



A SOURCE ASSESSMENT ON MARINE LITTER IN THE SKAGERRAK SUBREGION

Outcome of an international litter ID workshop 2022

Technical Report from DCE – Danish Centre for Environment and Energy

No. 298

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Strand, J.¹
Feld, L.¹
Strietman, W.J.²
Tairova, Z.¹
Metcalf, R.d'A.³

¹ Aarhus University, Department of Ecoscience

² Wageningen Economic Research

³ KIMO Denmark



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Author(s):	Strand J ¹ , Feld L ¹ , Strietman W.J. ² , Tairova Z ¹ , Metcalfe R.d'A. ³
Institution(s):	¹ Aarhus University, ² Wageningen Economic Research, ³ KIMO Denmark
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Abstract:	This report summarises the output of the international workshop on in-depth analyses of beach litter collected in 2022 from different Danish and Swedish sites in the Skagerrak subregion. Skagerrak generally receives large amounts of litter, primarily from local land-based and maritime sources as well as transboundary transport via ocean currents entering from the Greater North Sea. The assessment of the geographical origin of mainly labelled litter items representing different types of packing materials showed that about 1/3 originated from Nordic countries, 1/3 from other North Sea countries and the remaining 1/3 from countries outside the North Sea. An age assessment of these items showed that most were from recent years. Regarding the analyses of fishery-related litter items, it was assessed that a relatively large proportion could be assigned to discarded and mismanaged waste from net cuttings. However, also several other types of fishery-related litter were recorded. Methods for improving source identification and allocation of beach litter using the so-called matrix scoring techniques were also explored at the workshop.
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Preface

This report describes the main output of an international Litter ID workshop on source assessment of marine litter in the Skagerrak. The workshop was organised by participants from the Danish National Centre for Environment and Energy at Aarhus University in cooperation with Ryan Metcalfe from KIMO Denmark. The project established for organising the workshop and analysing and reporting the main findings was funded by the Ministry of Environment of Denmark.

Sammenfatning

Denne rapport sammenfatter resultatet af den internationale workshop om grundig analyse af marint strandaffald, der blev indsamlet i 2022 på fire lokaliteter i Skagerrak-regionen. Skagerrak er et område, der er delt af Danmark, Sverige og Norge, og hvor der generelt forekommer høje niveauer af marint affald fra både lokale landbaserede og maritime kilder samt bidrag fra lande via transport med havstrømme fra Nordsøen. En bedre forståelse af kilderne og transportvejene til marint affald er væsentlig for at kunne iværksætte effektive tiltag til at reducere mængderne af marint affald, både på national, regional og bredere international skala. Rapporten understreger betydningen af internationalt samarbejde for at tackle problemet.

Workshopdeltagerne omfattede eksperter og praktiske udøvere fra flere europæiske lande, som også er involveret i den praktiske overvågning af marint affald på strande i OSPAR-regionen. Workshoppen havde primært fokus på følgende tre elementer: 1) geografisk oprindelse og aldring af strandaffald, 2) betydning af forskellige fiskerirelaterede aktiviteter og 3) tilgange til bedre kildeallokering. Der blev dedikeret workshop-sessioner til at arbejde detaljeret med hver af de tre primære emner.

Resultaterne vedrørende den geografiske oprindelse og alderen af det undersøgte affald i Skagerrak-regionen blev baseret på sortering og undersøgelse af en større mængde affald indsamlet på to danske og en svensk indsamlingsplads. Fokus lå på forskellige typer af emballage, hvor den geografiske oprindelse blev bestemt ved at undersøge mærkater og design. Data viste, at 52 % af de undersøgte genstande kunne tilskrives en geografisk oprindelse, hvoraf 33 % stammede fra nordiske lande, 36 % fra andre Nordsølande og 34% fra lande uden for Nordsøen. Tilførsler fra andre lande transporteret med havstrømme samt havbaserede aktiviteter blev identificeret som potentielle faktorer for marint affald med geografisk oprindelse uden for Skagerrak-regionen. Mens der var en lignende tendens i den geografiske oprindelse af affald fra uden for Skagerrak-regionen på tværs af lokaliteterne, var der forskelle mellem lokaliteterne i Danmark og Sverige, når det kom til nationale bidrag fra de nordiske lande. Dette understøtter, at også lokale kilder er vigtige. Mht. alderen på det marine affald på Skagerraks kyster viste undersøgelserne, at størstedelen af emballagen var mærket med datoer fra de seneste år, hvilket støtter op om, at tilførslerne til Skagerrak er af nyere oprindelse.

Hvad angår analyserne af det indsamlede affald relateret til fiskeri fra Skagerrak-kysterne, fokuserede workshoppen på tabte, mistede eller kasserede fiskeredskaber (ALDFG) samt affaldsgenstande, som kan tillægges slid og fragmentering af fiskeredskaber eller akvakultur. Under denne session vurderede eksperter sammen med to lokale fiskere genstandenes oprindelse, og det blev konstateret, at størstedelen af netstykkerne stammede fra trawlfiskeri. Hovedparten af de større stykker net (>50 cm) kunne identificeres som såkaldte netafskæringer fra reparationer af trawlnet, og kun en mindre andel på 20 % vurderedes at stamme fra iturevne tabte redskaber. Også de mindre netstykker (<50 cm) og snore blev vurderet fortrinsvist at stamme fra trawlfiskeri, herunder reparationer af net. Undersøgelsen understregede vigtigheden af at forbedre indsamlingsprocedurer for affald i havne, om bord på fiskerfartøjer

og under operationer til søs for at forebygge tilførslerne af affald til havmiljøet. Resultaterne stemte overens med observationer i andre dele af Nordatlanten og understregede behovet for målrettede løsninger.

Under workshop-sessionen om at udvikle metoder til at foretage bedre kildeallokering af marint affald på kysterne blev der hentet inspiration fra tidligere studier i OSPAR-regionen. Her blev især potentialet ved brugen af matrixscoreteknikker til vurdering af sandsynligheden for forskellige kilders bidrag til specifikke affaldstyper diskuteret. Der blev identificeret et behov for at foreslå en mere harmoniseret metode, der kan anvendes i forskellige delregioner inden for Nordsøen, herunder med fokus på affaldsgenstande såsom engangsplastik og emballage, der kan stamme fra flere forskellige kilder. Tolv primære kildegrupper blev identificeret, og de omfattede både flere hav- og landbaserede kilder til marint affald. Diskussionerne omfattede også muligheden for at opdele visse kildekategorier såsom rekreativt fiskeri som et dellement af fiskeri eller havneaktiviteter som en del af de generelle skibsrelaterede aktiviteter. Forslaget til de tolv kildegrupper afveg en smule fra dem, der er blevet brugt i tidligere studier, hvilket understreger behovet for yderligere præcisering og enighed om definitionen af hver kildekategori. Dette arbejde kan derfor også have relevans for det videre arbejde med marint affald i regi af den regionale havkonvention OSPAR og de tilknyttede faglige ekspertgrupper involveret i problemstillinger om vurdering af tiltag, kilder, forekomst og miljøpåvirkninger af marint affald i det Nordøstlige Atlanterhav, inklusive Nordsøen. Der var enighed om, at en videreudvikling af matrixscoreteknikken kan danne grundlag for forbedret kildeidentifikation og -allokering både i forbindelse med rutinemæssig overvågning og bredere tiltag målrettet mod at begrænse marint affald på kysterne.

Summary

This report summarises the output of the international workshop on in-depth analyses of beach litter collected in 2022 at four sites in the Skagerrak subregion shared by Denmark, Sweden and Norway. Skagerrak receive generally large amounts of litter, primarily from local land-based sources, maritime sources, and transboundary transport via ocean currents entering from the Greater North Sea.

The workshop participants included OSPAR monitoring experts and beach litter surveyors from several European countries. The focus of the workshop was on the following three elements: 1) geographical origin and age of the beach litter items, 2) importance of different fishery-related activities and 3) approaches to perform better source allocation. Dedicated workshop sessions were held to work in detail on each of the three primary focus topics.

The results of the geographical origin of the examined litter in the Skagerrak region were based on sorting and examination of beach litter collected at two Danish sites and one Swedish site. The focus was in this part on litter of different types of packaging items labelled with relevant product information combined with the languages used, consequently indicating the geographical origin of the litter. The data showed that 52% of the examined items could be assigned to a geographical location, 33% originating from Nordic countries, 36% from other North Sea countries and 34% from countries outside the North Sea. Transboundary transport from the Greater North Sea and sea-based activities were identified as potential sources of litter with geographical origin from outside the Skagerrak-region. While there was a similar trend in the geographical origin of litter from outside the Skagerrak region across the sites, there were differences between the sites in Denmark and that in Sweden when it came to the national contributions from the Nordic countries. This supports the suggestion that also local sources are important. The report also discusses the age of litter items, noting that most packaging labels showed dates from recent years, indicating that the marine litter items found on the Skagerrak shorelines had entered the sea relatively recently.

Regarding the analyses of fishery-related litter items from the Skagerrak shorelines, the workshop session focused on abandoned, lost and discarded fishing gear (ALDFG), litter items from fishing gear abrasion and fragmentation and aquaculture-related litter. During the session, experts and local fishermen evaluated the origin and age of the litter, finding that most larger net pieces (>50 cm) were derived from trawl nets, with a significant proportion being mismanaged waste from net cuttings. Also smaller net pieces (<50 cm) and strings were assessed mainly to origin from trawl net fishery, and many items could be assigned to net repairs and maintenance. The examination emphasised the importance of improving waste collection procedures on the deck of trawling vessels during operation at sea to prevent such litter from entering the sea. The findings aligned with observations in other parts of the North Atlantic region, emphasising the need for addressing this issue at both national and international level.

During the workshop session on approaches to perform better source allocations, inspiration was drawn from previous studies from the OSPAR region.

The potential of matrix scoring techniques for assessing the likelihood of different sources contributing to specific litter types was discussed. The workshop aimed to propose a harmonised method applicable to various sub-regions within the Greater North Sea, with focus on litter items such as single-use plastics and packaging originating from multiple sources. Twelve main source groups were identified, encompassing both sea-based and land-based contributors to marine litter. The discussions also considered the possibility of subgrouping certain source categories, such as recreational fishing within the broader fishery group or harbour activities within different shipping activities. The identified source groups deviated slightly from those used in previous studies, highlighting the need for further refinement and agreement on definitions of each source category. The workshop's outcome holds relevance for the work within the OSPAR framework and the affiliated scientific expert groups, pointing at the needs for further harmonised source assessments in the future, also between different OSPAR subregions. This exploration of matrix scoring techniques provides a foundation for improved source identification and allocation in routine beach litter monitoring and broader marine litter management efforts.

1 Introduction

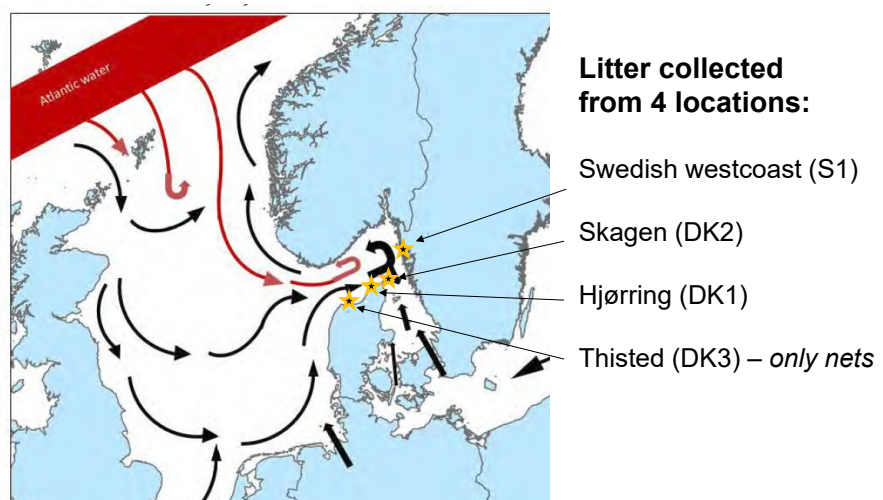
Skagerrak is a sub-region of the North Sea shared by Denmark, Sweden and Norway, where high amounts of litter often can be found washed up on the shorelines. The latest OSPAR assessment of beach litter in the Northeast Atlantic (Lacroix et al., 2023) also identified Skagerrak as a sub-region where transboundary transport of pollution due to wind and currents can exacerbate litter on the shorelines, such transport thereby becoming an important contributor to local source litter input. However, there are also several knowledge gaps, highlighting the need for further studies aimed at identifying important litter sources at a (sub-)regional scale within the OSPAR region.

This report summarises the output of the international workshop on in-depth analyses of beach litter from the Skagerrak sub-region with the aim of assessing important sources and the origin of litter. The five-day workshop (14-18 November 2022) was organised by Aarhus University and KIMO Denmark and held in Northern Jutland, Denmark.

The workshop participants included several OSPAR monitoring experts and beach litter surveyors from Denmark, Sweden, Norway, the Netherlands, France, England, Iceland and Portugal. The discussions were supplemented with practical exercises in sorting and analysing large amounts of collected beach litter. Local fishermen also attended a dedicated Litter ID session on net pieces and other types of litter items identified as fishing gear. In addition, participants from Danish stakeholder organisations like KIMO, the Danish Plastic Center and the Danish EPA attended a workshop session on improving source characterisation.

The analysed litter was collected by local municipalities and voluntary beach cleaners during beach clean-ups at three Danish sites and one Swedish site from different parts of the Skagerrak coastlines during autumn August to October 2022 (Figure 1.1).

Figure 1.1. Map of ocean currents contributing to the transboundary transport of litter from the Greater North Sea into the sub-region of Skagerrak. The locations for the collected litter analysed at the workshop are marked with ★, including Skagen, Hjørring and Thisted in Denmark and Musön at the west coast of Sweden.



In total, more than two filled containers of beach litter were collected, and about 1/3 was sorted for further analysis. Litter from the different collection sites was examined separately.



Figure 1.2a, b. Photos of the two containers filled with beach litter collected at a) Hjørring (green container) and b) Skagen (blue container). In addition, two big bags of beach litter from the Swedish west coast site Musön as well of two pallets of fishing nets from a third Danish site, Thisted, were collected.

The primary aims of the workshop were to focus on analyses of:

- 1) Geographical origin and age of the beach litter items
- 2) Determining the sources of fishery-related litter
- 3) Approaches to perform better source allocation.

Dedicated workshop sessions were held to work in detail on the three focus subjects.

The workshop programme:

Day 0-1: Coarse sorting of litter items from the three collection sites and welcome and introduction to the workshop.

Day 2: Sorting and identification of geographical origin with main focus on single use plastics (SUP), consumer plastics and packaging items.

Day 3: Analyses of fishery-related litter.

Day 4: Exercise and discussions of the assignment of sources to litter codes and development of matrix scores. In addition, a guided visit at the municipally owned waste handling and recycling company AVV in Hjørring.

Day 5: Discussion of preliminary findings and wrapping up of the workshop.

The coarse sorting of litter was based on OSPAR litter categories (OSPAR, 2020a) supplemented with some additional categories for fishery related items listed at the European Joint List of Litter Categories for Marine Macro-litter Monitoring (Fleet et al, 2021) and some specific fishery-related strings and net cuttings Strietman et al., 2021).

2 The geographical origin of litter in the Skagerrak region

The Skagerrak sub-region, shared by Denmark, Sweden and Norway, is of significant importance for litter studies due to the occurrence of high levels of litter in comparison to other sub-regions in the Greater North Sea. The coastlines in Skagerrak receive substantial amounts of litter from local land-based and maritime sources as well as litter derived from transboundary transport via ocean currents from the Greater North Sea. As a result, a more thorough assessment of the contributions from sources outside the sub-region, and determination of the relative contributions from the different sources is crucial to improve the efforts to reduce the amount of litter in the area. By understanding the sources and pathways of litter in Skagerrak, more effective combating measures can better be identified.

Furthermore, when conducting broader environmental assessments, it may be necessary to take into account the transboundary litter transport, and for instance comparisons with the EU threshold values for good environmental status might reveal the extent to which the transboundary litter inputs impact the overall environmental quality of the Skagerrak region. Thus, it is important to recognise that national management actions alone may be insufficient for addressing the litter challenges, and international cooperation is, therefore, essential to effectively tackle the problem of litter in the Skagerrak region.

The sorting was performed on litter collected at three sites, i.e. the two Danish sites Skagen (DK1) and Hjørring (DK2) and the Swedish site Musön (S1). The litter was sorted into the general OSPAR CEMP categories of beach litter (OSPAR, 2018) before conducting further analyses.

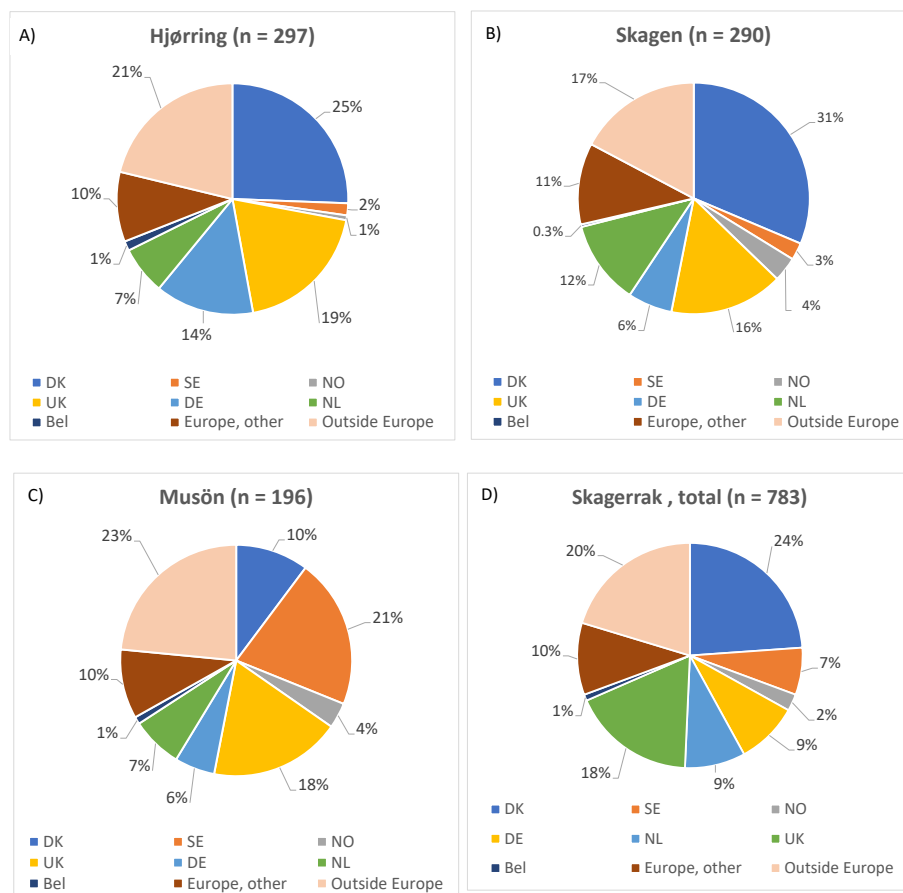
The characterisation of the geographical origin of litter items was performed by examining the label text, both glued on and melted into the package, on mainly single use plastics (SUP) such as packaging used for food and sweets, drink bottles and other types of user plastics, for example containers from cosmetics or chemicals or other material. Relevant product information on trade and/or production site and the language were applied as the main indicators of geographical origin. In some cases, knowledge of certain logo/brands (national brands unique for a certain country/country group, e.g. Scandinavian countries) and the design of product packaging (unique for a country/group of countries, e.g. Scandinavian countries and/or a specific time period) were included. The assignments should therefore be regarded as indicative of the likelihood of the geographical origin of litter items transported via the sea to shorelines. Also ship-assisted transport and travelers (e.g. tourists) may, to some extent, be involved in the transport of litter from one country or (sub-)region of the sea to another.

A total of 1516 items (~500 litter items per site) were examined for geographical origin. The assignment of geographical origin was successful for 52% of the items. Altogether 33% of the items were assigned to the Nordic countries Denmark, Sweden and Norway. Other North Sea countries contributed with 36%, most from the UK (18%), the Netherlands (9%), Germany (9%) and Belgium (1%), see Figure 2.1A-D. Other countries outside the North Sea contributed with 34%, covering litter items from both other European countries and

other continents like North and South America, Africa and Asia. The workshop participants represented a wide range of languages and countries, which was an advantage in the geographical assignment of a wide range of items.

The data showed a similar trend as for the geographical origin of litter collected at the three Skagerrak sites of Skagen, Hjørring and Musön (see Figure 2.1). However, there was a noticeable difference in the contribution of litter items from Denmark and Sweden, with a higher percentage of litter items of Danish origin being found along the Danish coastlines and a greater proportion of litter items of Swedish origin occurring at the Swedish sites. This observation supports the notion that local Nordic sources also contribute significantly to the litter along the Skagerrak coastlines.

Figure 2.1A-D. Assessment of the geographical origin based on mainly label text on different types of packaging and other plastic products among the beach litter collected at three sites in Skagerrak, i.e. A) Hjørring, B) Skagen, C) Musön, and D) in total.



The fact that almost equal proportions of litter at the Danish and Swedish sites were found to originate from other North Sea countries supports that transboundary transport of litter with ocean currents from the greater North Sea into the Skagerrak sub-region is a highly relevant pathway of litter. However, the possibility cannot be excluded that some parts may originate from sea-based activities in the area, such as commercial fishery and shipping, or are left behind by tourists on shorelines. Commercial shipping (e.g. cargo vessels and cruise ships) probably also contributes to the litter items with geographical origin from countries outside the North Sea region. About 100.000 larger vessels pass through the Skagerrak yearly as part of the ship traffic between the North Sea, the Nordic countries and the Baltic Sea.

A certain litter input from long-range transport with ocean currents cannot be excluded. A few litter items that could be assigned to North America, e.g. via a tag from a lobster trap with an identifiable code ID from Maine, USA (Figure 2.2), support that also trans-Atlantic transport of litter constitutes a pathway of litter into the Skagerrak.

Figure 2.2. Photo of identifiable tag from a lobster trap from Maine, USA, found among the beach litter collected at Hjørring on the Danish Skagerrak coast. Photo: Jakob Strand.



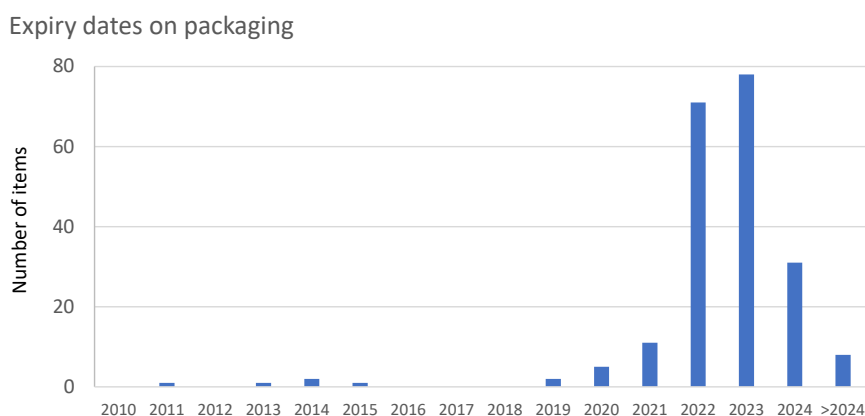
3 Age identification of litter items

Plastics and other forms of marine litter are commonly characterised as highly persistent materials. These materials break down extremely slowly in the marine environment, and the decomposition can take many years, decades or even centuries, depending on the type of material and the specific physical and chemical conditions of the environmental compartment in which they resided.

In the workshop analyses, the age identification of items was based on readable expiry dates on the labels (both glued on and melted markings) at different types of packaging items collected at the three Skagerrak locations DK1, DK2 and S1. The identification was performed on a subset of 211 different types of litter items covering plastic bottles (n = 103), crisp/sweets wrapping (n = 28), food packaging and tetrapak (n = 22), metal drink cans (n = 39) and glass bottles and jars (n = 19).

The examination of the collected packaging items revealed that the majority of the readable expiry dates were from recent years, 89% of the items showing expiry dates from 2022 or later (see Figure 3.1). Only a small proportion of items, 3%, had expiry dates prior to 2020, and the oldest date identified was from 2011. It is worth noting that there may be some bias in the analyses as many expiry dates are printed on packaging using ink, which tends to fade over time (quicker than the packaging itself). Furthermore, some products may have a long shelf life and do not expire until several years after production and selling dates. Nevertheless, the data suggest that some types of the packaging found on the Skagerrak shorelines have entered the sea relatively recently and originate from either land- or sea-based source.

Figure 3.1. Distribution of expiry dates observed on different types of packaging items collected at the three Skagerrak locations (n = 211).



4 Analyses of fishery-related litter items

4.1 Introduction

Fishery-related litter items consist of fishing gear such as nets, ropes and buoys as well as other fishery-related items such as gloves and fish boxes. Such items are used for fishing operations or in the handling of fish and shellfish at sea, near shore or in harbours. Litter from fishing gear in the sea is often characterised as abandoned, lost or discarded fishing gear (ALDFG). Furthermore, aquaculture can be a contributor to fishery-related litter items, for instance stiffer and black net pieces, large tubes and so-called 'tahitians'. Angling may be another possible source, for instance monofilament strings, bait containers, wobblers and hooks.

4.2 Method

At the workshop, different types of typical fishery-related litter, mainly nets, ropes and traps, were analysed in detail by the participants in collaboration with two local fishermen.

The main aim of this part of the workshop activity was to determine the composition, sources and age of fishery- and aquaculture-related litter items as well as to assess the likely causes for these items to have entered the sea. The collaboration with and input from the two fishermen as local fishing gear experts were very useful in this exercise.

Figure 4.1. Practical analyses of net pieces >50 cm performed by monitoring experts and local fishermen. Photo: Jakob Strand.



For the assessment of fishing nets and ropes, a protocol was used that has previously been applied in other parts of the North Atlantic (e.g. Strietman, 2021). As part of this protocol, a further analysis was carried out of fishery-related items within several OSPAR categories, including a specific assessment of fishing nets >50 cm.

The assessment protocol for net pieces >50 cm includes:

- Quantitative measurements of length and width, weight, mesh size and number of sides torn or cut.
- Qualitative assessments of level of wear and tear, type of fishery and origin (based on mesh size), age (based on the level of colour fading, fraying and type of material used) and cause for the net to have ended up in the sea as marine litter (based on an assessment of the sides of each net).

Larger net pieces were identified as net cuttings and thereby mismanaged waste when one or more sides of the nets showed clear signs of having been cut off from a larger piece of net with a knife.

All the net pieces >50 cm originated from the Danish collection sites – 15 from Skagen (DK1) and 19 from Thisted (DK3).

For the analyses of smaller items, i.e. net pieces <50 cm and small net cuttings, repair cords, dolly rope and other strings and ropes were sorted and characterised using a shortened protocol based on the count and mass of these items (Figure 4.2).

Figure 4.2. Workshop analyses of smaller net pieces, net cuttings, dolly rope, strings and ropes. Photo: Jakob Strand.



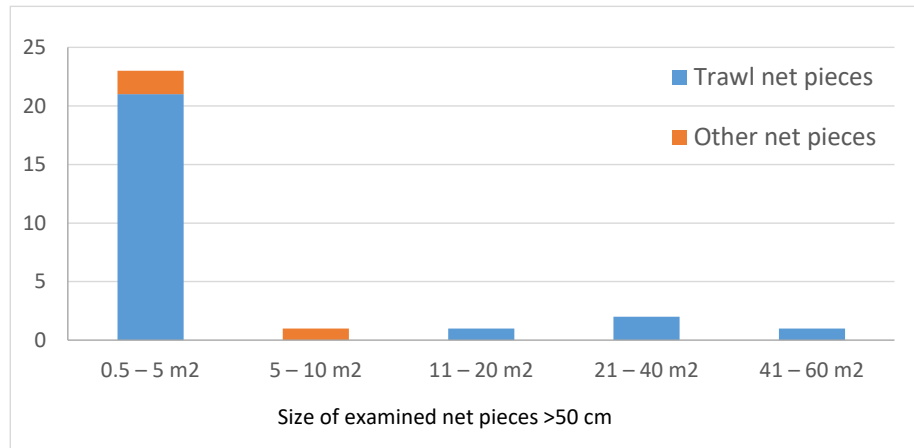
4.3 Results

Most of the larger net pieces >50 cm as well as smaller net cuttings, repair cords and dolly rope collected at the Skagerrak shorelines could easily be assigned to fishery activities.

Among the larger net pieces >50 cm, most were related to trawling (n = 25), although some gill nets (n = 8), a lobster trap net (n = 1) and cargo nets (n = 2) were also identified. Of the trawl nets >50 cm, all were pieces of larger nets

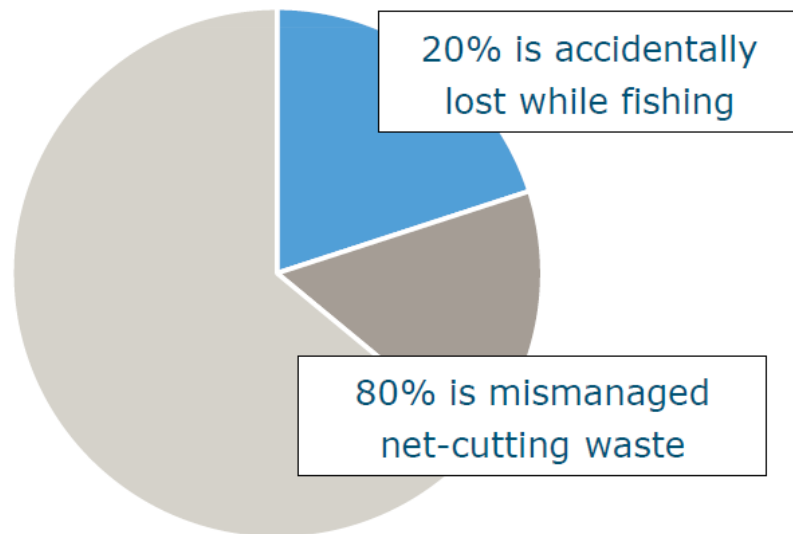
rather than complete nets. The majority of the trawl net pieces, 85%, were less than 5 m² in size (Figure 4.3).

Figure 4.3. The size of the examined net pieces >50 cm excepting gill nets that could not be untangled.



The results regarding the proportions of accidentally lost fishing gear (20%) and mismanaged waste cuttings (80%) showed that most of the net pieces >50 cm were mismanaged cuttings (Figure 4.4). This finding is consistent with observations made at similar ID sessions on litter collected on shorelines in other parts of the North Atlantic region (Strietman et al., 2021).

Figure 4.4. >50 cm characterised as accidentally lost while fishing or as mismanaged net cutting waste, being either remains from new net rolls or waste after repair of old nets.



- Accidentally lost
- Mismanaged leftovers from new roll of net
- Mismanaged after repairs of the net

Based on visual examination of the conditions of the ropes and strings of which the trawl net pieces were made, it was assessed that the majority of the net pieces >50 cm were less than five years old, accounting for 60% of the total. However, the remaining nets may be older than five years. As for the gill nets, all the six nets were older than five years.

It was determined that the trawl net pieces originated from two types of fishing gear: beam trawl and flyshoot nets. The types of gill nets indicated that they had been used for catching specific target species: cod (three nets), flatfish/demersal fish (two nets) and lumpsucker (one net).

The examination of smaller net pieces <50 cm and other minor net cuttings revealed that these were particularly abundant among the litter collected at both the Danish and Swedish Skagerrak sites. In all, 250 kg of these items were sorted and mass fractions determined. The smaller pieces mainly originated from waste produced by trawl net fishery, often remains from the repair of trawl nets. Additionally, another frequently found type of string was pieces of typical repair cords used for repairing trawl nets (Figure 4.5).

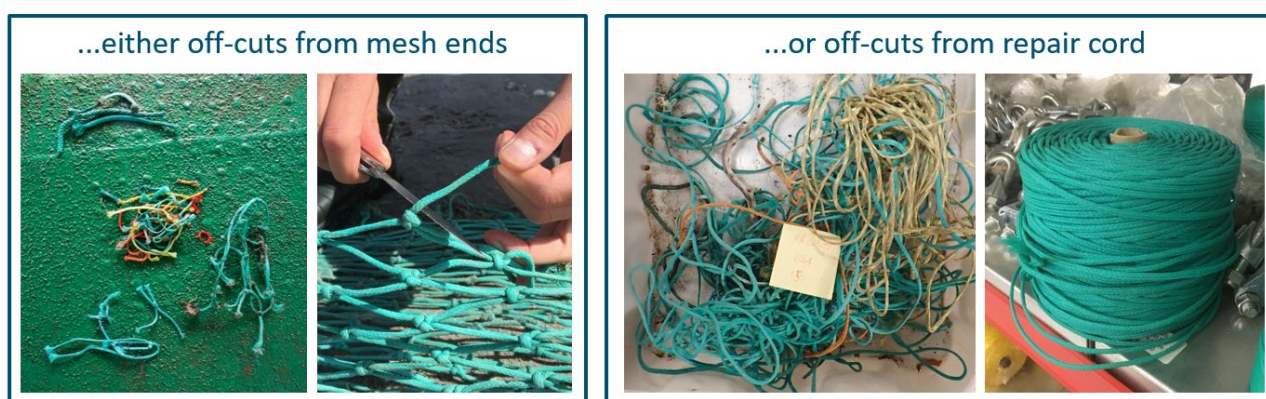


Figure 4.5. Examples of small net cuttings and net pieces from mesh end (left) and typical flat repair cords. Photos: Wouter Jan Strietman.

Another category of fishery-related strings was dolly rope, which is made of PE monofilament strings (typically coloured orange, blue or black), which are attached as protection beneath some types of bottom trawl nets applied in the North Sea. Dolly rope occurred abundantly among the litter items, either as twisted bundles or entanglements of strings or as single strings, as shown in Figure 4.6.

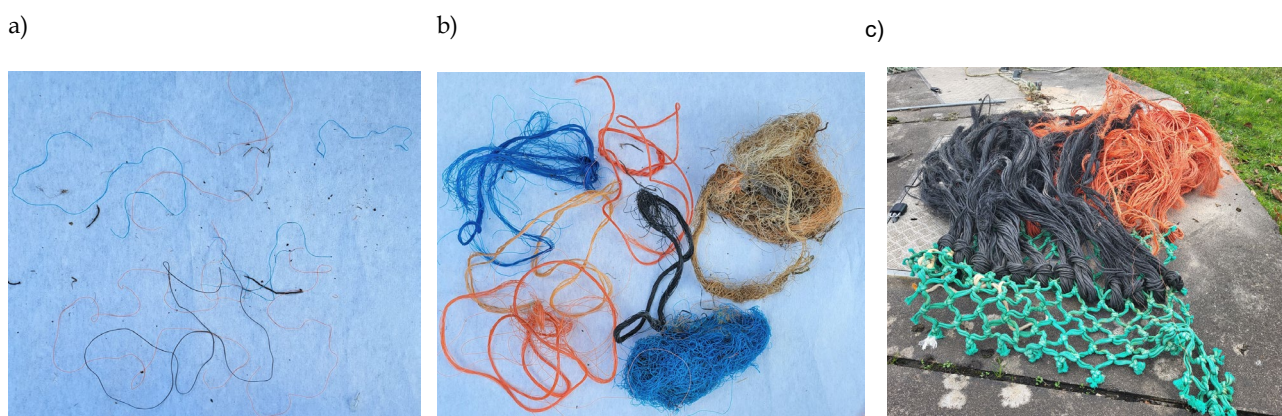


Figure 4.6. Examples of a) single strings of dolly rope, b) twisted bundles and entanglements of dolly rope and c) net piece >50 cm with attached dolly rope. Photo: Jakob Strand.

After analysis of the data, it was evident that there was a significant variation in the distribution of smaller net pieces, net cuttings, strings and ropes as to whether they were measured by count or mass.

The smaller items, such as smaller net cuttings, repair cords, dolly rope and other strings with a diameter <1 cm constituted more than 90% of the items when counted. On the other hand, thicker ropes with a diameter >1 cm contributed 70% of the mass (Figure 4.7). This highlights the importance of the measurement basis, particularly when comparing data from routine beach litter monitoring surveys (based on counts) and data on waste in general (often based on mass), where the larger items, of course, are larger contributors to the overall weight.

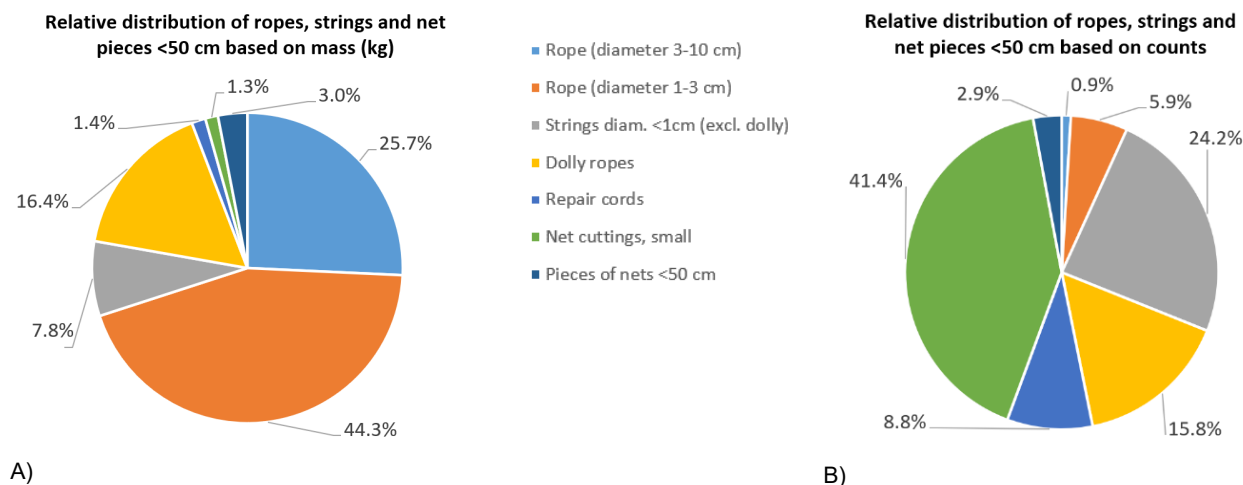


Figure 4.7. The relative distribution of the different types of sorted ropes, strings, dolly rope and net pieces <50 cm based on A) counted items and B) weight of items in kg. The figures are based on totals for all collection sites.

During the workshop, the participants, including local fishermen, also discussed and qualitatively assessed the origin of all other types of strings with a diameter <1 cm as well as ropes with a diameter >1 cm. It was recognised that although these types of items are also used in commercial shipping, recreational boating and aquaculture, the litter likely originated from fishery in the region. After deliberation by the workshop participants, it was agreed that about 80% of these types of strings and ropes also originated from fishery.

4.4 Discussion

In summary, fishery, especially trawl fishery, was assessed to be the most important source of many of the litter items found at the Skagerrak beaches.

The assessment of the large amounts of different types of fishery-related litter items occurring at the Skagerrak beaches in Denmark and Sweden, made in collaboration with local fishing gear experts, was very useful in determining the type of fishery, causes and age. The analysis showed that both larger and smaller net cuttings are frequently occurring litter items, indicating that mismanaged and discarded pieces of net and rope produced during repair and maintenance of trawl nets are an important litter source.

Mismanaged fishery waste produced on deck, either at sea or in harbours, probably reaches the sea during deck cleaning operations or is washed/swept overboard at sea. This supports the suggestion that an important solution to

combat litter is to improve the waste collection and handling procedures on deck of the fishery vessels and while working at sea. Traditionally, most fishing vessels have no waste storage facility on the deck. Similar conclusion have been made for other parts of the Northeast Atlantic and the Arctic (Metcalf & Bentley, 2020; Strietman, 2021).



Figure 4.8. Improving waste handling after repair and maintenance of trawl nets on board ships and in harbours is important to avoid that both large and small net cuttings end up in the sea. Illustration: Wouter Jan Strietman.

Accidentally abandoned, lost or discarded fishing gear (ALDFG) as well as abrasion of gear during use (e.g. dolly rope) are also sources of net pieces and string items, and these require other solutions. The proportions of accidentally lost fishing gear and mismanaged and discarded waste cuttings found at the workshop are in line with findings in other parts of the North Atlantic region.

Figure 4.9. Collection of net pieces, ropes, strings and dolly rope from the Skagerrak locations examined during the workshop. Photo: Jakob Strand.



Several other types of fishery-related litter items were also identified among the litter from the three collection sites in addition to net pieces, strings and ropes, including fish boxes of hard plastic, floats of both hard plastics and EPS and fishing traps/cages used for catching, for instance, lobsters. Several types of minor parts or fragments derived from fishing traps were also identified, such as plastic covers, hooks for closing, bait containers and tags attached to the traps. Also some examples of stiffer and black net pieces, tahitian sheetings and larger plastic tubes specifically used for aquaculture of probably mussels or oysters were identified among the collected litter. These additional fishery-related items were not thoroughly examined and quantified during the workshop session.

5 Developments on approaches to perform better source allocations

During the workshop session on approaches to improve the assessment of litter sources, the so-called matrix scoring technique was applied in an exercise on some typical litter items (e.g. SUP and packaging items) originating from multiple sources. This approach has previously been applied in studies performed in Germany (Schäfer, 2019) and Spain (ICG-ML, 2020). It has been argued that development of such matrix scores at a (sub-)regional scale can benefit future source assessments based on routine beach litter monitoring data, also within the Greater North Sea.

A keystone in the matrix score method is the pre-definition of the specific source groups and the assignment of likelihood ratios for each of the different sources potentially contributing to certain litter types. It was discussed if broader source groups could be identified and whether these could be relevant and applied in wider OSPAR assessments in order to obtain a harmonised and thus more comparable method across different sub-regions. The discussion took into account the source groups applied in previous studies of the matrix scoring technique from Germany and Spain (Schäfer, 2019; OSPAR, 2020b).

As a result of the workshop, the following twelve main source groups were identified. Additional relevant subgroups of these source groups were also identified, for instance recreational fishery as a subgroup of fishery, and harbour activities as a subgroup of different shipping activities. It was argued that identification of additional subgroups could be made in an exercise looking specifically into the detailed source groups.

Source allocations were divided into five sea-based and seven land-based groups of sources of litter in the sea.

Sea-based sources:

- Aquaculture
- Fishery (incl. commercial and recreational fishery)
- Recreational boating (incl. marinas)
- Shipping (incl. harbour operations, cruise ships/ferries and commercial shipping)
- Other maritime activities (e.g. offshore)

Land-based sources:

- Coastal/beach tourism
- Retail and food services
- Construction and demolition
- Agriculture
- Land-based transport and industry
- Sewage outlets and rainwater overflow
- Other mismanaged waste from land (incl. loss from waste handling)

The list of these source groups deviated to a minor degree from the source groups applied in the two studies from Spain and Germany. Further discussions on defining litter groups could also be relevant for the OSPAR expert group on Beach Litter (BLEG) within the Intersessional Correspondence Group on Marine litter (ICG-ML) in relation to the future work on harmonising source assessments between OSPAR (sub)regions.

6 Acknowledgments

All the workshop participants are acknowledged for their dedicated contributions to the sorting and examination of litter items and to the discussions. The three municipalities of Frederikshavn, Hjørring and Thisted and the group of local beach cleaners are acknowledged for collecting huge piles of litter from Skagerrak coastline. We are grateful to Eva Blidberg from Keep Sweden Tidy for coordinating the Swedish input to the workshop, and we thank Hjørring municipality and its waste handling facility for their friendly support to the logistic planning and with meeting facilities.

We thank fisheries and marine litter expert Wouter Jan Strietman from Wageningen Economic Research in the Netherlands for leading and efficiently coordinating the workshop session on analysing fishery-related items, which provided important output.

We are grateful to the Danish Ministry for Environment for funding. The project also benefitted from inputs from the EU Horizon-funded EUROqCHARM project regarding discussions on further needs for harmonisation of litter identification protocols including some new (sub)categories of macrolitter items, which potentially is relevant for adoption within wider monitoring frameworks.

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8 Appendix 1. Data table on assignments of geographical origin and expiry dates

Table A1.1. Counts showing the geographical origin of examined litter items from the three collection sites Skagen (DK), Hjørring (DK) and Musön, (SE).

	Skagen, DK	Hjørring, DK	Musön, SE	Total
Denmark (DK)	91	76	20	187
Sweden (SE)	7	5	41	53
Norway (NO)	10	2	7	19
Germany (DE)	18	41	11	70
Netherlands (NL)	34	20	14	68
United Kingdom (UK)	46	57	36	139
Belgium (B)	1	4	2	7
Europe, other	33	29	19	81
Outside Europe	50	63	46	159
Unknown	238	194	301	733

Table A1.2. Year of expiry of the examined litter items by counts.

Year of expiry	Skagen, DK	Hjørring, DK	Musön, SE	Total
2010	0	0	0	0
2011	0	0	1	1
2012	0	0	0	0
2013	0	0	1	1
2014	1	0	1	2
2015	1	0	0	1
2016	0	0	0	0
2017	0	0	0	0
2018	0	0	0	0
2019	1	0	1	2
2020	0	0	5	5
2021	7	3	1	11
2022	36	21	14	71
2023	50	12	16	78
2024	24	2	5	31
>2024	4	1	3	8

9 Appendix 2. Data table on analysed fishing nets, strings and ropes

A2.1. Analysed net pieces >50 cm from Skagerrak coastlines.

Net pieces >50cm	Number of examined net pieces	Mass of examined net pieces (kg)
Trawl nets	29	
Gill nets (entangled)	6	
Cargo nets	2	
Size 0.5 – 5 m ²	20	
5 – 10 m ²	2	
10 – 20 m ²	1	
20 – 40 m ²	2	
40 – 60 m ²	1	
Accidentally lost net pieces from trawl fishery	9	
Lost because of mismanaged net cuttings	17	
Net cuttings >50 cm of unused pieces from net repairs	3	

A2.2. Different types of sorted ropes, strings, dolly rope, small net cuttings and other net pieces <50 cm from the three Skagerrak locations.

	Skagen, DK (kg items)	Hjørring, DK (kg items)	Musön, SE (kg items)	Mean distribution based on mass	Distribution of counted items
Rope (diameter 3-10 cm)	4.70	48.30	11.00	25.7%	0.9%
Rope (diameter 1-3 cm)	9.70	110.80	12.10	44.3%	5.9%
Strings diam. <1 cm (excl. dolly)	4.20	1.55	2.03	7.8%	24.2%
Dolly rope	5.80	20.54	5.20	16.4%	15.8%
Repair cord	0.50	0.08	0.77	1.4%	8.8%
Net cuttings, small	0.53	0.27	0.58	1.3%	41.4%
Net pieces <50 cm	0.30	8.80	1.10	3.0%	2.9%

10 Appendix 3. List of workshop participants

- Jakob Strand, Aarhus University, Denmark
- Louise Feld, Aarhus University, Denmark
- Ryan d’Arcy Metcalfe, KIMO Denmark, Denmark
- Wouter Jan Strietman, Wargeningen University, the Netherlands
- Zhanna Tairova, Aarhus University, Denmark
- Florina Lachman, Väst kuststiftelsen, Strandstädning, Sweden
- Tomas Erikson, Sweden
- Mattias Sannerholm, Orust kommun, Arbetsledare Strandstädning, Sweden
- Eva Blidberg, Hold Sverige Rent, Sweden
- Malin Dahl, Hold Norge Rent, Sweden
- Anja Meland Rød, BLEG, Norwegian Centre Against Marine Litter (Marfo), Norway
- Helga Bårdsdatter Kristiansen, Norwegian Centre Against Marine Litter (Marfo), Norway
- Liv-Marit Hansen Toverud, Oslofjordens’s Outdoor Council, Norway
- Anne Lise Bekken, Oslofjordens Outdoor Council, Norway
- Pedro Miguel Correia Sepulveda Monteiro, Madeira
- Marine Paul, Cedre, France
- Charlotte Reeve, CEFAS, UK
- K. Sóley Bjarnadóttir, Environment Agency of Iceland, Iceland
- Claus Hjørne Pedersen, fisherman, Danmarks Fiskeriforening, Denmark
- Henning Thøgersen, Lemvig, fisherman, Denmark
- Bente Nedergaard Christensen, Plast Center Danmark, Esbjerg, Denmark
- Kristian Ege Nielsen, Danish EPA, Denmark

A SOURCE ASSESSMENT ON MARINE LITTER IN THE SKAGERRAK SUBREGION

Outcome of an international litter ID workshop 2022

This report summarises the output of the international workshop on in-depth analyses of beach litter collected in 2022 from different Danish and Swedish sites in the Skagerrak subregion. Skagerrak receive generally large amounts of litter, primarily from local land-based sources, maritime sources, and transboundary transport via ocean currents entering from the Greater North Sea. The assessment of geographical origin of mainly labelled litter items representing different types of packing materials showed that about 1/3 originated from Nordic countries, 1/3 from other North Sea countries, and the remaining 1/3 from countries outside the North Sea. An assessment of age of these items showed that most of these items were from recent years. Regarding the analyses of fishery-related litter items, it was assessed that a relatively large proportion could be assigned mismanaged waste from net cuttings. However, also several other types of fishery related litter were recorded. Methods for improving source identification and allocation of beach litter using the so-called matrix-scoring techniques was also explored at the workshop.