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A Treatment Scheme for Derelict Fishing Gear

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Glossary

DFG, ALDFG: Abandoned, lost or otherwise discarded fishing gear, often shortened to „Derelict Fishing Gear“ (DFG).[1]

End-of-life fishing gear: fishing gear, nets, ropes sorted out and removed by fishers after the end of its useful operating lifetime, typically because of damage and loss of net or rope strength.

Pre-processing: Preparation of retrieved and end-of-life fishing gears for waste collection or recycling.

Processing: Industrial further stages required to recycle or thermally exploit fishing gears.

Pyrolysis: Thermal process producing a liquid condensate („pyrolysis oil“) and synthetic gas from organic matter or plastics by heating to 400-800°C. This process required dry input material.

Steam reforming: Thermal process converting organic matter or plastics to hydrogen-rich synthetic gas by evaporation at temperatures above 1000°C. This process allows material humidities of up to 30%.

[1] Macfadyen, G., Huntington, T., Cappell, R.: Abandoned, lost or otherwise discarded fishing gear. UNEP Regional Seas Reports and Studies No.185; FAO Fisheries and Aquaculture Technical Paper, No. 523. Rome, UNEP/FAO (2009)

Relevant MARELITT Baltic literature

This ALDFG Treatment Scheme contains a summary of several MARELITT Baltic reports and external studies. The most relevant documents forming the basis for the Treatment Scheme are listed below. All documents are available for download on the MARELITT Baltic website https://marelittbaltic.eu.

Recycling Options for Derelict Fishing Gear
Authors: *Andrea Stolte (WWF Germany), Falk Schneider (University of Bath, UK)*
Recycling Feasibility Study for fishing gear retrieved from the sea, describing all material recycling and thermal processing trials carried out during MARELITT Baltic. A concise, illustrated executive summary is available together with the recycling report on https://marelittbaltic.eu/documents.

MARELITT Baltic Pre-Processing Recommendations for Retrieved Fishing Gears
Author: *Marek Press (Keep the Estonian Sea Tidy)*
Practical recommendations for the handling and processing of retrieved fishing gear in the harbour.

Harbour Survey
Author: *Marek Press (Keep the Estonian Sea Tidy)*
Survey on reception facilities in 50 selected fishing harbours around the Baltic Sea covering all 4 MARELITT Baltic partner countries Estonia, Germany, Poland, and Sweden. Special focus is placed on reception facilities for ALDFG and end-of-life fishing gears. Both studies are available on https://marelittbaltic.eu.

Study on required logistics and economic viability
Authors: *Ralf Bertling, Jochen Nühlen (Fraunhofer UMSICHT Oberhausen, Germany)*
External study investigating the necessary infrastructure in harbours and the logistics required to provide a reasonable waste management pathway for retrieved fishing gears (ALDFG). The economic viability and requirements are also covered. The study includes a survey of the waste path of ALDFG in each MARELITT Baltic country and is available on https://marelittbaltic.eu.

The MARELITT Baltic Sea Blueprint for Derelict Fishing Gear
Authors: *Frössberg, A., Kalinowska, M., Lamp, J., Migdal, S., Press, M., Stolte, A., Tschernji, V.*
Summary of the overall MARELITT Baltic project results for each of the 3 pillars: search & retrieval, waste management, fishing gear loss prevention. Recommendations for national/EU implementation are provided for each pillar, and the relevant MARELITT Baltic reports are referenced. The MARELITT Baltic Blueprint is available as the project summary on the MARELITT Baltic website.

1 Introduction

1.1 MARELITT Baltic and the treatment of fishing gear retrieved from the sea

The project MARELITT Baltic financed by the EU INTERREG Baltic Sea Region programme deals with mitigation measures for the impact of abandoned, lost or otherwise discarded fishing gear (ALDFG)[2] in the Baltic Sea. Also called derelict fishing gear (DFG) or ghost gear for short, lost fishing gear encompasses one of the omnipresent marine litter fractions in all seas worldwide. Surveys have found that between 15 and 46% of plastics litter might be originating from the fisheries sector, including ALDFG as a major contribution (NLWKN 2015[3], The Ocean Conservancy 2018[4]). Fostered by the increasing knowledge of the impact of derelict fishing gear on the marine environment, numerous projects, networks and NGOs dedicated to the removal of lost fishing gear from the seas have been initiated worldwide. Among the two most long-standing initiatives are i) the yearly retrieval campaigns by the North-West Straits Foundation (https://nwstraitsfoundation.org/), having recovered almost 6000 gillnets and hundreds of thousands of crab pots from the Puget Sound over more than 25 years of effort, and ii) the yearly lost gear retrievals carried out by the Norwegian Fiskeries Direktorat and Environmental Agency as the only regular government initiative[5]. In both projects, traps in good working conditions are returned to the owners, hence providing financial incentive for the fishers to report loss positions. While these and uncountable small-scale projects reduce the impact of lost fishing gear on the marine environment, none of these projects has systematically investigated solutions for the waste management and recycling of retrieved gears. MARELITT Baltic is the first project to approach retrieved gear management systematically through a series of material and thermal recycling experiments with the aim to find a pathway into the existing waste management system for retrieved fishing gears.

During the 3-year MARELITT Baltic project timeframe, partners from the 4 Baltic countries Estonia, Germany, Poland and Sweden have developed and tested best-practice methodologies for the search and retrieval of ALDFG at sea, the processing of retrieved DFG in harbours, waste management and recycling options, as well as prevention methods against gear loss in the future. A summary of all four pillars can be found in the *MARELITT Baltic Blueprint for DFG* available on the MARELITT Baltic website https://marelittbaltic.eu [6].

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[2] Macfadyen, G., Huntington, T., Cappell, R.: Abandoned, lost or otherwise discarded fishing gear. UNEP Regional Seas Reports and Studies No.185; FAO Fisheries and Aquaculture Technical Paper, No. 523. Rome, UNEP/FAO (2009)

[3] Dau, K., Millat, G., Brandt, T., Möllmann, N. 2014: Pilotprojekt „Fising for Litter“ in Niedersachsen, avaiable for download at https://www.nationalpark-wattenmeer.de/sites/default/files/media/pdf/abschlussbericht_aktualisierte_fassung_f4l_nds_2013-_2014.pdf

[4] Lebreton, L., Slat, B., Ferrari, F., et al. for The Ocean Cleanup: Evidence that the Great Pacific Garbage Patch is rapidly accumulating plastic, Scientific Reports, Vol. 8, Article 4666 (2018)

[5] https://www.fiskeridir.no/English/Fisheries/Retrieval-surveys-for-lost-gill-nets

[6] Frössberg, A., Kalinowska, M., Lamp, J., Migdal, S., Press, M., Stolte, A., Tschernji, V.: The MARELITT Baltic Blueprint (2019), available for download at: https://marelittbaltic.eu

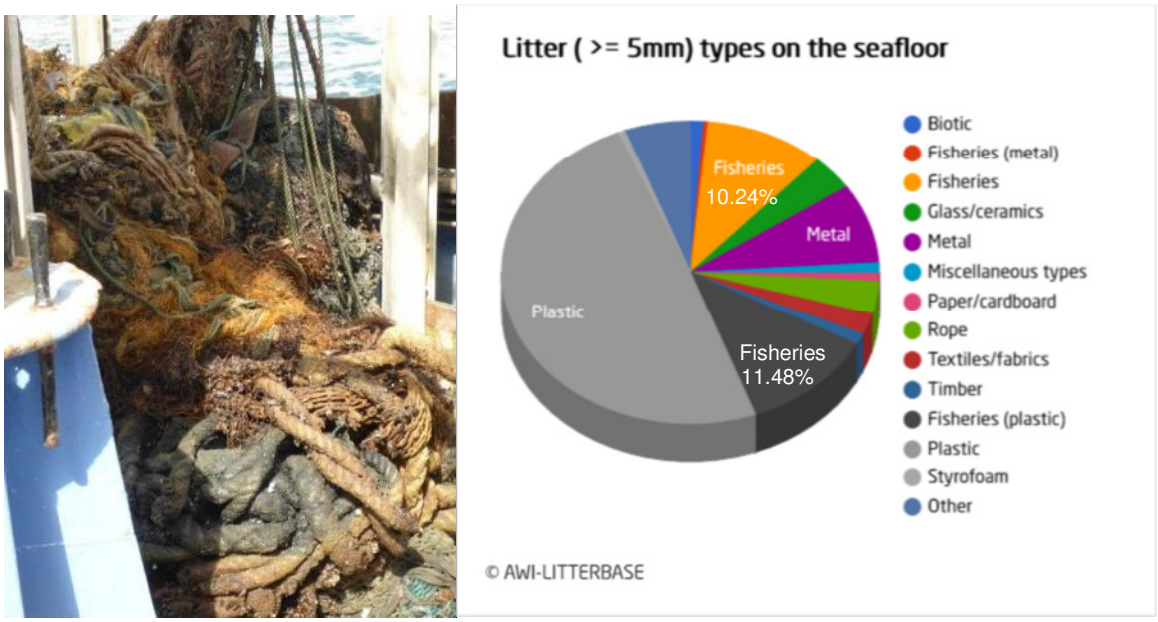

Fig. 1 Left: Lost fishing gear retrieved from the Baltic Sea near Sassnitz, Rügen Island, Germany (© Andrea Stolte, WWF). Right: Globally, more than 20% of marine litter on the seafloor are estimated to originate from the fishing sector.

During the project retrieval actions, it has become clear that today, no pathway for retrieved fishing gears in the existing waste management infrastructure exists. The fibres in trawl fragments and gillnets are hazardous to cutting machinery, as they can wind around rotors and get trapped between blades. They also cause blades to become blund quickly and hence cause excessive wear on cutting machinery. Even worse, complete gillnets comprise one of the largest fractions of ALDFG retrieved from the Baltic Sea. Gillnets are composed of a nylon net body – a valuable material for plastics recycling in principle – a swim line made of polyethylene and polypropylene mixed materials (PE/PP), and a sink line where lead fragments are embedded in a PET mantle. While lead is a valueable scrap metal that can easily be recycled when isolated, the lead lines are heavily entangled and the PET sheathing prevents the lead from being extracted. Because these nets can only be disentangled with extensive manual labour and time effort, extracting the mixed material fractions for recycling is not a viable option. With up to 30% of lead by weight, the lead content in gillnets can be higher than the European threshold for mixed household and industrial wastes of 0.3% by a factor of 100. Gillnets therefore need to be considered hazardous waste that cannot be incinerated or processed in standard waste processing facilities. In Germany, the only option currently available for ALDFG is dumping in open-air hazardous waste landfills. This option is highly undesireable because i) the polymers and organic matter can be used to generate energy, ii) some of the poylmers might be extracted for recycling, and iii) the metal and lead content is valueable recycling material when extracted. The methodologies for retrieving lost fishing gear from the sea have been developed in MARELITT Baltic and – for other marine environments – in a series of mitigation projects worldwide. The sooner lost gears are recovered from the sea, the less hazardous they become for marine fauna and the less contaminated they are with sediments, mud, organic substances and the less entangled they become with other forms of marine litter. An efficient system to report loss positions as established, e.g., in Norway enables speedy retrievals and facilitates the recovery of the materials involved. But speedy retrievals require a functioning collection and waste management system for ALDFG.

As the German partner in the MARELITT Baltic project, WWF Germany conducted a series of practical experiments together with associated partner Tönsmeier Waste Management GmbH (now Prezero Recycling) to develop an ecologically and economically viable pathway for managing fishing gear retrieved from the sea[7]. In addition, available and required logistics and harbour infrastructure were summarised in a study carried out for MARELITT Baltic by Fraunhofer UMSICHT. Keep the Estonian Sea Tidy, MARELITT Baltic's Estonian partner, conducted a survey on existing harbour infrastructure and carried out practical tests of DFG pre-processing at the quayside[8]. The harbour survey revealed that

- 70% of harbours can organise or have in place collection services for end-of-life fishing nets sorted out by fishers each year
- Among these, 28% of all harbours have permanent collection facilities for end-of-life fishing gears
- **0% or no harbours have facilities to collect fishing gears retrieved from the sea**

This means that today, all retrieved fishing gear is discarded in unsorted municipal or commercial waste (household/residual waste) ending up in incineration facilities or landfills. This is not desirable because of contamination with toxic lead from sink lines or copper from anti-fowling coating which are hazardous materials not supposed to be present in residual waste. At the same time, an alternative pathway for the dismantling and processing of ALDFG is not available. Some of the collected material, especially trawl nets and ropes retrieved from the sea, are composed of uniform polymers with a high recycling value. Yet, the waste management stream of these materials is small and alternative waste management solutions to common large-scale practices need to be developed.

Fig. 2 Dedicated collection area for end-of-life fishing materials.

Of all 50 fisheries harbours investigated during the survey, 15-20% participate either in Fishing for Litter projects or MARELITT Baltic ALDFG retrievals. In these harbours, collections of fishing gears, nets and ropes are at least temporarily available. These harbours provide a well-prepared starting point for regional regular collections of both end-of-life and retrieved fishing gears. At the moment,

[7] Stolte, A., Schneider, F. 2018: Recycling options for Derelict Fishing Gear, available for download on https://marelittbaltic.eu/documentation

[8] Press, M. 2018: Harbour Reception Survey, available for download on https://marelittbaltic.eu/documentation

the provided containers are financed through NGO projects. Collection of end-of-life fishing gears is organised yearly by the fisheries associations, yet only in the larger fisheries ports. In the long term, both end-of-life and retrieved fishing gears need to enter existing waste management systems.

This DFG treatment scheme provides a summary of the key findings and the infrastructure requirements and recommendations that resulted from all MARELITT Baltic ALDFG processing trials. The treatment scheme is meant to be a guidance document for harbours and municipalities dealing with ALDFG landings in their ports, as well as for policy makers working on EU mitigation regulations against marine litter, such as the EU plastics strategy and corresponding Directive against Single-Use Plastics, as well as the Directive on Port Reception Facilities (PRF[9]). Some of these recommendations have been suggested for the draft version of the PRF revision. If implemented, these recommendations would provide harbours and fisherfolk with the infrastructure to collect both ALDFG and end-of-life fishing gears for sorting, waste management and recycling. In the EU plastics strategy, a producer responsibility scheme is suggested for fishing gears. This, too, would be a major achievement towards a more circular economy approach for fishing materials, as is already practiced by the Icelandic fishing fleet[10] and by the Norwegian Fiskeries Directorate. Following these positive examples and our own findings during the 3 pilot years of MARELITT Baltic, we provide here the roadmap of what would be needed to bring the MARELITT Baltic results into implementation in fisheries harbours in all Baltic countries and throughout Europe.

1.2 Overview of ALDFG handling

After the retrieval of lost fishing gear at sea, three steps are involved to allow that ALDFG can enter the waste management stream. First, infrastructure needs to be available in harbours such that ALDFG can be landed. In most harbours visited during the harbour survey, areas for fishing gears in use are provided, but containers for ALDFG or end-of-life fishing gears are not permanently available. Secondly, basic material sorting is required to remove hazardous wastes, such as lead from sink lines, from ropes and nets, requiring space for pre-processing. Ideally, sorting of materials for recycling or other processing pathways can already be carried out before collection at the harbour. As the third step, waste managers need to be prepared to collect ALDFG, and processing pathways need to be available. These required stages are illustrated in Fig. 3. The requirements to implement each handling stage into a regular processing system for fishing gears are presented in the following sections.

[9] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52018PC0033
[10] https://sfs.is/wp-content/uploads/2018/09/Environmental_report_2017.pdf

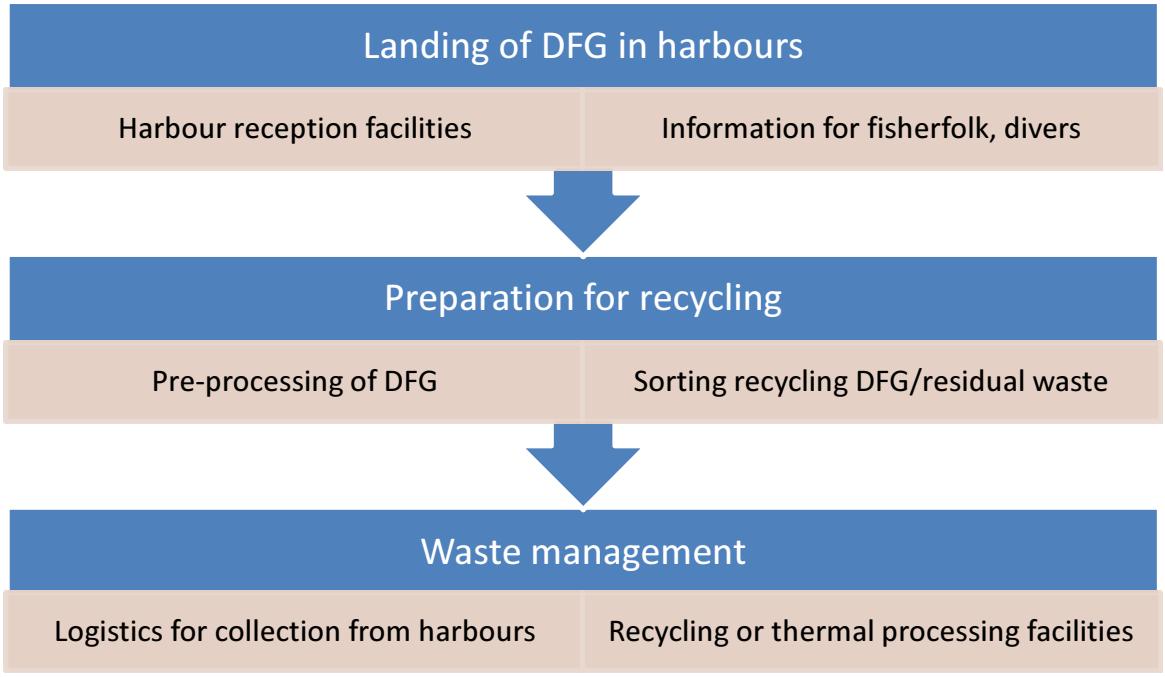

Fig. 3 The process of retrieving and landing of lost fishing gears and waste management of ALDFG.

2 Landing of ALDFG in harbours

Under the European Maritime and Fisheries Fund (EMFF), stakeholders from the fisheries sector are eligible to receive financial support for activities improving the marine ecosystem. Among the explicitly allocated activities are cleaning actions of DFG and other types of marine plastics litter.

As EMFF funds are accessible to the fisheries sector, fisherfolk are expected to be a major group of experts carrying out search and retrieval operations at sea. A crucial requirement for such operations is the availability of reception infrastructure at fisheries harbours. To date, dedicated reception facilities for lost and retrieved fishing gear are not available on a regular basis in any of the harbours investigated in MARELITT Baltic[11].

In harbours participating in „Fishing for Litter" Schemes, containers for marine litter collected during regular fishing activities at sea and brought back by fishers to port might be available. These containers are reserved for nets and ropes in addition to plastic waste collected in fishing nets during active trawling at sea. Dedicated search and retrieval actions for DFG result in larger quantities of ALDFG, typically between 500kg and a few tonnes of material hauled during one recovery, exceeding the capacity of available containers.

[11] Press, M. 2018: Harbour Reception Survey, available for download on https://marelittbaltic.eu/documentation

Fig. 4 Dedicated collection areas for end-of-life fishing nets are common (left, Port of Mrzezyno, Poland, © Marek Press), but collection points for retrieved gears from the sea are rare (right, Freest fisheries harbour, Germany, © Andrea Stolte).

In 70% of the harbours investigated during the MARELITT Baltic harbour survey[12], services for end-of-life fishing gear collection can be ordered or end-of-life gears are collected on a regular basis (28% of all harbours investigated). The Smögen fisheries association FF Norden[13] collects, cuts and sorts fishing gears from several harbours in the West-Sweden coastal area. The nets, ropes and traps are sorted to allow for as much material recycling as possible.[14] This is one of the best-working examples where gears are actually prepared to enter the plastics recycling system. On the West Swedish Coast, predominantly trawls and pots are used by the fishing industry, which facilitates recycling (limited amount of gillnets, lead lines can be extracted). The process requires a substantial amount of manual labour. The preparation steps can be summarised as follows:

- Traps are compressed with a hydraulic press to minimise transport volume. The recycler extracts the metal for metal recycling by melting off the plastic netting.
- Gillnets are cut into 1-2m sections, lead lines are removed. Clean polyamide gillnets are send to Aquafil for depolymerisation and spinning into yarns.
- Trawls are cut into sections. PP/PE trawl and rope materials are sent to Plastix A/S in Denmark to be recycled into granulates for the recycling market.
- Objects such as floats, wires/lines, and sink lines or weights are extracted and re-used as much as possible to avoid extra cost. Netting, so far, cannot be re-used because mesh widths and fibre sturdiness degrade with time and exposure to the marine environment.

In Smögen, 1500 tonnes of end-of-life fishing gear are processed each year, which implies that ALDFG will be on the order of 1% of the total amount of fishing gear collected, and hence can be neglected compared to the effort and economic return generated from end-of-life gear. This allows processing of ALDFG where possible together with end-of-life gear because the "good material" volume is substantially higher than the mixed material. From the total collection, 10-20% by weight of the residual waste go to incineration, while 80-90% are either reused directly by the participating fisheries or shipped for recycling in some form, either to Plastix (PE/PP) in Denmark, or to Nofir in Lithuania for dismantling (pots/trawls) and onwards to Aquafil for recycling (extracted PA6).

[12] Press, M. 2018: Harbour Reception Survey, available for download on https://marelittbaltic.eu/documentation
[13] http://www.ffnorden.se/
[14] https://static1.squarespace.com/static/58525fe86a4963931b99a5d1/t/5b1e392c2b6a28564d072214/1528707489667/Thord+G%C3%B6rling%2C+Fisheries+Association+Norden.pdf

Both Plastix and Aquafil can only deal with pre-cut and cleaned net segments of a single-polymer pre-sorted material type. While a relatively clean material state can be achieved for end-of-life gear, lost fishing gear retrieved from the sea is heavily entangled, infused with fine-grained sediments, and might have trapped large amounts of scrap metal and other marine litter. Typical DFG is therefore not fit for recycling unless extensive manual processing is applied.

Fig. 5 Bulk of DFG during retrieval from the Baltic Sea (left), including a rusty diving bottle and firehoses (middle). All larger metal items need to be manually removed prior to processing (right). © Andrea Stolte

In Germany, both end-of-life gear and DFG are incinerated with some level of energy recovery. However, gillnets contain a large fraction of toxic lead from sink lines which can be up to 30% by weight. As most DFG bundles contain gillnets or gillnet fragments, this type of DFG has to be considered hazardous waste, which can only be dumped in open-air hazardous waste landfills in the present waste management systems. At the same time, lead is a high-value scrap metal and extraction is desirable even if the plastic content of DFG cannot be recovered for material recycling. With entangled DFG, the extraction of lead and other metals for metal recycling requires substantial manual labour, which is currently not supported by the EMFF or other funding schemes.

One waste management problem lies in waste classification. Both ALDFG and end-of-life fishing gear are currently not classified as a dedicated waste stream in the European waste classification scheme. For commercial waste, the general classification “waste from the fishing industry” applies, yet for the sub-category “metal waste” there is no distinction between non-hazardous steel/iron-type metals and potentially hazardous metals such as lead. Originators of commercial waste are required by law to separate materials, esp. metals, plastics, glass, paper for recycling – this would imply that fisherfolk need to extract lead lines and all other metal objects from gear for waste processing. Commercial waste can also be send to a dedicated sorting facility, if proper records are provided that the commercial waste was send to a facility capable of treating such waste.

The situation is different for divers and NGOs when ALDFG is retrieved: in this case, ALDFG is not commercial waste and even the general category “waste from the fishing industry” does not apply. The only available option is household waste, however, larger fractions of lead are not allowed in household waste. Lead is only considered hazardous when in fine-grained form, and not when in a bulk, where it can easily be recycled. However, for recycling it is crucial that lead is extracted from the entangled net material and the PET sheathing, which is mostly unfeasible in entangled ALDFG. Alternative thermal processing scenarios resulted in the extraction of lead while generating energy gas or fuel from the polymer mix. Other methods, such as melting off of the PET mantle to extract the lead, would have to be investigated. A more detailed classification and according handling

prescriptions for fishing gear as a waste fraction would facilitate the processing and waste management of both retrieved and end-of-life fishing gears.

The identified requirements during the MARELITT Baltic feasibility studies are summarised below and illustrated in Fig. 6.

Requirements to facilitate ALDFG retrieval and landing at fisheries harbours

Support required for fisherfolk to facilitate ALDFG retrieval & landing

- Dedicated containers or areas where ALDFG is collected
- Dedicated areas where fisherfolk can process DFG (cutting, extraction of metals/lead, cleaning where feasible, sorting, bundling up plastic fibres for recycling where possible)
- Financial support not only for retrieval actions, but also for manual labour during sorting and processing, in addition to existing EMFF support schemes
- Facilitate EMFF application procedures such that the currently unexploited funds can be utilised by fisherfolk for DFG cleaning actions at sea and processing at shore

Support required for harbours and infrastructure

- Regular collection of non-recyclable DFG material with other waste by the local waste management company
- Education of harbour managers and fisherfolk regarding sorting protocols, as required by recycling companies to facilitate waste management and especially recycling
- Support for further infrastructure that might be required to avoid losses during harbour processing, e.g. fenced in areas, sheds, winches to extract lead lines, etc.
- Waste reception and handling plans to provide efficient port reception services that meet the needs of harbour users including a description of proper collection and recycling procedures for DFG and end-of-life fishing gear
- Online information on the harbour webpage regarding available facilities and contact information such that harbour users can easily inform port authorities and facility providers about DFG landings to ensure the necessary infrastructure is available when required.

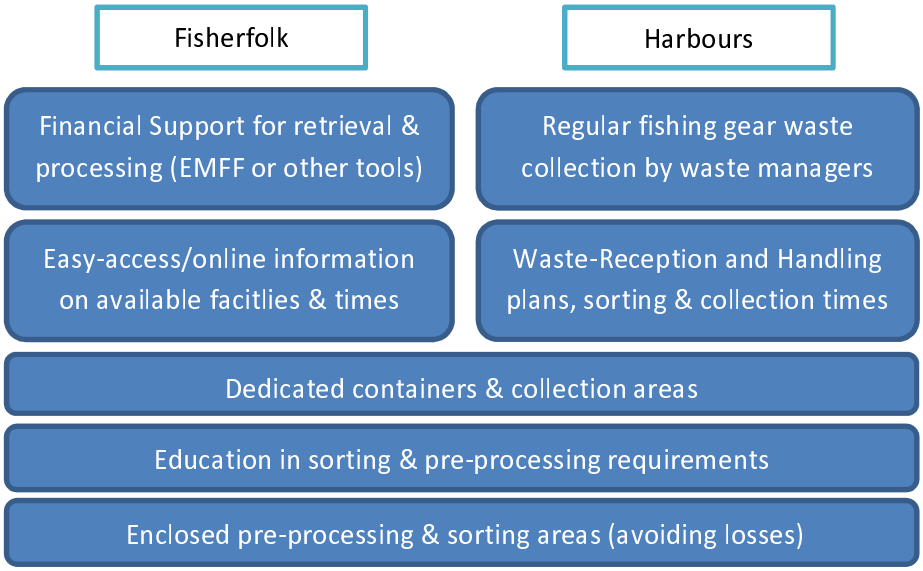

Fig. 6 Requirements for ALDFG retrievals by fisherfolk and collection in harbours

Fig. 7 Dedicated area where fishing nets are sorted and kept. The space could also be used to pre-process and disentangle retrieved fishing gears from the sea (© Andrea Stolte).

3 Preparation for recycling

Both DFG and end-of-life fishing gear require sorting and manual processing activities and facilities to enable material recycling that are not in place today. Some of the problems faced in DFG recycling are illustrated in Figs. 8 & 9. For the alternative thermal processing methodologies tested during MARELITT Baltic (see MARELITT Baltic Recycling Feasibility Study, Stolte & Schneider 2018) [15], it was sufficient to apply a single shredding stage to cut fibres to a length of 2-4cm. With the tested technologies, a more flexible energy return in the form of fuel or synthetic gas would be available than with state-of-the-art incineration plants. A more important advantage of alternative thermal processing technologies is that the toxic lead component is extracted in the solid residue and lead lines do not need to be removed manually beforehand. On the other hand, incineration plants are widely available in most Baltic countries, and energy recovery in the form of heat is common in modern plants. It is therefore no surprise that incineration of fishing gear is common practice especially in countries such as Germany where landfills were replaced by incineration and energy recovery for non-hazardous waste.

However, fishing gear consists of high-value recycling materials, such as polyamide in gillnets and ropes, comparably pure PP/PE fractions in trawl netting and traps. In addition, the metal content can be exploited when fishing gear is prepared for recycling.

The following steps are needed to allow for material recycling in existing companies:

1. Sorting out of comparably clean net and rope fragments, cleaning of retrieved DFG
2. Separation of polymer types: polyamide, polypropylene, polyethylene, PET need to be distinguished
3. Removal of lead lines to avoid toxic contamination

[15] Stolte, A., Schneider, F. 2018: Recycling Options for Derelict Fishing Gear, available for download at https://marelittbaltic.eu

4. Cutting into 50cm fragments or shredding to 2-4cm fibre length is usually required both for thermal processig and material recycling

Without cutting, incineration plants face the risk that long threads get trapped in the gripping hooks of the crane and transport sparks from the furnace back to the storage compartment. Hence longer net fragments impose the risk of storage burns in incineration plants, which should be avoided by all means. Fisherfolk typically use sharpened fishing knives for net cutting. While this works well, DFG is interleaved with sediments, rocks, metal cables, lines, and other litter. This causes blades to become blund even more rapidly than with pure netting, which is already difficult to cut. During the MARELITT Baltic processing trials, a variety of tools were used (Press, M. 2019)[16]. These included garden scissors, cable cutters, in addition to carpet knives and other equipment. It turned out that so-called "tomato"-knives proved very useful to cut thinner netting, because the small, serrated blades allow for easy access in entangled fishing gears. Fishing knives are another easy option as they are readily available in fishing harbours and allow for easy regular re-sharpening. For thicker netting, especially trawl fragments, plate shears have proven more efficient than other cutting devices. It is crucial to involve fisherfolk in this pre-processing stage, as they are most skilled in treating fishing nets and they can identify and remove objects such as sink lines or floats that are fit for re-use, which is preferable to recycling or disposal.

Fig. 8 Illustration of the difficulties faced during sorting and the obstacles for recycling. Left: Even single ropes might contain several polymers, as identified with near-infrared spectroscopy (© Signe Vahur). Right: Shredded & washed gillnet fibres showing the diversity of material types included in fishing gear (© Andrea Stolte).

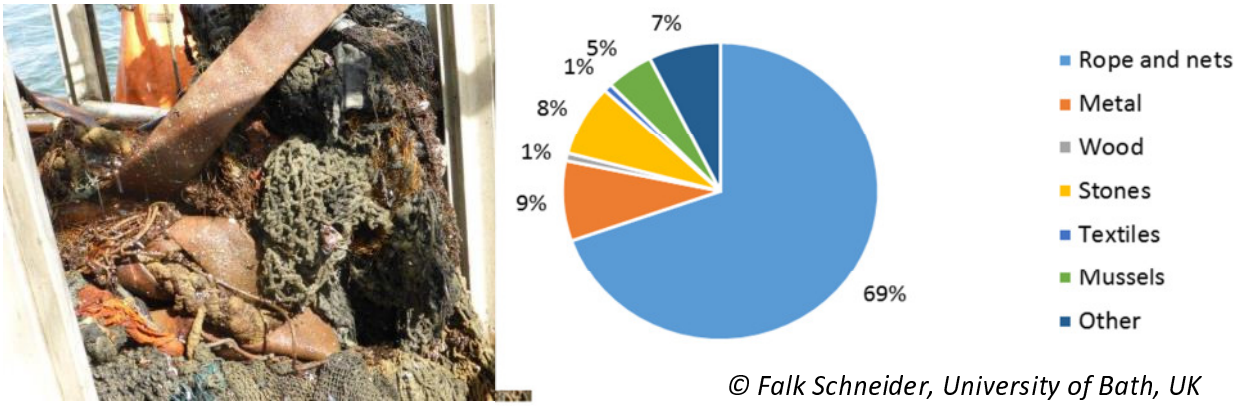

Fig. 9 Material mix in retrieved ALDFG. Left: Trawl and gillnet fragments, fire hoses and other marine litter are visible (© Andrea Stolte). Right: Manual extraction of litter shows the mix ALDFG can collect on the seafloor (© Falk Schneider).

[16] Press, M. 2019: MARELITT Baltic Pre-Processing Recommendations for Retrieved Fishing Gears, available for download at https://marelittbaltic.eu

Fig. 10 Pre-processing of retrieved gillnets during MARELITT Baltic trials in Karlskrona, Sweden: a) Tools used for cutting and measuring, b) entangled gillnet with float line and sink line, c) removal of float line from polyamide netting, d) extracted float line which can be re-used (all images © Marek Press).

When larger batches of net material or ropes need to be cut, knives or other hand-held tools cannot handle amounts of several tonnes of material. If material recycling is not an option because of entanglement of too many material fractions or disturbances by other types of litter, thermal processing in energy-generating facilities is the best option. For dedicated thermal processing plants, such as pyrolysis ovens or high-temperature polymer evaporation plants ("steam reforming"), the input material must be shredded to 2-4cm fibre and fragment sizes. Small-scale industrial single-shaft shredders with anti-wind-up mechanisms are available and the best shredding option. These shredders avoid two common problems encountered when cutting fibre materials: i) the knives are robust and do not become blund as rapidly as in normal shredding mills, and ii) the anti-wind-up mechanism prohibits long fibre segments or ropes to get wound up around the rotor, hence avoiding manual disentanglement of the machine or excessive heat-up. For larger batches that need to be thermally processed, small-scale shredders were identified as the most convenient cutting option[17].

[17] For examples of the industrial shredders used in MARELITT Baltic trials see https://vecoplan.com/de/produkte/zerkleinern/ and the Recycling Feasibility Study.

Cleaning of DFG and end-of-life gear can be carried out either with pressure cleaners, which worked well in MARELITT Baltic pre-processing trials, or by composting. Before further processing, it is common practice among fisherfolk to place nets in barrels for composting for 2 months to remove organic contaminants, such as algae, seagrass and organisms or overgrowth. Composting is a cheap and easy means to remove organic matter from DFG prior to further processing. However, barrels and space have to be made available in harbour areas where the composting smells are not affecting visitors.

Support required to facilitate preparation for recycling, in addition to infrastructure mentioned above

- Education on material properties, distinguishing base polymer types of nets and ropes, and identification of DFG that can be pre-processed for recycling as opposed to DFG that is too contaminated and needs to be prepared for thermal processing
- Eligibility to obtain financial support for cutting tools, possibly small-scale shredding units in a few decentralised harbour locations
- Collection point for metal and lead, with safety measures to avoid lead contamination
- Cleaning tools such as pressure washers and composting areas would be beneficial to allow for larger material recycling fractions

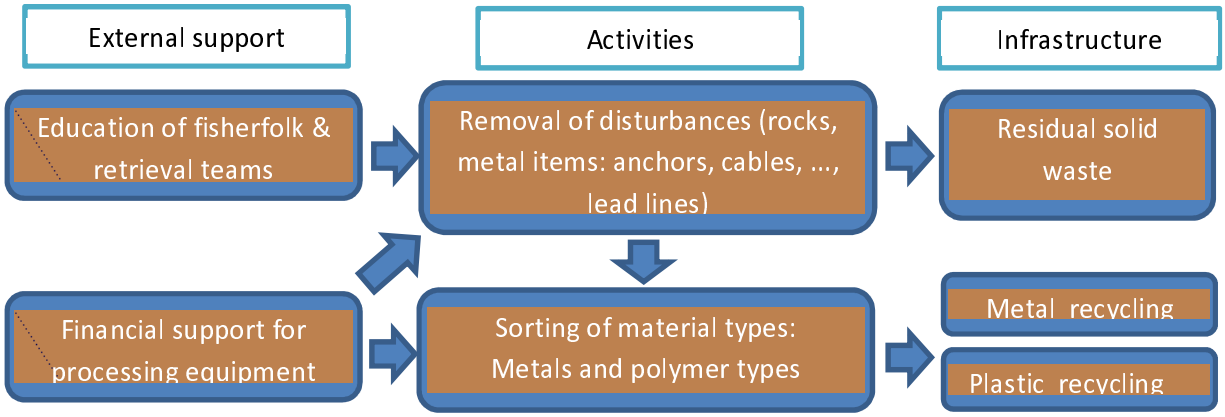

Fig. 11 Requirements and pre-processing pathway of DFG in preparation for waste management and recycling.

Fig. 12 Modern waste collection area at the Port of Dziwnów, Poland (left), which could also host a metal and end-of-life fishing gear container. Because of smell disturbance, a more separated area would have to be found for ALDFG. Temporary dedicated DFG dismantling area with lifting equipment at Sandhamn fishing harbour (right). © Marek Press

4 Waste management chain

Once ALDFG (and end-of-life fishing gears) are properly pre-sorted and prepared in harbours, the pathways are open for either material recycling or thermal processing. The following facilities are currently available on an industrial scale for different material fractions:

Company	Input fractions	Materials	Process
Nofir A/S, Norway/Lithuania/Turkey https://nofir.no/	End-of-life ropes, nets, fish traps	Polyamide, PP, PE, metal contaminants	Dismantling & sorting of polymer types to enable recycling of metals & synthetic materials, sent onwards to Aquafil (PA6) or Plastix (PP/PE)
Plastix A/S, Lemvig, Denmark http://plastixglobal.com/	End-of-life ropes, nets, fish boxes	Polypropylene (95% pure), polyethylene (95% pure HDPE and LDPE)	Material recycling: granulation into recyclates
Aquafil, Slowenia https://www.aquafil.com	End-of-life nets	Polyamide 6 (very pure)	Material recycling: "*econyl*" yarn spinning in mix with post-production carpet residues
Nehlsen, Germany https://www.nehlsen.com/start/	Ropes, nets, all other non-packaging plastics	All polymers, organic matter, metals (lead content less than 0.3%)	Incineration: Net and rope fragments need to be pre-cut to 50cm length or squares

During MARELITT Baltic, other thermal processing options such as pyrolysis and high-temperature polymer evaporation were tested. Especially high-temperature evaporation („steam reforming") yielded very promising results for contaminated materials, because lead and other metals were efficiently extracted in the process. Polymers and organic matter were vaporised into energy gas, such that organic content was also not problematic. Pyrolysis trials with fishing gears led to more difficulties because of toxic emissions from disintegrated polyamide and cristalisation from PET, which would need to be solved to use this technology for mixed marine litter.[18] However, these methods -- although frequently discussed in the context of marine litter processing on land or at sea -- are currently not available in existing industrial or small-scale waste management facilities. Employing these technologies for small batches of specialised materials, such as ALDFG, electronic, or medical and other hazardous wastes, requires a wider acceptance of alternative waste processing technologies by waste managing companies. The discussion around marine litter has pushed the political discussion towards consideration of alternatives, such that these technologies might become available for DFG processing in the near future.

[18] Details on the limitations faced during pyrolysis trials with fishing gears can be found in the Recycling Feasibility Study and its Executive Summary available for download on https://marelittbaltic.eu/documents.

The two layers of infrastructure required concern the pre-processing in preparation for recycling or thermal energy regain and the waste management treatment and infrastructure necessary to allow for ALDFG processing, as illustrated in Fig. 13:

1. Processing chain:
    a. Landing
    b. Composting, cleaning
    c. Cutting, removal of hazardous substances
    d. Sorting

2. Waste management chain (Logistics)
    a. Reception in harbours
    b. Collection by waste managers
    c. Distribution to material recycling facilities, where feasible
    d. Residual material delivery to (alternative) thermal processing plant

Fig. 13 From harbour landing to waste management. Top: Pre-processing chain in preparation for waste management. Bottom: Waste management chain from harbour reception to material recycling or thermal processing facilities (© Andrea Stolte where not indicated otherwise). Lower second right: Plastix facilities, lower right; EXOY steam reforming reactor.

Currently, a waste management system capable of processing ALDFG does not exist, and processing of end-of-life fishing gears is also limited to a few facilities. At the same time, the European Maritime and Fisheries Fund encourages the fishing sector to retrieve lost fishing gears with the aim to achieve a good environmental status of the European seas. This is supported as an action against marine litter in the Marine Strategy Framework Directive. Removal of marine litter is also desired to avoid break-up into microfibres and particles capable of entering the marine food web, including seafood for human consumption.[19] However, if fisherfolk are encouraged to retrieve ALDFG they encounter at sea, a waste management pathway has to be available for the retrieved materials. Such a system needs to be able to address

- The mix of polymers, organic matter, large metal items and rocks
- Contamination with lead
- Sorting of toxic and non-toxic fractions
- Shredding of large batches of mixed materials without harm to machinery

As detailed in the recycling report (Stolte & Schneider 2018)[20], none of these requirements are currently available. In order to identify the logistical needs to establish a handling system for fishing gear, Fraunhofer UMSICHT Oberhausen was commissioned with a study on logistics requirements and economic viability of ALDFG treatment (Bertling & Nühlen 2019)[21]. The results of the study are summarised below. The full study is available for download on the MARELITT Baltic webpage.

4.1.1. Centralised *versus* decentralised infrastructure

As the two extreme cases, both centralised waste management options and decentralised facilities near harbour locations were considered. Fraunhofer UMSICHT recommends a mix of decentralised and centralised logistics to allow for optimal and cost-efficient processing of fishing gears. To minise transport costs, pre-processing – the removal of large metal items and rocks – should take place in or near the recepting harbours. Likewise, the separation between clean, single-polymer materials and low-quality mixed ALDFG has to occur early in the process, preferably already at the fishing harbour. Smögen harbour provides an excellent example where several fishing harbours along the Swedish West Coast collaborate and their common collected materials are processed in Smögen as one regional location where all required harbour pre-processing, sorting and separated storage infrastructure is present.[22] Material collection and distribution to disposal or recycling facilities must be organised with minimal transport ways to reduce costs, which implies collection of end-of-life fishing gears and ALDFG at the same time during a few tours along the entire coast in each country each year. It is crucial that end-of-life fishing gear and clean, single-polymer ALDFG, which might be material recycled, is collected in separate containers and remains separated from low-quality and

[19] see, e.g., van Cauwenberghe & Janssen 2015: https://www.expeditionmed.eu/fr/wp-content/uploads/2015/02/Van-Cauwenberghe-2014-microplastics-in-cultured-shellfish1.pdf
Wieczorek et al. 2018: https://www.frontiersin.org/articles/10.3389/fmars.2018.00039/full

[20] Stolte, A., Schneider, F. 2018: Recycling Options for Derelict Fishing Gear, available for download at https://marelittbaltic.eu/documents

[21] Bertling, R., Nühlen, J. 2019 (Fraunhofer UMSICHT Oberhausen, Germany): Recycling of Abandoned, Lost and Discarded Fishing Gear (ALDFG) and End-of-Life Fishing Gear: Sub-studies on logistics requirements and economic viability, available for download on https://marelittbaltic.eu

[22] http://www.ffnorden.se,
https://static1.squarespace.com/static/58525fe86a4963931b99a5d1/t/5b1e392c2b6a28564d072214/1528707489667/Thord+G%C3%B6rling%2C+Fisheries+Association+Norden.pdf

mixed ALDFG during transport. Before sending onwards to material recycling or thermal processing, further sorting can either take place decentrally in or near fishing harbours, potentially with a dedicated collection point in one regional harbour, such as Smögen in Sweden, or in a regional sorting facility located at a strategically central point in short transporting distance from a number of harbours. Here, the fishing gear would be sorted into high-quality materials for material recycling and low-quality materials for thermal processing and energy recovery. Such a dedicated sorting point might be more efficient and provide more uniform material fractions as compared to sorting of high- and low-quality materials in each harbour by local fisherfolk. An example of a centralised dismantling facility of end-of-life fishing gears and fish traps retrieved in Norway is the Norwegian company Nofir (https://nofir.no/). Nofir collects nets from the Norwegian retrieval campaigns each year, and might also receive materials from Smögen and other fishing gear collecting harbours. In preparation for recycling, the municipality of Sotenäs, where Smögen fishing harbour is located, has invested in a regional plastic collection center for household and fisheries waste (www.rambo.se). Currently run as a pilot facility, household waste and plastic waste from the fishing sector including nets, fish boxes and floats, are sorted into individual material fractions for forwarding to the respective recycling or disposal facilities. In combination with onwards shipping to Nofir and Plastix for further processing and recycling, this provides a model for a combination of a regional and centralised approach to managing fisheries waste. In dedicated, centralised manual processing plants in Lithuania and Turkey, the gears are dismantled, metal contaminants are removed for scrap metal recycling, and plastic nets and ropes are sorted into individual polymer types, which are sent onwards to Aquafil for polyamide and Plastix for PP/PE recycling (www.nofir.no).

For the final waste management, two scenarios are envisioned (see also Fig. 15):

Scenario 1: Decentral thermal processing plants with low processing volumes of a few tonnes per year. If small-scale, container-type pyrolysis or steam reforming facilities will be established, these could be placed between several nearby fishing harbours. Both ALDFG and low-quality, mixed end-of-life fishing gears would be transported to these facilities and thermally processed to regain residual metal, lead, and energy.

Scenario 2: Central thermal processing plants with high processing capacity: These plants are omnipresent at least in Germany with travelling times of less than 1 hour from each fishing harbour (Fig. 14), and located in numerous locations in Sweden and Poland. A map of the distance of each German fishing harbour considered in the MARELITT Baltic harbour survey to a thermal processing facility is provided below (Fig. 14), more detailed maps can be found in the logistics study on the marelittbaltic.eu website (Bertling & Nühlen 2019)[23].

[23] Bertling, R., Nühlen, J. 2019 (Fraunhofer UMSICHT Oberhausen, Germany): Recycling of Abandoned, Lost and Discarded Fishing Gear (ALDFG) and End-of-Life Fishing Gear: Sub-studies on logistics requirements and economic viability, available for download on https://marelittbaltic.eu

In both scenarios, high-quality end-of-life fishing gear and particularly clean, single-material ALDFG would be transported after sorting to a material recycling facility, such as Plastix in Denmark or Aquafil in Slowenia. In this case, the transporting distance and fuel use has to be considered and balanced against the recycling material value. A decentralised approach to material recycling is not feasible, as the final cleaning, separation of residual sediments and salts, as well as blending or extruding into recyclates or yarns requires dedicated machinery and fibre processing units. The Plastix facilities demonstrate the required level of complexity, including separate cleaning and

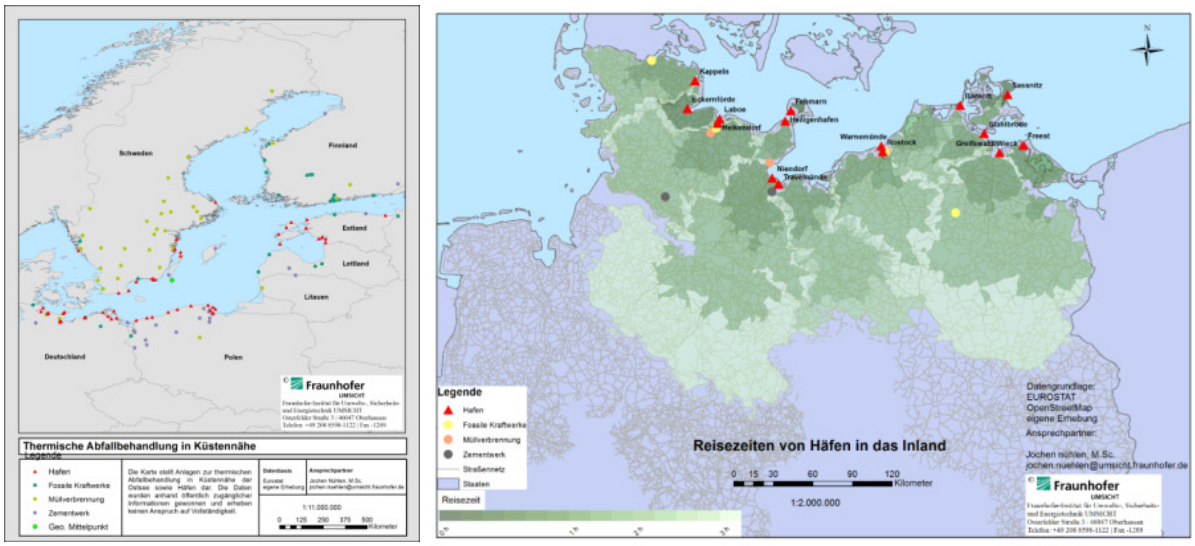

Fig. 14 Available thermal waste processing plants around the Baltic coast (left) and travelling times from German fishing harbours to nearby thermal incineration or concrete production plants, with typical travelling times of less than 1 hour. © Fraunhofer UMSICHT (Bertling & Nühlen 2019)

density-separation strands for fishing nets and ropes as opposed to fish boxes. The facilities encompass several processing halls, and the financial effort and technical challenge of building such a facility do not allow for a large number of decentralised recycling plants.

Fraunhofer UMSICHT estimates that the collection costs for several transporting tours along all German coastal harbours are in the range of 100,000 Euros per year. Initially, these costs could be partially financed through EMFF support, which explicitely allows for waste management and infrastructure for marine litter reduction programmes. In the long term, a system needs to be established that is self-sufficient, e.g. by generating funds from scrap metal and lead recycling as well as from polymer material recycling.

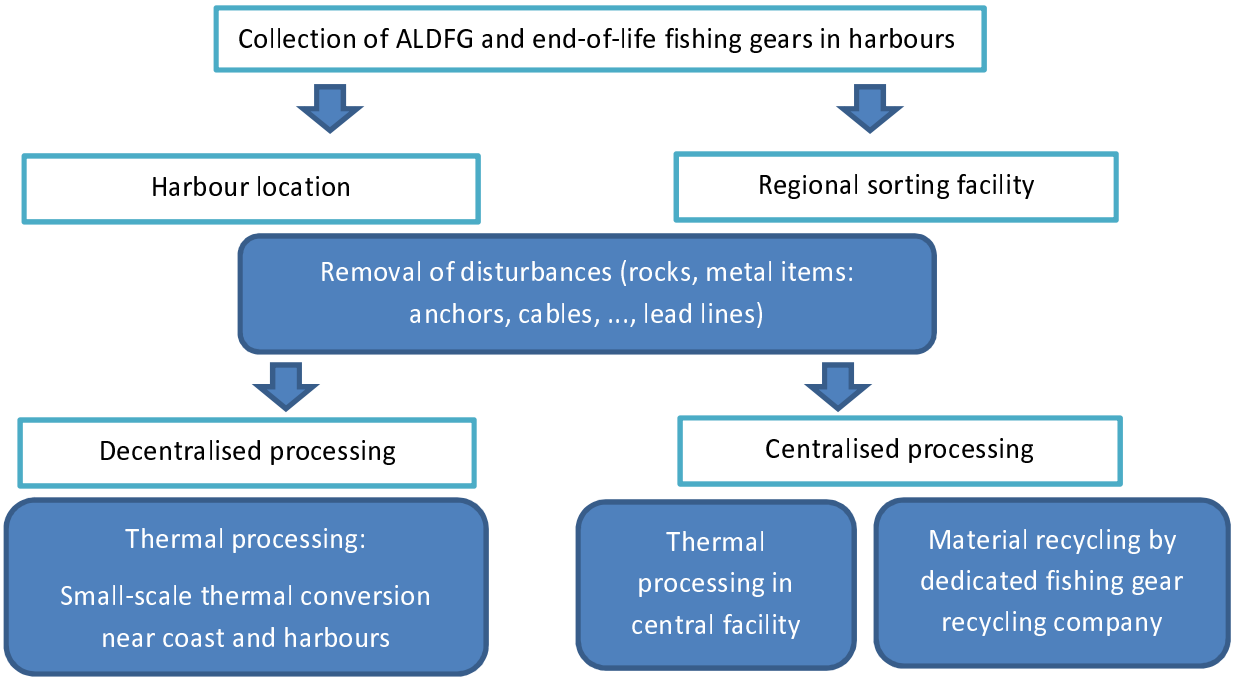

Fig. 15 Centralised and decentralised processing options for ALDFG and end-of-life fishing gear waste management.

4.1.2 Economic viability considerations

Given the difficulties in processing ALDFG mixed materials, and the fact that currently no waste management solution exists, it cannot be assumed that the depicted system will be economically self-sustaining in the near future. Waste management of ALDFG requires the development of new facilities. The minimum requirement is a centralised sorting facility, where hazardous substances can be extracted from the gear and the residual materials can be forwarded to the dedicated processing and recycling plants (metals to production, polymers either to incineration and energy regain or to plastics recyclers). In the case the authorities decide to support small-scale processing infrastructure in harbours, several harbour locations need to be selected to build low-volume pyrolysis or steam reforming plants. This is likely one of the most expensive options, as such systems – though extensively tested by different institutions and companies at present, as detailed in the MARELITT Baltic recycling report (Stolte & Schneider 2018) – are not available as a plug-and-play system today. In the case that such systems are further developed by science and industry, however, alternative thermal processing might become viable in the future. This option is particularly interesting to keep in mind for ALDFG because it allows the extraction of lead on-the-fly without inefficient manual labour, substantially facilitating the pre-processing effort. For small-scale thermal processing plants, the input material needs to be pre-shredded to particle/fibre sizes of 2-4cm to allow for efficient thermal conversion. Hence, also in this scenario large-scale rocks and metal items have to be removed during pre-processing.

Fig. 16 Industrial shredder with anti-blocking system used in MARELITT Baltic trials to shred net fibres to 2-4cm length (left, at Vecoplan AG); rotor with counter-blade triangles and sieve (middle), and gillnet fibres with lead fragments after shredding. This material can be used for alternative thermal processing such as steam reforming (evaporation).

The logistically simplest solution is the use of the existing waste management system. The minimum requirement for the use of incineration facilities in all EU member countries is the reduction of the lead content in the input material to below the acceptance threshold of 3.3 g/kg (0.3%). In this case, only the lead has to be removed efficiently in the sorting facility. Technically, this is challenging because ALDFG are heavily entangled and the lead lines are embedded in PET sheathing. A shredding facility with a non-magnetic metal separation unit might facilitate the extraction of lead and other non-magnetic metals in addition to magnetic iron/steel separation. Plastix A/S, for instance, has a non-magnetic metal detection system. Likewise, the sorting facility „Brockmann Recycling“ in Nothern Germany has a non-magnetic metal separator behind their automated shredding unit, which might have the capacity to shred nets, ropes and extract the metal items in one single process. Further testing is required to confirm the efficiency of lead line removal in such systems. The remaining material can then be processed in any thermal processing plant, including classical incineration plants as established in Germany and Sweden for household waste processing. The study by Fraunhofer UMSICHT finds that in Germany, a densely populated country, the maximum distance to incineration facilities is 2 hours from each harbour. However, a non-magnetic metal separation is not available in each of these facilities, such that a first transport to a more centralised sorting facility might be required. The distances in all other MARELITT Baltic partner countries with lower population density and more geographically dispersed fishing fleets and landing harbours have to be assumed greater than in the German testcase, leading to higher transportation costs.

At the present time, only the last scenario – centralised pre-shredding with lead extraction followed by incineration – is available for mixed ALDFG materials in the existing waste management systems. Every other pathway envisioned – and potentially desirable for polymer recycling – would require investments into new facilities and infrastructure. If alternative thermal waste processing facilities will become available in the near future, e.g. for medical or electronic wastes and other special-treatment fractions, such facilities can be beneficial for the small amounts of ALDFG being retrieved each year.

5 Policy Recommendations

From the MARELITT Baltic ALDFG processing trials, studies and considerations above, the following practical and policy recommendations are derived:

1. Availability of reception facilities in harbours
2. Decentralised processing locations as in Smögen in a few harbours in each Baltic country, with dedicated ALDFG collection points
3. Awareness of material quality among both fishers and waste managers to enable material recycling of high-quality DFG and metals
4. Small-batch thermal processing options for mixed DFG not treatable for material recycling
5. Financial support for fisherfolk and harbours to allow for processing, in addition to search & retrieval, has to be anchored in legislation, and responsible authorities for implementation have to be identified
6. Research & Development support for waste managers prepared to deal with small-scale batches with the aim to find ecologically viable alternative solutions to classical incineration and energy recovery plants
7. Open funding schemes for investments in alternative pilot thermal processing facilities

In addition, incentives should be increased to enable the return of end-of-life fishing gear, e.g. in the form of an extended producer responsibility (EPR) scheme. Together with the EMFF actions against marine litter, the generated fees can be used to support ALDFG retrievals at sea and the built-up of a proper waste management system for both end-of-life and retrieved fishing gears. An EPR scheme for fishing gear is envisioned in the recently adopted European Single-Use Plastics Directive[24]. For the implementation of the directive into national law, the financial support for the processing of all waste fishing gear has to be of particular focus.

MARELITT Baltic recommendations to facilitate fishing gear recycling schemes

During the Harbour Survey (Press 2018)[25], MARELITT Baltic framed the following additional recommendations to aid a better waste management and awareness in the fishing sector:

- Promote responsible recycling
  - Improve end-of-life fishing gear disposal procedures
  - promote responsible recycling initiatives for end-of-life fishing gear
- Economic incentives
  - Reasonable cost recovery systems
  - economic incentives to hand over/collect and recycle fishing gear
  - promote full implementation of the no-special-fee system for fishing harbours
- Educational initiatives
  - Better awareness about damaging environmental and socio-economic effects of DFG (what happens if / when lost fishing gear is not reported and retrieved)
  - educational initiatives about responsible collection and recycling of fishing gear
- Proper lost gear reporting

[24] https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX%3A52018PC0340
[25] Press, M. 2018: Harbour Survey, available for download at https://marelittbaltic.eu/documents.

    - Information available and clearly visible at harbours about proper lost gear reporting and retrieval procedures
    - guidance on ALDFG recovery possibilities
- Common code of practice
    - Fisheries organisations should strive to achieve a common code of practice on the regional level (targeting, reporting and monitoring gear losses and recycling procedures for end-of-life fishing gear)
    - Overcome procedural bottle necks, e.g. clear and quick regulation on clarification of ownership of the nets e.g. through an extended gear marking system and easy permit to recycle/process fishing gear without complicated legal procedures.

6 Conclusions & the way forward

Small-scale fisheries have a long-standing tradition in the Baltic Sea. They provide a local source of income, nourishment and delicacies for coastal inhabitants and tourists alike. Since the advent of synthetic fibres, fishing gear has been made of long-lasting plastic materials. While the durability of these materials is beneficial to the fishing activities, the loss of synthetic fishing gear causes longterm harmful impacts to the marine environment (Werner et al., JRC, 2016[26]). The MARELITT Baltic project addressed the mitigation of the impact of lost fishing gear on the Baltic Sea through the search and retrieval of DFG, waste management, and gear marking to reduce future gear loss rates. It would be helpful if especially gillnets or pots/traps were marked in more locations. Currently, marking takes place on the bouys at the surface, and when the bouy is lost, the identification of the owner is lost. There are simple as well as more complex ways to mark fishing gear, which would also promote net loss reporting and recovery:

- Small metal tags attached to each net segment with the owner ID would enable return to the owner, identification of areas where nets are more prone to be lost, and would facilitate a possible return system in the spirit of the EPR scheme envisioned in the EU Plastics Directive (example: Sweden).
- Chemical/colour fibre fingerprints with a unique identification of each manufactured net would allow the identification of trawl fragments regarding the owner and producer; chemical fingerprints become increasingly common and would also facilitate a return and EPR system.
- GPS tags at the beginning/end of a net and possibly in the centre, attached to a surface bouy would allow recovery when flags and marker bouys are lost.
- Accoustic echo-sounder pingers which reflect an echosounder signal with a modificadtion containing the ID of the owner would allow all echosounding vessels to identify lost nets or net fragments under water and would be the first technology that allows location of lost and displaced fishing gear at the seafloor (e.g. the PingMe pilot system might be a promising technology https://www.sintef.no/en/latest-news/entrepreneurs-aim-to-end-ghostfishing/).

An extended marking system would incentivise reporting and foster collaboration between fisherfolk and ALDFG retrieval teams and responsible authorities. It would also help to minimise long-term

[26] Werner, S., Budziak, A., van Franeker, J. A., et al., JRC Report 2016: Harm caused by Marine Litter, available for download at https://ec.europa.eu/jrc/en/publication/harm-caused-marine-litter

impacts on the marine ecosystem. Even with modern GPS tracking of underwater obstacles and wrecks and meterological advancements in weather forecasting, the occasional loss of fishing gear cannot entirely be impeded. If lost gear cannot immediately be recovered by the responsible fisher, it might stay in the sea for long periods of time, sometimes decades. When gear is retrieved from the sea, it is most often entangled and mixed with other types of marine litter. This mixed waste is very difficult to process in the existing waste management system.

In the MARELITT Baltic project, different pathways were tested to determine how fishing gear retrieved from the sea can be recycled or otherwise managed. So far, no existing waste management

Fig. 17 Illustrated material recycling pathway for DFG from nets on the seafloor via cleaned fibres to pellets made from pre-sorted and pre-processed nets retrieved from the German Baltic Sea. The dark colour of the recyclate results from the high granulation temperature used in this experiment. © Andrea Stolte, WWF

path is available for mixed and entangled ALDFG including lead lines from gillnets. For other forms of DFG, removal of bulky items and pre-cutting into 0.5-1m segments is the minimum requirement even for incineration plants. The advantage of incineration is the use of existing waste management infrastructure and the fact that no extensive sorting is required. Lead lines, however, are hazardous waste and cannot be incinerated. Alternative thermal processing technologies such as steam reforming are promising when processing mixed DFG (and other forms of marine litter) because residual metals including lead are efficiently extracted and the energy content in plastic and organic matter is harnessed. In the existing waste management systems in the MARELITT Baltic partner countries, such facilities are not available. In the longer term, considering building small-scale facilities in dedicated locations where ALDFG could be processed along with other special wastes would be beneficial. In the short term, the minimum requirements to allow for continuous DFG retrievals by fisherfolk, divers and local authorities are availability of reception facilities for DFG in fishing harbours, pre-processing areas where bulky items and lead lines can be removed, as well as providing a cutting or shredding technique that allows DFG to enter the existing incineration or recycling plants. As requested by the revised European Directive for Reception Facilities in Ports (PRF[27]), containers or collection areas for end-of-life fishing gears will be beneficial and will allow sorting of materials to maximise material recycling amounts. DFG recycling would benefit from this infrastructure because single-polymer netting and ropes might enter the same recycling pathway as end-of-life nets.

In summary, harbour infrastructure and the development of waste management pathways for DFG in the existing systems are the necessary next steps to allow for a successful continuation of DFG retrievals from the Baltic Sea.

[27] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52018PC0033

As the way forward, legislation is required to establish a permanent system for the retrieval of lost fishing gears from the sea, the collection of end-of-life fishing gears and the waste management of all types of fishing gears. The European Single-Use Plastics Directive demands an EPR scheme for fishing gears and serves as a starting point for national legislation. The implementation of the Directive implies that responsible authorities need to be identified:

i) National authorities financially responsible for the development of a pathway to process retrieved fishing gears
ii) National, State or Communal authorities responsible for establishing a harbour collection system and other required waste management infrastructure
iii) National or State authorities responsible for the coordination of regular ALDFG retrieval activities at sea, which must include the responsibility for the distribution of funds to enable continuous retrievals at sea, especially regarding historical DFG.

The EPR scheme for fishing gears anticipated in the EU Plastics Directive is one possible long-term financing solution for a retrieval and waste management scheme for fishing gears. Adopting fishing gear in the common European waste classification system will facilitate the acceptance of fishing gears by regular waste management facilities. This is especially crucial for gillnets and other gear containing lead weights otherwise considered as hazardous waste, where strict European acceptance limits are in place. European-wide waste keys for fishing gears and recommendations for waste sorting facilities for the handling of single-type and mixed fishing gears with and without lead components will be required in this process. The EPR scheme can be used to incentivise innovative new net materials from single polymers and non-hazardous alternatives to lead weights. New nets with less material fractions will facilitate the complex sorting process and will be easier to recycle.

The implementation of the EU Single-Use Plastics Directive offers the opportunity to build a common European system enabling fishing gear waste management that will facilitate the proper treatment of fishing gear waste in each European country, and the delivery of recyclable materials to the few existing recycling facilities for single-material fishing gears. Only if legislation includes proper treatment of waste from the fishing sector and a financing scheme for regular ALDFG retrievals can the amount of fishing gear in the European seas be continuously reduced and further hazards originating from lost fishing gear can be prevented.

Fig. 18 Fishers engaged in retrieving a historical trawl segment near the German fishing harbour of Sassnitz on Rügen Island. Incentives for gear loss reporting and support for retrieval activities would help mitigate the negative impacts of both historical and recent lost fishing gear on the Baltic Sea marine environment. © Andrea Stolte

Appendix A: Path of retrieved fishing gear from the Baltic Sea in each MARELITT Baltic partner country

The Fraunhofer Institute UMSICHT investigates alternative polymer materials and deals with the waste management of uncommon waste streams. On behalf of MARELITT Baltic, WWF Germany commissioned Fraunhofer UMSICHT to economically and ecologically assess the required infrastructure and logistics to process retrieved fishing gear. Fraunhofer UMSICHT also conducted a survey among selected harbours and waste management companies in each of the four MARELITT Baltic partner countries to trace the pathway of retrieved ALDFG from landing to the final waste handling destination. The survey results confirmed that no common pathway for ALDFG exists in the current waste management infrastructure. The results are summarised below. In none of the MARELITT Baltic partner countries regular retrievals by authorities or fisheries associations are carried out.

In the study on logistics requirements and economic viability for regular ALDFG retrievals[28], Fraunhofer UMSICHT identifies the involved stakeholders as depicted below (Fig. A1), and conducts interviews with stakeholders from each category in each country, where possible.

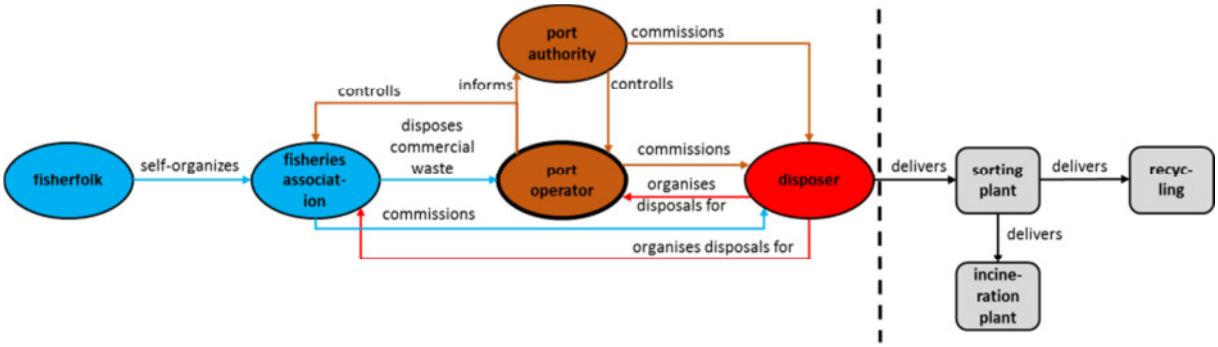

Fig. A1: Identification of stakeholders along the ALDFG waste management pathway (© Fraunhofer UMSICHT).

Estonia: Some fishing harbours offer collection points for end-of-life fishing gears, which are then sent onwards to recycling facilities, such as Nofir in Lithuania, for dismantling. In the case that no dedicated waste management pathway exists, it has to be assumed that ALDFG is deposited in landfills. In Estonia, approximately 7% of municipal waste is still deposited in landfills according to the OECD[29]. Prior to disposal, fishing gear is collected separately, e.g. in big bags, and sink lines containing lead are removed for scrap metal recycling.

Germany: Some fisheries associations organise containers once or twice per year so that fishers can sort out and discard end-of-life fishing gear. Lead lines are previously removed and nets are cut into 50cm segments. The containers are collected by the responsible disposal provider of the respective harbour and transported to the nearest incineration plant. All waste managers confirmed that removal of lead lines and pre-cutting into small sections is crucial. In fishing harbours, either commercial waste facilities or household waste containers are provided. When fisherfolk retrieve historically lost fishing gear from the sea, it is therefore likely that the existing channels are used and

[28] Bertling, R., Nühlen, J. 2019: Recycling of Abandoned, Lost and Discarded Fishing Gear and End-of-Life Fishing gear: Sub-studies on logistics requirements and economic viability, available at https://marelittbaltic.eu.
[29] https://www.oecd.org/environment/country-reviews/OECD_EPR_Estonia_Highlights.pdf

nets are deposited in these containers. It is unclear whether lead lines are usually removed from heavily entangled gear. Several German fishing harbours participate in Fishing for Litter campaigns organised by the German NGO NABU. In these harbours, NABU provides containers for marine litter collected during regular fishing activities, which includes between 15 and 30% of recovered fishing gear fragments. NABU additionally observed that some fishers seem to also use these containers to discard end-of-life nets. This suggests that larger nets retrieved from the sea outside regular fishing activities might also be placed in Fishing for Litter containers. This can currently not be confirmed nor excluded. The advantage of this misplacement lies in the fact that NABU carries our yearly sorting and analysis campaigns. Hence hazardous waste would be removed prior to sending recovered marine litter to a recycling or incineration facility. If lead lines cannot be removed, the only available path for retrieved, mixed fishing gear is the open-air, hazardous waste landfill.

Poland: During the 2015 BalticSea2020 large-scale recovery campaign, WWF Poland organised for the fishing sector the search and retrieval of lost gear from the most frequented fishing grounds. In total, 270 tonnes of collected gear were brought to port by 101 fishing vessels in 14,000 hours at sea[30]. The material was forwarded to the company Metalex for dismantling. The company removed and sold metal for recycling, and made efforts to separate the different polymer types. They also tried to generate recyclates from the shredded fibres. Apparently, the procedures were too tideous and not sufficiently economically productive as the company has since been closed. According to WWF Poland, Metalex finally had to send the remaining materials to incineration plants, although this cannot be confirmed directly through the company anymore.

Sweden: This is the only MARELITT Baltic partner country with a regular dismantling facility for fishing gear. The Fisheries Association FF Norden dismantles mostly end-of-life gears, but also recovered crab pots and traps. FF Norden activities are financed through selling pre-sorted and pre-cleaned materials, including both metals and plastics, to recycling companies such as Plastix in Denmark and Nofir in Lithuania. The process has to be sufficiently efficient to be financially viable. Mixed and entangled retrieved fishing gear cannot be handled because of the extensive effort required to separate material fractions. However, a plastic sorting facility in the Smögen municipality has recently agreed to carry out a dismantling trial with the DFG retrieved during MARELITT Baltic. Results will be available afterwards from the MARELITT Baltic lead partner, the Marine Center of the Municipality of Simrishamn.

In summary, no regular waste management structure could be identified for ALDFG in Estonia, Germany, Poland and Sweden. A private processing facility exclusively exists in Sweden, operated by the Fisheries Association Norden in the Smögen municipality fishing harbour. This facility has to be economically viable as it is not supported by government funding. Non-recyclable ALDFG is most likely incinerated in Germany, Poland and Sweden, and landfilled in Estonia, though the path of DFG could not be conclusively confirmed with certainty in any of the MARELITT Baltic partner countries despite extensive effort during the survey by Fraunhofer UMSICHT.

[30] Szulc, M., Kasperek, S., Gruszka, P. et al. (2015 for WWF Poland): Removal of derelict fishing gear, lost or discarded by fishermen in the Baltic Sea, available at https://www.researchgate.net/publication/308419284_Removal_of_derelict_fishing_gear_lost_or_discarded_by_fishermen_in_the_Baltic_Sea_-_Final_project_report

Appendix B: Recommendations for harbour managers and municipalities

1. Install no-special-fee systems to discourage dumping or leaving retrieved marine litter at sea.
2. Provide separate reception facilities for end-of-life and retrieved fishing gears.
3. Dedicate a certain space to pre-processing, where nets can be spread out and cleaned from disturbances such as anchors, rocks, cables and other marine litter.
4. Provide scrap metal containers, and separate containers for lead lines.
5. Provide education materials promoting sorting of high- and low-quality materials, also providing information that nets need to be pre-cut into 1 meter pieces and that lead lines are toxic hazardous waste that should not enter household or commercial waste streams.
6. Support fishers, divers and other retrieval teams with collection and transport of DFG, possibly together with end-of-life net collections, to ensure each material enters the appropriate waste management pathway.
7. Consult with the local waste managing company regarding the best solutions and pass this information on to harbour users.

Appendix C: Recommendations for policy and authorities

1. Promote reporting of lost gear by defining who is responsible for retrievals and by identifying a funding scheme supporting retrieval actions at sea.
2. Support municipalities and harbours willing to expand infrastructure and reception facilities for DFG and end-of-life fishing gear collection.
3. Encourage no-special-fee systems in harbours as an incentive to bring marine litter back to port.
4. Encourage waste sorting facilities and existing waste processing plants to find technological solutions for the treatment of fishing gears – at least one pathway needs to be developed that allows to dispose of DFG in an ecologically and technically sound way.
5. Support waste sorting facilities and harbours in pre-processing removal of lead lines to avoid DFG having to be dumped as hazardous waste.
6. Encourage retrieval actions and promote good-practice treatment of ALDFG through pre-processing in harbours and reception by waste management companies.
7. Support public funding schemes in setting up at least one high-end alternative thermal processing facility in each country to be financed and tested as pilot projects.

MARELITT Baltic

Interreg Baltic Sea Region

EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND

The MARELITT Baltic project

Derelict fishing gear (DFG) is addressed worldwide as a source of marine litter with extensive hazardous effects on the marine ecosystem. From 5.500 to 10.000 gillnets and trawl nets are lost every year and despite intense media focus – the problem is poorly known in the fisheries industry and among politicians.

The MARELITT Baltic project is one of the first transnational initiatives in the world to provide an operation oriented all-in-one solution for how to approach DFG. It will turn a diffuse problem into a clear and apprehensible topic that can contribute to an enhanced international readiness to act.

The project is divided into five work packages (WP), where package 2, 3 and 4 are the major parts concerning the cleaning, prevention and recycling of lost fishing gear.

Cleaning the sea and planning future action at sea
The aim of WP 2 is to plan and execute DFG retrievals in Sweden, Estonia, Poland and Germany both on the seafloor and wrecks. The activities will be based on methodologies and techniques tested in earlier national projects. These experiences will contribute to a common methodology which is crucial given the extreme hydrographic and morphological variation in the Baltic Sea. The new operation platform will make cleaning operations both transparent and demonstrate if the task is physically possible.

Responsible fisheries prevention scheme
The aim of WP 3 is to develop an overall approach to mitigate the problem of lost fishing gear in the future. It can roughly be divided into three types of actions. Firstly, the project will increase knowledge on fishing technological and strategic changes over time and how these changes have influenced the evolution of gear loss. In the second step, the project will focus on the potential causes to why fishing gears are lost. The third category of action includes development of preventive methods such as gear marking technologies helping to track irresponsible fishermen or assisting responsible fishermen to locate lost gears.

Marine litter reception facilities and recycling
The aim of WP 4 is to identify the options for a safe and fully sustainable handling and recycling of the lost fishing gear in a circular approach. Within this work package the phase from reaching the harbour through cleaning, sorting, transport until processing of recycling of the nets will be dealt with. The work encloses a variety of approaches such as creating a knowledge baseline about the transnational status and capacities of harbours, waste handling systems and industries in the Baltic Sea countries.

Projectpartners

Sweden
Municipality of Simrishamn, Lead partner
Keep Sweden Tidy

Germany
WWF Germany

Poland
WWF Poland Foundation
Maritime University of Szczecin
Kolobrzeg Fish Producers Group
Institute of Logistics and Warehousing

Estonia
Keep the Estonian Sea Tidy
Estonian Divers Association

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