This was reflected in the low number of gillnets (5) in the samples of fishing nets >50 cm as compared to the relatively high number of trawl nets (211). Because of the relatively low representation of gillnets in this category (2.4%) and the absence in the <50 cm category, it was decided to leave gillnets out of the results presented in this report and to concentrate on trawl nets.

Samenvatting

S.1 Belangrijkste resultaten

- Uit de resultaten van deze studie blijkt dat alle op stranden in het Arctische en Noordoostelijke deel van de Atlantische Oceaan aangespoelde visnetten die voor deze studie onderzocht zijn, netdelen te zijn. Geen van de onderzochte netdelen bleek een compleet/intact netwerk te zijn, dat ook kan bestaan uit touwen, boeien, staaldraad en ander materiaal. De netdelen die op stranden gevonden worden zijn over het algemeen relatief klein en afkomstig van netten die gebruikt worden in de bodemtrawlvisserij. Waar een beperkt gedeelte hiervan in zee terechtkomt door schade aan het net tijdens het vissen, komt het grootste gedeelte in zee terecht als gevolg van inadequaat afvalmanagement aan boord van schepen. Daarbij worden losgesneden netdelen, ook wel 'afsnijdsels' genoemd, niet tijdig verzameld en opgeslagen, waardoor deze onder invloed van zeewater, van het dek gespoeld kunnen worden of bij het schoonmaken van het dek overboord gezet worden.
- Uit dit rapport blijkt dat, naar de mening van de betrokken visserijdeskundigen, het meeste visnetafval dat op de stranden in het onderzoeksgebied terechtkomt, afkomstig is van bodemtrawlschepen die actief zijn in visgebieden in relatieve nabijheid van de locaties waar de betreffende netdelen verzameld zijn. Hierbij gaat het zowel om visserij die onder nationale jurisdictie binnen de 12-mijlszone plaatsvindt als visserij buiten deze zone waarbij zowel nationaal als internationaal geregistreerde vaartuigen betrokken zijn.
- Gebaseerd op de resultaten van deze studie is de belangrijkste aanbeveling om verdere verbeteringen door te voeren in de verzameling en opslag van nettenafval (afsnijdsels) aan boord van bodemtrawlschepen, in adequate inzameling van dit afval in visserijhavens en de kwestie van adequaat afvalbeheer op nationaal, regionaal en internationaal niveau aan te pakken. Dit zal niet alleen een positief effect hebben op het mariene milieu maar ook op de scheepvaartveiligheid in het Arctische en het noordoostelijke gedeelte van de Atlantische Oceaan en helpen bij het naleven van de MARPOL Annex V wetgeving van de Internationale Maritieme Organisatie (IMO). De resultaten laten ook zien dat andere indirecte maatregelen om te voorkomen dat vistuig in zee terechtkomt, zoals het markeren van vistuig, het melden van verloren vistuig of het stellen van inzamelingsdoelen voor gebruikt vistuig, ontoereikend zijn om te voorkomen dat netdelen op stranden terechtkomen, met name de kleinere delen die het meeste aangetroffen worden. De belangrijkste conclusie van dit rapport is dan ook dat een beter afvalbeheer van afgesneden netdelen aan boord van bodemtrawlschepen en in havens de meest effectieve maatregel is om het aanspoelen van visnetten op stranden te voorkomen. In hoofdstuk 5.2 worden deze aanbevelingen verder toegelicht.
- In dit rapport wordt erkend dat er op dit moment veel wordt gedaan om te voorkomen dat vistuig afval in zee terechtkomt en dat hierin de afgelopen tijd belangrijke stappen zijn gezet. De bevindingen en aanbevelingen van dit rapport (zie hiervoor specifiek hoofdstuk 5.2) kunnen dan ook relevant zijn voor dergelijke initiatieven. Die omvatten, maar zijn niet beperkt tot, initiatieven van de visserijsector zelf, van non-gouvernementele organisaties (ngo's), de Intersessional Correspondence Group on Marine Litter (Regional Action Plan for Marine Litter) van OSPAR, de Arctische Raad ('Regional Action Plan on Marine Litter'), de IMO (Marine Litter Action plan), de inspanningen van IMO om de 'Cape Town Agreement 8ort he Safety of Fishing Vessels' te implementeren, het werk van de Nordic Council of Ministers, Regionale Visserijovereenkomsten, de EU-richtlijn inzake kunststoffen voor eenmalig gebruik – 2019/904 / EU, de EU-strategie inzake kunststoffen, de EU-Kaderrichtlijn Mariene Strategie (2008/56 / EG) de EU Green Deal en de EU Zero Pollution Action Plan.

S.2 Overige resultaten

- Voor netdelen van >50 cm (gemeten bij het langste gedeelte), werd vastgesteld dat terwijl sommige van de grotere stukken bijna 200 m^2 groot waren, de meeste stukken relatief klein waren: 62% viel binnen de categorie 0,5 – 5 m^2. Ook bleek dat 79% van de netdelen afgesneden te zijn tijdens

herstelwerkzaamheden aan de netten. Eenentwintig procent van de netten bleek tijdens het vissen in zee terechtgekomen te zijn door slijtage.
- Voor netdelen van <50 cm (gemeten bij het kortste gedeelte), werd vastgesteld dat de meeste hiervan bestonden uit afgesneden uiteindes van mazen en een kleine hoeveelheid bestond uit stukken koord, beiden afkomstig van netten die gebruikt worden in de sleepnet visserij. Vanwege de kleine omvang van de onderzochte netdelen in deze grootteklasse kon het type trawlvisserij en de geografische oorsprong niet bepaald worden.
- Het is de eerste keer dat in het onderzoeksgebied een systematisch grootschalig onderzoek naar de bronnen en oorzaken van gestrande visnetten heeft plaatsgevonden. Uit de bevindingen van het rapport blijkt dat de in het kader van deze studie ontwikkelde 'Fishing Net Assessment Protocol' hierbij een succesvol hulpmiddel is gebleken. Gebruikmakend van deze methode kan aanvullend onderzoek helpen om een beter begrip te krijgen van dit fenomeen, niet alleen in andere gebieden binnen het noordpoolgebied en het noordoostelijke deel van de Atlantische Oceaan, maar ook in gebieden daarbuiten.
- Hoewel het niet bekend is of de bodemtrawlvisserij de belangrijkste bron van visnetten afval in zee vormt, is dat met deze studie wel bekend bij dergelijk afval dat aanspoelt op stranden. Om een meer holistisch beeld te krijgen van de bronnen van alle visnetten die in zee terechtkomen en de onderliggende oorzaken daarvan, wordt aanbevolen om (naast analyses van visnetten verzameld op stranden – de focus van dit rapport) ook dergelijke analyses uit te voeren op visnetten verzameld van de zeebodem (de focus van toekomstig onderzoek) en beide gegevens met elkaar te combineren.

S.3 Methodologie

Vanwege de algemene karakterisering van visnetten in OSPAR-strandafval monitoringgegevens in het arctische en noordoostelijke gebied van de Atlantische Oceaan, is er nog veel onbekend over de bronnen en de onderliggende oorzaken dat deze netten in zee terechtkomen. Dit gebrek aan kennis was de drijfveer achter de ontwikkeling van het Fishing Net Assessment Protocol door Wageningen Economic Research in 2017. Sindsdien is dit protocol toegepast op verschillende locaties in het noordpoolgebied en het noordoostelijke deel van de Atlantische Oceaan:

- Voor deze studie zijn in totaal 211 stukken bodemtrawlvisnet van >50 cm in lengte (gemeten bij het langste gedeelte) onderzocht. Deze waren verzameld tijdens strandafval opruimacties in Groenland, Ijsland, Jan Mayen, Spitsbergen, Noorwegen en Nederland. Met de hulp van vistuig experts uit de betrokken gebieden werd zoveel mogelijk kwantitatieve en kwalitatieve informatie verzameld over de herkomst, het type net, de visserijsector en de onderliggende oorzaken dat deze in zee terechtgekomen zijn. Hierbij werd onder andere het gebruikte materiaal, kenmerken zoals maaswijdte, mate van slijtage en snij- of scheursporen aan elke kant van het net geanalyseerd.
- Daarnaast zijn 2.908 stukken bodemtrawlvisnet van <50 cm (gemeten bij het langste gedeelte) onderzocht die verzameld waren op stranden in Groenland, Ijsland, Spitsbergen, Nederland en Groenland. Door het kleine formaat en het daardoor ontbreken van voldoende aanwijzingen, kon er minder informatie worden verkregen waardoor niet alle criteria van het Fishing Net Assessment Protocol konden worden toegepast. De specifieke bron (type visserij) en de herkomst konden daarom niet bepaald worden. Wat wel kon worden bepaald, was zowel de algemene bron als de meest waarschijnlijke oorzaak dat deze netdelen in zee terechtgekomen waren (waar een dergelijke beoordeling haalbaar was).

In een deel van het onderzoeksgebied zijn naast bodemtrawlnetten ook kieuwnetten onderzocht. Kieuwnetten worden meestal op de zeebodem gebruikt en hebben een laag drijfvermogen, waardoor ze de neiging hebben te zinken, terwijl de meeste sleepnetten een hoog drijfvermogen hebben en drijven. Dit verkleint dus de kans om grote hoeveelheden kieuwnetten op stranden aan te treffen. Dit kwam tot uiting in het lage aantal kieuwnetten (5) in de categorie 'netdelen >50 cm' in vergelijking met het relatief hoge aantal bodemtrawlnetten (211) en het ontbreken van kieuwnetten in de categorie 'netdelen <50 cm'. Vanwege de relatief lage vertegenwoordiging (2,4%) van kieuwnetten in de eerste categorie en de afwezigheid in de categorie <50 cm, is besloten kieuwnetten buiten de resultaten van dit rapport te laten.

1 Introduction

1.1 Fishing gear as a source of marine plastic pollution in the Arctic and North-East Atlantic region

Many studies have investigated the issue of marine litter and marine plastic pollution in the Arctic and North-East Atlantic region, in particular in the geographical area subject to the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention).[1]

The most common method to monitor marine litter in the OSPAR maritime (North-East Atlantic) region is beach litter surveys, which shed light on the abundance, composition, spatial distribution, and sources of stranded litter (Schulz et al., 2013; Schulz et al., 2019, Falk-Andersson et al., 2019).

Applying the OSPAR Beach Litter Monitoring Guideline (OSPAR, 2010), which includes a list of 112 litter item categories, each beach litter item found on the beach litter survey sites is allocated to one of those litter type categories. Table 1.1 shows a selection of litter item categories that are specifically related to the fisheries sector and fishing nets in particular.

Table 1.1 *A selection of litter item categories in the OSPAR Beach Litter Monitoring Guideline (OSPAR, 2010) which are related to the fisheries sector*

OSPAR ID	Unep ID	Items	Total
29		Oyster trays (round from oyster cultures)	
30		Plastic sheeting from mussel culture (Tahitians)	
31		Rope (diameter more than 1 cm)	
32		String and cord (diameter less than 1 cm)	
115		Nets and pieces of net < 50 cm	
116		Nets and pieces of net > 50 cm	
33		Tangled nets/cord/rope and string	
34		Fish boxes	
35		Fishing line (angling)	
36		Light sticks (tubes with fluid)	
37		Floats/Buoys	

Based on OSPAR data on the abundance and composition of beach litter in the in the North-East Atlantic in the six year reporting period April 2012 to January 2017, and trends in the abundance of litter for the period December 2009 to January 2018, it was concluded that, in terms of numbers, plastic fragments, fishing gear and packaging are the most common types of litter. 13% of all litter items are fishing gear, of which 15% are OSPAR ID 115 'nets and pieces of net <50 cm' + OSPAR ID 116 'nets and pieces of net >50 cm'. In particular, 'Nets and pieces of net <f50 cm' are one of the most widespread top litter items: on 26% of the survey sites it is one of the most frequently encountered items. It was also found that the trend in the abundance of fishing gear on survey sites is decreasing (OSPAR, 2021b).

[1] OSPAR is the mechanism by which 15 Governments & the EU cooperate to protect the marine environment of the North-East Atlantic. OSPAR is so named because of the original Oslo and Paris Conventions ('OS' for Oslo and 'PAR' for Paris). The fifteen Governments are Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Luxembourg, The Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom (OSPAR, 2021a).

Fishing gear that may end up in the marine environment, such as nets and ropes, but also lines, fishing rods, hooks, and traps are often referred to as 'Abandoned, Lost or Otherwise Discarded Fishing Gear' (ALDFG) (Link et al., 2019). ALDFG is considered to be a very persistent type of marine litter with numerous harmful effects for the coastal and marine environment, human livelihoods and well-being (Brown and Macfadyen, 2007; Baeta et al., 2009; Good et al., 2010; Arthur et al., 2014; Gilman et al., 2015). In fact, ALDFG has been identified as one of the most biologically threatening types of marine litter (Newman et al., 2011; McElwee et al., 2012; Kühn et al., 2015; Consoli et al., 2019).

ALDFG in the marine environment has to be understood as an accumulation of (1) loss due to wear and tear, (2) loss of gear and gear parts which cannot be retrieved or are too risky to retrieve, and (3) unintentional and intentional dumping, with net pieces from net mending washed over board or intentional discarding of gear and gear parts (Viool et al., 2018). The annual loss of ALDFG in European waters is estimated to amount to 2,000-12,000 tonnes a year. Given the development of the European fishing fleet over the past five decades, it was estimated that 130,000-550,000 tonnes might have accumulated in this region (EUNOMIA, 2016).

A better understanding of the sources and pathways of such litter, can provide the building blocks to target the root causes. However, due to the general characterisation of fishing net litter in OSPAR beach litter monitoring data, much is still unknown about the sources and pathways (the manner in which the piece of net entered the sea and how from that occurrence it ended up stranded on a beach) of fishing nets found on beaches in the Arctic and North-East Atlantic region. More extensive characterisation such as origin, type of net, and fishing sector would help establish a deeper understanding of sources and pathways.

1.2 WUR research on the sources and pathways of fishing nets collected on beaches input to OSPAR Action 36

The need for a more detailed characterisation of the sources and pathways of beach litter was the motivation for Wageningen Economic Research (part of Wageningen University & Research - WUR) in 2017 to start developing more in-depth knowledge and gathering new beach litter data. By engaging stakeholders in an in-depth analysis procedure, a better understanding of the root causes and solutions to beach litter is created (Strietman et al., 2020, Strietman et al., 2021). This new knowledge can then be used by stakeholders to refine ongoing actions or measures or develop new ones.

One of the OSPAR beach litter categories that has been a special focus in the research work on beach litter since 2017 is fishing nets. In 2020, Rijkswaterstaat Water Verkeer and Leefomgeving commissioned Wageningen Economic Research to write a report summarising its current findings and recommendations arising out of its ongoing research into the sources and pathways of beached fishing nets as input to Action 36 of the OSPAR Regional Action Plan.

The objective of OSPAR's Regional Action Plan is to 'substantially reduce marine litter in the OSPAR maritime area to levels where properties and quantities do not cause harm to the marine environment' and to 'develop appropriate programmes and measures to reduce amounts of litter in the marine environment and to stop litter entering the marine environment, both from sea-based and land-based sources'. Action 36 is aimed at 'developing and promoting best practice in the fishing industry in relation to marine litter' (OSPAR, 2014).

1.3 Aim

The aim of this report is to provide an overview of the research results into the sources, origin and pathways of beached fishing nets and/or pieces of fishing nets in the Arctic and North-East Atlantic region between 2017 and 2019. The key findings and recommendations provided in this report feed directly into the implementation of the OSPAR Regional Action Plan for Marine Litter and the EU Member States marine litter related measures carried out within the Marine Strategy Framework Directive (MSFD). The findings and recommendations can also be used to further strengthen other ongoing initiatives by the fishing industry, governments, NGOs and international organisations (e.g. IMO, FAO, EU, and the Arctic Council).

1.4 Reading guide

Chapter 2 provides an overview on how data was collected and which methodology was applied to analyse the fishing net samples. Chapter 3 presents the results of the analysis. In Chapter 4 the results are discussed, while in Chapter 5, the main results are summarised and recommendations for further action are provided.

2 Methodology

2.1 Background

Back in 2017, during fieldwork visits to Jan Mayen and Svalbard, as part of Arctic Marine Litter Project[2], fishing nets were quite often encountered on beaches. To the author's knowledge at the time, nobody had taken a deeper look into the origin and sources of stranded fishing nets in the region. Because of this lack of research it was therefore difficult to address the issue at source, including industry, Government, and international participants (e.g. IMO, FAO, EU, OSPAR and the Arctic Council), without further analysis.

In September of 2017, a Dutch ex-trawler fisherman voluntarily joined the author had the opportunity to analyse a large number of fishing net pieces that had been collected earlier that summer on beaches all around the Svalbard archipelago by cruise ship passengers and local volunteers. This litter was temporarily stored at the waste management facility in Longyearbyen.

When examining the first couple of trawl nets, it was noticed that when untangled, it was possible to gain more in-depth information about such nets by doing certain measurements (e.g. length/width and mesh size) and interpreting cut and tear marks. This approach provided insights into the origin and source but also the underlying cause of why those nets had ended up in the sea. To facilitate this analysis the Fishing Net Assessment Protocol was developed. Using this protocol, a 42 fishing nets was measured, photographed and analysed and the results were registered in Microsoft Excel.

Figure 2.1 *Examining the fishing nets in Longyearbyen, September 2017*
Photo: W.J. Strietman.

In September of 2018, two Norwegian fishing gear experts and a representative of an international fishing gear manufacturer participated in the analysis of a second sample of fishing nets collected from beaches around the Svalbard Archipelago. They were asked for their opinion on the Fishing Net Assessment Protocol and to verify the results of the first sample of nets that had been analysed in 2017. Based on their expert judgement, it was concluded that the protocol worked as a tool to gain more in-depth information on stranded fishing nets and didn't need any more adjustments. Since then it has been applied as part of beach litter analysis studies carried out throughout the Arctic and North-East Atlantic region (see also section 2.3).

[2] https://www.wur.nl/en/Research-Results/Research-Institutes/Economic-Research/projects-Economic-Research/The-Arctic-Marine-Litter-Project.htm

2.2 The Fishing Net Assessment Protocol

2.2.1 Aim and approach

The aim of the Fishing Net Assessment Protocol is to obtain as much information on beached fishing nets as feasibly possible. The Protocol entails a more detailed and comprehensive characterisation and analysis of fishing nets in order to obtain a deeper understanding of the sources and root causes of such litter in the coastal environment and pinpoint tailor-made management responses. The combination of both quantitative and qualitative elements in the examination procedure is intended to provide a better understanding of the sources, origin and pathways of such nets. Using the protocol, each net is examined in a consistent and systematic way, which makes the results comparable.

2.2.2 All nets are divided between those shorter and longer than 50 cm

The smaller the size of the net, the fewer aspects can be examined and therefore the fewer conclusions can be drawn. Consequently, it was decided to draw a distinction between smaller and larger nets in the analysis. A distinction line of 50 cm in length was chosen, based on the OSPAR characterisation for fishing nets in its Beach Litter Monitoring Guideline (OSPAR, 2010). The OSPAR guideline includes two categories that relate to fishing nets: 'Nets and pieces of net <50 cm' and 'Nets and pieces of net >50 cm'.

In terms of the analysis method used to examine each fishing net in more detail, the Fishing Net Assessment Protocol was applied to analyse those nets of 50 cm and over in their longest dimension (Figure 2.2). Pieces of fishing net of 50 cm and shorter in their longest dimension (Figure 2.3) were also examined using the protocol. Because of the small size and lack of sufficient clues in smaller pieces of fishing net, less information can be obtained so not all criteria of the Fishing Net Assessment Protocol can be applied.

Figure 2.2 *Fishing nets >50 cm on Svalbard (left) and Jan Mayen (right)*
Photos: W.J. Strietman.

Figure 2.3 *Examples of pieces of fishing nets <50 cm on Terschelling (left) and in Scotland (right)*
Photos: W.J. Strietman.

2.2.3 Fishing Net Assessment Protocol for nets >50 cm

The analysis protocol for nets of 50cm and over measured at their longest dimension (>50 cm) is divided into two analysis steps:

1. A quantitative assessment is carried out of the length, width, weight, mesh size, level of wear and tear and the analysis of cut or tear marks on each side of the net; and.
2. A qualitative assessment is carried out to determine the source (fishing sector involved), age, origin and pathways to have ended up in the sea..

Each examination is carried out by a researcher of Wageningen Economic Research together with a (local) fishing gear expert and/or expert with a background in fishing. For the interpretation part of the analysis, the involvement of such experts has shown to be of crucial importance.

As a first step, each fishing net is untangled and stretched out on the floor. The untangling of each net is a crucial step, because only then it becomes possible to conduct an extensive analysis of the source, origin and pathway of each net. After untangling a net, the following quantitative aspects are measured and registered:

- The length and width (total size registered in one of six size classes);
- The weight;
- The mesh size;
- The number of pieces within the net (a net can consist of different pieces joined together sometimes consisting of different mesh sizes);
- The level of wear of the material including the number of tear holes in the net; and
- The presence and type of cut and/or tear marks on each side of the net including:
- Cut marks made with a certain pattern along the side of the net that have been made to cut a net into the right shape before use;
- Cut marks that are the result of having cut-out a piece of fishing net during repairs (replacing a torn or worn out piece); and
- Tear marks that show an irregular pattern, typical of wear and tear.

For the second qualitative step, the results are interpreted with the help of a (local) fishing gear expert and/or expert with a background in fishing to determine:

- The most probable fishing sector involved (based on the type of fishing net and mesh size);
- The area where such fishing nets are being used (also based on the type of fishing net and mesh size);
- The age of the net: less or more than 5 years;
- The reason for the net sample to have ended up in the sea as follows:
  1. Accidental loss (after being entangled, for example on the seabed);
  2. Mismanaged net waste:
     a. Pieces of net that are damaged through regular wear and tear or by accident are cut from the rest of the net. Usually but not always (if the remaining damaged area is very small) the net is mended with new netting material. The net is mended by joining new pieces to the net. If the net cutting is then not properly collected and stored, it may end up in the sea. Mismanaged net waste can therefore be caused by unintentional or intentional discarding (d'Arcy Metcalfe and Bentley, 2020).
     b. Additionally, after replacement of a broken or worn piece of fishing net with new netting material, there could be 'leftovers' on the new roll of net. These leftovers may then not be collected and properly stored and end up in the sea, again due to unintentional or intentional discarding.

The results of the quantitative and qualitative assessments are registered in an excel database. A photo is taken of each untangled net for further reference.

Figure 2.4 *Examining cut and tear marks and registration of the results (the Netherlands left/Greenland right)*
Photos: W.J. Strietman (left), A. van den Brink (right).

2.2.4 Fishing Net Assessment Protocol for nets <50 cm

The Fishing Net Assessment Protocol is also used to examine fishing nets shorter than 50 cm in their longest dimension. Because of the small size and lack of sufficient clues in smaller pieces of fishing net, less information can be obtained so not all criteria of the Fishing Net Assessment Protocol can be applied. What can be determined is the general source based on the type of gear (trawl net or gillnet) as well as the most probable cause (where such an assessment is feasible).

2.2.5 Gillnets were examined but results not presented in this report

Gillnets are mostly used on the seabed and have a low buoyancy, so they tend to sink, whereas most trawl nets have a high buoyancy and float. Therefore, this reduces the probability of finding large quantities of gillnets on beaches. This was reflected in the relatively low number of gillnets (5) in the samples of fishing nets >50 cm as compared to the relatively high number of trawl nets (211). Because of the low representation of gillnets in this category and the absence in the category <50cm, it was decided to leave gillnets out of the results presented in this report and to concentrate on trawl nets.

2.2.6 Overview of the procedure to analyse fishing nets and data presented in this report

As a result of the research efforts between 2017 and 2019, 211 pieces of trawl net of 50cm and over measured at their longest dimension (>50 cm), and 2,908 pieces of fishing net of 50cm and shorter measured at their longest dimension (<50 cm), have been analysed. In addition, five gillnets >50cm had also been analysed, the results of which are not presented in this report. Figure 2.5 presents a schematic overview of the procedure for the analysis of fishing nets presented in this report.

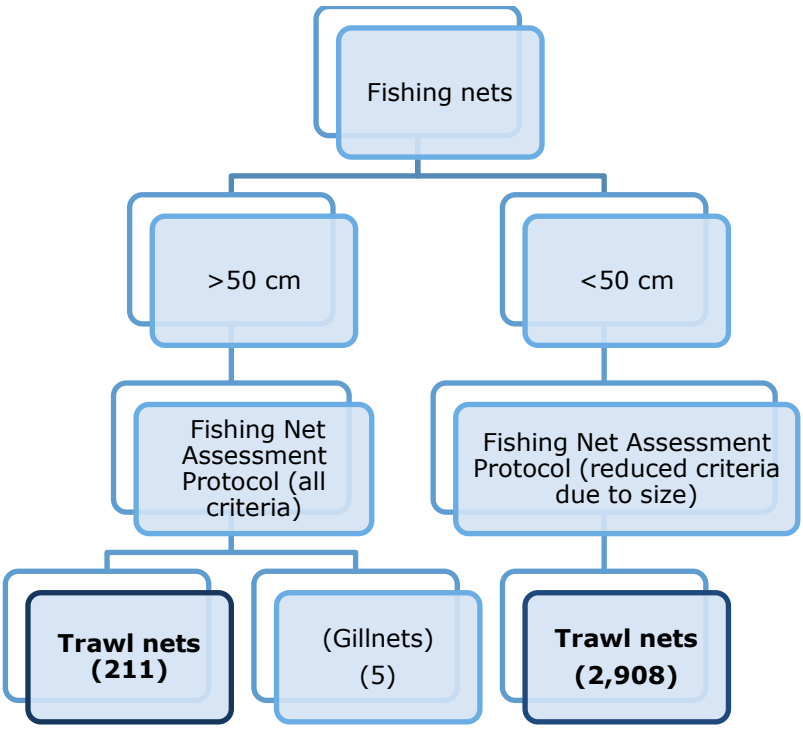

Figure 2.5 *Schematic overview of the procedure to analyse fishing nets depending on the net size. Numbers in parenthesis represent the sample size for each category. Categories in bold are presented in this report*

2.3 Study areas and data collection

Since 2017, the protocol has been applied to analyse fishing nets collected in the Netherlands (Strietman et al., 2020), Iceland (Strietman et al, in prep.), Scotland (unpublished), Jan Mayen (unpublished), mainland Norway (unpublished), Svalbard (Falk-Andersson & Strietman, 2019) and Greenland (Strietman et al., 2021).

Due to the Covid-19 crisis, no fieldwork has taken place since November 2019 and therefore no additional data was collected since then. For the purpose of this report, the data collected up until November 2019 is summarised. Once fieldwork can start again, more data will be collected on beach litter (including fishing nets) at other locations, that will give a further and broader insight into this important problem.

Depending on the location, data was either collected on fishing nets >50 cm, <50 cm or both. Figure 2.6 provides an overview of the study areas where this data was collected.

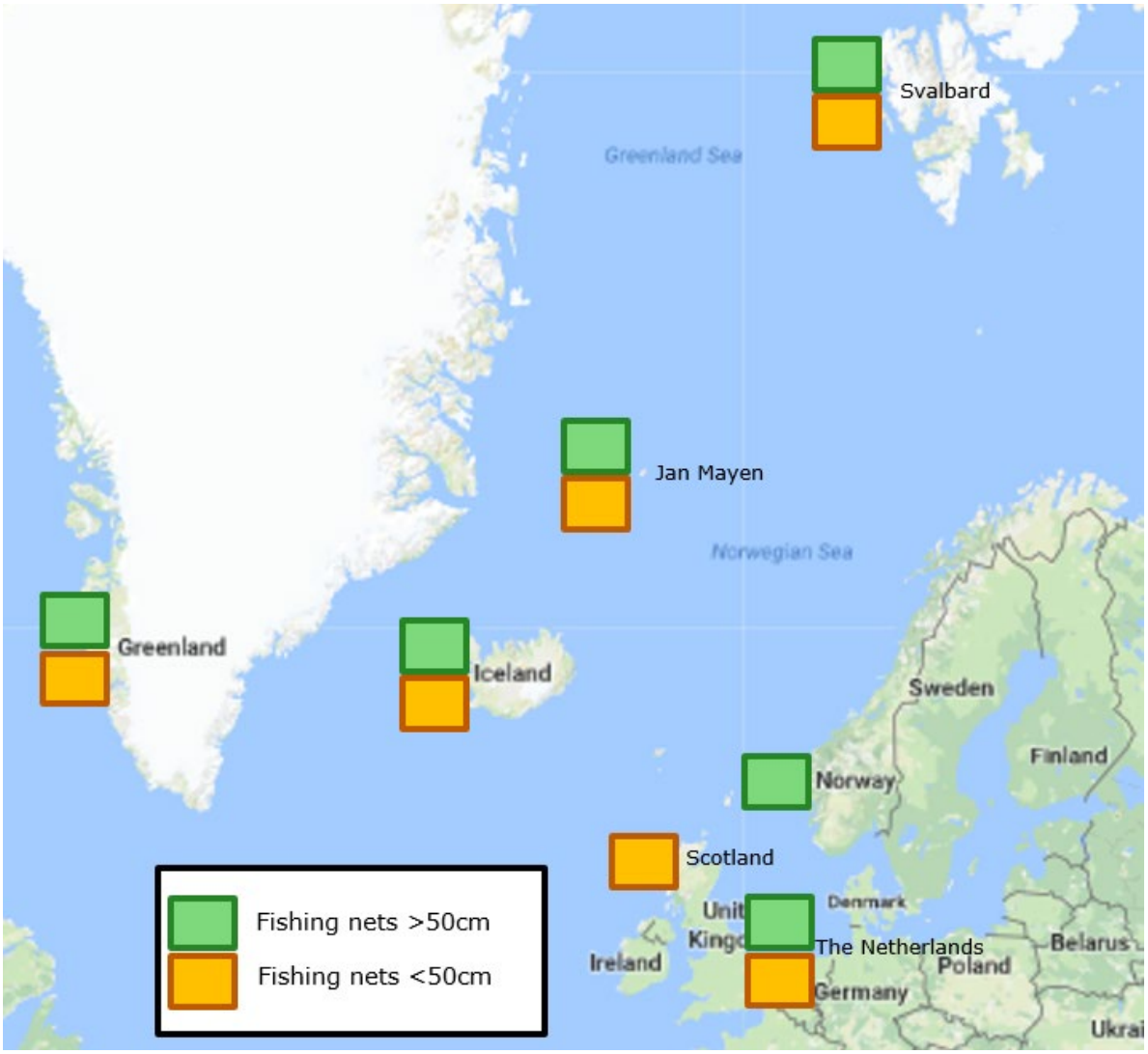

Figure 2.6 *Study areas where data on fishing nets was collected (green: fishing nets >50 cm, orange: fishing nets <50 cm)*
Source: Wageningen Economic Research.

Between 2017 and 2019, 211 trawl nets >50 cm and 2,908 pieces of trawl nets <50 cm were analysed. Table 2.1 provides a description of where and how each sample was collected and analysed.

Table 2.1 *Sample collection*

Study area	Specific location	Analysis date and location	Nr. of nets >50 cm	Nr. of nets <50 cm	Description
Norway	*Jan Mayen*	*May 2017, MV Ortelius*		22	22 net pieces <50 cm were examined by Wageningen Economic Research as part of a beach litter monitoring effort at Kvalrusbukta during a trip with Oceanwide Expeditions as part of the Arctic Marine Litter Project (unpublished)
Norway	*Svalbard (14 locations)*	*June & August, 2017, MV Ortelius & Longyearbyen*		341	The 341 net pieces <50 cm were examined by Wageningen Economic Research as part of a beach litter study of litter collected at 14 different beaches all around the Svalbard Archipelago during two trips with Oceanwide Expeditions as part of the Arctic Marine Litter Project (June and August 2017), and by volunteers of Project Isfjorden who carried out beach clean-ups at different beaches around Isfjorden during the summer of 2017 (unpublished)
Norway	*Svalbard (unknown locations)*	*11 Sep. 2017, Longyearbyen*	*42*		*42 net pieces >50 cm were examined in 2017 and 62 in 2018. All of these had been collected at locations all around the Svalbard archipelago, either as part of dedicated beach-clean-ups or by cruise passengers as part of the Cleanup Svalbard initiative (AECO, 2021). The analysis of 42 net pieces in 2017 was carried out with the help of a Dutch ex-trawler fisherman as part of the Arctic Marine Litter Project. The preliminary results of that exercise were verified and missing information on the fishing sector was added in 2018 based on a review by Norwegian fishing gear experts from the University of Tromso and the Norwegian Fisheries Directorate. Those two experts, along with a representative from an international trawl net manufacturing company participated in the 2018 analysis, where 62 nets were analysed as part of an in-depth ('Deep Dive') beach litter analysis workshop coordinated by SALT and Wageningen Economic Research in Longyearbyen, Svalbard (Falk-Andersson & Strietman, 2019).*
Norway	*Svalbard (unknown locations)*	*7 Sep. 2018, Longyearbyen*	*62*		
The Netherlands	*Terschelling (North Sea side)*	*27 April 2019, West-Terschelling*	*29*		*In the Netherlands, a total of 40 pieces of trawl net >50 cm were analysed: 29 collected on the island of Terschelling as part of a study into the sources and pathways of stranded fishing nets carried out by Wageningen Economic Research (Stichting De Noordzee, 2019) and 11 pieces during a Litter-ID session to analyse beach litter collected from the island of Griend organised by Wageningen University & Research (Strietman et al., 2020). Both analyses were carried out together with the same Dutch ex-trawler fisherman who also participated in the 2017 analysis on Svalbard. During the Litter-ID session, 155 pieces of fishing net <50 cm were also analysed.*
The Netherlands	*Griend (Wadden Sea)*	*23 Oct. 2019, Harlingen*	*11*	*155*	

Study area	Specific location	Analysis date and location	Nr. of nets >50 cm	Nr. of nets <50 cm	Description
Iceland	*Holmavik (Westfjords)*	*5 Sep. 2019, Isafjordur*	*33*	*2,220*	*In Iceland, 33 nets >50 cm and 2220 fishing nets <50 cm were collected at a beach near Holmavik, by students of the University of the Westfjords. They were later analysed together with a fishing gear expert from the University of the Westfjords as part of the Arctic Marine Litter Project during a Litter-ID session in Isafjordur coordinated by Wageningen Economic Research (Strietman et al., in prep.).*
Norway	*Sognefjord*	*9 Oct. 2019, Slemmestad*	*8*		*In Sognefjord, 8 trawl nets >50 cm were collected by volunteers as part of local beach clean-up efforts.*
Norway	*Jan Mayen*	*9 Oct. 2019, Slemmestad*	*14*		*On the island of Jan Mayen, 14 trawl nets >50 cm were collected during a beach clean-up effort (at the beaches of Haugenstranden, Helenesanden, Maria Much, and Lagunevolden). Fishing nets from both locations were analysed with the help of the same fishing gear expert from the Norwegian Fisheries Directorate who also participated in the 2018 analysis on Svalbard. The analysis was carried out in collaboration with consultancy agency Mepex and the organisation Hold Norge Rent as part of an in-depth beach litter analysis workshop that took place in Slemmestad (Oslo), October 2019 (unpublished).*
Greenland	*Amerloq Fjord (Sisimiut)*	*12 Nov.2019, Sisimiut*	*8*	*32*	*In Greenland, a total of 12 trawl nets >50 cm and 64 nets <50 cm collected near Sisimiut, Maniitsoq and Qaqortoq were analysed as part of the Arctic Marine Litter Project during a Litter-ID session coordinated by Wageningen Economic Research in November 2019 in Sisimiut (Strietman et al., in prep a). The analysis was carried out together with a fishing gear expert from the local supplier of fishing and trawl gear.*
Greenland	*Maniitsoq*	*12 Nov. 12 2019, Sisimiut*	*3*	*20*	
Greenland	*Qaqortoq*	*12 Nov. 2019, Sisimiut*	*1*	*12*	
Scotland	*Old Dorney Harbour*	*6 Dec. 2019*		*106*	*As part of a beach litter monitoring effort by Wageningen Economic Research on a beach near Old Dorney Harbour, 106 pieces of fishing net <50 cm were collected and analysed.*

Source: Wageningen Economic Research.

3 Results

3.1 Fishing nets >50 cm

3.1.1 The average size is around 14 m^2 and the average weight around 7.6 kg

In Table 3.1, the number of nets >50 cm in length, their average size and weight are provided for each study area.

Table 3.1 *Number of nets analysed and average size of each net for each sample*

	Svalbard	Iceland	Jan Mayen	Greenland	Mainland Norway	The Netherlands	Total
Number of nets	104	33	14	12	8	41	**211**
Average size (m^2)	20.8	3.7	7.7	24.0	16.5	3.0	**13.9**
Average weight (kg)	11.6**	3.7	4.8	9.9	3.2	1.63**	**7.6**

**: data partially unavailable; the average is based on those nets where the weight was measured.

Source: Wageningen Economic Research.

The average size is 13.9 m^2 and the average weight 7.6 kg (69 of the 211 nets could not be weighed due to the absence of scales at the location where the analysis took place). The average size of nets differs slightly for each sample region. Any differences between regions might be explained by either differences in sample size (and the representativeness of the sample) or by differences in the sizes of trawl fishing nets that are used by vessels operating in those areas.

Of all the nets analysed, none were intact trawl nets: all were pieces/parts of trawl nets. These pieces ranged in size from relatively small to very large (over 61 m^2 in size). However, most pieces measured less than 6 m^2 (Figure 3.1).

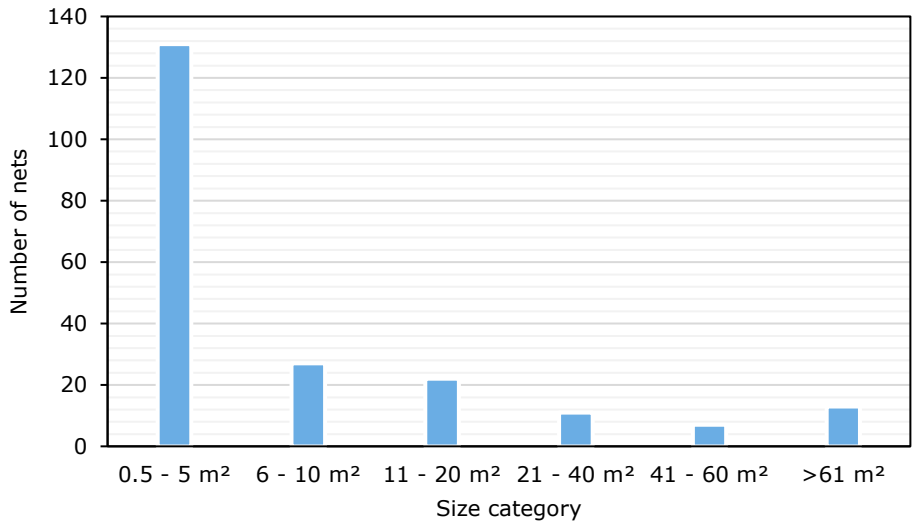

Figure 3.1 *Distribution of all trawl fishing nets sorted into six size categories*
Source: Wageningen Economic Research.

3.1.2 Most nets that end up on beaches originate from the region itself

Based on the mesh size and other indications, the most probable source (fishing sector) of each net was determined by the fishing gear experts. Figure 3.2 shows the most probable sources of all nets analysed. For a number of bottom trawl nets it was not possible to determine the exact fishing sector due to similar mesh sizes being used in different fishing sectors.

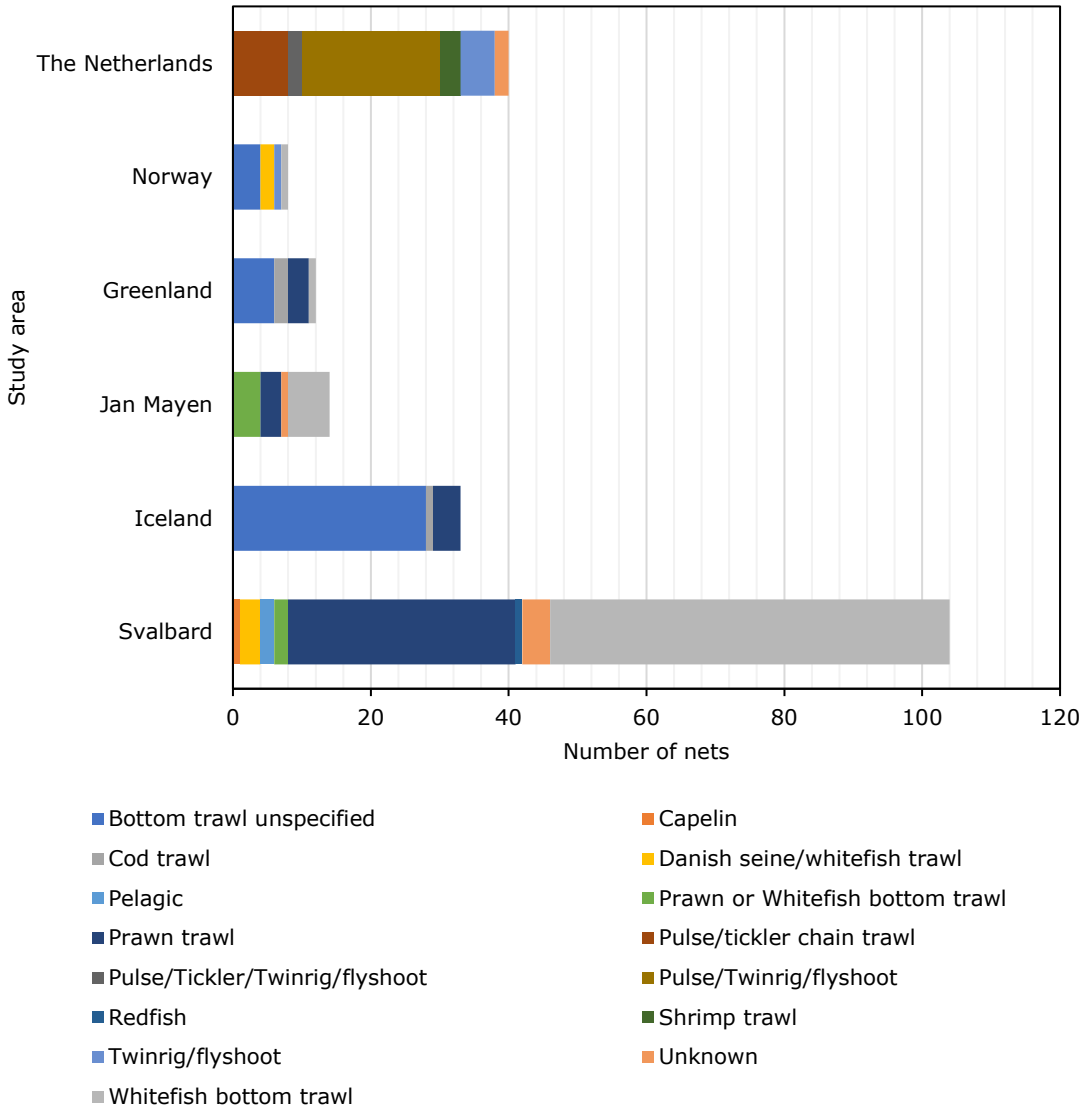

Figure 3.2 *Number of trawl nets >50 cm examined in each study area and their sources*
Source: Wageningen Economic Research.

Based on the analyses carried out to determine the most probable fishing sector involved, and discussing the outcomes with the fishing gear experts involved, it was their opinion that the most probable source of the trawl net samples that end up on beaches are mostly from vessels that operate near the study areas. For example, all of the nets collected in the Netherlands could be traced back to fleets that operate in the southern North Sea, while those collected on Svalbard could be traced back to fleets that operate in the Norwegian and Barents Seas. This means that most trawl nets on beaches are not the result of long-range transport, aided by wind and ocean currents (e.g. it is unlikely to find a trawl net from the Southern North Sea on a beach in Svalbard).

Determining which vessels from which flag states that operate near the study areas are involved is more difficult to determine though. The reason for this is that vessels operating in the same fishing area might be using the same type of fishing technique and thus the same type of gear. For example,

in the Barents Sea, the Norwegian and Russian fishing fleets are the main fleets using similar fishing techniques and gear (according to the representative from an international trawl net manufacturing company that was present during one of the analysis sessions, the type of fishing net that was collected on beaches around Svalbard are being used by vessels from both fleets).

3.1.3 79% of the larger fishing nets are mismanaged net waste

Based on expert judgement, for each of the 211 nets, the most probable cause that a net ended up in the sea (pathway) was determined. Of all the nets examined, 21% have most probably been accidentally lost whilst fishing, while 79% have most probably ended up in the sea due to inadequate net waste collection and storage procedures on board fishing vessels and subsequently having been unintentionally washed overboard or deliberately discarded (see chapter 5, discussion). The results break down as follows (Figure 3.3):

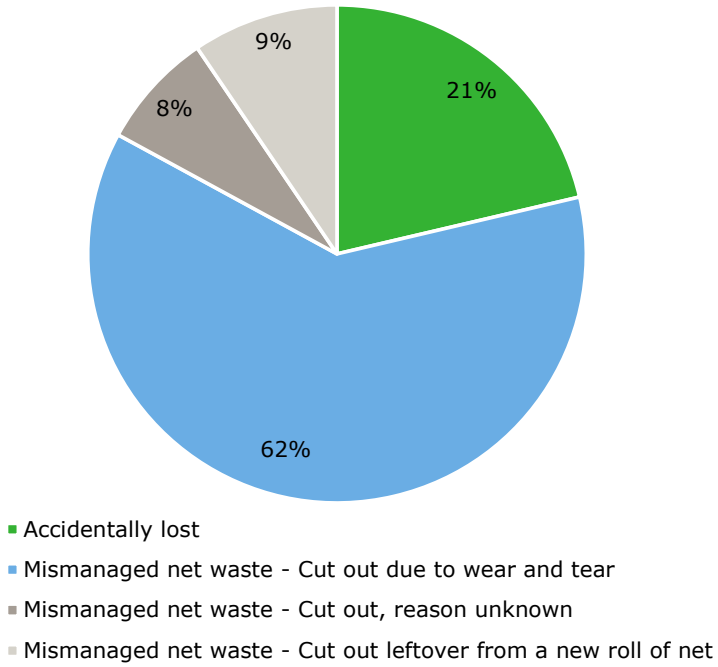

Figure 3.3 *Most probable pathways for fishing nets >50 cm to have ended up in the sea*
Source: Wageningen Economic Research.

Figure 3.4 *Typical examples of mismanaged net waste: a cut-out piece of fishing net (left) and a leftover from a new roll of fishing net (right)*
Photos: W.J. Strietman.

For each of the size classes, the level of 'accidental loss' (entanglement on seabed whilst fishing) versus 'mismanaged net waste' differs slightly. As is shown in Figure 3.5, the level of 'mismanaged net waste' is relatively higher in the smallest size classes and lower in the largest size classes, while the level of 'accidental loss' is higher in the large size classes and lower in the lowest size classes.

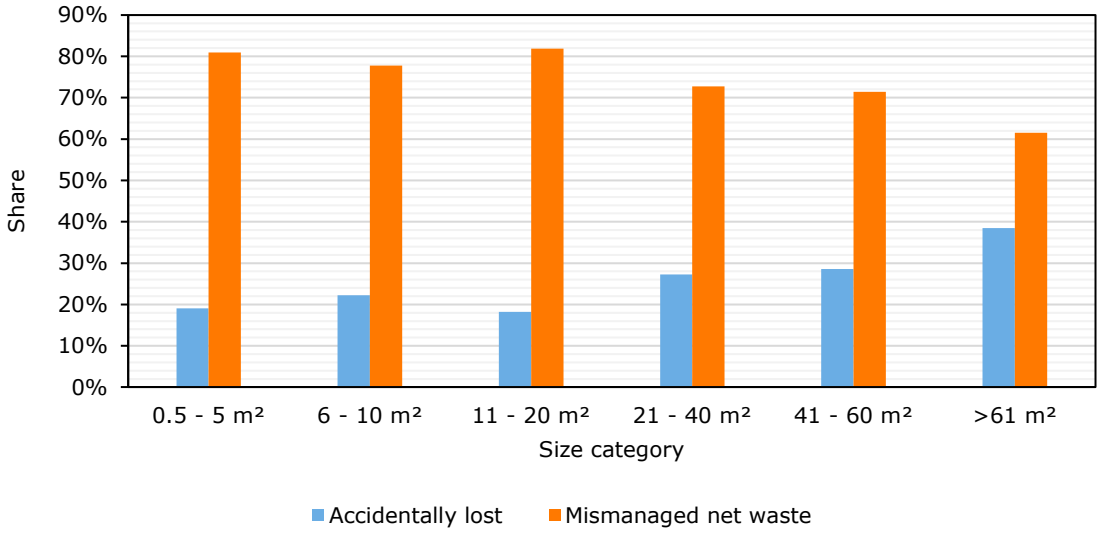

Figure 3.5 *Most probable pathways for fishing nets >50 cm to have ended up in the sea, divided by size class*
Source: Wageningen Economic Research.

In terms of the most probable cause (pathway) for each trawl net to have ended up in the sea, the results differ for each geographical region (Figure 3.6).

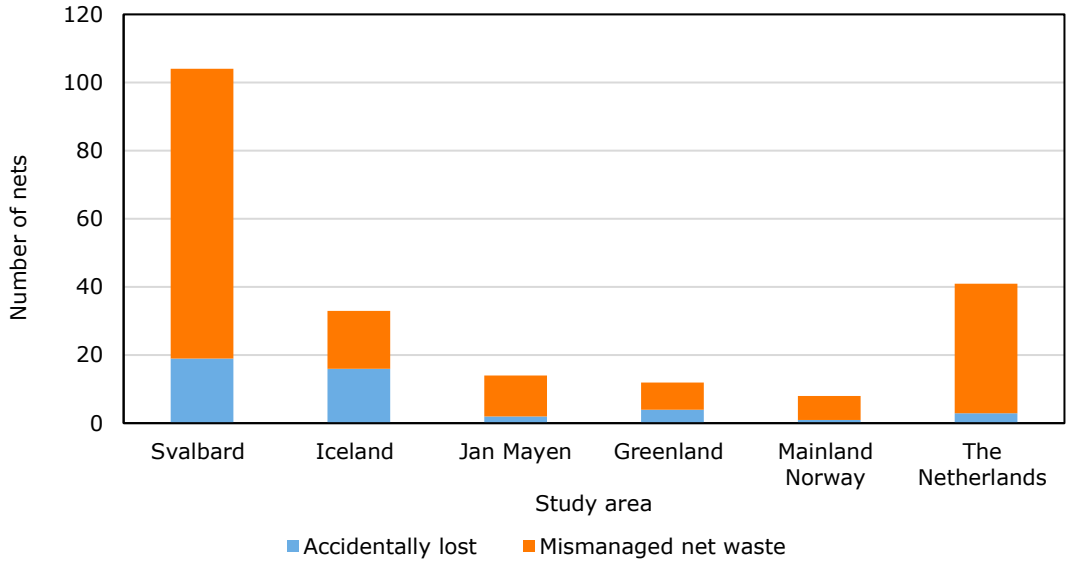

Figure 3.6 *The number of nets that are most probably accidentally lost or ended up in the sea due to inadequate waste management, divided by study area*
Source: Wageningen Economic Research.

3.2 Fishing nets <50 cm

Smaller pieces of fishing net were analysed as part of Litter-ID sessions in the Netherlands, Iceland and Greenland and a beach litter analysis in Scotland. As set out in section 2.2.4, due to the relatively small size of the items and scarcity of clear clues which could tell more about the sources, origin or pathways, less criteria of the Fishing Net Assessment Protocol were used to analyse this category of nets.

3.2.1 The exact sources and origin could not be determined

Because of the design and material used (polyethylene), all of the smaller pieces of fishing net could be traced back to trawl fisheries; none of the (pieces of) fishing nets in this category were gillnets. Due to lack of further clues, the exact type of trawl fisheries and the origin could not be determined.

3.2.2 Most of the pieces were most likely cut-off mesh ends

Based on their appearance, most of the smaller pieces were either mesh ends or pieces of twine cord that are used to make and mend nets. During mending procedures, smaller mesh ends are cut-off and might fall on the deck or in between the nets and get washed overboard if these are not collected right away. It could not be definitively determined which part of these smaller pieces had been cut off during mending work on the nets. However, given their appearance (most of them were between 1 and 15 cm in length) it is highly likely that a significant amount (perhaps most) were indeed cut-off mesh ends (Figure 3.7).

Figure 3.7 *A cut-off mesh end on the beach (left) and the way that loose mesh ends are cut (right) Photos: W.J. Strietman.*

Longer pieces of twine cords used to make nets and also carried by fishing vessels for mending nets (either on board fishing vessels or in port) were also encountered in the beach litter samples. These could be either cutting waste or accidentally lost due to wear and tear of the net. It could not be determined which of these causes was the most common one (Figure 3.8).

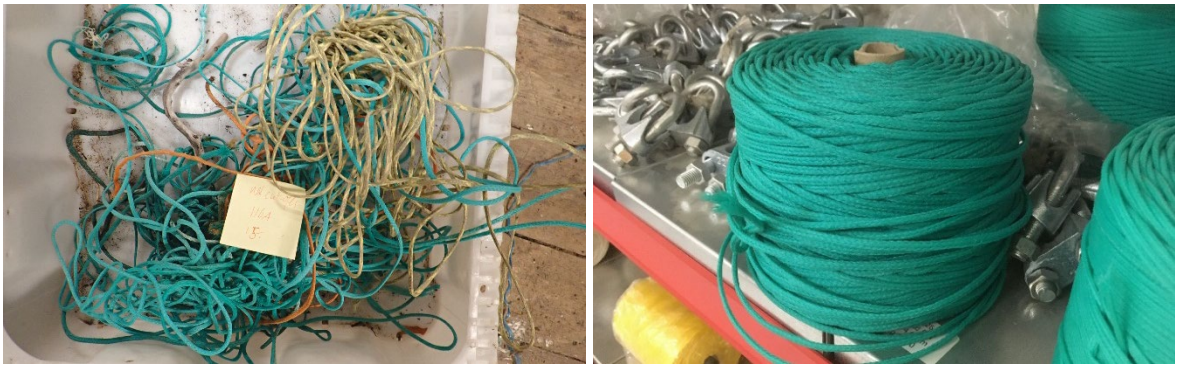

Figure 3.8 *Pieces of twine cords for making and mending nets collected at a beach (left) and a new roll of such twine cord in a fishing gear supply store (right)*
Photos: W.J. Strietman.

4 Discussion

4.1 Inadequate net waste collection & storage main cause

4.1.1 Most pieces are mismanaged net cutting waste

In terms of the *larger pieces of fishing net (>50 cm)*, most are mismanaged net cutting waste that reach the sea due to not having effective waste management systems in place for the collection and the correct disposal of such waste and are either being unintentionally washed overboard or deliberately discarded.

The share of mismanaged larger pieces of fishing nets averages at 79% but varies between each of the sampled locations. This variance might be explained by:

- The size of each sample (especially those of Jan Mayen, Greenland and mainland Norway are relatively small and therefore likely less representative);
- Slight differences in expert judgement by gear experts; and
- The extent to which (certain) vessels operating in the different study areas have adequate fishing net waste management procedures in place.

For the smaller pieces of fishing net (<50 cm) the exact share of mismanaged netting waste could not be determined. But due to their appearance (most were short pieces less than 15 cm in length), almost all of such short pieces were in all likelihood mismanaged off-cuts from fishing nets that have either been unintentionally washed overboard or deliberately discarded.

Based on interviews conducted by KIMO (Metcalfe and Bentley, 2020), it was found that the primary source of such smaller net cuttings is careless disposal (dropping or throwing onto the deck, net or quayside) during the mending of nets. This might arise out of habit or through the need to keep up a certain speed or efficiency of mending work. If such smaller cuttings are not removed quickly from the deck or quayside, they can either be washed overboard or swept overboard when the (mended) trawl net is rolled out from the deck into the water for fishing.

4.1.2 Fishing net waste in relation to other types of fisheries waste

Another relevant related aspect is that fishing net waste is just one waste category that is produced on board fishing vessels. The other being other operational waste (e.g. rope, dollyrope, strapping band), household waste (e.g. kitchen waste such as food packaging) and chemical waste (e.g. engine oil). Such other waste also ends up on beaches in the Arctic and North-East Atlantic region. In that sense, mismanaged fishing net waste could potentially be connected to a wider issue of waste mismanagement on board (trawl) fishing vessels within certain fleets. One example of an area where this is likely the case is the Svalbard region including the Barents Sea (Falk-Andersson & Strietman, 2019), but it is not unlikely that this is also the case in other regions.

4.2 Beached trawl nets originate from areas close-by

Even though ocean currents can cause long-range transport of marine litter from one continent to the other, the experts engaged in this report are of the opinion that most pieces of fishing net ending up on beaches originate from vessels operating in fishing areas relatively close to the study areas.

4.3 All nets are pieces, none are intact

None of the fishing net samples examined were intact nets. All were pieces, most of which were the result of inadequate waste collection and storage procedures on board trawl vessels. This is an important aspect to keep in mind when discussing the topic of 'lost gear' with different stakeholders as the perception of this concept might differ depending on the type of stakeholder.

For example, in conversations with fishers, it is often heard that in their perception, 'lost gear' refers to an intact net that has been lost. In the perception of researchers, policymakers and volunteers engaged in clean-ups, 'lost gear' can mean all types, pieces and sizes of gear. Such differences in perception may cause a mismatch in the understanding of the phenomenon and the most effective solutions.

4.4 Fishing net waste presents a safety hazard to shipping

It is clear from the findings in this report that some of the fishing net samples in the >50 cm category are very large. This clearly represents a serious navigational hazard for ships and fishing vessels, particularly the danger of fouled propellers, which was also the strong opinion of fishing experts engaged in this study. This problem is extended further when considering the areas of study. It is well known that the further North fishing vessels travel the harsher the conditions, the more remoteness, and therefore difficulty for search and rescue operations to take place. It is also understood that fishing activity in Arctic waters has increased in recent years. Data from PAME has recently highlighted the increased number of fishing vessels in the Arctic (Hreinsson, 2019).

To compound this problem of net pieces posing safety hazards for fishing vessels and merchant ships, this is part of a wider problem of waste from fishing vessels that also includes items such as ropes, as referred to at paragraph 4.1.2. In particular, abandoned, lost or otherwise discarded fishing gear are estimated to account for up to 10% of total plastics in our oceans (MacFadyen et al., 2009).

In this context it is also noteworthy that the United Nation's International Maritime Organization's 2012 Cape Town Agreement for the safety of fishing vessels has yet to come into force. It is popularly believed that this Convention would help to greatly reduce the problem of fishing gear ending up in the world's oceans through the enhancement of the requirements for safety on fishing vessels and the enforcement of those provisions (International Maritime Organization, 2021 & International Maritime Organization, 2020).

4.5 In OSPAR beach litter monitoring efforts, net cut-offs may have been mistakenly assigned to the 'string and cord' category (OSPAR ID 32)

A small but perhaps significant point to raise is that in the current version of the Photo Guide that is an appendix to the OSPAR Beach Litter Monitoring Guideline, there is one litter category that might have resulted in the misidentification and subsequent erroneous registration of fishing nets: 'String and cord, diameter less than 1 cm' (OSPAR ID 32).

The accompanying photo in the Photo Guide shows an example of a piece of string/cord that has a diameter less than 1 cm. However, what it actually shows is a cut-off mesh end of a trawl net, which is in fact part of a fishing net and would be more suitably placed in the OSPAR category 'Nets and pieces of net <50 cm' (Figure 4.1).

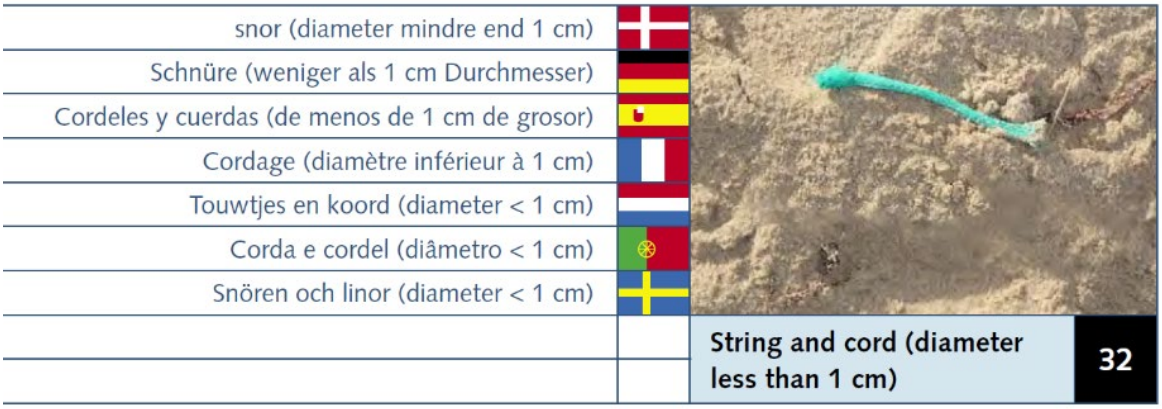

Figure 4.1 *OSPAR ID 32: 'String and cord'*
Source: OSPAR, 2010.

Following the guide publication in 2010, the accompanying photo may have led to confusion for people conducting beach litter surveys and who are not familiar with the technicalities and recognition of fishing net waste. Instead of assigning these litters items to the OSPAR category 'Nets and pieces of net <50 cm' they may have mistakenly been assigned to the category 'String and cord, diameter less than 1 cm'. Due to potential misidentification of net cuttings it is therefore possible that there may have been an under-reporting of fishing nets as a source of litter in the OSPAR maritime region.

4.6 Representativity of the results

4.6.1 Results and findings likely similar for other areas in the North-East Atlantic

In this report, the results of all fishing net analyses carried out by Wageningen Economic Research between 2017 and 2019 are summarised. Those analyses took place on locations throughout the Arctic and North-East Atlantic region. The locations where those beach litter monitoring efforts took place cover a significant part of the North-East Atlantic, but not the entire region. In that way, it could be argued that the results presented in this report may not be representative of the entire region.

However, during the 2017-2019 period, the more analyses took place, the more it became clear that no matter where the analysis took place, the sources tended to be local/regional and the pathways similar (most trawl nets on beaches tended to be mismanaged net cuttings). It is expected that when fieldwork starts again in other areas of the Arctic and North-East Atlantic region, the results will likely be similar to those presented in this report.

4.6.2 The role of gillnets as a source of marine litter could be better understood by analysing fishing nets collected from the seabed

Gillnets are mostly used on the seabed and have a low buoyancy, so they tend to sink, whereas most trawl nets have a high buoyancy and float. Therefore, this reduces the probability of finding large quantities of gillnets on beaches. Because of the low representation of gillnets in the samples found (2.4%), it was decided for the purposes of this study to concentrate on trawl nets.

Whilst bottom trawl nets may or may not represent the main source of fishing net litter in the marine environment, they do represent the most common source of fishing net litter *on beaches*. More information on gillnets as a source of seabed litter in the North Atlantic region can be found in the 2020 report published by the Nordic Council of Ministers as part of the Clean Nordic Oceans project (Langedal et al, 2020). The report describes the current knowledge on gillnets (along with other types of passive and active gear) as a source of seabed litter in the North Atlantic region and provides practical recommendations on how to improve the situation.

5 Conclusion and recommendations

5.1 Conclusion

This report shows that of the study areas analysed in the Arctic and North-East Atlantic region, all fishing net litter that washes up on beaches are pieces rather than complete nets. Complete nets can otherwise be known as 'lost gear' that may also include attached ropes, buoys, steel wire and other materials. Most of these pieces are relatively small in size and originate from nets used in bottom trawl fisheries. The pieces found on beaches are, predominantly, the result of mismanagement of net cutting waste during mending on deck and, to a lesser extent, the result of damage during trawling. Net cuttings reach the sea due to not having effective waste management systems in place for the collection and disposal of such waste and are either being unintentionally washed overboard or deliberately discarded.

For trawl net pieces >50 cm, it was determined that 79% of the pieces were found to be deliberate off-cuts from trawl nets, the result of mending work, while 21% were found to have been accidentally lost due to wear and tear during trawling. While some of the larger pieces reached almost 200 m^2 in size, most of the pieces were relatively small: 62% of the nets were in the 0.5 - 5 m^2 category. In the opinion of the fishing experts engaged, most pieces originate from vessels operating in fishing areas relatively close to where the pieces were found and collected.

For trawl net pieces <50 cm, it was determined that most were cut-off mesh ends and a small amount were twine cord. Both are used in trawl fisheries. Due to the small size of pieces in this size category the specific fishing sector and the geographical origin could not be determined.

The conclusion of this report, then, is that improved waste management of net cuttings on board bottom trawling vessels and in ports is the most effective mitigation measure to prevent most fishing net litter on beaches.

5.2 Recommendations

Throughout the last decade, many initiatives have sprung up to tackle the sources of marine litter. Within this context, the fishing industry has made important progress in trying to prevent fisheries waste from becoming marine litter. Preventive measures are also the most cost-effective when it comes to solving the problem of fishing net litter in the marine and coastal environment.

Taking preventive action by further improving the collection and storage procedures of net cuttings on board bottom trawling vessels in combination with having adequate waste reception facilities in (fishing) ports, would substantially reduce the chance of this waste material from being washed overboard or being discarded, and would significantly improve marine environmental conditions and safety of navigation for ships and fishing vessels in the Arctic and North-East Atlantic region. It is also clear that the prevention of the discharge of net cuttings into the sea would assist with the existing obligations under MARPOL ANNEX V regulations for the prevention of pollution by marine litter from ships and fishing vessels.

5.2.1 Focus mitigation efforts on preventing net cuttings litter from entering the sea

During and after mending work on the nets, both smaller and larger net cuttings will likely be littered over the area where the work has been carried out, including the netting itself. To reduce the chance of this waste material from being swept overboard or being discarded and becoming marine litter, it is

recommended to focus efforts on improving the collection and storage procedures of net cuttings waste on board bottom trawl vessels in combination with having adequate waste reception facilities in (fishing) ports.

In that context, a 2020 report by KIMO (Metcalfe and Bentley, 2020a) on best practices for mitigation of net cuttings litter provides valuable insights and recommendations. Based on interviews with fishers and harbour authorities in the Netherlands, Denmark, Sweden and Scotland, information was gathered about the sources of net cuttings and practices that mitigate inputs to the marine environment. It was recognised that even though it is not realistic to expect that every piece of net can be collected, much more can be done by fishers, skippers, crews and port authorities to prevent net cutting waste from entering the marine environment, including:

1. Having appropriate waste collection bins in place, that cuttings can be dropped into instead of dropping them directly onto the deck, specifically in areas on deck of fishing vessels or quaysides where the repair work is being carried out, or to consider alternative methods of collecting waste materials before they are swept overboard and become marine litter;
2. Improving waste management on board vessels with the captain taking leadership and implementing and enforcing stricter waste management procedures with his crew; and
3. Having adequate waste management plans and practices in place at fishing ports.

A best practices guide has been developed to accompany the above mentioned KIMO report. The guide is the result of both background research and interviews and dialogue with fishers and harbour authorities and gives practical examples of measures on board vessels and in fishing harbours that could be incorporated to reduce net cuttings from entering the environment and (Metcalfe and Bentley, 2020b).

The report that came out of the Clean Nordic Oceans initiative (Langedal et al, 2020) also highlights the need to improve awareness and attitudes amongst fishers, as well as developing and implementing appropriate regulations, including secure reception facilities and the establishment of systems for reporting lost fishing gear with subsequent clean-up. This report further enhances those recommendations.

5.2.2 Consider the suitability of proposed mitigation measures for fishing net litter

In the public discourse and policy arena, current and proposed mitigation measures such as marking of nets, reporting lost gear, or setting a collection target are often presented as being best-practices to prevent fishing gear from ending up in the marine environment and thus on beaches. In light of this report's findings, such best practices are, in themselves, inadequate in preventing most fishing nets pieces from ending up *on beaches,* as they do not address the mismanagement of net cutting waste, the root cause of such litter.

Marking of fishing nets
There is a school of thought that marking or tagging of fishing gear can contribute to easier identification of ownership, thereby creating a disincentive to discarding. However, the report's findings are that fishing net waste on beaches is made up entirely of pieces (rather than complete nets), most of which are relatively small. This would suggest that such a marking solution on its own is inadequate as a mitigation measure to prevent fishing net waste from ending up on beaches, unless a technical solution can be found to mark, and thus identify, the owner, of small pieces of netting.

Reporting lost gear
Council Regulation (EC) No 1224/2009 (European Commission, 2009) requires EU fishing vessels to have the equipment on board for the retrieval of '*lost gear or parts of it'*. In cases where gear is lost, the master of the vessel is to attempt to retrieve it as soon as possible or inform the authorities of its flag Member State within 24 hours if the lost gear or parts of it cannot be retrieved.

It is the report's findings, that an estimated 21% of all the pieces of fishing net >50 cm are accidentally lost while trawling, where, within that category, the level of 'accidental loss' is higher in

the large size classes and lower in the lowest size classes. It is unknown, to which extent such accidental losses are reported, as there may be a 'grey area' as to what would define *'parts of it* [lost gear]*'* under the Directive.

Setting a collection target

Another measure often mentioned to tackle fishing net litter is to set a collection target for used fishing nets as an incentive to bring back to port as much used fishing gear as possible. In such an option, a target would be set for fishing vessels or fishing harbours for the amount of used fishing gear to be delivered to port in weight, based on an assumption of what could be expected to be delivered to port on an annual basis. Such a target could then act as a benchmark to compare the actual amount of used fishing gear brought back to port on an annual basis and to create action plans to improve the situation.

Theoretically, such an option might look like a reasonable option. However, in practice, such a measure may also be inadequate to prevent, in particular, smaller net cuttings ending up in the sea. Consider, for example, a collection target for fishing nets to be set at 90%. Such a target could theoretically be reached by collecting and taking back to port most larger pieces of net cuttings, which are relatively heavy in weight. However, it is mostly smaller, light-weight pieces of net cuttings that ends up in the sea. In weight such items could theoretically make up 10% of the material used, while in numbers, such smaller items make up the main share of fishing net litter on beaches (and also floating, out at sea, as marine litter). Unless a solution can be found to address this practical issue, such a measure appears to be inadequate in preventing fishing net litter *on beaches*.

Accordingly, the key message of this report is that improved waste management on board vessels is the most effective mitigation measure to prevent most fishing net litter on beaches.

5.2.3 Address better (fishing net) waste management procedures on board fishing vessels on the national and international scale to improve marine environmental conditions and safety of navigation for ships and fishing vessels

This report shows, that further improving the collection and storage procedures of net cuttings waste on board bottom trawl vessels, in combination with having adequate waste reception facilities in (fishing) ports should significantly reduce the environmental impact and the risk to safety of navigation for vessels of waste material from fishing nets in the Arctic and North-East Atlantic region.

In the opinion of the fishing experts engaged, that most fishing net waste ending up on beaches in the Arctic and North-East Atlantic region originate from vessels operating in fishing areas relatively close to where the net pieces were found and collected, both inside States' 12-mile territorial limit, and in international waters outside the 12-mile zone, involving national and internationally registered vessels. Accordingly, the issue of adequate waste management should be addressed on a national, regional, and international level.

This report acknowledges that much work is being carried out to address this problem. The report's findings will contribute to on-going initiatives which include, but are not limited to, those by the fishing industry, NGOs, individual States, OSPAR's Intersessional Correspondence Group on Marine Litter, IMO's Marine Litter Action plan, the Arctic Council's Protection of the Arctic Marine Environment Working Group's Regional Action Plan on Marine Litter, the Nordic Council of Minister's work, FAO's Regional Fisheries Agreement work, the EU's Single-Use Plastics Directive - 2019/904/EU, and the EU's Plastics Strategy, the EU's Marine Strategy Framework Directive (2008/56/EC), the EU's Green Deal, and the EU's Zero Pollution Action Plan.

In addition to emphasizing the importance of addressing adequate collection and storage of fishing net waste, the report also highlights the importance of improving safety of navigation and the need for the United Nation's International Maritime Organization's 2012 Cape Town Agreement for the safety of fishing vessels to come into effect.

5.2.4 Incorporate better fishing net waste management procedures in a wider strategy aimed at improving fisheries waste management as a whole

Mitigation measures aimed at improving fishing net waste management procedures on board bottom trawl vessels and waste reception facilities in fisheries harbours could be incorporated in a wider strategy aimed at addressing other types of fisheries waste as well, especially the type of items that are often found on beaches in the North-East Atlantic Area. Examples of such items are ropes, dollyrope, strapping band, rubber gloves and household waste (specifically kitchen and sanitary waste) (Strietman et al., 2020, Strietman et al., 2021, Strietman and van den Heuvel-Greve, in prep.).

5.2.5 Also examine the sources and pathways of fishing nets ending up on the seabed

Whilst bottom trawl nets may or may not represent the main source of fishing net litter in the marine environment, they do represent the most common source of fishing net litter on beaches. To gain a more holistic view of the sources and pathways of all (pieces of) fishing nets ending up in the marine environment, it is recommended to combine in-depth analyses of fishing nets collected from beaches, which is the focus of this report, with analyses of fishing nets collected from the seabed which could be the focus of future work.

5.2.6 Replace the photo that currently illustrates item category 32 the OSPAR Beach Litter Monitoring Guideline with one that does not depict a piece of fishing net

In terms of the OSPAR Beach Litter Monitoring Guideline, the photo currently used to illustrate category 32 is a cut-off mesh-end from a fishing net and would be better suited to illustrate item category 155 'Nets and pieces of net <50 cm'. To avoid confusion, it is recommended to replace the photo that currently illustrates item category 32 'String and cord, diameter less than 1 cm' with a photo of a piece of string or cord that is *not* a piece of fishing net.

5.2.7 Carry out further field work into the sources of fishing nets

The study presented in this report is the first time that such a systematic large-scale examination of stranded fishing nets has taken place in this region, which involved the development of the Fishing Net Assessment Protocol. It is the report's findings that this method has proven to be a successful tool in helping to determine the sources and pathways of stranded fishing net litter. In light of this, it is clear from the findings of this report that further field work should be carried out to enhance the understanding of these issues, not only in the North Atlantic Region, but also in other areas, using the same analysis method.

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