WP2 Report

Derelict fishing gear mapping and retrieval methodologies

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Abstract

Derelict fishing gears (DFG) are recognised worldwide as a source of marine litter with extensive hazardous effects on the marine environment. In 2016, the MARELITT Baltic project was initiated as a response to the DFG problem in the Baltic Sea.

One of the most important aims of the MARELITT Baltic project was to develop, test and apply DFG mapping and retrieval methodologies, define the pattern according to which the DFG are distributed and based on that, present a justified method for removing them from the sea. Regional approach was applied in order to allow for proper identification of host and hot spots areas, as well as their types. The combination of various data, including fishing effort data, knowledge of fishing patterns of different fleets and data on the seabed morphology were used together with practical knowledge of the sea users to understand how the abovementioned factors influence the fishing strategy and the use of fishing gear in various areas.

A map of host areas was developed on the basis of the methodology as well as the outcomes of retrieval operations. Additionally, an attempt to estimate the amount and geographical distribution of the DFG in the study area was made, as well as an estimation of the costs related to the cleaning operations.

In order to check the effectiveness in detecting underwater objects by acoustic methods, sonar trials were carried out in the framework of the project. The trials had produced positive results, therefore an underwater identification with the use of this modern technique was recommended as a practical tool for the purposes of DFG search and retrieval projects.

The MARELITT Baltic project was the first initiative on such a scale in the Baltic Sea region. Various actions at sea, including identification of areas with a probability of derelict fishing gear occurrence, search and retrieval operations carried out by fishermen as well as location, identification and cleaning of shipwrecks conducted by divers, resulted in many observations and lessons learned. These are provided in the following document as recommendations, related to key issues, such as practical activities at sea and mitigation measures.

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1. Introduction

Derelict fishing gears (DFG) are one of the components of plastic marine debris. The definition of derelict fishing gears is included, among others, in the HELCOM Baltic Marine Litter Action Plan and reads as follows: "*collective terms for commercial and recreational fishing gear that has been abandoned, lost or otherwise discarded into the marine environment and causes negative biological impacts through, e.g. unintentional catches of fish* (*a process which is often referred to as "ghost fishing*"), *coverage of sensitive habitats and/or fragmentation into micro-particles that could enter the food chain*"[1].

The negative impact of lost or abandoned fishing gears on the marine environment has dramatically increased in the second half of the 20th century, when fishermen started to use gears made of synthetic fibres. The transition from natural fibres to synthetic ones was initiated by an increasing demand for fish, higher competition among fishermen, and reduced biomass of fish stocks. To meet the new requirements, fishermen were obliged to change their fishing techniques and increase the effort by using more durable and long-lasting synthetic materials. At the same time, synthetic fibres became regularly available in industrial production and at increasingly cheaper prices with the growth of the plastics industry. Thus, the negative impact of derelict fishing gears on the marine environment has increased due to this properties of the fishing gears and a global increase in the fishing intensity. After loss or abandonment, such gears remain in the marine environment for decades and may have a negative impact on the ecosystem, among others through uncontrolled catch of fish and endangered species such as harbour porpoises or grey seals in the Baltic Sea.

Besides the impact on marine and land ecosystems, negative economic and social impacts of derelict fishing gears were also identified. Fishing gear loss is a direct economic loss for fishermen, related to the investment in new gears, as well as to the expenses connected with the retrieval of lost nets. In addition, the net loss results in a temporary suspension of the fishing activity. All these factors negatively influence the economic viability of individual fishermen. Another economic impact caused by derelict fishing gears is related to uncontrolled catches of economically important species. The catchability of derelict fishing gears, mostly gill nets, remains at around 6% of their natural catchability even after 2 years[2]. Negative social impact is connected with old fishing gears remaining in the sea that could create and preserve a negative perception of fishermen as irresponsible sea users, even though most of the cases of fishing gear loss are unintentional. Derelict nets

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[1] HELCOM, 2015. Regional Action Plan for Marine Litter in the Baltic Sea.

[2] Tschernij, V. and Larsson, P.O., 2003. Ghost fishing by lost cod gill nets in the Baltic Sea. Fisheries Research, 64(2-3), pp. 151-162.

washed ashore could reduce the attractiveness of tourist areas. Trawl nets deposited at shipwrecks could damage wrecks that are or could be an object of historical heritage. Derelict fishing gears entangled on shipwrecks could also reduce the attractiveness of these objects to divers and at the same time pose serious threat to the safety of those who decide to penetrate them.

The precise assessment of the quantities of derelict fishing gears deposited in the Baltic Sea is lacking. Several attempts to assess the number of gill nets lost by fishermen in the Baltic Sea region have been made. Under the FANTARED 2 project it was estimated that in 1997 each individual Swedish fishing vessel lost approximately 3.9 pieces of gill nets annually. Extrapolation made with relation to the entire Swedish fleet indicated that 165 kilometres of gill nets had been lost annually by Swedish fishermen, which is less than 0.1% of all fishing gears used[3]. In 2011, under the WWF Poland project, based on the data on the fishing effort of the EU fleets operating in the Baltic Sea, it was assessed that in the period 2005–2008 the number of gillnets lost by the EU fleet operating in the Baltic amounted to approx. 5.500–10.000 nets annually[4]. The assessments were re-calculated under the subsequent WWF project. On the basis of the fishing effort data from 2009, it was estimated that the number of nets lost by the Polish gillnet fleet was approx. 1.500 pieces and by the Lithuanian fleet approx. 150 pieces annually (data from 2009). Under the same study the preliminary assessment of the quantities of lost nets at ship wrecks was conducted. As a result, a rough estimate of fishing gears deposited at shipwrecks was presented: 150 to 450 tonnes in the Polish EEZ and 67 – 100 tonnes in the Lithuanian EEZ[5]. It could be assumed that due to stable reduction of the fishing effort in the Baltic region observed in the last decade the quantities of lost fishing gears have also been decreasing.

The MARELITT Baltic project is a natural follow-up of the above described initiatives, which were carried out independently in the Baltic region. The concept of a Baltic–wide derelict fishing gear project was developed under the EU-founded MARELITT project. In 2014, the MARELITT project supported the initiation of four marine litter retention and one derelict fishing gear retrieval projects in Europe, one in the Baltic Sea, one in the North East Atlantic, two in the Mediterranean Sea and one in the Black Sea. MARELITT worked with each host organization on the business case for their project and assisted each of them in the preparation of regional workshops gathering potential project partners and funding bodies.

[3] Macfadyen, G., Huntington, T. and Cappell, R., 2009. Abandoned, lost or otherwise discarded fishing gear. Food and Agriculture Organization of the United Nations (FAO).
[4] Kasperek, S. and Prędki, P., 2011. Ecological effects of ghost net retrieval in the Baltic Sea. Final report. WWF Poland.
[5] Szulc, M., 2013. Collecting ghost nets in the Baltic Sea. Final report on the activities conducted in 2012. WWF Poland.

The business case developed by WWF Poland, as well as the workshop organized in Warsaw paved the way for the MARELITT Baltic project, which was further developed by all partners with the support of the original MARELITT team.

The focus of the MARELITT Baltic project is to reduce the impact of marine litter in the form of derelict fishing gear in the Baltic Sea. The project is divided into five work packages. Packages 2, 3 and 4 are the major parts of the project that focus on the retrieval, prevention and recycling of derelict fishing gears.

The aim of the project, in line with the HELCOM Baltic Marine Litter Action Plan, is to develop cost-efficient, safe and environmentally friendly derelict fishing gear retrieval methods identified through demonstration actions for exemplary targets (soft seabed/wrecks/rocky bottoms), including an environmental impact assessment analysis for sensitive areas.

It is foreseen that MARELITT Baltic project will constitute the baseline for future cleaning operations, while gaining an overview of host and hot-spot areas in the Baltic Sea in the form of a map and developing a post-project action plan.

This report focuses on the results of the Work Package 2, "*Cleaning the sea and planning future actions at sea*" aimed at development and testing of a methodology for mapping and retrieval of derelict fishing gears. The main goal of this report is to presents the information on the methodology used for identifying the host and hot-spot areas and selecting retrieval areas, the analysis of the data from retrieval activities carried out in 2017 and 2018, as well as the recommendations related to the future activities as a part of mitigation of derelict fishing gear impact connected with the fishing operations.

2. Marine debris – focus on derelict fishing gears

Although the impact of debris on marine ecosystems is not fully recognised, there is a global consensus that aggregation of human related wastes in the oceans, seas and inland waters poses threats to both fauna and flora as well as to ecological processes that occur in marine and inland water ecosystems. Ingestion of plastic debris by birds, whales and fish, entanglements of marine mammals in derelict fishing gears or sunlight deficiency and limited photosynthesis caused by debris floating at the water surface are the most common impacts described in the literature[6]. Microplastics and their impact on marine ecosystems[7] are also a growing concern. Recent studies clearly

[6] Jeftic, L., Sheavly, S. and Adler, E., 2009. Marine Litter: A Global Challenge. UNEP.

[7] Cole, M., Lindeque, P., Halsband, C. and Galloway, T., 2011. Microplastics as contaminants in the marine environment: A review. Marine Pollution Bulletin, 62, p. 2589.

show that microplastics are present in 90% of table salt[8] as well as in e.g. the stomachs of demersal and pelagic fish from the North Sea and the Baltic Sea[9]. Although the presence of microplastics in the environment has been proven, further studies are needed to fully understand the scope and the scale of negative influences caused by microparticles and -fibres.

Detailed qualitative and quantitative data related to marine litter is still scarce, both globally and regionally, including the levels of contamination in the Baltic Sea. Many studies were carried out to assess the quantity of marine litter but due to different approaches and methodologies, the comparison of the existing data is difficult. However, the analysis of available information allows the identification of general patterns. Approximately 80% of marine litter are estimated to originate from land-based sources and the remaining approximately 20% are a result of human activities at sea[10]. The same data clearly show that plastic debris is the most common type of marine litter and accounts for about 60 – 80% of all debris in seas and oceans[11]. According to recent studies, fishing gears or their fragments account for 27% of all plastics found on the beaches of the EU countries[12].

The domination of plastic debris in the marine environment is not a surprise, considering the wide use of plastics in most products. Wide usage of plastic components is related to the physical properties of this material, of which strength and durability are the most desirable for producers and consumers. These properties had been recognised by the industry a long time ago and resulted in a boom in plastics production in the second half of 20th century. In 1950, the global production of plastics amounted to 1.7 million tonnes. Since then, it has increased by more than 200 times.[13] The production is expected to double again in the next 20 years[14]. At the same time, another very important characteristics of plastics, which is the ability to be recycled, had not been fully recognised and is even now only marginally exploited by the industry. The introduction of plastics was not followed by the development of effective waste management strategies. For many years,

[8] Karami, A., Golieskardi, A., Choo, C.K., Larat, V., Galloway, T.S. and Salamatinia, B., 2017. The presence of microplastics in commercial salts from different countries. Scientific Reports, 7, p. 46173.

[9] Lenz, R., Enders, K., Beer, S., Sørensen, T.K. and Stedmon, C.A., 2016. Analysis of microplastic in the stomachs of herring and cod from the North Sea and Baltic Sea. DTU Aqua National Institute of Aquatic Resources.

[10] Sheavly, S.B. and Register, K.M., 2007. Marine debris & plastics: environmental concerns, sources, impacts and solutions. Journal of Polymers and the Environment, 15(4), pp. 301-305.

[11] Derraik, J.G., 2002. The pollution of the marine environment by plastic debris: a review. Marine pollution bulletin, 44(9), pp. 842-852.

[12] Sherrington, C., Darrah, C., Hann, S., Cole, G. and Corbin, M., 2016. Study to support the development of measures to combat a range of marine litter sources. Report for European Commission DG Environment.

[13] PlasticsEurope Market Research Group (PEMRG) / Consultic Marketing & Industrieberatung GmbH.

[14] Communication from the commission to the European Parliament, the council, the European economic and social Committee and the committee of the regions. A European Strategy for Plastics in a Circular Economy. {SWD(2018) 16 final}. European Commission. 2018.

plastic was used, among others, to produce single use items such as bags and other packages. Currently, 59% of all plastic waste comes from single-use packaging material[15]. The lack of proper waste management strategies has led to a situation in which more than half of the plastic debris in European Union is landfilled (31%) or incinerated (39%). This results in an economic loss due to material value loss of 70 to 105 billion Euro annually[16]. Globally, 5 to 13 million tonnes of plastics, which constitutes 1.5-4% of the global production, ends up in the oceans every year[17]. In the European Union, the amount of plastic waste entering the oceans every year is lower, but is still estimated to be between 150.000 and 500.000 tonnes[18].

2.1 Derelict fishing gears in the marine environment

In contrast to marine litter, the problem of derelict fishing gears (the term "*lost nets*" will be used throughout this report as a synonym) has been recognised a long time ago. The first recorded provision prohibiting disposal of fishing gears and other waste from ships into the marine environment was included in the International Convention for the Prevention of Pollution from Ships, in 1997.[19] Another attempt to reduce the amount of lost nets as well as the impact of gears that had been lost was made by the Food and Agriculture Organisation of the United Nations. The Code of Conduct for Responsible Fisheries, adopted in 1995, states that: "*States should cooperate to develop and apply technologies, materials and operational methods that minimize the loss of fishing gear and the ghost fishing effects of lost or abandoned fishing gear*". A detailed review of regional and international legislation related to derelict fishing gear is included in chapter: "Legislation related to derelict fishing gears" below.

The impact of derelict fishing gears on the environment is also well studied. A detailed analysis of the potential negative effects of lost fishing gears is presented in the next chapter of this report. But at this stage, it is worth mentioning that uncontrolled catches are one of the most important significant impacts. The scale of such uncontrolled catches depends on the fishing gear's type. Lost trawl nets, due to their high weight usually lose their fishing capacity. The uncontrolled catches performed by gill nets, which are commonly used in the Baltic Sea, are well documented. The fishing capacity

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[15] Bio Intelligence Service, 2011. Plastic waste in the environment – Final Report. European Commission.

[16] Ellen MacArthur Foundation, The new plastics economy, 2016. (https://www.ellenmacarthurfoundation.org/assets/downloads/EllenMacArthurFoundation_TheNewPlasticsEconomy_Pages.pdf).

[17] Jambeck, J.R., Geyer, R., Wilcox, C., Siegler, T.R., Perryman, M., Andrady, A., Narayan, R. and Law, K.L., 2015. Plastic waste inputs from land into the ocean. Science, 347(6223), pp. 768-771.

[18] Sherrington, C., Darrah, C., Hann, S., Cole, G. and Corbin, M., 2016. Study to support the development of measures to combat a range of marine litter sources. Report for European Commission DG Environment.

[19] International Convention for the Prevention of Pollution from Ships, 1973. International Maritime Organisation (IMO).

of lost gill nets gradually decreases, starting from approximately 20% of initial catchability just after loss, to approximately 6% after 27 months of deposition in the sea.[20] The table below presents the main fishing techniques and their potential catchability after loss.

Gear type	Ghost fishing impact on ecosystems
Gillnets	1
Trammel nets	3
Handlining	10
Longlining	9
Pots	3
Traps	8
Spear, harpoon	10
Pelagic trawl	9
Demersal trawl	9
Beam trawl	9
Shrimp trawl	9
Seine net	9
Purse seine	9
Beach seine	10

Table 1. Generalised estimates of the ghost fishing effect of different fishing methods - ranked on a scale from 1 (high impact) to 10 (low impact)[21].

2.2 The main causes of fishing gear loss

The factors contributing to the loss of fishing gears by fishermen vary considerably from one region to another, and the pattern changes over time. In the Baltic region, the main factors affecting the occurrence of derelict fishing gears in the past and at present were identified through interviews with fishermen that had been carried out, among others, in the framework of WWF Poland ghost fishing retrieval projects, as well as under the MARELITT Baltic project. The factors presented below are the "*end events*" resulting in the physical loss of the fishing gear. Detailed, in-depth analysis of the preliminary causes leading to "*end events*", with the use of e.g. fault tree analysis, allows for a better understanding of the real causes of fishing gear loss. In the following paragraphs, the modified fault tree methodology applied in the Arafura Sea[22] region is used to better understand the primary

[20] Tschernij, V. and Larsson, P.O., 2003. Ghost fishing by lost cod gill nets in the Baltic Sea. Fisheries Research, 64(2-3), pp. 151-162.

[21] Cochraine, K.L. ed., 2002. A fishery manager's guidebook: management measures and their application. FAO.

[22] Richardson, K., Gunn, R., Wilcox, C. and Hardesty, B.D., 2018. Understanding causes of gear loss provides a sound basis for fisheries management. Marine Policy, 96, pp. 278-284.

causes for the occurrence of derelict fishing gear in the Baltic Sea. At the same time, it should be highlighted that the analysis made below is done by the author of this publication. It is advised to further consult fishermen and other stakeholders regarding the proposed primary causes of derelict fishing gear occurrence as well as the proposed remedial measures, e.g. during a regional workshop similar to the one organised in the Arafura Sea region.

In the framework of the MARELITT Baltic project, interviews with fishermen were carried out to identify the main causes of fishing gear loss. In total, 160 fishermen from Estonia, Poland and Sweden were interviewed. The results, divided between historical and present factors for gear loss, were as follows:

	Estonia		**Poland**		**Sweden**		
Factors	**Past**	**Present**	**Past**	**Present**	**Past**	**Present**	**Total**
Seabed objects (rocks, "*hooks*" etc.)	-	29	47	40	21	21	158
Conflicts (between fishing gears types, non-fishing vessels)	-	26	19	27	40	43	155
Ship wrecks	-	9	24	23	16	19	91
Environment (strong current)	-	0	9	10	14	12	45
Environment (ice)	-	23	0	0	0	0	23
Environment (wind/waves)	-	14	0	0	0	0	14
Other reasons (theft, sabotage)	-	-	-	-	9	5	14

Table 2. A table summarising the results of the fishermen survey conducted in Estonia, Poland and Sweden based on 160 interviews.

The results presented above are similar to those obtained during previous projects carried out in the Baltic Sea Region, e.g. in the framework of the pilot project carried out by WWF Poland in cooperation with the Baltic Sea 2020 Foundation in 2011, with the main goals to retrieve derelict fishing gears and quantifies the losses and ecological impact. The presented data clearly point out the regional differences related to the main factors contributing to gear loss, as discussed below. This should not be a surprise, given the differences in the morphology of the sea bottom, the fishing effort and the behaviour of fishermen in all studied parts of the Baltic Sea. It should also be noted, that the identified factors are in fact the "*end events*" that result from primary factors. The identification of the primary factors with the use of a modified fault tree could help to develop mitigation measures, which could contribute to the reduction of the amount of lost fishing gears. The first attempt to apply the fault tree methodology in the Baltic Sea region is undertaken below for each of the identified "*end events*":

1. Fishing gear loss due to the objects located at the sea bottom (rocks, "*hooks*", etc.)

Fishing gear loss caused by snagging on the seabed objects such as rocks, different type of underwater obstacles called "*hooks*" and other underwater morphological structures was reported by fishermen as the main factor contributing to the occurrence of derelict fishing gear, both in Poland and Estonia. In Sweden, this factor was ranked second, after conflicts between different sea users.

It should be noted that fishing gear loss caused by underwater obstacles mainly refers to active fishing gears used close to or at the sea bottom. The probability of passive gear loss due to snagging on underwater obstacles is rather low, as after setting, these fishing gears remain stable in one position. Several primary factors, contributing to the entanglement of active nets on underwater obstacles could be identified, such as the lack of knowledge on the seabed morphology among fishermen, lack of knowledge on the location of underwater obstacles called "*hooks*", fishing activities deliberately carried out in the areas with potential high risk of net loss, where high aggregations of fish could be expected, and the lack of proper technical equipment to avoid these areas (refers in particular to the fishing vessels shorter than 12 meters, which are not equipped with e.g. VMS or GPS devices).

Possible measures to reduce the potential primary factors (listed above) include enhanced cooperation with the authorities and institutions, which could provide the necessary information. The information on the locations of underwear obstacles could be provided to fishermen by national authorities, responsible for navigation and safety at sea. The map of the seabed morphology is available, e.g. through HELCOM map services, but the resolution of provided data is low . Open questions, which need to be consulted with the sector are: will such additional data help fishermen to avoid areas with a high risk of gear loss? Will fishermen avoid these areas, if, in consequence, their catches decrease and do fishermen have the necessary equipment to use the above-mentioned data during the fishing operations?

2. Fishing gear loss due to the interactions with ship wrecks

Fishing gear loss due to the interactions with ship wrecks was reported as an important factor by Polish and Swedish fishermen. It should be noted that in Sweden the impact of this factor, according to fishermen, is bigger at present than in the past. Snagging on wrecks being a dominant factor for fishing gear loss at present is surprising because the knowledge of wreck locations has substantially increased with the GPS technology. This factor was also identified by Estonian fishermen, but other factors were more significant in the Estonian waters.

Similarly to underwater obstacles, gear loss due to the interactions with ship wrecks mainly refers to active gears, used at or close to the sea bottom. However, passive gears set in the vicinity of wrecks could also be affected, e.g. if the net drifts due to strong currents. Fishermen highlighted that gill nets are very often set close to ship wrecks, because wrecks constitute ideal habitats for large, economically more valuable fish. The loss of both types of the fishing gears at ship wrecks had been proven during the retrieval operations, when both passive and active gears were found and retrieved.

The primary factors which lead to fishing gear loss at ship wrecks are similar to the factors described in point 1, and include: lack of knowledge related to the position of all ship wrecks among fishermen, fishing activities deliberately carried out in the areas with potential high risk of fishing gear loss, where high aggregations of fish could be expected, and the lack of proper technical equipment to avoid areas with high risk of fishing gear loss (especially on fishing vessels with a length of less than 12 meters). Among possible solutions aimed at eliminating the listed primary factors are those related to the enhanced cooperation with the authorities and those related to the technical issues. The information related to ship wreck locations could be provided to fishermen by national authorities. Ship wreck locations should also be included in the maps that are used by the fishermen. However, some wreck locations which are cultural heritage sites might not be shared with the wide public. The exchange of information among the sea users on the position of wrecks is also an important factor, especially because small wrecks could change their position over time. With regard to the technical factor, the funds available under the EMFF should be used to equip small scale vessels with the tools required to allow accurate navigation, such as the GPS devices. At the same time, these tools should improve the efficiency, and not contribute to increasing the fishing capacity.

3. Fishing gear loss due to conflicts with other sea users

Swedish fishermen reported that conflicts with other sea users have been the main cause of fishing gear loss. In Estonia and Poland, this factor was reported as the second most important factor of net loss. .

The impact of this factor has increased, especially in the post "*cod boom*" era, after 1992. It could be assumed that one of the reasons for such an increase is the higher competition for resources among fishermen using different fishing techniques (passive and active), as well as the increased exploitation of the Baltic Sea resources, including space, by other sea users, such as e.g. transport or energy sectors.

The existing regulatory framework, the behaviour of sea users and the state of the resources could be identified as the potential primary factors, which lead to these conflicts. Conflicts between fishermen, who use different types of fishing gears could be caused both by the lack of proper regulations aimed at spatial separation of different types of fishery, as well as by increased competition for the exploitation of limited resources. Lack of regulations related to the maximum soak time of passive fishing gears could also contribute to their potential loss. Conflicts with other sea users could also be caused by the lack of a spatial management plan for the Baltic Sea, which would separate all types of possible activities of different sea users, both in space and/or over time.

Another potential primary factor is related to the requirements for the marking of fishing gears. It could be assumed that the requirements, which are currently in force do not always allow to identify the nets during the operations at sea. This could lead, for example, to breaking set nets by trawlers, which operate in the same area.

The possible measures aimed at excluding the mentioned primary factors of different conflicts are related to the enhanced cooperation between sea users and decision-makers responsible for improving and developing proper strategies and regulations. The spatial planning measures permit to create zones for different types of fishing activities, e.g. using passive and active fishing gears, and can be imposed by technical regulations, decided in cooperation with fishermen. The same applies to the development of regulations related to the maximum soak time of passive gears. The spatial management through zoning could also be introduced through non-regulatory framework, such as regional or local codes of conducts for responsible fishery. A regulatory framework was introduced e.g. by Poland and Germany in coastal waters, where the use of trawls is forbidden. The same methods apply to spatial management of the activities carried out by different sea users. This could be done through the introduction of regional, Baltic – wide, or national spatial management plans. Before implementation, there should be consultations carried out with all sea users to identify all provisions in order to find an acceptable compromise.

The primary factor is related to the marking of the fishing gear. Provisions related to marking are part of the existing regulatory framework of the Common Fisheries Policy. The requirements for fishing gear marking are included in regulations both at the EU and national levels. Consultations with fishermen and other sea users are advised to discuss whether the regulations in force are sufficient. For example, in Germany set nets are marked at the beginning and the end point, which are typically 500 meters apart. When conditions at sea are sufficiently windy to produce waves, buoys and flags are easily overlooked. A more densely spaced marking system would enhance visibility and avoid set gear to be driven by other vessels.

Mitigation of the primary factor of conflicts related to the competition for the exploitation of limited resources could be the biggest challenge. The recovery of resources, which could mitigate this factor is time-consuming. Nevertheless, further measures aimed at fish stock recovery should be implemented.

4. Fishing gear loss due to geographical factors and weather conditions such as strong currents and ice coverage

Fishing gear loss due to geographical factors and weather conditions was indicated as one of the factors by fishermen from all four countries. Fishermen from Estonia pointed at ice coverage as the main environmental factor, which could lead to gear loss. Likewise, WWF Germany retrieved gillnets that had been lost during rapid coastal ice formation. Swedish and Polish fishermen indicated that strong currents are also one of the factors of loss. These experiences reflect different environmental conditions in the four MARELITT Baltic project partner countries.

Although the environmental factors leading to gear loss differ between regions, the possible primary factors related to this "*end event*" are probably the same. Loss of a fishing net due to strong currents or ice-breaking can be caused by inaccurate weather forecasts or by economic factors, such as the need to increase the fishing effort even in bad weather conditions to ensure adequate profits for the fishing companies. One of the primary factors could also be related to the increase of the occurrence of unusual, hard to predict weather phenomena.

To avoid gear loss due to environmental conditions, updated and detailed weather forecasts should be available to all fishermen, including the small-scale fleet. Further work on the development and improvement of weather analysis systems should be carried out to adjust the systems to changes in the natural processes induced by climate change. The economic factors forcing an increase in the fishing effort could be mitigated by further measures aimed at fish stock recovery, which were described in the point above.

5. Fishing gear loss due to theft or sabotage

Theft and sabotage were indicated by the Swedish and German fishermen as one of the reason for fishing gear loss. There are many possible primary factors, which lead to such practices, including the lack of a proper monitoring system, lack of proper enforcement and compliance or unethical practices of individuals. However, due to a wide range of primary factors, as well as the illegal character of such "*end events*", a detailed analysis of possible primary factors and mitigating measures is not possible at this stage.

Each case should be reported to proper institutions (coast guard) and further examined.

6. Deliberate abandonment of fishing gears in the sea

Deliberate abandonment of fishing gears in the sea was not mentioned by fishermen in the interviews carried out in the framework of the MARELITT Baltic project. However such "*end event*" was highlighted under the interviews carried out by WWF Poland in the framework of previous derelict fishing gear retrieval projects, and mentioned during unofficial discussions with fishermen (mostly related to IUU (illegal, unreported and unregulated) fishing). Therefore, this factor should not be omitted, although probably the number of such events is rather limited today.

The primary factors that lead to the deliberate abandonment of fishing gears in the sea could be related to the lack of proper infrastructure for fishing gear collection, high costs of recycling or disposal, or low awareness on the impact of derelict fishing gears among the sea users. Another important factor is related to the IUU fishing. It can be expected that the percentage of fishing gears that are deliberately left in the sea by poachers is much higher than in the case of legal fishing activities.

Possible measures to overcome these primary factors should focus on the improvement of the access to proper infrastructure in harbours, either by adjusting the existing waste management strategies or developing new strategies, which would include derelict fishing gear and end-of-life gears as one of the components of the regular waste stream, development of solid and cost--effective recycling technology (see also the MARELITT Baltic project report on recycling options for derelict fishing gears), inclusion of derelict fishing gears and end-of-life gears under the no-special fee systems and extended producer responsibility schemes, development of refund schemes for old nets and further work related to the dissemination of knowledge aimed at enhancing the ecological awareness among the sea users.

With regard to the IUU fishing, further measures to ensure compliance are necessary, including better cooperation between fishery inspection authorities and fishermen.

7. Loss during recreational fishing activities

In both Sweden and Estonia it is allowed for recreational fishers to use set nets. As a result, gillnets of low quality compared to the nets employed by professional fishers are regularly used. Both Sweden and Estonia have pointed out that according to present estimates, 50% of the cases of gear loss originate at present from recreational fishing. Recreational nets do not have professional marking systems, are of a lower netting quality and hence break more easily. In addition, recreational fishers might not be as familiar with the fishing grounds and the seafloor, leading to more frequent snagging and net loss.

"End event"	**Primary factors**	**Proposed remedial measures**
Gear loss due to snagging on sea bed objects	Lack of information related to the seabed morphology.	Detailed maps of seabed morphology provided by e.g. HELCOM.
	Lack of information on underwater obstacles.	Detailed maps of underwater obstacles to be provided by national authorities.
	Fishing activities deliberately carried out near underwater obstacles (fish aggregation areas).	Creation of protection zones around obstacles and seabed morphological structures, which could cause fishing gear loss.
Gear loss due to snagging on ship wrecks	Lack of knowledge among fishermen related to the position of all ship wrecks	Detailed maps with ship wreck positions to be provided by national authorities, as far as possible while protecting cultural heritage sites
	Fishing deliberately carried out in the areas of potential risk, where high aggregation of fish could be expected	Creation of protection zones around ship wrecks, which could cause fishing gears loss
	Lack of proper technical equipment to avoid areas with high risk of fishing gear loss (especially on the fishing vessels below 12 meters)	Investment in navigation equipment with the support from EMFF (without increase of the fishing capacity).
Gear loss due to conflicts with other sea users	Lack of proper regulations or non-regulatory measures aimed at spatial management of different types of fishery	Introduction of technical regulations or codes of conducts in consultation with fishermen
	Leaving the passive gears unattended	Regulation on the allowed soak time of the passive fishing gears
	Increased competition for limited resources	Activities aimed at fish stocks' recovery

"End event"	**Primary factors**	**Proposed remedial measures**
	Lack of detailed spatial management plan for the Baltic Sea	Implementation of Baltic-wide or national spatial management plans
	Insufficient requirements related to proper marking of fishing gears	Consultation with sea – users under the existing regulatory framework, or possibly development of new marking systems and regulations
Loss of fishing gears due to environmental conditions such as strong currents and ice coverage	Inaccurate weather forecast	Access to up-to-date detailed weather forecast should be available for all fishermen at reasonable price
	Economic factors such as the need to increase the fishing effort	Activities aimed at fish stocks' recovery Further adjustment of the fishing capacity to available resources
	The increase of the occurrence of unusual, hard to predict weather phenomena	Development and improvement of weather analysis systems to adjust the systems to changes in the natural processes due to climate change
Deliberate abandonment of the fishing gears in the sea	Lack of proper infrastructure for fishing gears collection in harbours	Inclusion of DFG as one of the components of the waste management strategies of ports
	High costs of recycling	Development of solid and cost – effective recycling technologies for fishing gear Inclusion of DFG in the non-special fee scheme Introduction of refund schemes or extended producer responsibility
	IUU fishing and poaching	Further work to ensure compliance with the existing regulations

"End event"	**Primary factors**	**Proposed remedial measures**
	Low awareness on the environmental impact of derelict fishing gears	Dissemination of information through different bodies such as FAO, advisory councils, regional fisheries organizations Further engagement of the fishermen in the projects related to DFG retrieval
Loss during recreational fishing activities	Lack of experience and knowledge on the use of fishing gears and selection of the fishing grounds	Improved general information addressed to recreational fishers by responsible authorities A national license for recreational fishers and limitations to the number of allowed fishing gears (e.g. nets)

Table 3. Analysis of primary factors, end events and remedial measures related to fishing gear loss.

2.3 The amount of fishing gears deposited in the Baltic Sea and in other regions

All factors mentioned in the chapter above have resulted in a constant, and probably stable input of fishing gears into the environment in the past. At present, due to reduced fishing capacity and improvements of the weather prediction and navigation it could be assumed that the input is smaller than in the past. Most of the gear loss is caused by external factors. Fishing gears, especially the active ones such as trawls, are very expensive. Therefore fishermen undertake all possible effort to avoid their loss. Furthermore, taking into account the state of the fish stocks and the low profitability of the fishing sector, even the loss of relatively cheaper gillnets could have significant economic implications for fishermen.

An accurate assessment of the amount of fishing gears lost annually in different fisheries and different regions is difficult due to the lack of proper reporting. The same applies to the amount of fishing gears that are deposited during regular fishing activities at sea in different regions. Although fishermen in the EU are obliged to report each fishing gear loss, the data are scarce. Some rough estimates were made in different parts of the globe on the basis of the interviews with fishermen, the fishing effort, or extrapolation of the results of retrieval operations. The results of these analyses vary between regions and fishing gear types and are presented in the table below.

Region	Fishery/gear type	Indicator of gear loss (data source)
North Sea & NE Atlantic	Bottom-set gillnets	0.02–0.09% nets lost per boat per year (EC contract FAIR-PL98-4338 (2003))
English Channel & North Sea (France)	Gillnets	Gillnets 0.2% (sole & plaice) to 2.11% (sea bass) nets lost per boat per year (EC contract FAIR-PL98-4338 (2003))
Mediterranean	Gillnets	0.05% (inshore hake) to 3.2% (sea bream) nets lost per boat per year (EC contract FAIR-PL98-4338 (2003)
Gulf of Aden	Traps	20% lost per boat per year (Al-Masroori, 2002)
ROPME Sea Area (UAE)	Traps	260 000 lost per year in 2002 (Gary Morgan, personal communication, 2007)
Indian Ocean	Maldives tuna longline	3% loss of hooks/set (Anderson & Waheed, 1998)
Australia (Queensland)	Blue swimmer crab trap fishery	35 traps lost per boat per year (McKauge, undated)
NE Pacific	Bristol Bay king crab trap fishery	7 000 to 31 000 traps lost in the fishery per year (Stevens, 1996; Paul et al.; 1994; Kruse and Kimker, 1993)
NW Atlantic	Newfoundland cod gillnet fishery	5 000 nets per year (Breen, 1990)
Canadian Atlantic gillnet fisheries	Not specified	2% nets lost per boat per year (Chopin et al., 1995)
Gulf of St Lawrence snow crab	Traps	792 traps per year
New England lobster fishery	Traps	20–30% traps lost per boat per year (Smolowitz, 1978)
Chesapeake Bay	Traps	Up to 30% traps lost per boat per year (NOAA Chesapeake Bay Office, 2007)
Caribbean	Guadeloupe trap fishery	20 000 traps lost per year, mainly in the hurricane season (Burke and Maidens, 2004)

Table 4. Summary of gear loss/abandonment/discard indicators from around the world[23].

One of the attempts to assess the number of gill nets lost by fishermen in the Baltic Sea region were made in the framework of WWF Poland derelict

[23] Macfadyen, G., Huntington, T. and Cappell, R., 2009. Abandoned, lost or otherwise discarded fishing gear. Food and Agriculture Organization of the United Nations (FAO).

fishing gear retrieval projects carried out between 2011 and 2013. In 2011, a general analysis of the problem was carried out, using the data on the fishing effort of the EU fleets operating in the Baltic Sea, as part of the pilot project "*Collecting ghost nets from the Baltic Sea*". It was concluded that in the period 2005–2008 the number of gillnets lost by the EU fleet operating in the Baltic amounted to approx. 5.500–10.000 nets annually[24]. The assessments were re-calculated under the subsequent WWF project. On the basis of the fishing effort data from 2009, it was estimated that the number of nets lost by the Polish gillnet fleet was approx. 1.500 pieces and by the Lithuanian fleet approx. 150 pieces (data from 2009). These quantities do not directly correspond to the amount of gear lost by the fleets from both countries, as most of the fishing effort of the Polish and Lithuanian fleet was employed outside the Exclusive Economic Zones (EEZ) of these countries. The calculation made for Lithuania is consistent with the result of the interviews with Lithuanian fishermen. On the basis of the answers received, it was calculated that Lithuanian fishermen lost approx. 138 pieces of gill nets annually. Under the same study the preliminary assessment of the quantities of lost nets at shipwrecks was conducted. As a result, a rough estimate of fishing gears deposited at shipwrecks was presented: 150 to 450 tonnes in the Polish EEZ and 67 – 100 tonnes in the Lithuanian EEZ[25].

Another study related to the quantities of gill net lost in the Swedish waters of the Baltic Sea was conducted under the FANTARED 2 project in 2002. It was estimated that each individual fishing vessel lost approximately 3.9 pieces of gill nets annually. Extrapolation made to the entire Swedish fleet showed that 165 kilometres of gill nets were lost annually by Swedish fishermen at that time, which is less than 0.1% of all fishing gears used. The report shows also that the number of fishing gears that are lost increase proportionally to the distance from the shore, as well as that the biggest losses are observed in the fisheries targeting demersal species[26].

An attempt to assess the frequency of fishing gear loss by fishermen from Poland, Estonia and Sweden was made also under the MARELITT Baltic project. The results show that most of the fishermen lose their fishing gears occasionally – once per year or even less often. Only in Poland, the frequency of fishing gear loss is sometimes higher, but no detailed information on the factors were provided by the fishermen. The detailed results are presented below:

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[24] Kasperek, S. and Prędki, P., 2011. Ecological effects of ghost net retrieval in the Baltic Sea. Final report. WWF Poland.

[25] Szulc, M., 2013. Collecting ghost nets in the Baltic Sea. Final report on the activities conducted in 2012. WWF Poland.

[26] Macfadyen, G., Huntington, T. and Cappell, R., 2009. Abandoned, lost or otherwise discarded fishing gear. Food and Agriculture Organization of the United Nations (FAO).

	Less than ones/year	ones /year	ones /month	never
Polish	22	30	12	
Swedish	4	2	-	
Estonian	4	-	1	18

Table 5. The frequency of fishing gear loss by fishermen – results of the interviews with fishermen conducted under the MARELITT Baltic project.

Further analysis of the amount of derelict fishing gears deposited in the Baltic Sea was made in the framework of the MARELITT Baltic project based on the results of the retrieval operations carried out in 2017 – 2018. Detailed information can be found in chapter 8.

2.4 Port reception facilities

As described in the chapter above, the lack of proper port reception facilities for collecting and further processing of derelict fishing gears as well as end-of-life fishing nets is one of the factors contributing to the occurrence of the problem. It could be expected, and it was confirmed in the interviews with fishermen, that some fishermen throw the old fishing gears directly into the sea, because no general waste management or recycling options are provided to them or the provided systems are too expensive.

Within work package 4 of the MARELITT Baltic project, a detailed assessment of the readiness, capability and capacity of the Baltic Sea fishing harbours to receive, separately collect and sort the derelict fishing gears retrieved from the sea as well as end-of-life fishing gear was undertaken. Fifty fishing harbours located at the Baltic Sea coast in all four partner countries were visited and assessed during the project in 2017[27]. An excerpt from the summary of this report is provided below:

"The results reveal that more than half of the harbours selected for participation in the survey have organised waste management services at a reasonably good level. The survey results also indicate that fishing harbours in Germany and Poland have somewhat better general ability to organise waste management than those in Sweden and Estonia. The survey reveals that almost half of the harbours do not have enough containers suitable for the separate collection of waste. However, it must be noted that adding more containers alone will not solve the deficiencies and problems of waste management at harbours. The addition of containers and other reception facilities must be accompanied by an increase in the quantity and quality of suitable supporting waste management services." (Survey on Harbour Reception

[27] Press, M., 2017. Harbour Survey. Survey on Harbour Reception Facilities at selected Baltic Sea fishing harbours. Keep the Estonian Sea Tidy.

Facilities at selected Baltic Sea fishing harbours, Marek Press, Keep the Estonian Sea Tidy Tallinn, June 2017).

At present, fishing gears (derelict fishing gears and end-of-life fishing gear) are not separately collected in almost half of the fishing harbours. Instead, they are deposited in the same containers as other municipal waste. In most cases, the harbour staff does not know what happens later to the fishing gears collected separately, if the waste management companies to which the waste is transferred have the competence and technical facilities required for reprocessing and recovery of the material. Such lack of knowledge and information does not promote separate collection and handling of fishing gear at harbours. The report also reveals that there are deficiencies in the provision of information to the harbour users. Fishermen do not always know where and when the end-of-life fishing gear must be collected. No attention has been given to ICT opportunities for introducing the waste management rules and organisation of the work in harbours (e.g. the harbour's website does not provide enough information). Few exceptions aside, it can be said that there is a lack of regional cooperation in solving the problems caused by the derelict fishing gears

The outcome of the MARELITT Baltic project study on port reception facilities confirms the information gathered by WWF Poland in 2012 under the "*Collecting Ghost Nets in the Baltic Sea*" project. Nine Polish harbours were visited in 2012 to assess the fishing vessel-generated waste management strategies as well as to verify how the retrieved derelict fishing gears are handled. The survey clearly indicated that all examined ports had developed plans for the management of fishing vessel – generated waste, including the fishing gears, but so far the fishing gears have only been disposed of at landfills. Furthermore, several of the surveyed ports had no separate containers for retrieved or end-of-life fishing gears. The fishing gears were collected together with other types of waste. No recycling was carried out[28].

On the basis of both reports, it can be concluded that at present both derelict fishing gears as well as end-of-life fishing gears are rarely collected, because fishing gears are not considered as recyclable items. As the first step, it is recommended to develop a recycling path, because regular waste management companies do not currently offer recycling technologies for fishing gears[29]. Secondly, the principles set out in the EU waste management hierarchy, which promote waste prevention, reuse and recovery of materials, must be better followed not only when developing and implementing waste reception and handling plans, but at each stage of product (fishing gear)

[28] Szulc, M., 2013. Collecting ghost nets in the Baltic Sea. Final report on the activities conducted in 2012. WWF Poland.

[29] Stolte, A. and Schneider, F. 2018. Recycling options for Derelict Fishing Gear. University of Bath, UK August 2018, Stralsund.

lifecycle management. The latest European Commission proposal for the Directive on the reduction of the impact of certain plastic products on the environment[30], if adopted, could serve as the first step to improving the waste management of fishing gears in the harbours.

3. Impact of derelict fishing gears

As already stated in the introduction to this report, the impact of marine litter, including derelict fishing gears, is not fully investigated and studied. The available data and information are fragmented and there is a lack of a uniform methodology that would allow to compare the data available from different parts of the globe. Development and implementation of unique principles to assess the impact of marine litter and, in particular, the impact of derelict fishing gear is a challenge that needs to be met. The available data related to derelict fishing gear impact is also fragmented. The sources of available information are often not fully reliable, based on individual observations or general interviews with fishermen or other sea users. Although the information is not gathered in a systematic way, there is a global agreement and many evidences that derelict fishing gears pose multidimensional risks such as negative impact on marine ecosystems and their components (flora, fauna and seafloor habitat), economic losses to local societies and direct danger to sea users such as divers. Each impact is described in detail below.

3.1 Ecological impact

There is an agreement that the biggest impact caused by derelict fishing gears is related to constant, uncontrolled catches of fish and other organisms, including protected species. The impact depends on the type of the fishing gear. It is assumed, and partially confirmed, that the biggest impact is caused by lost traps and gillnets as a consequence of their construction. Fishing gears such as trawls usually preserve rather lower ability to catch marine organism after loss, due to their heavy weight. The possible impact of the three fishing gear types most commonly used in the Baltic Sea is described below.

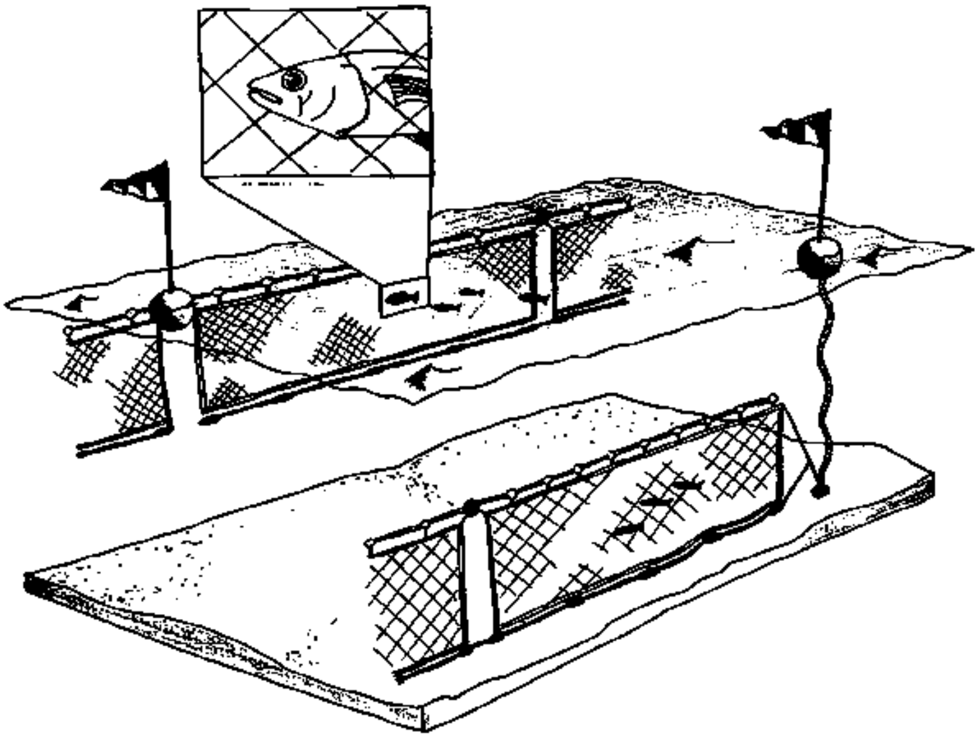
The detailed analyses of the impact of derelict fishing gears in other regions are included in many publicly accessible publications, such as: "*Study to support the development of measures to combat a range of marine litter sources*"[31] or "*Technical report on harm caused by marine litter published by the European*

[30] Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the reduction of the impact of certain plastic products on the environment. Brussels, 28.5.2018 COM(2018) 340 final 2018/0172 (COD).

[31] Sherrington, C., Darrah, C., Hann, S., Cole, G. and Corbin, M., 2016. Study to support the development of measures to combat a range of marine litter sources. Report for European Commission DG Environment.

Commission in 2016"[32]. Therefore this chapter will focus on the information related to the impact at the regional Baltic Sea level.

Gill nets



(*Source: http://www.fao.org/fishery/geartype/107/en*)

As described by FAO "*Gillnets and entangling nets are strings of single, double or triple netting walls, vertical, near by the surface, in midwater or on the bottom, in which fish will gill, entangle or enmesh. Gillnets and entangling nets have floats on the upper line (headrope) and, in general, weights on the ground-line (footrope). Gillnets or entangling nets consist of single or, less commonly, double (both are known as "gillnets", strictly speaking) or triple netting (known as "trammel net") mounted together on the same frame ropes. Several types of nets may be combined in one gear (for example, combined gillnets-trammel nets). These nets can be used either alone or, as is more usual, in large numbers placed in line ('fleets' of nets). The gear can be set, anchored to the bottom or left drifting, free or connected with the vessel*."[33] In the Baltic Sea, gill nets are used both in pelagic and demersal fishery targeting species such as (but not exclusively): cod, flounder, plaice, herring or salmon.

The catchability of lost gill nets was assessed in the northern part of the Baltic Sea. The results show that the catchability of lost gill nets amounts to

[32] Werner, S., Budziak, A., Van Franeker, J.A., Galgani, F., Hanke, G., Maes, T., Matiddi, M., Nilsson, P., Oosterbaan, L., Priestland, E. and Thompson, R., 2016. Harm caused by marine litter.

[33] Fishing Gear types. Gillnets and entangling nets. Technology Fact Sheets. In: FAO Fisheries and Aquaculture Department [online]. Rome. Updated 13 September 2001. [Cited 25 May 2018]. http://www.fao.org/fishery/

approx. 20% of the initial catchability when used in fisheries during the first three months after the net loss. Afterwards, the catchability of a fishing net starts to decrease. After 27 months of deposition in the sea, the catchability remains at a stable level, which oscillates around 6%[34].

Although the observations and assessments made by Tschernij & Larsson (2003) had been confirmed in other regions such as the North Sea or the EEZ of the United States of America, uncontrolled catches of fish at the level suggested in the Swedish study were not confirmed during the retrieval activities carried out in Poland in 2015 by the Polish fishermen organisations. The analysis of available data indicates that the number of fish entangled in retrieved gill nets was rather low and was counted in pieces rather than in tonnes. Further investigations are needed to assess whether this is a result of retrieval of only old, inactive nets from the sea bottom or whether the actual catchability of derelict gill nets in the Baltic Sea is lower than presumed.

Several factors related to the reduction of catchability with time could be identified. Due to water currents, the nets start to twist and tangle over time. As a result, the mesh size and its geometry changes and the twisted meshes become inactive. The second factor is related to biofouling of the net – a process of accumulation of sessile organisms on the net, which results in an increase of the weight of the net and in consequence its sinking to the bottom[35]. Another factor which also leads to net sinking is related to the accumulation of entangled organisms which results in weight increase. It should be highlighted that most of the described factors have time-limited impact. The organisms caught in the nets or those who inhabit lost nets at the sea bottom decompose. In consequence, the nets become lighter and can be lifted by currents. It should also be underlined that the impact of these factors, especially overgrowth, decreases with depth as a consequence of decreasing sunlight, therefore the catchability of nets lost at greater depths might last longer[36].

The latest studies show that the number of species representing various groups of marine fauna known to have been affected by either entanglement in marine litter or ingestion of marine litter has doubled since 1997[37]. One of the groups affected by derelict fishing gears are marine mammals. The studies carried out in the German EEZ indicate that the death of 0.3% of all analysed dead animals was due to the entanglement in marine debris, as

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[34] Tschernij, V. and Larsson, P.O., 2003. Ghost fishing by lost cod gill nets in the Baltic Sea. Fisheries Research, 64(2-3).

[35] Stelfox, M., Hudgins, J. and Sweet, M., 2016. A review of ghost gear entanglement amongst marine mammals, reptiles and elasmobranchs. Marine pollution bulletin, 111(1-2), pp. 6-17.

[36] NOAA Marine Debris Program, 2015. Report on the impacts of "*ghost fishing*" via derelict fishing gear. Silver Spring, MD. pp. 25.

[37] Kühn, S., Rebolledo, E.L.B. and van Franeker, J.A., 2015. Deleterious effects of litter on marine life. Marine anthropogenic litter, pp. 75-116. Springer, Cham.

compared to 0.2% of all dead animals collected in the North Sea. Ingestion of marine debris was recorded in 1.8% of all necropsied carcasses from the Baltic Sea and in 0.8% of all necropsied carcasses from the North Sea[38]. At the same time it should be highlighted that even though the percentage of marine mammals entangled in marine debris, including derelict fishing gears, is low, its impact on critically endangered harbour porpoises should not be underestimated, as loss of each individual could negatively affect the whole population. Implementation of mitigation measures to minimise the impact of derelict fishing gears on these species is crucial, especially in the areas identified by the SAMBAH project as areas of high probability of harbour porpoise occurrence[39].

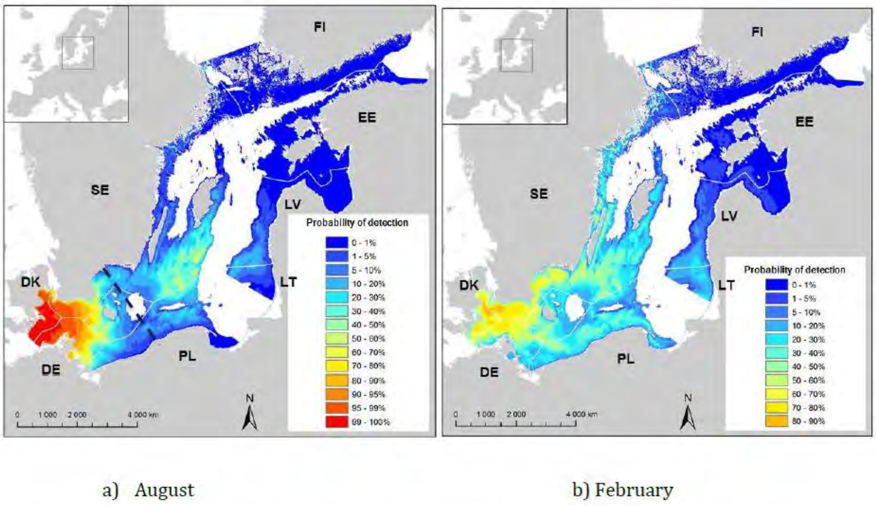


Figure 3a-b. Porpoise distribution modelled as the probability of detecting click trains for (a) August and (b) February . Dashed line in (a) indicates the proposed delimitation border between the two summer clusters.

(*Source: SAMBAH Project non-technical report*[40])

The impact of derelict gill nets on bird species in the Baltic Sea is not documented. Information from other regions suggests that marine birds could be caught in floating gill nets. Analysis of data collected by long-term derelict gear retrieval programs (Puget Sound, U.S.A.) suggested that almost 5000 nets removed from this one location caused the entanglement of more than 3.5 million animals per year including 1.300 marine mammals, 25.000 birds, 100.000 fish and over 3 million invertebrates. As estimated, 76 birds, 153 fish and 1.100 invertebrates were killed per year through the

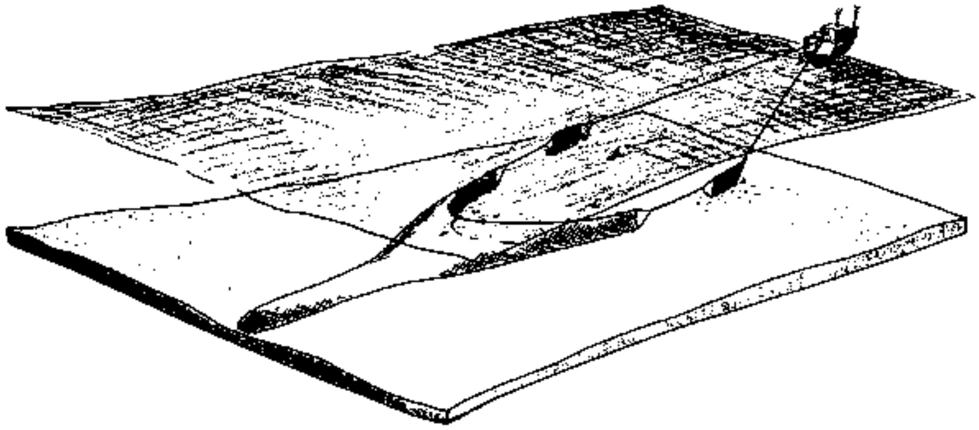
[38] Unger, B., Herr, H., Benke, H., Böhmert, M., Burkhardt-Holm, P., Dähne, M., Hillmann, M., Wolff-Schmidt, K., Wohlsein, P. and Siebert, U., 2017. Marine debris in harbour porpoises and seals from German waters. Marine environmental research, 130, pp. 77-84.

[39] SAMBAH, 2016. Non-technical report SAMBAH, Static Acoustic Monitoring of the Baltic Harbour porpoise. LIFE08 NAT/S/000261, p. 44. Available at: http://www.sambah.org/Non-technical-report-v.-1.8.1.pdf

[40] Heard but not seen. Sea-scale passive acoustic Survey Reveals a Remnant Baltic Sea Harbour Porpoise Population that Need Urgent Protection, Non-technical report, LIFE08 NAT/S/000261.

entanglement in a single gill net, including losses through decomposition and consumption[41].

Trawl nets



(*Source: http://www.fao.org/3/y3427e/y3427e04.htm#bm04.4*)

Trawl nets are described by FAO as "*cone-shaped net (made from two, four or more panels) which are towed, by one or two boats, on the bottom or in midwater (pelagic). The cone-shaped body ends in a bag or coded. The horizontal opening of the gear while it is towed is maintained by beams, otter boards or by the distance between the two towing vessels (pair trawling). Floats and weights and/or hydrodynamic devices provide for the vertical opening. Two parallel trawls might be rigged between two otter boards (twin trawls). The mesh size in the codend or special designed devices is used to regulate the size and species to be captured*."[42] In the Baltic Sea both bottom and pelagic trawls are used, targeting among others small pelagic species such as herring and sprat as well as demersal species such as cod or flounder.

The catchability of derelict trawl nets is rather low because, after loss, due to their high weigh, the nets sink rapidly and stay at the sea bottom, except for the case when lost nets snag on protruding objects such as wrecks and remain spread out in the water column. In such cases, the nets pose a threat of entanglement to marine mammals and birds, as well as for divers. This assumption is confirmed by several observations made under the derelict fishing gear retrieval projects carried out in the Baltic Sea region[43].

Another impact potentially caused by trawl nets is devastation of sensitive bottom habitats of the Baltic Sea, e.g. sensitive Eelgrass (*Zostera marina*)

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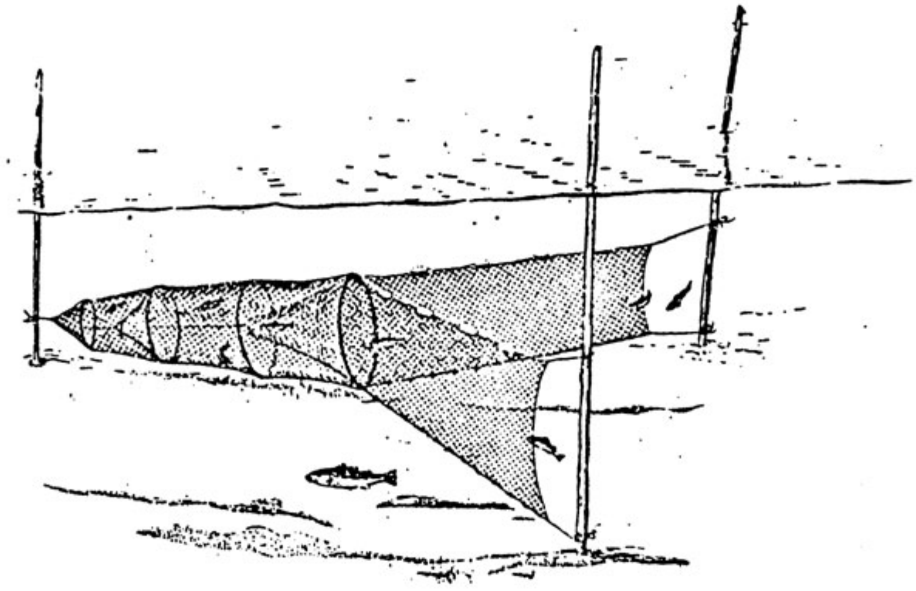
[41] Werner, S., Budziak, A., Van Franeker, J.A., Galgani, F., Hanke, G., Maes, T., Matiddi, M., Nilsson, P., Oosterbaan, L., Priestland, E. and Thompson, R., 2016. Harm caused by marine litter.

[42] Fishing Gear types. Trawls. Technology Fact Sheets. In: FAO Fisheries and Aquaculture Department [online]. Rome. Updated 13 September 2001.
[Cited 25 May 2018]. http://www.fao.org/fishery/

[43] Szulc, M., 2011. „*Ghost nets*" – fishing gears lost in the sea, its impact on living resources and the capabilities of removal. Outline of the problem. Presentation.

habitats. If the trawl net is lost in the area of occurrence of valuable habitats or is moved there by the currents, it can cause physical damages due to its weight and at the same time limit the light availability necessary for the growth of marine organisms ("*smothering*").

Trap nets



(*Source: http://www.fao.org/fishery/geartype/226/en*)

Traps are "stat*ionary nets or barrages or pots, are gears in which the fish are retained or enter voluntarily and will be hampered from escaping. They are designed in such manner that the entrance itself became a non-return device, allowing the fish to enter the trap but making it impossible to leave the catching chamber. Traps are baited or not. Pieces of fish are often used as bait. Artificial baits are also in use. Other types of traps are provided with large guiding panels made from netting to lead the fish into the catching chamber. Different materials are used for building a trap: wood, split bamboo, netting wire are some examples*."[44] In the Baltic Sea, traps are most often used in the northern and eastern regions. Since the 1960s, the traps used in Northern Europe are made from nylon instead of natural materials and hence contribute to marine plastics pollution. Traps were commonly used in German coastal waters about 20 years ago, but went out of fashion with decreasing fish population densities, because the returns did not warrant the manual labour effort to set and empty the traps anymore. The use of traps in the southern part of the Baltic Sea can also be impaired by strong currents. Traps are usually used in fisheries targeting salmon and seatrout.

[44] Fishing Gear types. Traps. Technology Fact Sheets. In: FAO Fisheries and Aquaculture Department [online]. Rome. Updated 13 September 2001.
[Cited 25 May 2018]. http://www.fao.org/fishery/

Research on the impact of derelict trap nets on the Baltic ecosystem and its components has not been carried out. However, data from other regions shows that trap nets, after loss, continue to catch both target and non-target species. Some traps are able to continue catches event 7 years after loss, as each new catch attracts other species to enter the net[45].

3.2 Economic and social impact

The impact of derelict fishing gears includes also direct and indirect economic and social effects. The gear loss is a dire economic loss to the fishermen, related to the investment in new gear, as well as to the expenses connected with the search aimed at retrieval of lost nets. In addition, the net loss results in a temporary suspension of the fishing activity. All these factors negatively influence the economic viability of individual fishermen.

It was roughly assessed that the costs uniquely related to the purchase of new gill nets to replace the lost nets amount to approximately 400.000 Euro annually for the fleet operating in the Baltic Sea[46].

Another economic impact caused by derelict fishing gears is related to uncontrolled catches of economically important species. As mentioned above, the catchability of derelict fishing gears, mostly gill nets, remains at around 6% of their natural catchability even after 2 years. In the report quoted in the paragraph above, it was assessed that the financial losses related only to the cod caught in derelict fishing gears in the Baltic Sea account for 12.000 Euro annually.

A more detailed analysis of potential economic losses caused by derelict fishing gear to fishermen was carried out by Brown & Macfadyen (2007)[47]. The authors used modelling to assess the cost to a hypothetical EU gillnet fishery. Factoring in the cost of the net lost plus the loss of available fish from the stock arising from the ghost fishing of a single fleet of gillnets, 26.400 Euro is lost to the fisherman. It is assumed that roughly one fleet of nets is lost per fishing boat per year, so this represents the yearly cost to one individual gillnetting vessel.[48]

A potential social impact of derelict fishing gear could also occur, but there are no detailed studies in this field. At least several impacts could be identified. Retention of old fishing gears in the sea could create and preserve a negative perception of fishermen as irresponsible sea users, even though

[45] Maselko, J., Bishop, G. and Murphy, P., 2013. Ghost fishing in the Southeast Alaska commercial Dungeness crab fishery. North American Journal of Fisheries Management, 33(2), pp. 422-431.

[46] Prędki, P., 2017. Conservation and restoration of marine biodiversity and ecosystems in the framework of sustainable fishing operations, consisting of retrieval of derelict fishing gear and marine litter.

[47] Brown, J. and Macfadyen, G., 2007. Ghost fishing in European waters: Impacts and management responses. Marine Policy, 31(4), pp. 488-504.

[48] Werner, S., Budziak, A., Van Franeker, J.A., Galgani, F., Hanke, G., Maes, T., Matiddi, M., Nilsson, P., Oosterbaan, L., Priestland, E. and Thompson, R., 2016. Harm caused by marine litter.

most of the cases of fishing gear loss are unintentional. The lost nets washed ashore could reduce the attractiveness of tourist areas. Trawl nets deposited at shipwrecks could damage wrecks that constitute or could constitute historical heritage. Derelict fishing gears entangled on shipwrecks could also reduce the attractiveness of these objects to divers and at the same time pose serious threat to the safety of those who decide to penetrate them.

3.3 Microplastics

Although microplastics could be included as one of the factors in the above mentioned impacts, it is advisable to describe the impact caused by microplastics separately. Since the mid-20th century, fishing gears have been made of many types of synthetics fibers, such as polyamide, polyester, polypropylene or polyethylene fibers. At the same time, natural materials in floats such as cork and glass bulbs for buoyancy were also replaced by low-density polypropylene and polyethylene floats and buoys. These materials have desirable physical properties for fishermen, such as longevity and strength and at the same time limited visibility for marine organisms. It must be assumed that microplastics are released from lost gears due to physical and biological impacts (abrasion on the seafloor, UV radiation on the sea surface and beaches, and overgrowth by mussels and other organisms breaking up the fibre structure). So far, no studies have been carried out to assess the amount of microparticles released from lost fishing gears directly into the marine environment. However, it has to be assumed that the amount of microplastics should be similar or close to the amount released from other items produced from the same types of materials.

The biggest threat connected to microplastics (plastic particles smaller than 5 mm) in the marine environment is associated with an easy introduction of such particles and fibres into the food chain. Small organisms can easily ingest such a material.[49] Many scientific publications refer to the bioaccumulation of plastic particles at different levels of the trophic food chain, which may negatively impact the immune and reproductive systems. Recent studies also found microplastics in the air, drinking water and foods like salt or honey, with yet unknown impacts on human health.[50] On average, 23% of North and Baltic Sea cod and herring contain microplastics in their stomachs, of which 83% are found to be fibres[51].

In total, it is estimated that between 75.000 and 300.000 tonnes of microplastics are released into the environment each year in the EU

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[49] Desforges, J.P.W., Galbraith, M. and Ross, P.S., 2015. Ingestion of microplastics by zooplankton in the Northeast Pacific Ocean. Archives of environmental contamination and toxicology, 69(3), pp. 320-330.

[50] Rainieri, S. and Alejandro, B., 2018. Microplastics, a food safety issue? Trends in Food Science & Technology. 10.1016/j.tifs.2018.12.009.

[51] Lenz, R., Enders, K., Beer, S., Sørensen, T.K. and Stedmon, C.A., 2016. Analysis of microplastic in the stomachs of herring and cod from the North Sea and Baltic Sea. DTU Aqua National Institute of Aquatic Resources. DOI, 10.

countries[52]. It is also highlighted in many documents that microplastics can accumulate toxic substances and pathogens at their surface, and therefore become disease vectors, dangerous for the living organisms or even the entire Baltic ecosystem.[53]

4. Legislation related to derelict fishing gears

Fishing gear loss is as old as the fishery. Fishermen have unintentionally lost their nets since hundreds of years. But only the introduction of hardly degradable materials, such as different types of synthetic fibers, resulted in the accumulation of indecomposable material in the marine ecosystem. This has initiated the process of setting regulatory measures, which aim at preventing gear loss and at the same time reduce the impact of lost gears.

The first recorded attempt to develop regulatory measures aimed at reducing the number of debris that enter the marine ecosystem was carried out under the International Convention for the Prevention of Pollution from Ships from 1988 (MARPOL). Under Annex V of this Convention, it is forbidden to dispose into the sea any types of plastic, including fishing gears, except for security reasons[54]. The regulation allows only for "*the accidental loss of fishing gear from a ship provided that all reasonable precautionary has been taken to prevent such a loss*". The definition of "*all reasonable precautions*" is not included, which opens a door for different interpretations. The call for developing measures aimed at reducing the number of fishing gear losses, and their impact on marine ecosystems is also included in the FAO Code of Conduct for Responsible Fisheries, adopted in 1995[55].

The EU legislation contains a detailed provision that unambiguously indicates the actions to be taken if the fishing gear is lost. This provision is included in the Council Regulation (EC) No 1224/2009 of 20 November 2009 establishing a Community control system for ensuring compliance with the rules of the common fisheries policy[56]. Article 48 of this Regulation states that:

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[52] Communication from the commission to the European Parliament, the council, the European economic and social Committee and the committee of the regions. A European Strategy for Plastics in a Circular Economy. {SWD(2018) 16 final}. European Commission. 2018.

[53] Hammer, C. and VanBrocklin, H., 2016. Microplastic Bioaccumulation in invertebrates, fish, and cormorants in Lake Champlain.

[54] International Convention for the Prevention of Pollution from Ships, 1973. International Maritime Organisation (IMO).

[55] Code of Conduct for Responsible Fisheries Food and Agriculture Organization of the United Nations, Rome, 1995 © FAO 1995.

[56] Council Regulation (EC) No 1224/2009 of 20 November 2009 establishing a Community control system for ensuring compliance with the rules of the common fisheries policy, amending Regulations (EC) No 847/96, (EC) No 2371/2002, (EC) No 811/2004, (EC) No 768/2005, (EC) No 2115/2005, (EC) No 2166/2005, (EC) No 388/2006, (EC) No 509/2007, (EC) No 676/2007, (EC) No 1098/2007, (EC) No 1300/2008, (EC) No 1342/2008 and repealing Regulations (EEC) No 2847/93, (EC) No 1627/94 and (EC) No 1966/2006.

"1. *A Community fishing vessel shall have the equipment on board to retrieve lost gear.*

2. The master of a Community fishing vessel that has lost gear or part of it shall attempt to retrieve it as soon as possible.

3. If the lost gear cannot be retrieved, the master of the vessel shall inform the competent authority of its flag Member State, which shall then inform the competent authority of the coastal Member State, within 24 hours of the following:

- *a) the external identification number and the name of the fishing vessel;*
- *b) the type of lost gear;*
- *c) the time when the gear was lost;*
- *d) the position where the gear was lost;*
- *e) the measures undertaken to retrieve the gear.*

4. If the gear that is retrieved by the competent authorities of the Member States has not been reported as lost, these authorities may recover the cost from the master of the fishing vessel that lost the gear.

5. A Member State may exempt Community fishing vessels of less than 12 metres' length overall flying its flag from the requirement set out in paragraph 1 if they:

a) operate exclusively within the territorial seas of the flag Member State; or

b) never spend more than 24 hours at sea from the time of departure to the return to port".

It should be assumed, that if the provision quoted above is fully implemented and complied with, the national and regional authorities should have the information related to both the exact scale of the problem as well as exact locations of gear loss. This information should be sufficient to develop mitigation measures aimed at reducing the amount of lost fishing gears as well as to carry out targeted actions aimed at retrieving lost fishing gears, which had not been collected by the fishermen themselves. Unfortunately, most fishermen do not comply with these provisions. The exact reasons for non-compliance are not known. It can be assumed that lost trawls nets, due to their high costs, are retrieved by fishermen with the use of their own resources. However, the cost of a single gill net is much lower, therefore it must be assumed that the costs of a retrieval operation, e.g. fuel needed to retrieve such a net and possibly professional divers to support the safe retrieval of the net, are much higher than the net itself. According to the information received from the Polish authorities under the previous derelict fishing gear retrieval projects, fishermen do not notify the authorities on any gear loss, regardless of the type.

The lack of compliance with the provisions of Article 48 of the Council Regulation (EC) No. 1224/2009 of 20 November 2009 was noticed by the Commission and addressed under the ongoing process of evaluation and revision of the EU fishery control system[57]. The amendments proposed by the Commission related to Article 48 of the control regulation aimed at:

- Improving the reporting of fishing gear loss, through the use of logbooks (electronic) for all categories of vessels, including gillnetters < 12m currently exempted from some of the reporting regulations.
- Removing the derogation applicable to vessels below 12m to carry on board the necessary equipment for the retrieval of lost gear.
- Setting the EU provisions on the marking and control of fishing gears currently enacted for professional fisheries only also for recreational fisheries.

The legislation process related to the revision of the fishery control system is ongoing and further discussions and negotiation with EU institutions and stakeholders are foreseen. The amendments proposed by the Commission should be seen as the first step towards more efficient implementation of the provisions aimed at mitigating the impact of derelict fishing gears. The extension of the requirement to carry on board the equipment necessary for the retrieval of lost fishing gear to vessels below 12 meters is of great importance. There are evidences that passive gears such as traps and set nets have a bigger uncontrolled catchability after loss than active gears, therefore measures aimed at reducing of the quantities of lost passive fishing gears should be prioritized. These types of nets and fishing gear are also most frequently lost. At the same time, it should be highlighted that improvement of the means used for reporting the loss of fishing gear alone (logbook) would not solve the problem of the lack of reporting. Further consultations with fishermen to identify why the provisions related to reporting included in the present Control regulation (COUNCIL REGULATION (EC) No. 1224/2009) are not followed should be conducted by the Commission to ensure that the new requirements overcome present difficulties related to reporting and are acceptable by the majority of fishermen.

Recognition of recreational fisheries as one of the sources of derelict fishing gear is also of great importance. The attempt made by the Commission to improve the monitoring and regulations related to recreational fishing should be supported, especially given the growing importance of the recreational fishery. At the same time, it should be highlighted that marking of recreational fishing gears and the corresponding control system should be implemented to ensure a high level of compliance. Simultaneously, educational and information activities aimed at awareness raising regarding

[57] Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL amending Council Regulation (EC) No 1224/2009, and amending Council Regulations (EC) No 768/2005, (EC) No 1967/2006, (EC) No 1005/2008, and Regulation (EU) No 2016/1139 of the European Parliament and of the Council as regards fisheries control COM/2018/368 final.

the impact of recreational fishing and derelict fishing gears on the marine environment should be intensified.

Appropriate marking of fishing gear can be an effective tool to combat gear loss or abandonment and to facilitate the identification and recovery of such gear. The improvements in gear marking were recently discussed by FAO[58]. Gear manufacturers and suppliers should be encouraged to facilitate traceability across the supply chain, from production to use and subsequent disposal to reduce the net loss due to e.g. illegal, unreported and unregulated (IUU) fishing. It was also advised to introduce e-reporting and e-monitoring systems based on GPS, which will allow skippers to provide spatial and temporal information on passive gears used in fisheries and potentially share this data with other marine users and control authorities. The evident concerns about the confidentiality, costs and software compatibility of such a system were highlighted. Nevertheless, it was stated that this system could help to solve the problem of conflicts between different sea users. The FAO report also provides detailed guidance for the marking of fishing gears to indicate position and reduce the number of lost nets.

Apart from the regulations directly referring to the fisheries management, provisions aimed at reducing the amount of marine litter and mitigating its impact on the environment are also included in the environmental legislation, such as the Marine Strategy Framework Directive (MSFD)[59] and the HELCOM Regional Action Plan for Marine Litter in the Baltic Sea adopted in 2015[60].

The main aim of the MSFD is to achieve the good environmental status (GES) of marine ecosystems by 2020. One of the descriptors of GES is related to marine litter, including derelict fishing gears. Good environmental status of the European seas could only be achieved if the properties and quantities of marine litter do not cause harm to the coastal and marine environments. In 2016, a study requested by the European Commission was conducted to support the development of measures under the MSFD to combat a range of marine litter sources in the EU[61]. Several measures related to derelict fishing gears were identified, including:

[58] FAO, 2016. Report of the Expert consultation on the Marking of Fishing Gear, Rome, Italy, 4–7 April 2016. FAO Fisheries and Aquaculture Report No. 1157. Rome, Italy.

[59] Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive).

[60] HELCOM, 2015. Regional Action Plan for Marine Litter in the Baltic Sea. p. 20.

[61] Sherrington, C., Darrah, C., Hann, S., Cole, G. and Corbin, M., 2016. Study to support the development of measures to combat a range of marine litter sources. Report for European Commission DG Environment.

- Mandatory use of the GPS system onboard all vessels to allow fishermen to easily locate lost nets as well as to avoid underwater obstacles;
- Use of non-harmful materials for the parts of the fishing gears with high probability of loss during the fishing operations;
- Reduce conflicts among sea users by introduction of a zoning system for static and non-static gear, implement improvements in gear marking systems or introduction of spatial management and zoning schemes;
- Control of the soak time of the fishing gears.

Many of the measures listed above are included in regional action plans on marine litter, including the Marine Litter Action Plan for the Baltic Sea, developed and implemented by HELCOM. The plan aims at significantly reducing the amount of marine litter by 2020, as compared to 2015. The measures related to mitigating the impact of derelict fishing gears as well as to reducing the number of lost fishing gears are as follow:

- Promotion and dissemination of best practices related to waste management within the fishing sector in order to limit the quantities of derelict fishing gears;
- Development of best practices related to the removal of derelict fishing gears from the sea;
- Identification of "*hot spots*", the areas with the highest probability of fishing gear loss and the areas of potential accumulation of derelict fishing gears;
- Active removal of derelict fishing gears from the environment;
- Increase of the awareness of sea users in relation to the impact of derelict fishing gears on the environment.

It has to be underlined that most of the measures proposed in the HELCOM action plan were further analysed and discussed under the MARELITT Baltic project with the main aim to propose more concrete solutions to the problem.

Waste management constitutes another dimension with regard to the legislation containing the measures aimed at mitigating of derelict fishing gear impact as well as decreasing the amount of lost fishing gears. Derelict fishing gears are in general treated by the EU legislation as waste, therefore they should not be omitted in the measures aimed at reaching the ambitious goal of the European Union, i.e. moving towards a circular economy, where the value of products, materials and resources is maintained in the economy for as long as possible and contributes to the reduction of waste.

In 2014, the European Commission set an ambitious target of reducing marine litter by 30% by 2020 for the ten most common types of litter found on beaches, as well as for fishing gear found at sea[62]. This goal is in line with one of the targets of the United Nations Sustainable Development Goal 14, which states that "*By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution*". The HELCOM Marine Litter Action Plan and the MSFD are environmental pillars that should lead to the achievement of this goal in the Baltic Sea. The regulations related to the implementation of a circular economy as well as the recently adopted Plastic Strategy and the ongoing work on the new Directive on port reception facilities for the delivery of waste from ships that will replace the Directive 2000/59/EC should also help to reach this ambitious goal.

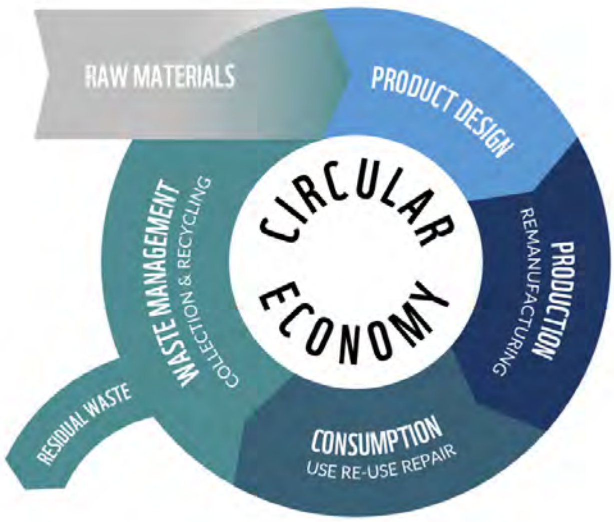

Figure 1. Circular Economy scheme.

The EU Action Plan for the Circular Economy[63] contains actions needed to ensure that the circular economy principles are implemented in each step of the value chain – from project, production, through distribution to consumption, repair and remanufacturing, waste management, and secondary raw materials that are fed back into the economy. The main aim is to maintain the value of the product through the entire life cycle. The principles of this plan also apply to fishing gears, but rather to the old gears that could be abandoned by fishermen and not to those gears that have already been lost, because the retrieved gears are usually contaminated (chemically or biologically) to such an extent, that the cost of cleaning is higher than the revenues related to recycling. If the action plan is implemented in fisheries, it could be expected that new technical solutions

[62] Communication from The Commission to The European Parliament, The Council, The European Economic and Social Committee and The Committee of The Regions. Towards a circular economy: A zero waste programme for Europe. {SWD(2014) 206 final} {SWD(2014) 211 final}.

[63] Communication from The Commission to The European Parliament, The Council, The European Economic And Social Committee And The Committee Of The Regions. Closing the loop - An EU action plan for the Circular Economy. COM(2015) 614 final.

as well as programs such as refund schemes or extended producer responsibility will be introduced to ensure that the old, end-of-life fishing gears are deposited and the precious synthetic material is re-used. The European Commission has made the first attempt to introduce the extended producer responsibility through the proposal of a new directive related to the reduction of the impact of certain plastic products on the environment[64], which is discussed below.

The EU Action Plan for the Circular Economy was adopted together with the Directive on waste (Waste Framework Directive)[65] under the so-called Circular Economy Package. The Waste Framework Directive sets out the basic concepts and definitions related to waste management, such as definitions of waste, recycling and recovery. It explains when waste ceases to be waste and becomes a secondary raw material (the so called end-of-waste criteria), and how to distinguish between waste and by-products. The Directive lays down some basic waste management principles: it requires that waste should be managed without endangering human health and harming the environment, and in particular without risk to water, air, soil, plants or animals, without causing a nuisance through noise or odors, and without adversely affecting the countryside or places of special interest. According to the Circular Economy Package, waste legislation and policy of the EU Member States shall apply as a waste hierarchy, in which waste management options are classified in order of priority of their environmental impact. The most preferred is avoidance, followed by reduction and preparing for re-use, recycling, recovery and disposal. The Waste Framework Directive introduces also the "*polluter pays principle*" and the "*extended producer responsibility*", which in the future is suggested to cover fishing gear producers.

Another regulation contributing to the mitigation of the impact of derelict fishing gears through the implementation of a circular economy is the Plastics Strategy adopted by the European Union in 2017[66]. The Strategy presents key commitments for action at EU level, among others the development of targeted measures for reducing the loss or abandonment of fishing gears at sea. Possible options provided in the document will be examined in terms of cost and efficiency. The outcomes of the MARELITT Baltic project could definitely serve as a beneficial input in this process.

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[64] Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the reduction of the impact of certain plastic products on the environment. Brussels, 28.5.2018 COM(2018) 340 final 2018/0172 (COD).

[65] Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives (Text with EEA relevance).

[66] COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS A European Strategy for Plastics in a Circular Economy {SWD(2018) 16 final}.

The provisions aimed at minimising the gear loss are also included in the proposal for a revised new directive on port reception facilities for the delivery of waste from ships, which is directly related to the Plastics Strategy described above. The draft directive is still being consulted. At this stage, the proposal takes into account:

- Inclusion of fishing vessels and recreational boats in the indirect fee system. As a result, the fishing vessels and recreational boats will be required to pay a fee to the port/harbor irrespective of whether they deliver any waste or not. These vessels will not be obliged to pay an extra fee if they bring to the port additional litter, including retrieved fishing gears and other marine plastics. At the same time, this provision aims at reducing the amount of nets that are intentionally thrown directly to the sea to avoid any costs related to the collection and recycling/disposal.
- Full introduction of separate waste collection for different waste streams of ship-generated waste, including derelict fishing gears, which is not the case in the Baltic region at present, as presented in the MARELITT Baltic project report on port reception facilities.
- Development of a single waste reception and handling facility for two or more neighbouring ports. This should result in better waste reception facilities in small, local harbours, which is not the case in the Baltic region at present, as referred to in the MARELITT Baltic project report on port reception facilities.

The most recent proposal directly linked to the Plastics Strategy and the EU Action Plan for the Circular Economy, put forward by the European Commission, is the proposal for a Directive on the reduction of the impact of certain plastic products on the environment[67]. The proposal includes targeted measures for reducing the loss or abandonment of fishing gear and their impact. The Commission aims "*to complete the existing policy framework with producer responsibility schemes for fishing gear containing plastic. Producers of plastic fishing gear will be required to cover the costs of waste collection from port reception facilities and its transport and treatment. They will also cover the costs of awareness-raising measures*"[68]. The proposal was recently discussed and accepted with many amendments by the European Parliament. The most important amendments related to derelict fishing gear proposed by the Parliament cover the inclusion of aquaculture gears in the category of derelict fishing gears as well as defining a measurable target amount of

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[67] Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the reduction of the impact of certain plastic products on the environment. Brussels, 28.5.2018 COM(2018) 340 final 2018/0172 (COD).

[68] European Commission - Press release. Single-use plastics: New EU rules to reduce marine litter. http://europa.eu/rapid/press-release_IP-18-3927_en.htm
Brussels, 28 May 2018.

derelict fishing gears that should be collected annually by member states[69]. The proposal will be further discussed under the European Union legislative procedure before the final adoption.

Although preventive measures are of the highest priority, remedial actions should also be considered, taking into account the impact of derelict fishing gears on the environment and the economy, as well as local societies. At present, the remedial measures, including retrieval operations of marine litter and derelict fishing gear at sea, could be funded through the national operation programs under the European Maritime and Fisheries Fund[70] for the period 2014 - 2020. The consultations on the post 2020 EU funding for the European fisheries sector are ongoing.

5. MARELITT Baltic project – the Genesis

The MARELITT Baltic project is a natural continuation of several national initiatives, which were carried out independently in the Baltic region. The first documented study related to the impact of derelict fishing gears on the Baltic ecosystem was conducted in 2003. The results confirmed that the catchability of gill nets is maintained after net loss[71]. The first documented retrieval trials were carried out in Poland by the National Marine Fisheries Research Institute (former Sea Fisheries Institute) in 2004 and the first documented cleaning operation on shipwrecks was made by Our Earth Foundation with the support of the Maritime University in Szczecin in 2007. During the trials carried out by the National Marine Fisheries Research Institute, a searching device (called "*the creeper*") equipped with small anchors was successfully tested[72]. The same equipment was used in the project carried out a few years later by WWF in cooperation with the Polish and Lithuanian Producers Organizations, as well as individually by the Polish and Lithuanian fisheries organisations. The detailed description of these projects, as well as reports summarising their outcomes can be found at web pages of WWF Poland and the MARE Foundation[73].

The concept of a Baltic–wide derelict fishing gear project was developed under the EU-founded MARELITT project[74]. In 2014, the MARELITT Project supported the initiation of four marine litter retention and one derelict

[69] REPORT on the proposal for a directive of the European Parliament and of the Council on the reduction of the impact of certain plastic products on the environment, (COM(2018)0340 – C8-0218/2018 – 2018/0172(COD)), Committee on the Environment, Public Health and Food Safety, Rapporteur: Frédérique Ries.

[70] REGULATION (EU) No 508/2014 of the European Parliament and of the Council of 15 May 2014 on the European Maritime and Fisheries Fund (EMFF).

[71] Tschernij, V. and Larsson, P.O., 2003. Ghost fishing by lost cod gill nets in the Baltic Sea. Fisheries Research, 64(2-3), pp. 151-162.

[72] Wiadomości rybackie (The Fisheries News), no 7–8 (139), 2004. Sea Fisheries Institute, Gdynia.

[73] https://fundacjamare.pl/akcja-czysty-baltyk

[74] Pilot project: Removal of marine litter from Europe's four regional seas, http://www.marelitt.eu

fishing gear retrieval projects in Europe, one in the Baltic Sea, one in the North East Atlantic, two in the Mediterranean Sea and one in the Black Sea. MARELITT worked with each host organization on the business case for their project and assisted each of them in the preparation of regional workshops gathering potential project partners and funding bodies. The business case developed by WWF Poland, as well as the workshop organized in Warsaw paved the way for the MARELITT Baltic project, which was further developed by all partners with the support of the original MARELITT team.

It is foreseen that MARELITT Baltic project will constitute the baseline for future cleaning operations, while gaining an overview of host and hot-spot areas in the Baltic Sea in the form of a map and developing a post-project action plan.

6. The methodology related to the identification of DFG host areas

One of the most important goals of the MARELITT Baltic project was to study and define the pattern according to which derelict fishing gears (DFG) are distributed in the Baltic Sea and, based on that present, a justified way to remove them. Regional approach was applied in order to allow for proper identification of host and hot spots areas, as well as their types.

On the basis of the methodology described below (used in 2017 and further adjusted in 2018) as well as the outcome of the retrieval operations carried out in randomly chosen areas, a map of host and hot-spot areas in the Baltic Sea was developed. In addition, based on the results of retrieval activities, an assessment of the total amount of derelict fishing gears deposited in the Baltic Sea was made. This assessment was used to estimate the total effort needed to clean up the entire Baltic Sea as well as the costs related to the Baltic-wide cleaning operations.

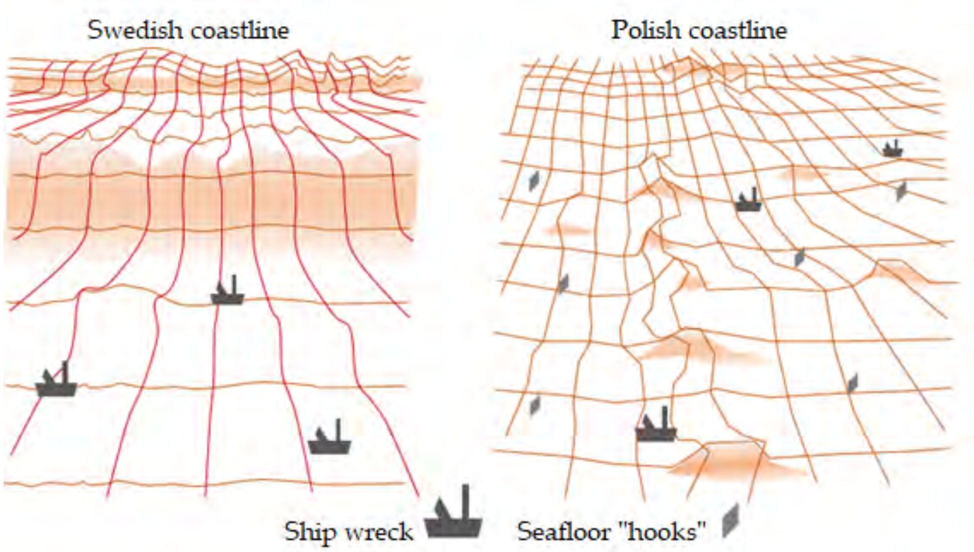
6.1 The methodology used to identify the areas to be searched with the use of the searching device in 2017

The methodology developed for defining and mapping DFG host areas was based on a hypothetical assumed DFG pattern, which was compiled using the fishing effort data, knowledge of fishing patterns for various fleets (merely active and passive) and morphological data. To combine all these three components, fishermen's knowledge was used to understand how effort, fishing pattern and environmental factors e.g. morphology influence the fishing strategy and use of the fishing gears in various areas.

The first attempt to develop and test the methodology was undertaken by the MARELITT Baltic project in 2016. During the preliminary discussion with project partners, it was concluded that it is not possible to apply the same approach in the entire Baltic Sea due to the differences in the sea bottom morphology, the environmental conditions (such as the differences in the strength of sea currents, different depth, length of ice coverage during winter) and national regulations (such as exclusion of trawling in the coastal zones in Poland and Germany, environmental and heritage protection laws). A regional approach was applied to allow proper identification of host areas and their categories as described below. In addition, it was agreed that due to insufficient data on the spatial distribution of the fishing effort as a baseline for hot-spot areas and the resulting inefficiency during the first search trials, as well as the limited availability of funds for random search activities in each country, the process used to identify potential retrieval areas in Germany and Estonia was primarily based on information gathered from divers on potential hot spots including wrecks and other underwater obstacles.

The basic principles of the methodology used in Poland and Sweden were the same to allow a comparison of the results even though several factors taken into account are different. The morphology of the sea bottom in Poland and Sweden differs strongly. On the Swedish coast the sea bottom is characterised by steep slopes following the eastern coast line and in Poland the sea bottom is flatter, with many local, natural and artificial obstacles.

Fishing patterns in Poland and Sweden are also different due to the natural correlation in the seafloor morphology. The more diversified seafloor, the more varying pattern of the geographical distribution of the fishing effort could be observed.



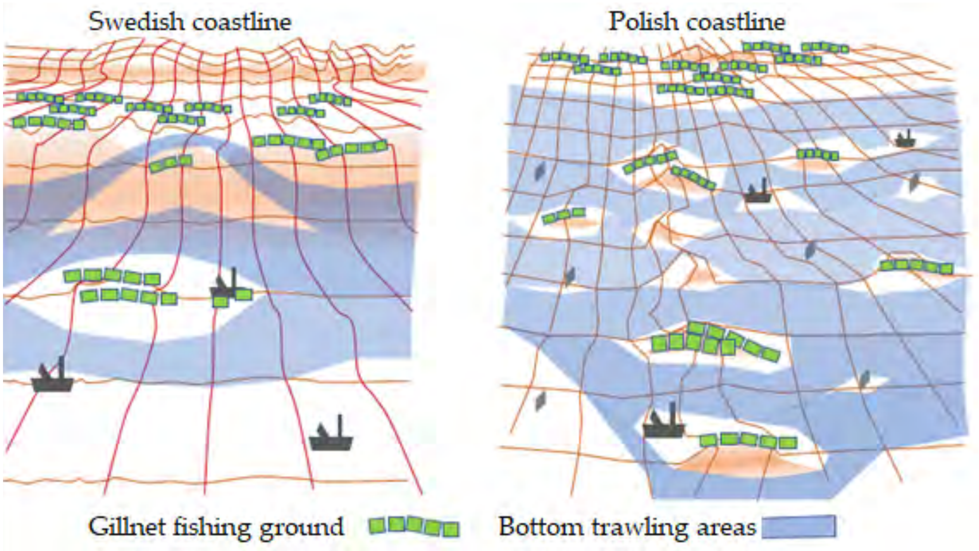


Figure 2. Illustrations of the hypothetical DFG host area distribution based on the combined knowledge of the fishing effort, geographical fishing patterns and morphology.

As assumed and tested under the project, there is a correlation between the fishing pattern and the number of areas with high probability of fishing gear loss. It was expected that the number of areas with high probability of fishing gear loss will be higher in Poland, where the overlapping of the gillnet and trawl fisheries is higher than in Sweden. In Sweden, it was expected that the number of areas with the high probability of derelict fishing gear occurrence will be lower than in Poland, but each area will be much bigger.

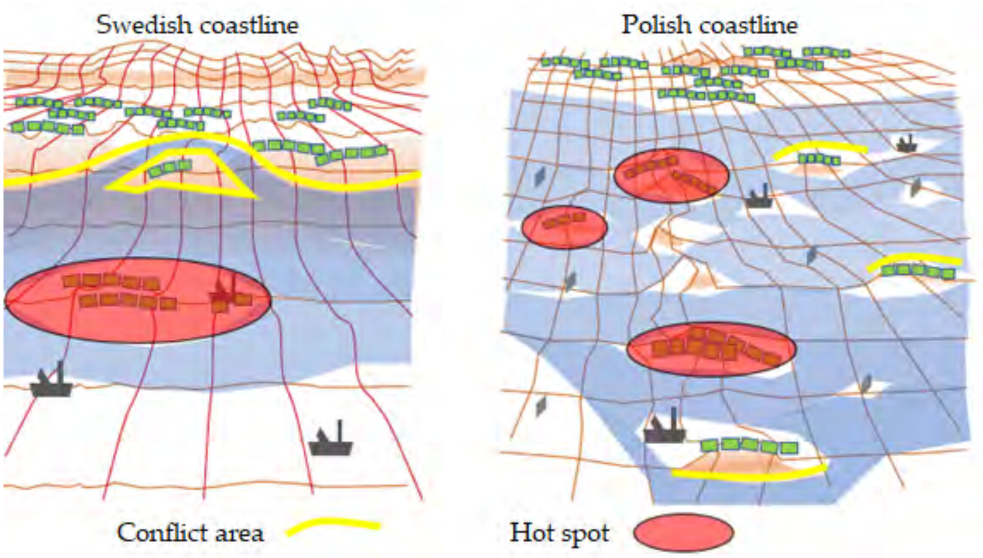


Figure 3. Hypothetical spatial distribution of DFG host areas based on the combined knowledge of the fishing effort, geographical fishing patterns and morphology.

The principles used to determine a hypothetical distribution of DFG were as follows:

1. The Polish and Swedish area of the Baltic Sea covering a depth of up to 60 meters was divided into squares: 1 minute of latitude by 2 minutes of longitude (approx. 2 km x 2 km) in Sweden and 10 minutes of latitude x 20 minutes of longitude (10 x10 miles) in Poland and granted each with category A, B or C, based on the analysis of the annual fishing effort and the type of the fishery. It should be highlighted that the Polish data used for identifying each category do not represent the exact location of the fishing activities. Monitoring of the fishing effort of the Polish fleet, especially the vessels which are not equipped with VMS, is based on the information from logbooks. The resolution of the data provided in the logbooks is low and might be inaccurate. The fishermen who do not use VMS (small vessels of less than 12 meters in length using set nets as the main fishing gear are not equipped with VMS) are obliged to report the squares (10 miles x 10 miles) where the fishing operations are carried out and not the exact locations. The fishing squares are used by Polish authorities for statistic purpose and differs from ICES squares. Each square lies within 10 minutes of latitude by 20 minutes of longitude. Therefore, in Poland the division into smaller squares (1 minute of latitude by 2 minutes of longitude) is strictly correlated with the category of the larger square (e.g. if the large square was granted category A, all the small squares within the big one were also granted category A). At the same time the data resolution in Sweden was much higher, and allowed exact identification of the category on each small square because the exact positions of set nets and trawls are reported. In Sweden the fishing effort data from 2014 was used as a baseline, as the constant reduction of total fishing effort of the Swedish fleet is observed and data from 2014 is more realistic because of higher loss rates a few years ago.
   Category A - bottom trawling areas, set out pursuant to the cumulative fishing effort data (the data covered at least three years [2012, 2014 and 2016] in Poland and 2014 in Sweden)
   Category B - typical gill net fishery areas, set out pursuant to the cumulative fishing effort data (the data covered at least three years in Poland [2012, 2014 and 2016] and 1997 in Sweden)
   Category C - areas of mixed fishing effort where both gillnets and bottom trawling might co-exist, set out as above and taking into account the isobaths density and hot-spot density as indicated by the consulted fishermen.

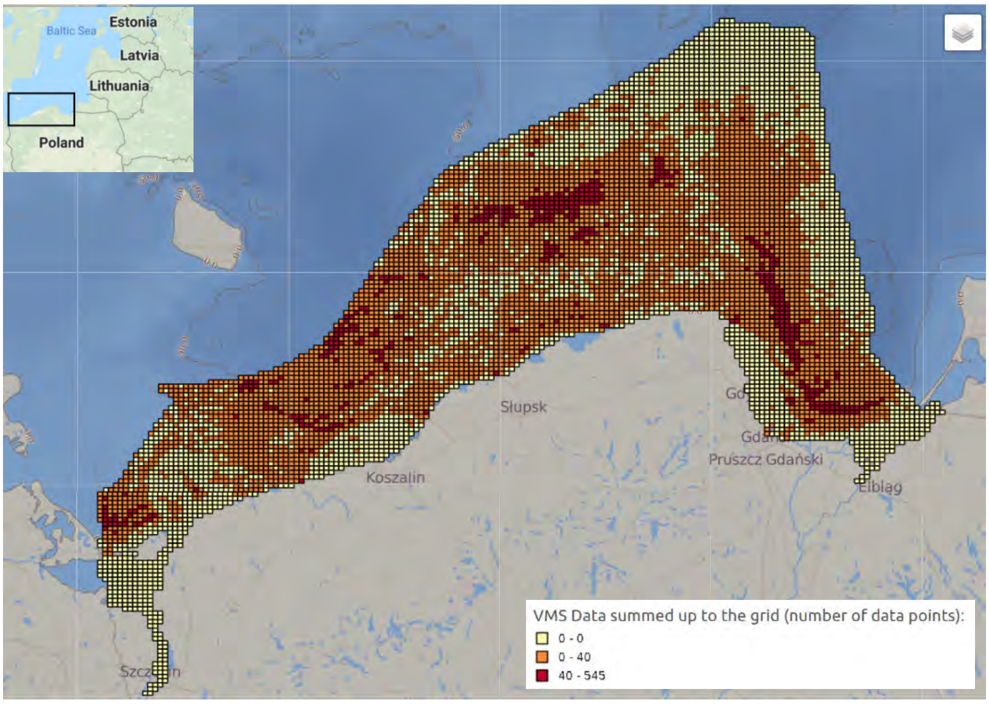


Figure 4. Categorisation of an Exclusive Economic Zone in Poland on the basis of the bottom trawling data.

The categories were established on the basis of the fishing effort data received from national authorities.

Pure bottom trawl grounds (area type A) were identified as areas with close to zero probability of derelict fishing gears occurrence. It was assumed that if a derelict fishing gear is deposited in these areas, it will be entangled or retrieved by a bottom trawl. Such a retrieved net would be hauled on board a vessel, but it cannot be determined whether it would be brought ashore or dumped back into the sea.

The areas dominated by the gill net fishing effort (type B) were identified by experts as the areas with the highest probability of derelict fishing gear occurrence. As mentioned above, in Poland, the reporting system related to the location of fishing activities is based on large squares - 10 minutes of latitude by 20 minutes of longitude, therefore the spatial resolution of the information related to fishing effort in Poland is low. To increase the accuracy of the selection of areas type B several additional factors such as underwater obstacles or rocky seabed were taken into account.

The areas where gill net and trawl net fishing effort overlaps (type C) were identified as areas with lower probability of derelict fishing gear occurrence than in type B areas (gill net areas), but higher than in type A areas (bottom trawl area), because the conflicts between different types of fishing activities increase the risk of loss of fishing gear, especially gill nets, in these areas. At the same time, lost nets could be retrieved by bottom trawling, which is not the case in type B areas where bottom trawling is not conducted. Whether loss through conflict between the different types of fisheries or retrieval through trawling dominates in any given area cannot be predicted.

2. The areas listed below were excluded from the dragging operations:
   - Areas where underwater munition is deposited (due to high risk related to the potential retrieval activities with the use of a searching device such as a creeper, anchor or hook)
   - Natura 2000 areas (due to possible negative impact of the search activities on the protected species and sensitive seafloor habitats)
   - Wrecks having confirmed location status (actions at ship wrecks were carried out by divers to avoid damage of wrecks and loss of search gear)
   - Permanently closed military areas.
3. As described above, in Poland each large square was divided into smaller sampling squares of the size 1 minute of latitude by 2 minutes of longitude, which is approx. 2 km x 2 km. This division was necessary to allow fishing vessels to fully search the selected areas within the available time (more details are presented below). As mentioned above, in Sweden, the accuracy of the Swedish fishing effort data permitted the use of small squares in the first phase of the analysis.
4. In testing the above described assumptions related to the density of derelict fishing gear in each area type (A, B, C), small sampling squares were randomly selected, taking into account the available fishing effort, to be used in systematic search and retrieval operations. In addition, to ensure a high efficiency of active searches (length of the trip minus time needed to access the search area) it was agreed to merge the squares into groups of 4 (Poland) and 3 (Sweden). In Poland, 25 selected areas were searched in 2017, as shown in the map below (Figure 5).

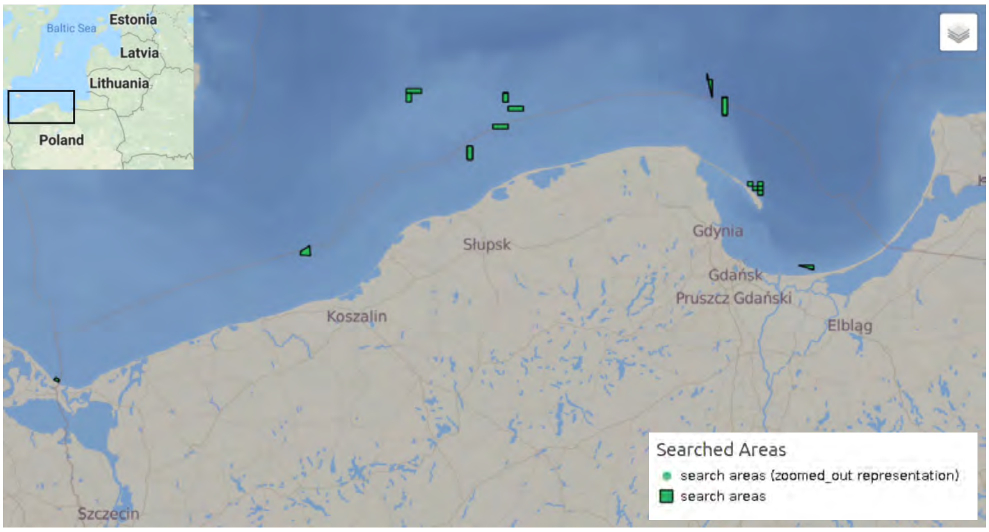


Figure 5. Areas selected for search and retrieval activities in Poland in 2017 (green squares).

In Sweden, proportionally to the size of the targeted area type, 90% of search actions in 2017 took place in areas B (gill net dominated areas) and 10% in areas C (mixed trawl and gill net fisheries). Areas A were excluded from the search actions, considering the low probability of the occurrence of derelict fishing gears in areas with intense trawling activity and no set nets.

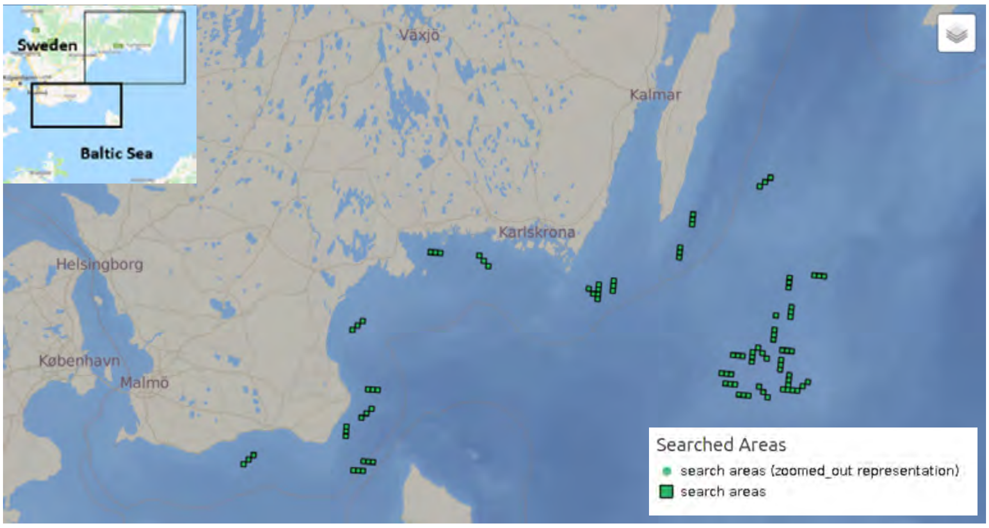


Figure 6. Areas selected for search and retrieval activities in Sweden in 2017 (green squares).

5. In addition, on the basis of practical knowledge, Polish fishermen selected several hot spot areas with the highest probability of derelict fishing gear occurrence according to their experience. These areas are shown in Figure 7.

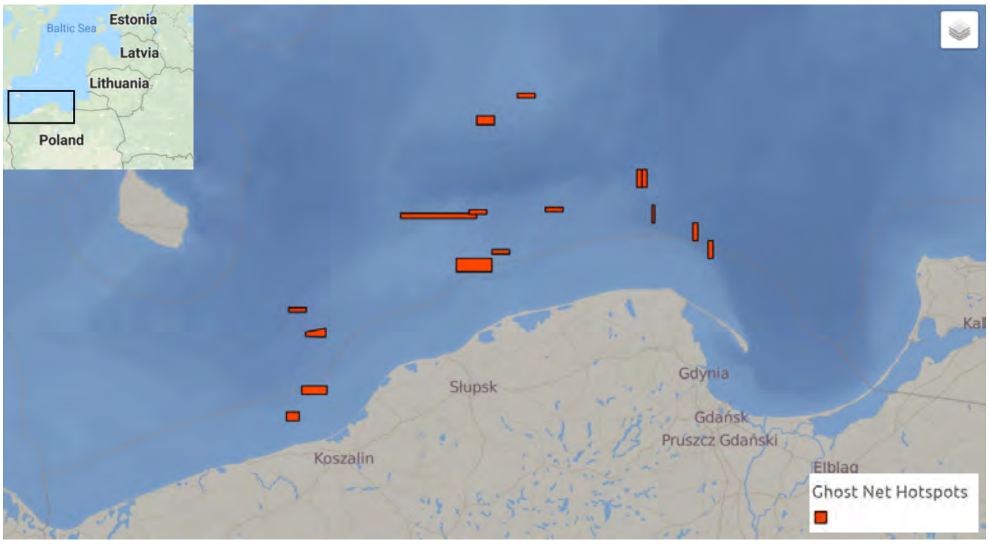


Figure 7. Hot spot areas selected for search and retrieval activities in Poland in 2017 (orange rectangles).

The exact location of areas selected for search and retrieval activities in Poland and Sweden in 2017 are included in the Appendix 1 and 2 of this report.

6.2 Selecting shipwrecks for retrieval operations

As the shipwrecks remain the hot spots where derelict fishing gears tend to accumulate, additional effort was taken to identify exact navigation coordinates of shipwrecks from which derelict fishing gears could be retrieved by divers.

It has to be highlighted that the retrieval activities at shipwrecks were carried out in 2017 only by Estonia. Shipwrecks in Poland, Sweden and Germany were cleaned up in 2018 following the verification process that was carried out in 2017, including identification of 4 shipwrecks in Sweden with the use of ROV robot.

Due to differences in national legislation and the range of available information related to shipwreck locations, the process of identification and verification of shipwrecks differs between countries. The detailed description of the selection methodology used by each country is described below.

Estonia

The selection of shipwrecks was based on personal knowledge and experience of divers. Personal contacts with divers allowed the identification of shipwrecks on which derelict fishing gears were identified and reported. All shipwrecks located at the depth below 30 meters as well as those on which diving is prohibited by the Estonian Heritage Board were excluded from further analysis.

In 2017, three shipwrecks were chosen for the retrieval operations, two located at a maximum depth of 16 meters (“*Vanja*” and “*Iljuša*”) and one at a depth of 26 meters. In 2018, one additional shipwreck, “*Christine*”, located at a depth of 29 meters was cleaned up.

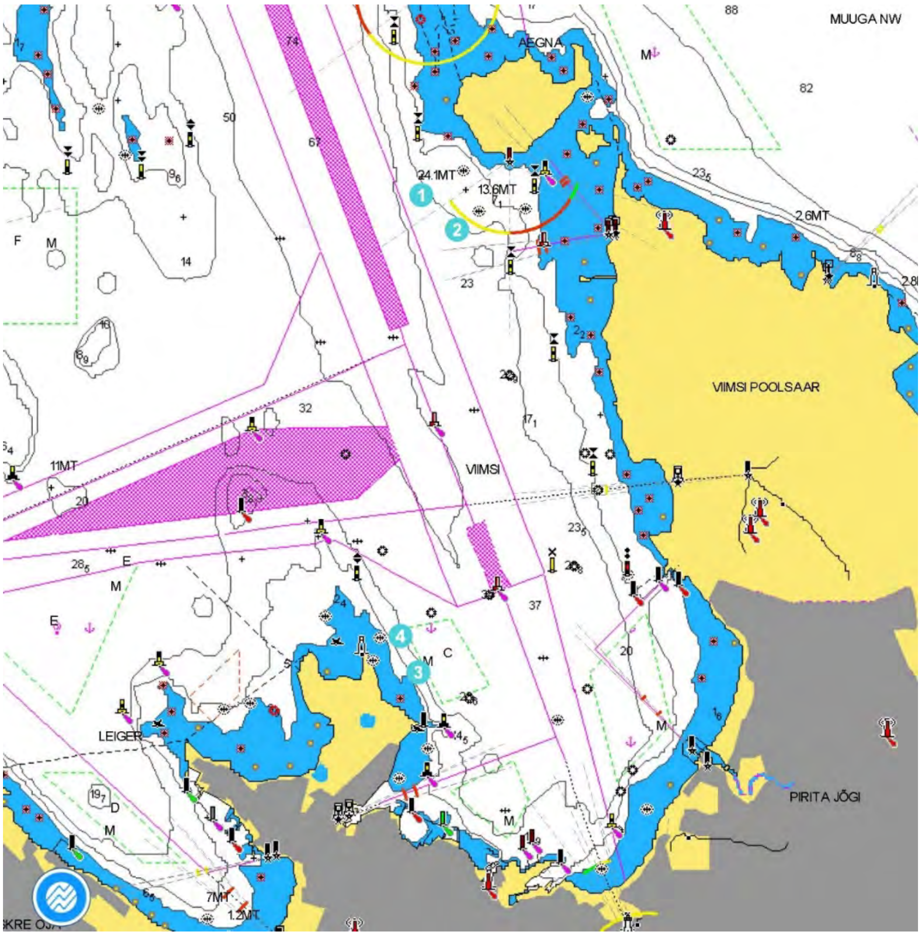


Figure 8. The location of four shipwrecks on which the retrieval activities were carried out in Estonia in 2017.

Germany

The selection of shipwrecks in Germany was based on the list of shipwrecks provided by the German authority responsible for hydrography and shipping (BSH). The list contains information on documented shipwrecks and the observed net coverage. 30 shipwrecks located in the Rügen island area were identified. An additional factor that was used to choose the shipwrecks was the depth. Due to the law requirements as well as for safety reasons, only shipwrecks located at a maximum depth of 25 meters were selected for retrieval activities. In addition, a consultation with the cultural heritage authority of Mecklenburg-Vorpommern to exclude the shipwrecks with cultural heritage status was carried out. The final list of shipwrecks selected for retrieval operations was consulted with local divers. In total, 3 shipwrecks were chosen for clean-up operations in 2018: "*Eimerkettenbagger*" at a depth of 20 meters, "*Erzschute*" at a depth of 18 meters and BSH 1820 at a depth of 20 meters. One additional shipwreck, Motorbarkasse located at the depth of 8 meters, was selected for retrieval operations on the basis of diver recommendations. No nets were found at the time of diving in May 2018 on two of the four inspected wrecks,. This suggests that nets can be torn off by currents especially during the winter and spring months. Inspection by a local diver shortly before planned retrieval activities is therefore crucial to ensure efficient and productive use of expensive retrieval diver teams. It should also be noted that retrievals of larger net fragments and nets entangled on wrecks where heavy cutting is involved should only be carried out by professional retrieval divers trained for heavy underwater work. Because professional teams work with umbilical air supply systems, this measure also helps to avoid unnecessary risk to divers through entanglement and injuries while on limited air supply. Sport divers should be discouraged from retrieving lost fishing gear because of the risk of entanglement.

Figure 9. The process of selecting shipwrecks in Germany.

Poland

In Poland, the shipwrecks were selected on the basis of experience and data gathered in previous projects carried out by WWF Poland in 2011, 2012 and 2015. The selection procedure included two stages. The first stage consisted of gathering the position data of shipwrecks, available in Poland. The most accurate data was acquired from the Hydrographic Office of the Polish Navy. During the second stage, verification of selected shipwreck positions was made directly at sea. The in situ verification had indicated that the positioning made during the identification procedure was not accurate. Additional effort was needed to position the shipwrecks. A sonar scan proved to be an effective tool to locate shipwrecks for which detailed and accurate positions had not been provided.

Additionally, the information provided by divers and fishermen was used to identify the shipwrecks covered by derelict fishing gears.

As a result, five shipwrecks were selected for retrieval operations in 2018, all located at the depth between 20 and 31 meters.

Sweden

The process of selecting shipwrecks in Sweden was similar to the one applied in Germany. As the first step, information from the Swedish National Heritage Board was acquired with the help of the public data base

FORNSÖK. A depth restriction to 40 meters was applied. The differences in the applied depth restriction between countries are related to the seabed morphology and the position of selected shipwrecks. An additional factor used in Sweden was related to the methodology described above. It was agreed that only shipwrecks located in the areas with high probability of the occurrence of derelict fishing gears were taken into account. The next step consisted of consultations with the National Maritime Museum and divers. Following these consultations, 8 shipwrecks were selected for retrieval activities. No shipwrecks were found at two positions. No fishing gears were detected at five other shipwrecks. Therefore, a retrieval operation was conducted only at one shipwreck at the depth of 38 meters.

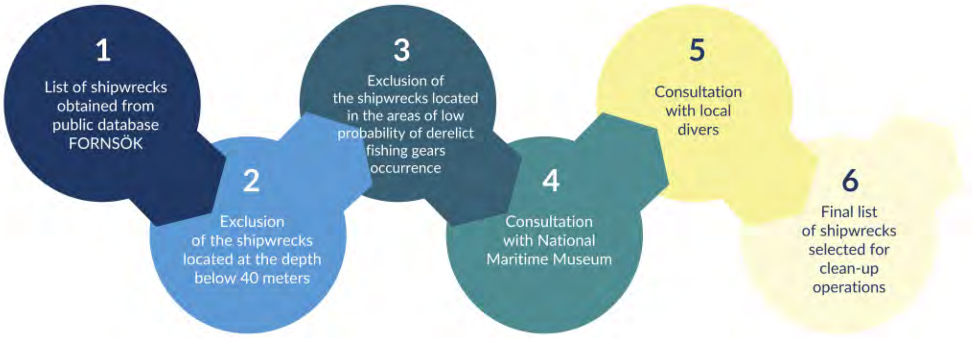


Figure 10. The process of selecting shipwrecks in Sweden.

7. Methodology related to the search operations

7.1 Search operations with the use of fishing vessels and a searching device (creeper, anchor or hook)

Sweden

Two vessels were deployed in each square, forming a paired search team. Each square (2 km x 2 km) was covered by six tracks. The vessel No. 1 ran a track 0.1 km from the border of the square. The vessel No. 2 simultaneously ran a parallel track with 0.2 km distance to the track run by vessel No. 1. Towing speed was 1 knot. After finalising the first pair of tracks, each of the vessels moved (at 8 knot speed) to the next pair of tracks and ran them with 0.2 km distance. The last pair of tracks was executed perpendicularly to the first four tracks with 0.66 km distance from the borders and from each other. The higher number of parallel tracks (4) was always run perpendicular to the course/direction used to deploy/shoot the net fleets. As a results of that, the dragging pattern varied from square to square. The lower number of tracks per square was possible based on earlier experience that nets in these areas are often intact i.e. they are at least several hundreds of meters long, fully stretched out.

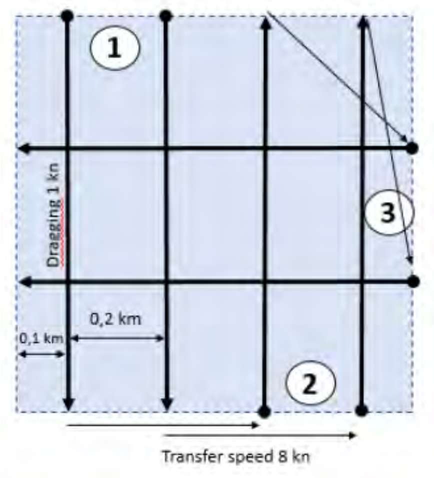


Figure 11. Searching patterns used in 2017 in Sweden (source: Tschernij, V., personal communication).

Poland

Each square (2 km x 2 km) was covered by 10 parallel tracks at distance intervals of 200 meters. Towing speed was 1 knot. After completing each track, a vessel moved to the next track with the highest possible speed, to ensure the highest efficiency of the operation. In some cases, if the allocated searching time was not fully used with the pattern described above, additional perpendicular tracks were carried out.

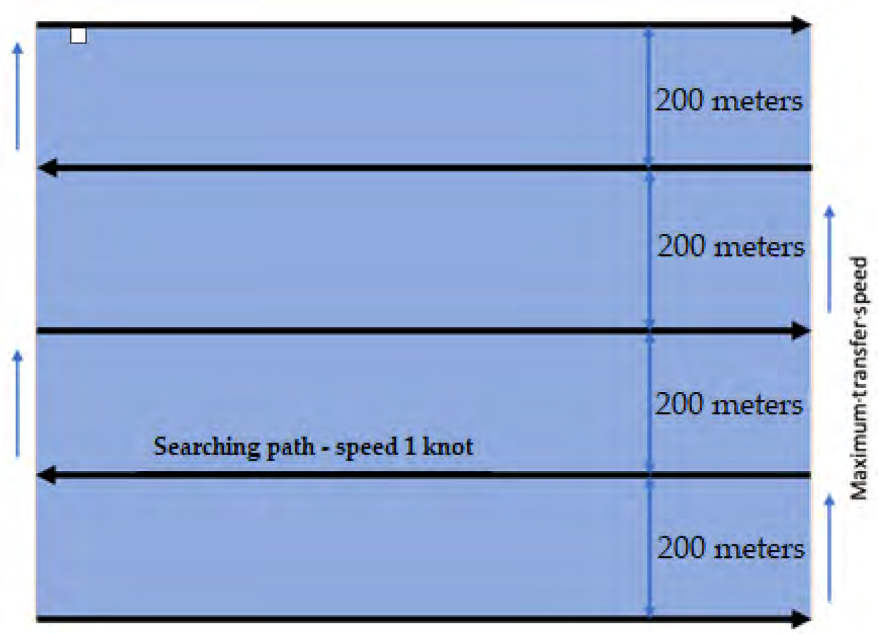


Figure 12. Searching patterns used in 2017 in Poland.

Estonia

Although the randomisation process was not carried out in Estonian waters, several retrieval activities with the use of small, 10 meter long vessels were conducted. The search areas were selected on the basis of interviews with professional and recreational fishermen, marine archaeologists and researchers, as well as data related to the sea bed morphology, spatial distribution of the fishing effort, locations of the fish landing facilities and shipwreck database, A/V documentation from the underwater archaeological studies. Several squares in the Gulf of Finland, Gulf of Pärnu and Gulf of Narva were selected for retrieval operations in 2017 and 2018.

The territorial waters of the northern coast of Estonia (the Gulf of Finland) are characterised by a rocky seabed, therefore the dragging operations had to be carried out with special precaution, using a lighter searching device. In addition, this area is exposed to strong winds and waves from the open sea which also negatively influences the possibility to undertake the search activities. To avoid loss of the searching device as well as to ensure high efficiency of dragging operations, a floating sonar and assistance of divers were needed during the operations in the Gulf of Finland.

In the Gulf of Pärnu area, where the seabed is sandy, the use of sonar and divers assistance were not required.

Germany

The randomisation process was not carried out in Germany, due to insufficient data on the spatial distribution of the fishing effort as a baseline for hot-spot areas and the resulting inefficiency during the first search trials, and the limited availability of funds for random search activities in each country. Nevertheless, several attempts to locate and retrieve derelict fishing gears from the German coastal waters with the use of a creeper as the searching device were carried out, with external financing secured by WWF Germany[75].

The Polish model of the creeper and the Estonian "*hook*" were used together with the 18 meter fishing vessel "*Einheit*" and a small 8 meter fish cutter. The search focused on 3 area types:

1. Active trawling area: the aim was to find trawl elements lying near underwater obstacles. Positioning of these obstacles were provided by fishermen (trawls snagged on these obstacles in the past).
2. Active gillnetting area, where gill nets were lost during accidents with non-fishing vessels in the past 2 years.
3. Coastal area where gill nets were lost several years ago in a storm with the occurrence of severe coastal ice.

Both creepers were towed at a speed between 0.8 and 1.5 knots in each area. In the trawling area, fishermen covered transects parallel to the coast just

[75] All search methodology tests in German waters were financed by the associated MARELITT Baltic project partner and WWF sponsor Tönsmeier Entsorgungs GmbH, and were not part of WWF Germanys MARELITT Baltic project work package.

beyond a distance of 3 nautical miles from the coast, as at present, trawling is only allowed outside the 3-mile zone. In the gillnetting area, first search passes with the Estonian-type hook did not yield any lost gill net fragments, but did result in the retrieval of a set of steel ropes. After two days of passes with the Estonian search hook, inspection of the area was carried out by divers, who confirmed that no nets were present. In the coastal gill netting area in front of Usedom island, rapid ice formation had destroyed a set of gill nets several years ago. The area was first searched by divers, and marker flags and buoys could be seen already a short distance from the sea surface. It was particularly critical to clean this area, as it was close to the swimmer, snorkelling and within the surfing zone of the touristic beach of Ahlbeck, such that the gill nets standing up in the water column imposed a health risk to swimmers, surfers and divers/snorkelers. After the presence of numerous gillnets had been confirmed, the 18 m fishing vessel "*Einheit*" searched the area in a systematic pattern, where long transects were covered, first parallel to the coast in two interleaved sets. Afterwards, a third set of transects was searched perpendicular to the first two sets. The total coverage took 4 full days, including the time needed to access the search area. More than 2 tonnes of gillnetting DFG was retrieved, including approximately 40 kg of dead and 20 kg of life fish, and the area was entirely clean after this search operation. Further areas where fishermen had reported loss of gill nets in accidents were searched with the Estonian hook to avoid breaking and missing the gill nets with the heavier creeper. The line was hand-held by a crew member to sense irregularities on the seabed that helped to find lost nets. In the other areas sampled in this way, no nets were found.

7.2 Searching device used for the retrieval operations

In the MARELITT Baltic project, several types of searching devices were used for searching and retrieval operations (excluding the operations carried out at shipwrecks). The devices used in each country differ slightly, depending on different depth, seabed morphology, the bottom substrate and experience of the involved fishermen. All search devices consist of two parts, the searching device and the supporting structure that keeps the searching device on the seabed.

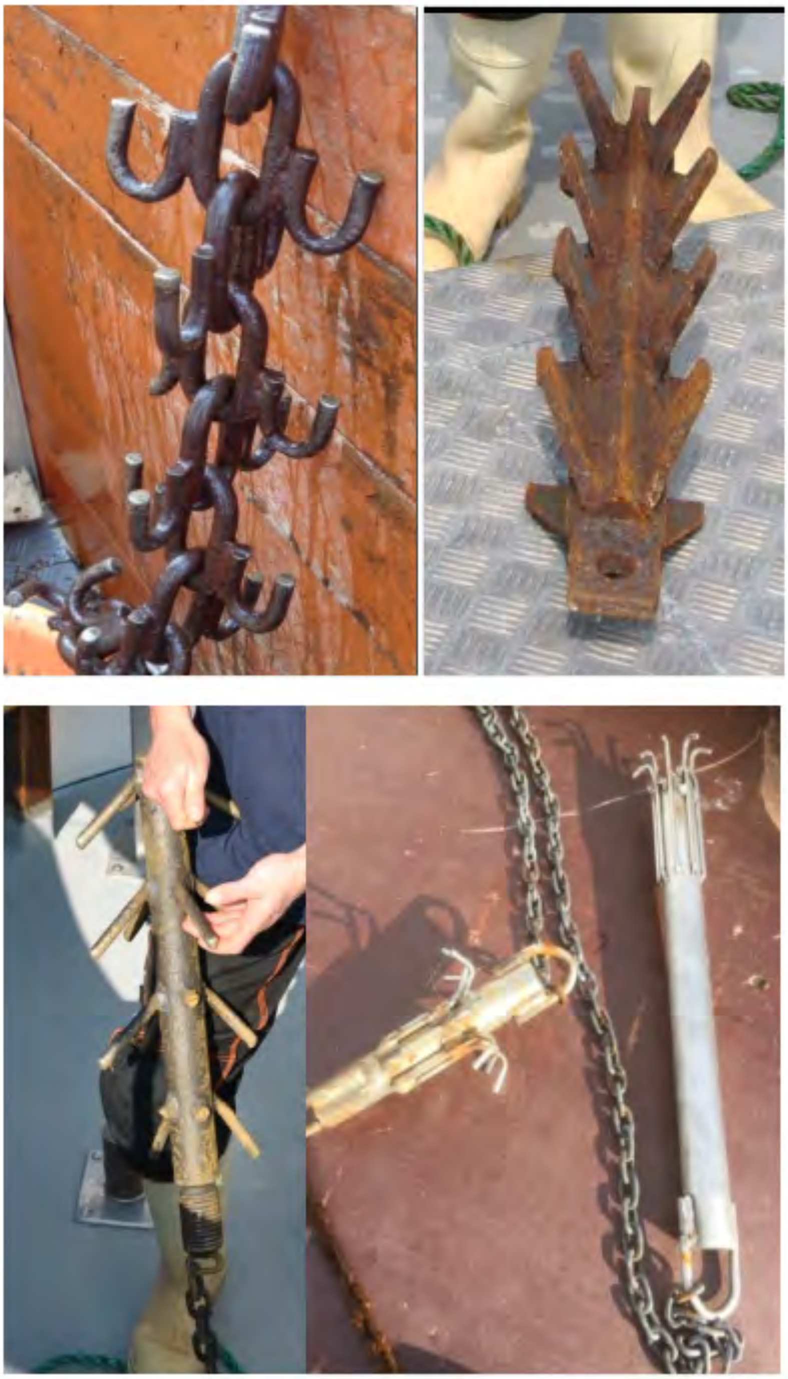


Figure 13. Searching devices used in Sweden.

The search devices used for retrieval operations were made of a single heavy-toothed steal bar with multiple hooks/claws attached. The weight of the entire structure and the number of "*hooks*" differ between regions, due to the factors described above. In Estonian waters and in German areas indicated as potential gillnet areas, the search device was lighter than the one used in Poland and Sweden. This allowed to stop the device quicker than the heavier one and prevented the breaking of entangled gillnets. Additional elements to maximise the contact of "*hooks*" with the seabed were used, such as chains and robber bobbins. The light weight of this device also allowed searches to be carried out in protected (Natura 2000) marine areas in German waters, where gillnetting takes place.

The detailed description of the search devices used in the MARELITT Baltic project as well as their environmental impact are presented in the Environmental Impact Assessment of Derelict Fishing Gear Retrieval in the Baltic Sea, coordinated by WWF Germany[76]. The report is available on the MARELITT Baltic project webpage.

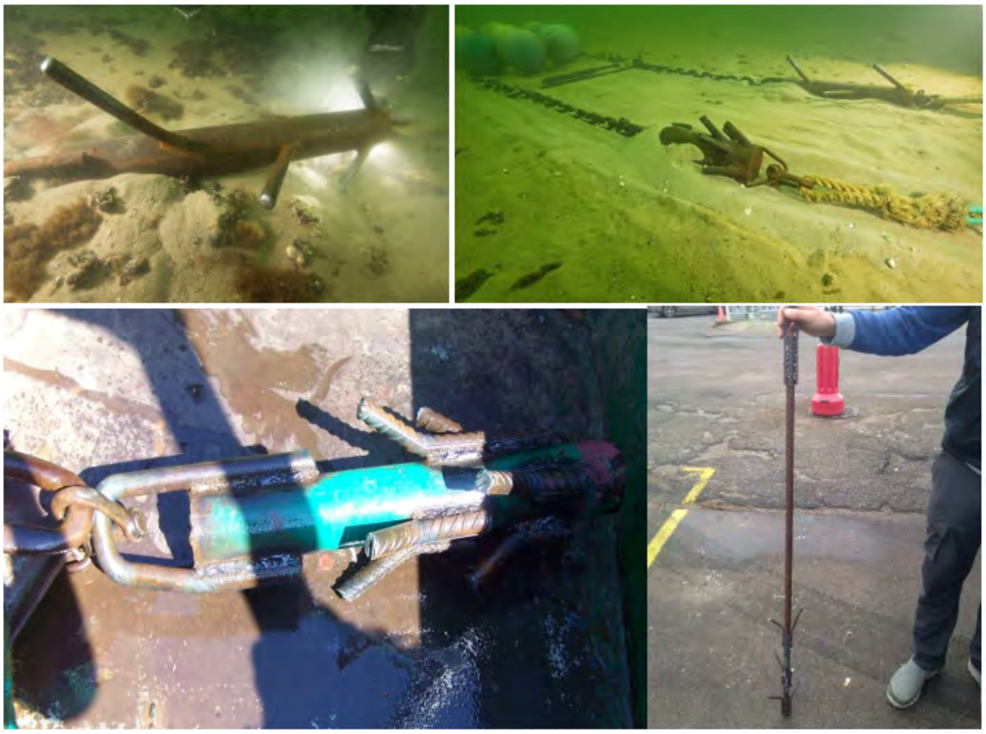


Figure 14. Upper right and left: searching devices used in Germany, (© Christian Howe). Lower left: searching device used in Poland. Lower right: searching device used in Estonia.

7.3 Reporting

The development of the reporting system related to the search and retrieval operations was one of the crucial elements of the MARELITT Baltic project. The reports provided by fishermen and divers were essential to summarize the project outcome and verify the effectiveness of the methodology applied in the project. In addition, an attempt to assess the average amount of derelict fishing gear deposited in each of the area types (A, B, C) was made.

Detailed templates of the reporting sheet were agreed upon and used in 2017. A separate template was developed for search and retrieval operations carried out by fishermen and divers. Both reporting sheets cover a wide range of information related to each operation at sea, including the date of

[76] Sahlin, J. and Tjensvoll I., 2018. Environmental Impact Assessment, Retrieval of derelict fishing gear from the Baltic Sea. WSP Sweden, Stockholm.

the action, exact coordinates of the searched area, type of search device used in the operation, depth of searching, amount, type and age of retrieved nets. Information related to captured species was also gathered.

Both templates are included as annexes to this report (Annex 1 and 2).

7.4 Selected shipwreck inspection and cleaning

As described in the chapter "*Selecting shipwrecks for retrieval operations*", the selection process of the shipwrecks differs between countries. The same applies to the retrieval operations carried out by divers. National requirements related to underwater work and, in particular, the safety of diving operations as well as to the protection of heritage sites have to be followed. Detailed information related to the search and retrieval operations carried out in each of the countries are presented in the following chapters.

8. Outcomes of the search and retrieval operations

8.1 Search and retrieval operations carried out in 2017

8.1.1 Search and retrieval operations carried out by fishermen

In 2017, the search operations with the use of search devices were carried out by fishermen in all 4 countries. In Estonia, 8 cruises were organised in August and September 2017. Germany started the retrieval operations already in 2016, and results are combined for 2016 and 2017. In Germany, 13 cruises were organised, 5 from June to September 2016 and 8 between May and September 2017. All search and retrieval activities at sea carried out in Germany were financed by WWF internal funding and not through MARELITT Baltic project, with the exception of wreck cleaning operations discussed below. In Poland, 31 combined cruises were organised between August and October. In Sweden, 96 combined cruises were organised in July. It was agreed that the 10 hour cruises could be merged to reduce the amount of time needed to reach the search areas, and increase the amount of time used for search operations.

The outcomes of the retrieval operations carried out by fishermen are summarised in the table below:

	Estonia	Germany[77]	Poland	Sweden
Number of cruises	8	13	31	96
Weight of retrieved gillnets [kg]	40	1962	217	4774,2
Weight of retrieved trawl nets [kg]	0	205	387	0
Weight of the nets not classified (e.g. mixed trawl/gillnets)	0	2960	7	0
Range of mesh sizes [mm]	40-65	not specified	6-160	57-120
Range of depth of retrieval [m]	2-16	3-40	21-85	28-49
Seabed structure where the nets were found	Sand, mud, stones	sand, gravel, rocks	mud, sand, stone	stones, pebble, gravel
Other information	8 flatfish were found in the net	60 kg of fish from life to skeleton stage in one retrieved gillnet, mussels, firehose, cables, anchors and other marine litter in trawl nets	2 kg of fish found in retrieved nets	71% of nets consists of fish - only bottom species

Table 6. Results of the retrieval operations carried out with the use of search devices in 2017.

[77] Numbers refer to years 2016 and 2017, due to the fact, that the methodology testing in Germany was started earlier.

In 2017, In Estonia a total of 40 kg of gillnets were retrieved in the course of search and retrieval operations carried out by fishermen.

In 2016 and 2017, in Germany, approximately 2 tonnes of gillnets were retrieved in the course of search and retrieval operations carried out by fishermen. The nets were found in a location provided by the fisheries control authority. One search in a high-density fishing area led to the collection of approximately 200 kg of trawl netting, and a total of approximately 3 tonnes were recovered at locations known by divers (discussed further below). Two other cruises which had targeted a location identified as a recent net loss site through boat accidents did not result in DFG recovery. Other cruises which had targeted randomly chosen areas did not result in the finding and retrieval of derelict gears, although the search was conducted at different depths (from 3 to 40 meters) and seafloor habitats (rocky areas, gravel and sandy areas).

Similar search and retrieval operations were carried out in Germany in 2016. In 2016 and 2017 combined, a total of 5.127 kg of derelict fishing gears were retrieved, including both gill nets and trawl nets. However, the weight of these two types of fishing gears could not always be specified as in many cases, trawls and gillnets were heavily entangled and could not be weighted separately. It should be noted that most of the nets (apart from 217 kg) were retrieved in the locations provided by divers or the fisheries control authority where the presence of DFG at the seafloor was already known. Only 217 kg of DFG (205 kg of which were trawl netting) were found during searches in high-intensity fishing areas where trawls had been lost in earlier times. The remaining 4910 kg were retrieved at known DFG locations, mostly in coastal waters.

In Poland, 3.037 kg of debris were retrieved during the search operations carried out in 2017, including 270 kg of gill nets and 386 kg of trawl nets. 6 kg of retrieved fishing gears were not classified.

Most of the retrieved fishing gears were found in the area of high gill net fishing effort (62% of all retrieved nets). 38% of fishing gears were found in the area of low gill net fishing effort. At the same time, it should be highlighted that most of the fishing gears were found in areas where the gill net effort (mostly high) overlaps with the trawl effort (mostly moderate). However, as highlighted in the chapter on the methodology, the division into small squares (2 km x 2 km) was made on the basis of bigger squares (10x10 miles), therefore this analysis should be treated with precaution.

Detailed information regarding the fishing gears found during the search operations is given in the table below.

Number of searched square	Type of retrieved net	Square category	Kg of retrieved nets

G4 (52, 62, 72)		High gill net effort (total net length more than 3 000 000 m)[78]	
	Trawl net		18
H4		High gill net effort (total net length more than 3 000 000 m)	
	Gillnet		60
	Trawl net		14
H4 (41, 51, 61)		High gill net effort (total net length more than 3 000 000 m)	
	Trawl net		17
J5 (53, 43, 32)		High gill net effort (total net length more than 3 000 000 m)	
	Gillnet		70
K5 (31, 41, 51)		High gill net effort (total net length more than 3 000 000 m)	
	Trawl net		45
L6 (8, 18, 28)		High gill net effort (total net length more than 3 000 000 m)	
	Net (not classified)		7
M7 (16, 17, 18)		High gill net effort (total net length more than 3 000 000 m)	
	Gillnet		25
M8 (85, 95) HOTSPOT		High gill net effort (total net length more than 3 000 000 m)	
	Gillnet		96
R7		Low gill net effort (total net length till 1 000 000 m)	
	Gillnet		20
	Trawl net		50
R8		Low gill net effort (total net length till 1 000 000 m)	
	Gillnet		180

[78] The amount refers to the total length of all nets together summed over the year placed in one square.

T4 (74)		High gill net effort (total net length more than 3 000 000 m)	
	Gillnet		60
		TOTAL	662

Table 7. Fishing gears retrieved during the search operations in Poland with the use of search devices, categorised by the area type (year 2017).

In 2017, in Sweden 4,774.2 kg of gill nets were retrieved (14 600 m, the value 1 m of gill net = 0.327 kg was used to calculate the weight of the retrieved nets). The nets were found at depths ranging from 28 to 49 meters. All nets were found in areas where the sea bottom is covered by stones, pebbles, or gravel. Fish were found in 71% of all retrieved fishing gears. Only demersal species were found in the nets. Most of the nets (approx. 60%) were retrieved from areas with a high probability of derelict fishing gear occurrence (type B - pure gillnet areas [within an assumed hot spot]). However, the remaining 40% of fishing gears were found in areas where the possibility of fishing gear accumulation was expected to be low (type B - pure gillnet area [within an assumed area with expected lower DFG density]). One of the visited locations with an expected lower retention probability was a steep slope south of Öland (a big island east of the city of Karlskrona) where unexpectedly high retention rates of DFG were observed during 2017 activities. Unexpectedly, high retention rates of DFG were also observed in the Bay of Hanö, outside a coastal fishing community.

On the other hand, net retrievals in one of the identified hot spot areas with the largest expected loss rate of fishing gear (area type B, hot spot, Southern Mid Sea Bank) were considerably lower than expected. However, these results can be explained. This shallow water area is exposed to strong currents and waves. Substantial quantities of derelict gears in this area could be expected to be broken into smaller pieces and fragments of nets, which then might have been easily transported way from the area by sea currents or buried in the seabed sediment.

The systematic dragging methodology revealed new aspects in the distribution pattern of DFG. In some cases, one of the two consecutive squares that had been searched had a smooth/sandy seabed whereas the other had a hard/rocky seabed. The derelict nets were most often found in the square with the rocky seabed. These observations confirm the existence of the same phenomenon as in the Polish waters, where nets accumulate on rocky seabed or in areas with other types of seabed obstacles that might cause snagging and retain the gears.

8.1.2 Search and retrieval operations carried out by divers

The retrieval operations at shipwrecks were carried out in 2017 only in Estonia and Germany. In total, 6 shipwrecks selected with the use of the methodology described in the chapter above were cleaned of DFG – 3 in Estonia and 3 in Germany. In Germany, not all netting could be removed from some of the wrecks.

Detailed information related to the activities carried out at shipwrecks is presented in the table below:

<table>
<tr><th></th><th>Number of shipwrecks cleaned</th><th>Depth of shipwrecks</th><th>Kg of retrieved DFG</th><th>Type of fishing gear retrieved</th><th>Marine organisms found in the retrieved fishing gear</th></tr>
<tr><td rowspan="3">Estonia</td><td rowspan="3">3</td><td>26 (Polaris)</td><td>61</td><td>Trawl net</td><td>Seal</td></tr>
<tr><td>16 (Iljuša)</td><td>1,8</td><td>Gillnet</td><td>Non</td></tr>
<tr><td>17 (Vanja)</td><td>14,2</td><td>Trawl net</td><td>Non</td></tr>
<tr><td rowspan="3">Germany</td><td rowspan="3">3</td><td>20 (Eimerkettenb-agger)</td><td rowspan="3">445</td><td rowspan="2">Trawl netting and gillnets</td><td rowspan="2">Non</td></tr>
<tr><td>18 (Erzschute)</td></tr>
<tr><td>20 (BSH 1820)</td><td>Trawl net</td><td>Non</td></tr>
</table>

Table 8. Results of retrieval operations carried out at shipwrecks in 2017.

8.1.3 Recommendation to improve the applied methodologies, based on the experience and results of the operations carried out in 2017

On the basis of the experience and outcomes of the operations carried out in 2017 in all countries, a detailed, in-depth discussion aimed at identifying possible ways to improve the methodologies was carried out with all partners of the project. As a result, several recommendations were identified, with a view to be implemented in 2018:

1. The reporting sheets for fishermen and divers should be simplified. The reporting sheets developed and provided to partners in 2017 were too detailed and difficult to fill in during the cruise. In consequence, it was not possible to gather all relevant data in a correct format. This hampered the analysis of the outcomes of the operations carried out in 2017. The simplified reporting sheets for the activities in 2018 are included in the annexes (Annex 3 and 4).
2. Additional training for fishermen and divers should be organised to explain in detail how the reporting sheets should be filled in. In addition, detailed, non-technical instructions should be provided to both groups in writing.

3. Where possible, volunteers or scientists should be engaged as observers on board during the retrieval operations. An observer should be responsible for filling the reporting sheets properly.
4. The methodology should be adjusted in Poland to secure the division into categories A, B, C in a better resolution. VMS data related to the exact positioning of trawling operations should be incorporated in the process.
5. Data related to the direction and strength of the currents should be included in the selection of the areas with high/low probability of fishing gear occurrence. As observed in Sweden, currents strongly influence the location of derelict fishing gears.
6. Additional focus should be given to the areas with underwater obstacles. In the course of 2017 activities it was confirmed that most of the fishing gears were found in such locations.
7. Additional focus should be given to the areas identified by fishermen, to verify if lost fishing gears change their location or remain in their original location, as reported by fishermen after loss.
8. Further adjustment of the dragging patterns should be implemented if three or more squares to be located horizontally or vertically next to each other. This should allow a reduction of the time needed to transfer the fishing vessels between the search transects.
9. If possible, VMS or GPS devices should be used on vessels to record the exact routes of search and retrieval operations.
10. The speed of the vessel during the search operation should be recorded. The retrieval projects carried out in the past concluded that the speed of the vessel during the search operations is one of the crucial factors influencing their efficiency. High speeds lead to faster area coverage, but hooks can break gillnets which decreases the detection and recovery efficiency. A compromise between area coverage and efficient DFG recovery has to be found. Therefore, it is crucial to collect this data and use it in the final assessment of the operations, as well as in the planning process for future operations. VMS or GPS equipment could be used for this purpose.
11. The exact width (contact area with the seabed) of the search device should be examined. Together with the speed and time of dragging preferably gained from VMS or GPS data, this information will allow an assessment of the real search area. This information will also allow further analysis of the efficiency of the actions at sea, as well as extrapolation of the collected data to assess the quantity of fishing gears deposited in the entire Baltic Sea.
12. If possible, further unification of tools and methods should be considered to allow a comparison of the outcomes obtained from all countries and assess all data together. The possibility to use vessels

with the same or comparable technical specifications, as well as the possibility to conduct the operation in the same water conditions and the same seabed structures should be examined. e.g. the basic range of accepted weather circumstances when the action could be carried out should be identified.

13. In some cases, a consultation with divers on the shipwrecks had proved less reliable than previously assumed. Some wrecks were free of nets despite the fact that net occurrence had been claimed just several months earlier. It could be assumed that some shipwrecks are cleaned by sport divers. As a result of this observation, it is recommended to verify DFG occurrence prior to a larger action, using professional divers. This verification can be carried out by a local scientific diving team.
14. The decision-making tree related to the shipwreck identification, verification and cleaning developed by WWF Poland should be used by all partners. This would allow more accurate comparison of the outcomes of the operations at sea. The decision making tree can be found in Annex 5.

8.1.4 Changes in the methodology implemented in Sweden and Poland in 2018

Based on the outcome of the search and retrieval operations carried out in 2017 in selected squares, several adjustments to the search area selection process were implemented. The main aim of these adjustments was to better reflect the spatial distribution of the fishing effort, as well as to better reflect such factors as the sea bed morphology and any detailed information provided by fishermen.

The adjustments in the process were made in Poland and Sweden, however the extent of these changes made in both countries differs due to the differences in data availability. The proposed improvements to the process were discussed between Polish and Swedish partners during a workshop in Warsaw, to ensure that the implemented amendments would not have a negative impact on the ability to compare the results gained during the search and retrieval operations.

Poland

As described in the chapter above, in 2017, the data used in Poland for the identification of each of the area types (A, B, C) do not reflect the exact location of the gill net fishery. The monitoring of the fishing effort of the Polish fleet, especially the vessels which are not equipped with VMS and the ones which use gill nets as the main type of fishing gear, typically vessels below 12 meters, is based on logbook data. The spatial resolution of the information provided in logbooks is low. Fishermen are obliged to report the fishing, statistical squares where the fishing operations are carried out. Each square covers an area of 10 minutes of latitude by 20 minutes of longitude.

Therefore, in Poland in 2017, the division into smaller squares (1 minute of latitude by 2 minutes of longitude) was strictly correlated with the category of the bigger square (e.g. if the big square was granted category A, all the small squares within the big one were also granted category A).

To increase the resolution of data used in 2018 and as a result of the accuracy in designating the area types, the VMS data of 2012 representing the activities of the Polish trawling vessels was incorporated into the model. On the basis of the available data on bottom trawling, the Polish part of the Baltic Sea was divided into squares (2 km x 2 km) characterised by:

A. high density of bottom trawling – low probability of derelict fishing gear occurrence;
B. low density of bottom trawling - moderate probability of derelict fishing gear occurrence;
C. close to zero bottom trawling – high probability of derelict fishing gear occurrence.

The above described change of the data used in 2018 allowed for a more precise division of the area with regard to the probability of derelict fishing gear occurrence. The available VMS data reflects the exact routes of the trawling vessels, therefore the probability of accurate designation of all three types of areas is much higher. At the same time, it should be noted that only the fishing vessels above 12 meters are equipped with VMS. The vessels below 12 meters can also use trawling as a fishing method. Therefore, despite the fact that the use of VMS data provides a better resolution and a more precise division into the area types, some uncertainty related to the omission of the trawling effort of vessels below 12 meters still exists. However, it should be emphasized, that due to a much lower resolution of the gillnet effort, the more exact analysis of the three categories remain less certain.

On the basis of the division described above, randomisation of the search areas for 2018 was undertaken. A random number generator was used to draw squares. The draw method consisted of several steps:

1. excluding areas deeper than 60 meters, as the search operations have low efficiency in such locations;
2. drawing large squares (10 minutes of latitude x 20 minutes of longitude);
3. drawing one hundred small squares within the large one (2 km x 2 km) (1 minute of latitude by 2 minutes of longitude)
4. Adding two adjacent squares to the one drawn in point 3 either vertically or horizontally (Figure 15).

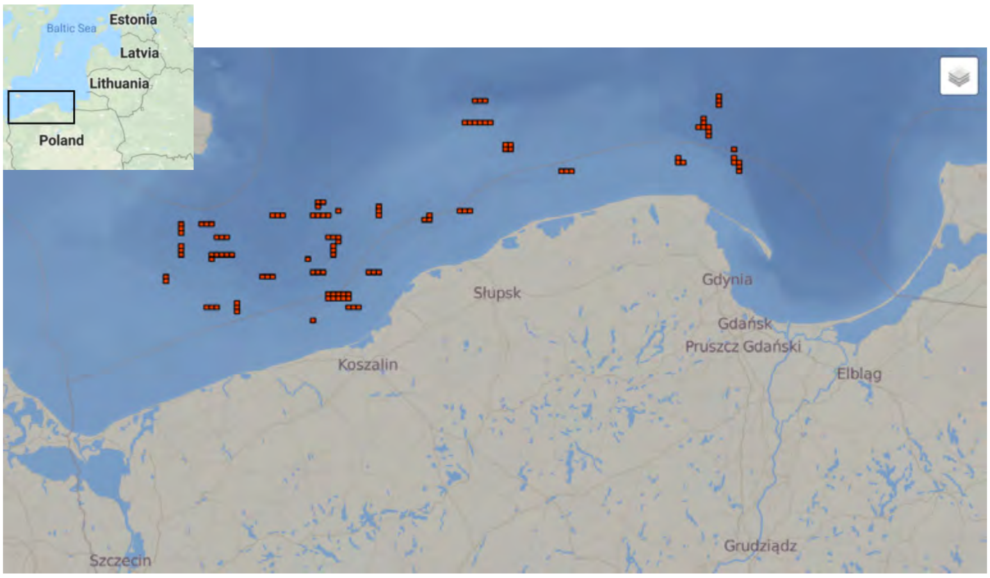


Figure 15. Areas selected for search operations in Poland in 2018.

In addition to the squares drawn in the above described process, hot spot areas were identified for search and retrieval operations carried out in cooperation with fishermen. In total, 133 small squares were selected for search and retrieval operations in 2018, 39% of these were hot spot areas with a high probability to host DFG and 61% were randomly chosen areas.

The searching patterns in Poland were the same as in 2017.

Sweden

One of the main outcomes of the retrieval operations carried out in 2017 in Sweden was the retrieval of fishing gears from the areas assessed to have low probability of derelict fishing gear occurrence. At the same time, the quantity of derelict fishing gears retrieved from the area that was assumed to be the biggest hot spot was well below the expectations. Shallow waters in the search area and strong currents were identified as the main factors of the low retrieval rate in this identified hot spot. It could be assumed that the substantial amounts of nets lost in the hot spot area were broken down into smaller pieces and carried away or buried in the bottom sediment. In addition, similarly to Poland, it was observed that the derelict fishing gears tend to accumulate in the areas where the seabed is covered with rocks or other underwater obstacles.

Seven new areas (Nos 2-8; see the map below) along the Swedish southern coast were selected as potential locations of DFG, to be targeted during retrieval operations planned for 2018. Two types of squares were chosen in each of these areas: i) squares identified by fishermen as areas with potential historic gear loss (compare the Polish method where fishermen designated areas with high retention possibility of DFG) and ii) randomly chosen squares. Due to this amendment, the methodologies used in Poland and Sweden were made more comparable.

In the case of the larger area (number 1 on the map below) covered with 6 sampled squares in 2017, the result was considered unsatisfactory due to exceptional circumstances. There were three reasons for this conclusion. Firstly, the sampling was too sparse in relation to the area size. Secondly, the topography in some parts of this huge area "*systematically varies*" thus resulting in a more fragmented fishing pattern and thirdly the area is crossed by two heavily used shipping routes, which contribute to the loss of surface markers and which had previously often resulted in gear loss.

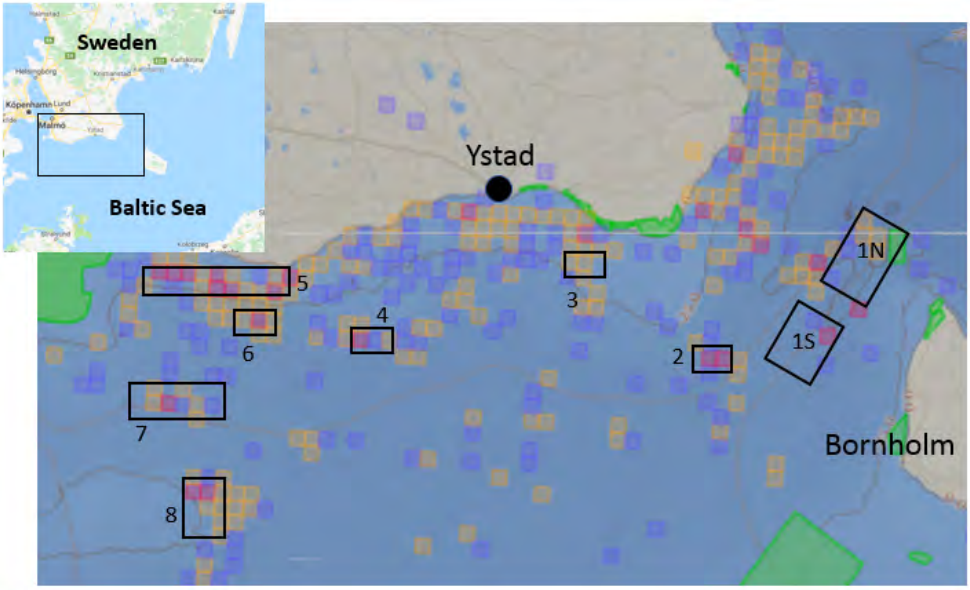


Figure 16. The areas selected for search activities, identified as a result of randomisation process in Sweden (2018).

On the basis of the results of the retrieval operations carried out in 2017, it was agreed that there was no need to make more effort to search the wide sand bank area in the east (Mid Sea Bank; see map No. 2). The surprisingly low retention rate in this area was a big relief to the experts, but logical, considering the type of seabed (sand or mud) and circumstances (shallow waters and strong currents). Due to the shallow waters, the nets lost in the area were either broken down into smaller pieces and carried away by water currents or buried into the seabed sediment.

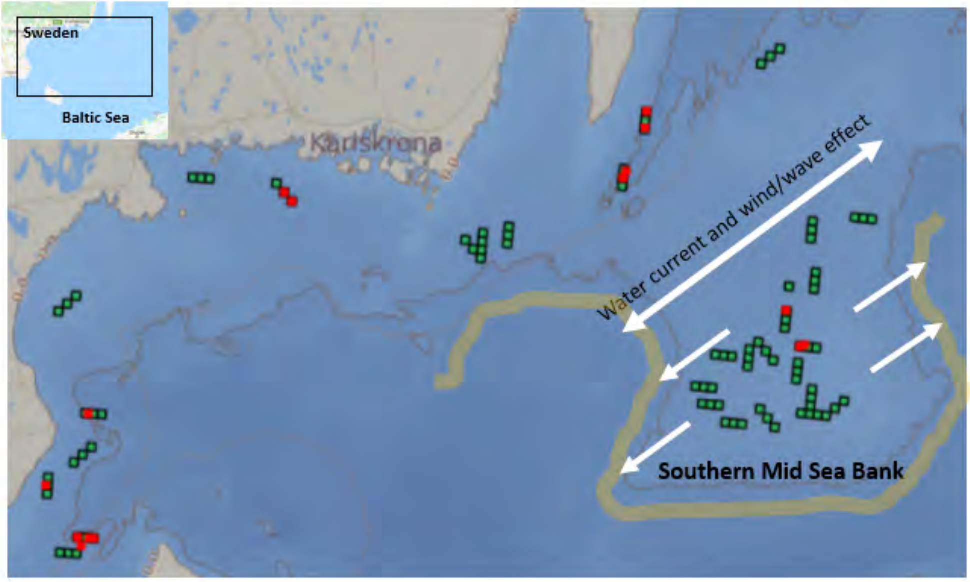


Figure 17. Southern Mid Sea Bank area (green squares – areas designated for search and retrieval operations, orange squares – net finding points).

Instead, the expert group moved its focus to a steep slope following the eastern coast line of Öland (No. 17 on Figure 18). Relatively large quantities of nets were found in four out of the six visited squares, which gave the highest overall retention rate for 2017 dragging operations. Interviews with older local fishermen confirmed that earlier (before 1997), from time to time, intensive gillnet fishing was conducted on these grounds by fishermen coming from the northern Baltic sea (Northern Sweden, Finland, Estonia etc.). The group of fishermen recommended complementary dragging operations in this area in water depths between 20 and 60 m.

Eight (8) additional areas (numbers 9 – 16) were recognized by fishermen/experts as highly interesting sites for the 2018 dragging operations.

Dragging was considered impossible in the large area marked with a dashed line on map 3 because of the extremely hard and sharp limestone seabed. Therefore, dragging operations were not planned there in 2018.

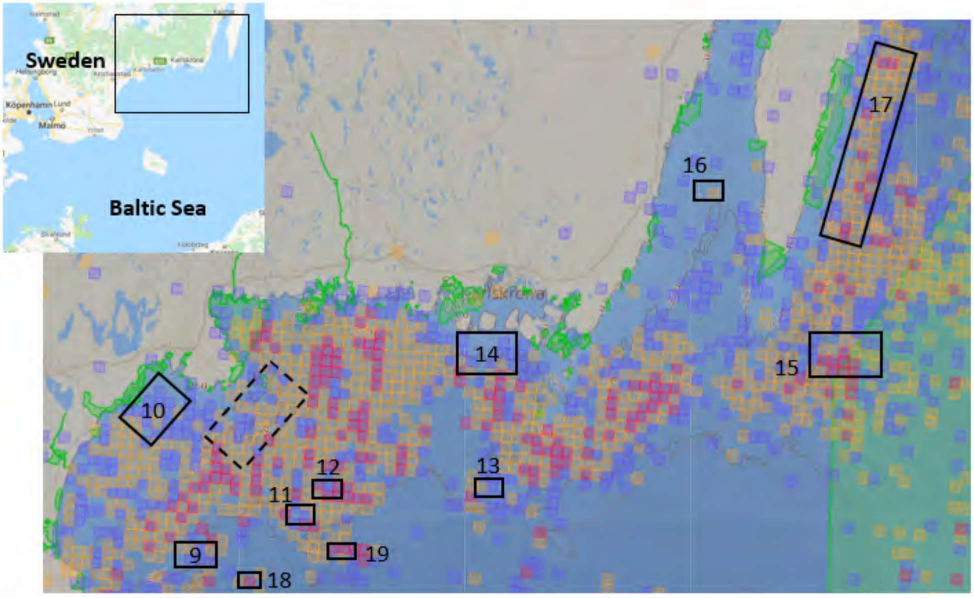


Figure 18. Search areas (including type B and C) selected for 2018 operations in Sweden.

The areas selected for the search actions in Sweden in 2018 are listed in appendix No. 8.

In addition, it was agreed to change the searching patterns in Sweden in 2018. In 2017, each square measuring 2 km by 2 km was cleaned in 6 track pattern (Figure 19 on the left).

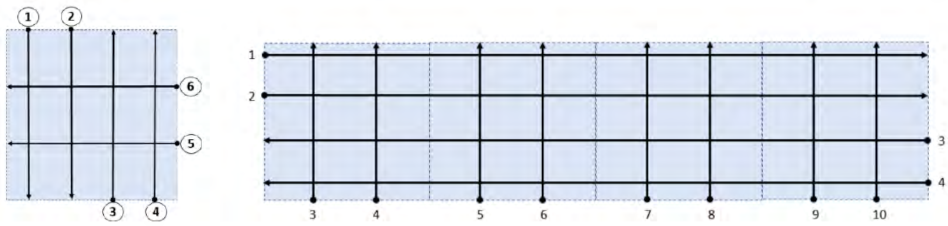


Figure 19. Comparison of searching patterns used in 2017 (left) and 2018 (right) in Sweden.

Where appropriate, this dragging pattern could be changed to include several consecutive squares (Figure 19 on the right). The consecutive squares can lie horizontally or vertically to each other depending on the characteristics of the area.

The benefits of this dragging pattern include the fact that the number of executed tracks can be decreased from 18 down to 10 with 4 continuous, longer tracks, which means less time spent for transfers between the tracks.

8.1.5 Improvements in the reporting system

One of the recommendations from the retrieval operations carried out in 2017 was to improve the reporting methodology. The reporting sheets developed and provided to partners in 2017 were too detailed and difficult to fill in during the cruise. In consequence, it was not possible to gather all relevant data in the correct format. This hampered the analysis of the outcomes of the operations carried out in 2017. Therefore, the new reporting template for fishermen for 2018 only contained the most important information, including the data related to the cruise (name and length of the fishing vessel, search date and time, name of searched square, type of search device used, substrate of the seabed), retrieved fishing gears (depth of retrieval, coordinates, type of the fishing gear, material, weight and length, estimated age), fauna and flora found in the retrieved nets (fish species, fish condition, other organisms) and other relevant information (other retrieved objects and additional comments).

The reporting sheet for retrieval operations carried out by divers at shipwrecks was also adjusted to correspond to the reporting sheet prepared for fishermen in sections related to the information on retrieved fishing gears (depth of retrieval, coordinates, type of the fishing gear, material, weight and length, estimated age), fauna and flora found in the retrieved nets (fish species, fish condition, other organisms) and other relevant information (other retrieved objects and comments).

8.2 Search and retrieval operations carried out in 2018

8.2.1 Search and retrieval operations carried out by fishermen

In 2018, 164 retrieval cruises were carried out by project partners from four countries:

- 77 cruises carried out in Poland between June and October
- 63 cruises carried out in Sweden between April and August
- 18 cruises carried out in Estonia between August and September
- 6 cruises carried out in Germany between June and August

Unfortunately, the recommendations from 2017, related to the use of the vessels with the same or similar technical characteristics, as well as the possibility to carry out retrieval operations in the same weather conditions and the same seabed structures could not be applied. The level of cooperation between the partners and fishermen in partner countries differed and this fact highly influenced the possibility to engage vessels with identical or similar technical properties. In addition, the weather conditions at the sea vary and are subject to quick changes, resulting in a different weather condition at the moment of the departure from port and the time of the dragging operation. In addition, the seabed morphology differs significantly, especially between the northern and southern part of the Baltic Sea, therefore the identification of similar seabed structures in selected categories was not possible.

In Germany, search and retrieval operations held in 2016 and 2017 had not yielded significant retrieval success. Since all retrieval activities except for the 2018 professional wreck cleaning were carried out with WWF Germany internal funding in the framework of the overarching ghost net removal project, DFG locations known by divers were systematically cleaned to mitigate the negative impact on the seafloor habitat. Hence, the retrieval amounts provided in this section do not result from search and retrieval operations as carried out in Poland and Sweden.

The outcomes of search and retrieval operations carried out in cooperation with fishermen are summarized in the table below:

	Estonia	Germany [known DFG locations & retrieval by divers]	Poland	Sweden
Number of cruises	18	6	77	63
Weight of retrieved gillnets [kg]	73,5	104	1797	4337
Weight of retrieved trawl nets [kg]	0	450	1232	1 trawl net
Weight of retrieved long lines [kg]	0	0	32	0
Weight of the nets not classified	0	0	597	0
Weight of other debris (ropes cables)	0	0	577	0
Range of mesh sizes [mm]	40-70	-	16-120	60 - 130
Range of depth of retrieval [m]	2.5-5	4 – 9	24-75	13-60
Seabed structure where the nets were found	Muddy, sand, stone	Sand, Stone	Stones, clay, sand	Gravel, stone
Other information	3 common roach, 5 crabs	Flat fish (60), *Phalacrocorax carbo* 2, cormorants 2	5 flounder, 1 shorthon sculip, 2 birds, blue mussels in high quantities	Several cod, flounder, sculpin, plaice

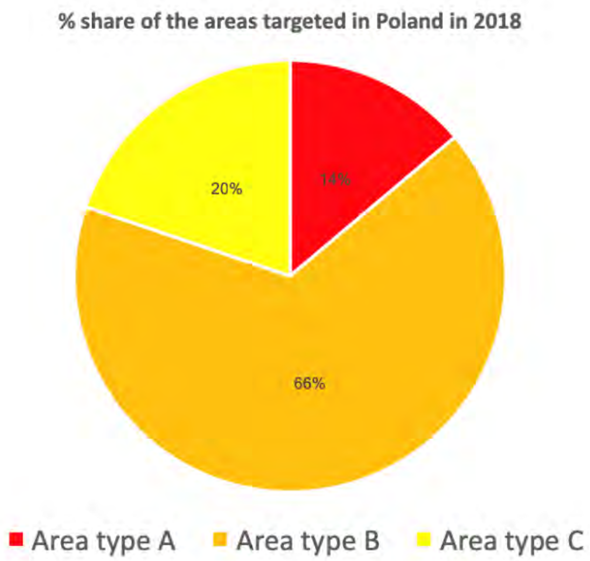
Table 9. Results of the retrieval activities carried out with the use of searching devices in 2018. In Germany, the retrieval operations at the sea bottom were carried out by divers, not by fishing vessels, and without the use of a searching device.

Poland

77 cruises were carried out in Poland, in the period between June and October 2018. Fishing vessels between 13 and 21 meters were engaged in the retrieval operations. In total, 4235 kg of debris were retrieved, including:

- 1797 kg of gill nets;
- 1232 kg of trawl nets;
- 32 kg of long lines;
- 597 kg of not classified fishing gears;
- 577 kg of other debris.

The Polish vessels carried out retrieval operations in 132 squares. The majority of the retrieval operations were carried out in areas type B – 88 squares (low density of bottom trawling activities - moderate probability of derelict fishing gear occurrence). Retrieval operations were also carried out in 18 squares categorised as type A and 26 as type C.



As presented below (Table 10), the majority of fishing gears (87%) were retrieved in areas with low demersal trawl fishing effort (type B area - low density of trawling activities - moderate probability of derelict fishing gear occurrence). In the two other areas the quantities were almost equal: 7% of derelict fishing gears were found in type C areas (close to zero trawling – high probability of derelict fishing gear occurrence) and 6% in type A area (high density of bottom trawling – low probability of derelict fishing gear occurrence). The outcomes presented for areas with high and low trawl fishing effort should be treated with precaution - the number of targeted type A and C areas was smaller than the area B (which was not intended as the squares were selected at random). At the same time, it is surprising that only 7% of all retrieved nets were located in areas with close to zero trawling activities (area C), as it was expected that derelict fishing gears should aggregate in this area type, as most of the fishing effort of the static gear is concentrated there. No trawl nets were retrieved in the type C areas which corresponds to the assumption that the probability of occurrence of trawl net in areas where no trawling activity is conducted is close to zero. As expected, it was discovered that in most cases, lost trawl nets are not carried by water currents due to their high weight and tend to remain in their original location.

From the high percentage of DFG found in areas with low trawl fishing intensity where also gillnetting takes place, it can be deduced that conflicts between different types of fisheries result in high net losses. A high occurrence of derelict fishing gears in type B areas could also be connected with the water depth. As presented in Table 12, the highest amounts of fishing gears were retrieved at water depths between 40 - 60 meters. The average depth of net retrieval in type B areas was 47 meters. This is in line with previous observations, clearly indicating that the possibility of net loss increases with the depth at which the fishing operation is carried out. Also, nets transported by current from shallower areas might accumulate in deeper basins where they remain.

Area types according to the randomisation process carried out in 2018 in Poland	**% of retrieved fishing gears**
High density of bottom trawling activities– low probability of derelict fishing gear occurrence (type A)	6%
Low density of bottom trawling activities - moderate probability of derelict fishing gear occurrence (type B)	87%
Close to zero trawling activities– high probability of derelict fishing gear occurrence (type C)	7%

Table 10. Percentage of retrieved fishing gears in areas categorized according to trawl fishing effort (data from 2012) in Poland.

	High density of bottom trawling activities (A)	**Low density of trawling activities, (B)**	**Close to zero density of trawling activities, (C)**	**Lack of coordinates**
Gill net	54%	53%	40%	0%
Trawl	35%	32%	0%	8%
Long lines	4%	1%	0%	2%
Net not classified	7%	14%	60%	90%

Table 11. Percentage of retrieved fishing gears in each area type, according to different fishing gear types.

	Depth [m]					
	20-30	31-40	41-50	50-60	Deeper than 61	not provided
Retrieved nets [%]	16%	21%	9%	31%	4%	19%

Table 12. Percentage of fishing gears retrieved in Poland in 2018 in areas categorised by depth (retrieval activities were not conducted in coastal waters less than 12 nm from the shore).

As in the previous year, almost no fish and other organisms was reported in the retrieved gears, with the exception of several flounder and cod. In addition, almost all retrieved gears were covered with mussels. Lack of fish as well as high mussel coverage could be explained by the considerable age of retrieved fishing gears (Table 13).

The outcome of retrieval activities in Poland in 2018 clearly shows that the probability of occurrence of derelict fishing gears cannot be determined by a single factor, such as the fishing effort of a given fishery. Other factors such as the use of different fishing methods, sea currents, wind and seabed morphology should also be taken into account in the hot spot identification process. The fact that most of the nets were retrieved from the area with low trawl fishing effort suggests that the conflicts between different fisheries (static and active gears) could be one of the main factors influencing the spatial distribution of derelict fishing gears.

Historical fishing effort is another factor which should be taken into account during the identification of expected hot spots. The data from the retrieval operations indicates that most fishing gear retrieved by Polish fishermen in 2018 was older than 5 years, and large quantities were assessed to be older than 10 years. The assessment of fishing gear age was based only on the experience of fishermen, but even if the results are treated with high precaution, the inclusion of additional, historical data on the fishing effort would confirm that losses are expected to have been higher in the past when the overall fishing intensity was much higher than today.

Age	**% of retrieved nets**
1-5	19%
6-10	51%
11-15	7%
16-20	11%
21 and more	12%

Table 13. Age of retrieved derelict fishing gears in Poland in 2018 based on the age assessment made by the fishermen retrieving the nets.

Last but not least, the presented outcomes of retrieval activities carried out in 2018 could have been highly impacted by the high retrieval effort taken by Polish fishermen between 2015 and 2017. A large-scale derelict fishing gear retrieval project was carried out in Poland during this period, financed by the European Maritime and Fisheries Fund (EMFF). Over 500 vessels participated in this project and only in 2017 retrieved 147 tonnes of derelict fishing gears. As the information regarding the exact locations of retrieval operations is not available, it cannot be excluded that the areas selected for retrieval operations in the framework of the MARELITT Baltic project had already been subject to previous cleaning operations.

Sweden

In Sweden, 63 cruises were carried out between April and August 2018. In total, 10925 meters of gillnets were retrieved (4 337 kg considering that 1 meter = 0.397 kg) as well as one trawl net. For more detailed results showing from which areas types (B or C) the nets were retrieved see chapter 11.1b.

In addition, other litter, including plastic items, fabric and domestic garbage was collected. Fish, including cod, flounder, plaice and sculpin were found in 60% of the retrieved gill nets, but the quantities were very low (single specimen). Some of the fish were alive, other dead. Similarly to Poland, the small observed catchability of retrieved gillnets could be connected with the old age of retrieved fishing gears. More than 80% of all retrieved gill nets were assessed to be between 11 and 20 years old.

Age	**% of retrieved nets**
1-5	0,3%
6-10	3%
11-15	41%
16-20	42%
21 and more	13,7%

Table 14. Age of retrieved derelict fishing gears in Sweden in 2018 based on the age assessment made by the fishermen.

In Sweden, as presented in Table 15, the highest amount of fishing gears was retrieved at the depth between 40 - 50 meters and in areas shallower than 30 meters. A high occurrence of derelict fishing gears at high depths is in line with the observations in Poland as well as with observations from previous projects which show that the possibility of net loss increases with the water depth at which the fishing operations are carried out[79][80].

	Depth [m]					
	Below 30	31-40	40-50	50-60	>60	not provided
Retrieved nets [%]	28%	19%	29%	17%	0%	7%

Table 15. Percentage of retrieved fishing gears in Sweden in 2018 in areas categorised by depth.

Estonia

In Estonia 18 cruises were conducted between August and October 2018 by two vessels (7 and 10 meters long):

- 6 full days of dragging in Väinameri area;
- 2 full day of dragging in the Gulf of Pärnu area;
- 6 full days of dragging in the Gulf of Narva and Purtse area;
- 4 full days of dragging in the Gulf of Hara and Eru area.

Additionally 6 days of retrieval operations were conducted in February 2019, resulting in 6.5 kg of retrieved gillnets. The idea was to use ROV to check Points Of Interest (POI) after scanning the seabed with sonar instead of divers. When sonar is used to find derelict fishing gear it results many POI marks on the map which all need to be visually checked. Usually it is done by divers or it can be done with a ROV.

During the tests, when a derelict gillnet had been found in POI, then ROV placed a hook on the net and lifted the net to the surface. Different hooks and hooking methods were tested. The tests revealed several problems. The ROV must have a very sensitive sonar to see the net in the low visibility from the distance and the ROV thrusters must have a thruster guards to avoid getting stuck in the net. Further tests are required.

In general, it is possible to use the ROV to check POI and lift the derelict fishing gear. It will be safer and cheaper than hiring the divers.

[79] Brown, J., Macfadyen, G., Huntington, T., Magnus, J. and Tumilty, J., 2005. Ghost fishing by lost fishing gear. Final Report to DG Fisheries and Maritime Affairs of the European Commission. Fish/2004/20. Institute for European Environmental Policy/Poseidon Aquatic Resource Management Ltd joint report, 151.

[80] Macfadyen, G., Huntington, T. and Cappell, R., 2009. Abandoned, lost or otherwise discarded fishing gear (No. 523). Food and Agriculture Organization of the United Nations (FAO).

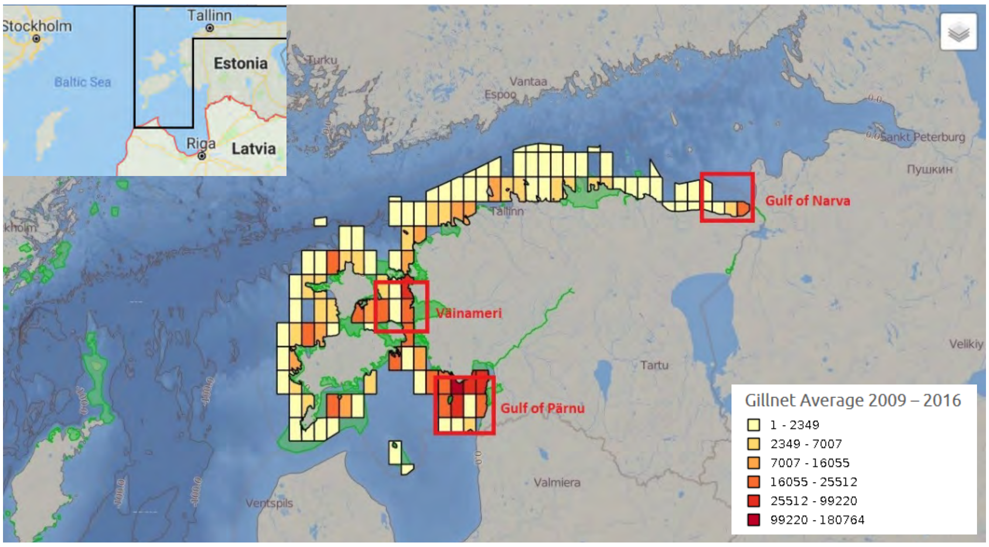


Figure 20. Search and retrieval operations with the use of a searching device in Estonia in 2018.

In total, 70 kg of gillnets were retrieved in the areas with high gill net fishing effort and no trawl fishing effort. All nets were identified as 1-month old and hence originated from recent fishing effort and not from historic fishing operations. It must be noted that in Estonia, recreational fishers are permitted to use gill nets while static gear is not allowed for recreational fishers in Germany and Poland. Several crabs and common roach were trapped in the nets. All nets were found at the depth between 2.5 and 5 meters. These shallow coastal areas are frequently used by recreational fishers.

Germany

In Germany, 6 retrieval activities were carried out between June and August 2018 in known DFG locations. All operations were carried out with the use of a small, 8-meter diving vessel. In addition, based on the outcome of activities carried out in 2017, it was decided not to use the searching device. Instead, a professional diving team was engaged to retrieve the nets from selected locations identified previously by a local diver.

In total, 554 kg of nets were retrieved, including 450 kg of trawl nets and 104 kg of gill nets. Most of the nets were retrieved at a depth of 8-9 meters (509 kg). The remaining 45 kg were retrieved at the depth of 4 meters. The age of the retrieved fishing gears could not be specified in most cases, but at least one entire, undamaged 500m gill net appeared new and was estimated to have been in the water for at most 2-3 months. Both fish (around 60 flat fishes) and birds (2 cormorants) were found in this new and undamaged gill net because the net stood up in the water column at its full length and retained its full catching capacity at the time of retrieval.

8.2.2 Search and retrieval operations carried out by divers

The retrieval operations at selected shipwrecks were carried out in 2018 by all four partner countries.

In Poland, 8 shipwrecks were cleaned up. 3165 kg of trawl and gill nets were retrieved. Retrieval operations at 3 shipwrecks were carried out with the use of the Navigator XXI ship owned by the Maritime University of Szczecin, the project partner. In addition, the University inspected three other shipwrecks located in the Baltic Sea area, between Kołobrzeg and Darłowo. Derelict fishing gears had been found on two shipwrecks, approximately 100-150 kg per wreck but retrieval actions were not conducted. The remaining shipwreck was inspected with the use of a side scan sonar only. According to the information received, no fishing gears were found.

In Sweden, 8 shipwrecks were selected for retrieval operations. Two shipwrecks could not be detected at the provided locations and no DFG were found at the remaining 5 shipwrecks. Therefore, a retrieval operation was conducted only at one shipwreck at a depth of 38 meters, where one big bag of gill nets was removed by a ROV remote-control robot. It was considered unsafe to engage divers in this retrieval operation since the nets hanging around the wreck were 38 to 21 meters in length and the depth imposed an additional health risk to divers.

In Germany, 3 shipwrecks were cleaned up and 350 kg of derelict fishing gears – a mix of trawl nets and gill nets - were retrieved.

In Estonia, 186 kg of trawl nets were retrieved from the Christine shipwreck located at a depth of 29 meters.

Detailed information regarding retrieval operations at selected shipwrecks is presented in the table below.

	Name of the shipwreck	Depth of shipwrecks [m]	Kg of retrieved fishing gears	Type of fishing gear retrieved	Marine organisms found in the retrieved f. Gear
Poland	**Parowiec Bliźniak**	20	25	Trawls/gillnets	Cod, flatfish – 6 kg
	Eberhard	19-20	38	Trawls/gillnets	Cod, flatfish – 9 kg
	Svanhild	22	194	Trawls/Angling gears	-
	Mount Vernon	28	20	Angling gears	-
	S-50	31	1388	Trawls/gillnets	6 cod
	Memel	15	800	Trawls/gillnets	1 cod, 6 eels, mussels, barnacles
	Kanonierka	11	150	Trawls/gillnets	Mussels, barnacles
	Sycylia	16-18	550	Trawls/gillnets	Mussels, barnacles
Sweden	**Vicci**	38	400	Gillnets	Cod 2
Germany	**Eimerkettenbagger**	20	5	Bottom trawl nets, angling gears	2 cod
	Trümmerfeld Ramme (Erzfrachter)	18	305	Gillnets	1 Cod, 1 Flounder, 1 shorthorn sculpin
	Motorbarkasse	8	40	Bottom trawl nets	None
Estonia	**Christine**	29	186	Trawl nets	Fish [without species specification]

Table 16. Results of retrieval activities carried out at shipwrecks in 2018 (inspected shipwrecks at which no fishing gears were found are not included).

9. Sonar technology for DFG detection

In order to assess the effectiveness of detecting underwater objects with acoustic methods, with particular emphasis on the DFG, sonar trials were carried out in the framework of the MARELITT Baltic project. Two series of tests were held, the first one with the use of 2D side-scan sonar, and second one with the use of sonar 3D.

2D side-scan sonar tests were provided by the Maritime University of Szczecin and held on the research vessel NAWIGATOR XXI, with the use of the sonar type: Deep Vision DE3468D, working on the frequencies: 340 kHz and 680 kHz. The results revealed that 2D side-scan sonar is an equipment precise enough to use in search for DFG on wrecks. The sonar images taken during the tests allow for an identification of characteristic elements of wrecks, e.g. masts. With a proper adjustment of distance and frequency, the identification of wrecks covered with DFG is very effective.

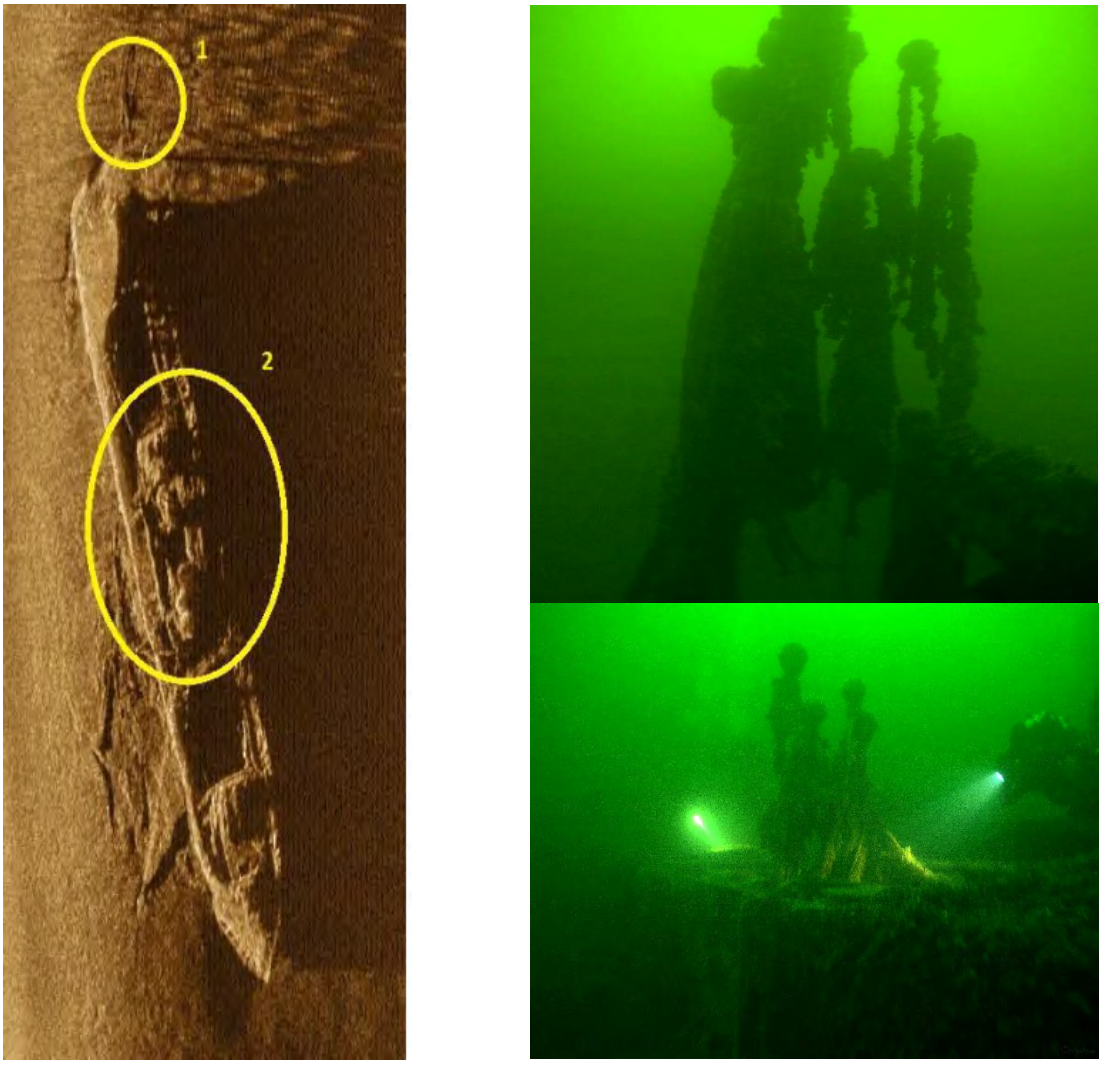


Figure 21. Underwater images of wreck "*Rugen*". On the left - an image taken with the use of 2D side-scan sonar, showing a wreck covered with DFG hooked on the 1) hull and 2) midship. On the right – underwater pictures of DFG taken by divers (Source: Maritime University in Szczecin).

The second series of tests were organised by WWF Poland Foundation in cooperation with Marine Technology Ltd., and conducted on the vessel KOŁ-111, with the use of 3DS-DX-450 sonar (working on the frequency 450 kHz) by Ping DSP. The system is characterised by high resolution of data collection. SoftSonar electronics combined with modern technology of acoustic transducers and a patented signal processing process ensure better bathymetric coverage thanks to the separation of returning signals from the seabed, water column and water surface. To determine the positions of underwater objects, Ekinox 2-D system was chosen.

3D sonar tests were divided into two stages: measurements of wrecks (covered with DFG) in known locations and measurements of nets set for testing purposes.

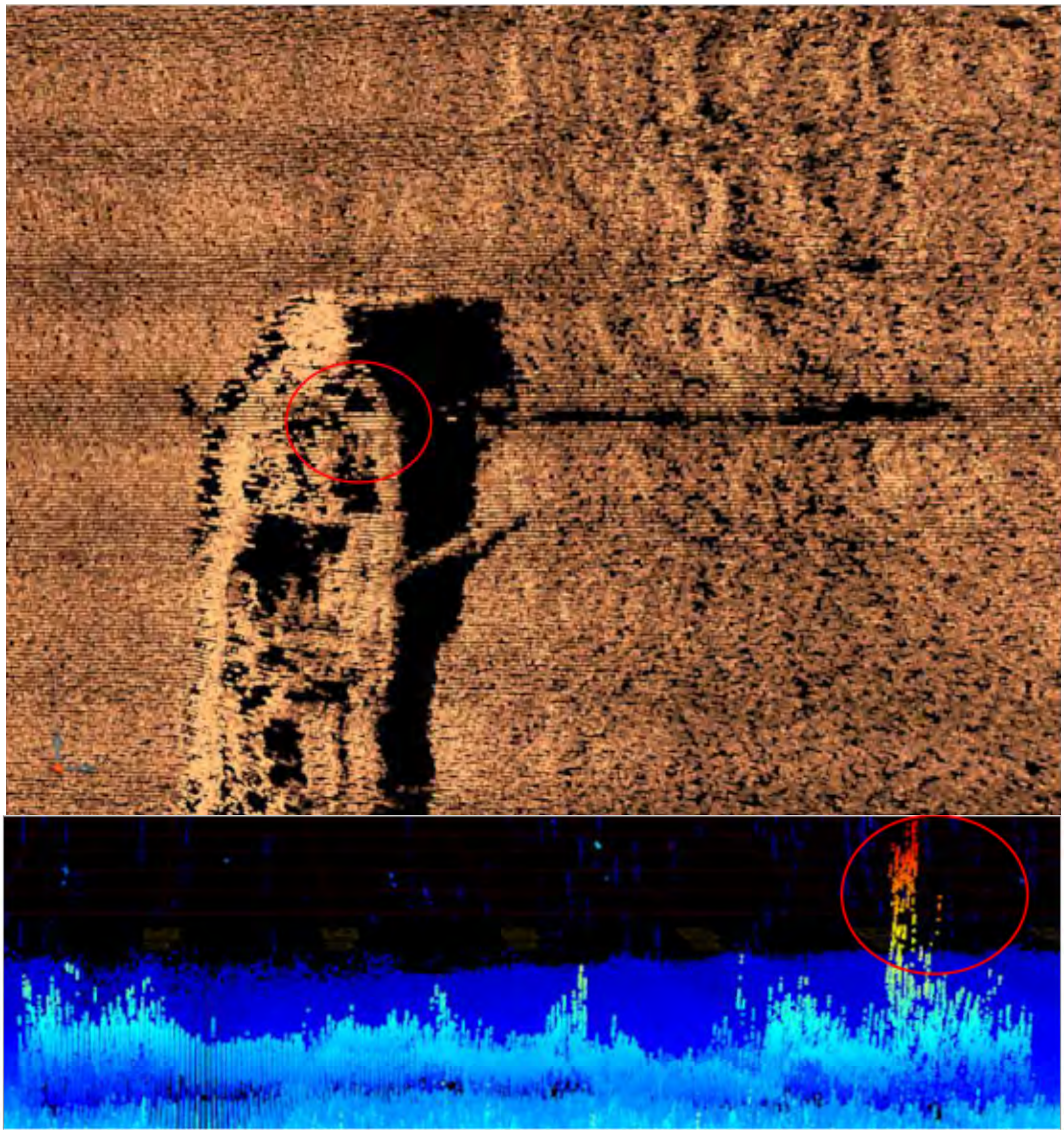


Figure 22. Sonograms of detected wrecks: sonogram 2D - upper image, sonogram 3D - lower image. (Source: Maritime Technology Ltd.).

Ping DSP's 3DSS-DX-450 sonar has demonstrated its usefulness in the process of detection of DFG. Based on the obtained results, sonars such as Sonar 3D 3DSS-DX-450 from Ping DSP can be recommended as a practical tool for the purposes of DFG search and retrieval projects.

Considering the results of tests described above, sonar technology seems to be very practical and effective method in the process of DFG detection. Therefore, the identification of shipwrecks and confirmation of the presence of DFG with the use of these modern techniques is recommended in the future before hiring a professional diving team.

Inspired by the promising results during the MARELITT Baltic project of using side-scan sonar technology (SSS) for surveying DFG, an experiment was arranged in Sweden in August 2018 in typical coastal gillnet fishing areas. Crayton Fenn, the American SSS expert present during the Site-visit in Stralsund/Germany in spring 2018, was involved in this experiment. For more detailed description of the experiment see Annex 6.

The experiment confirmed that the promising results are highly credible. The deployed, authentic, DFG nets retrieved earlier during the same year, were clearly detectable with the SSS instrument on typical both rockier and softer seabed in shallower water (Figure 23).

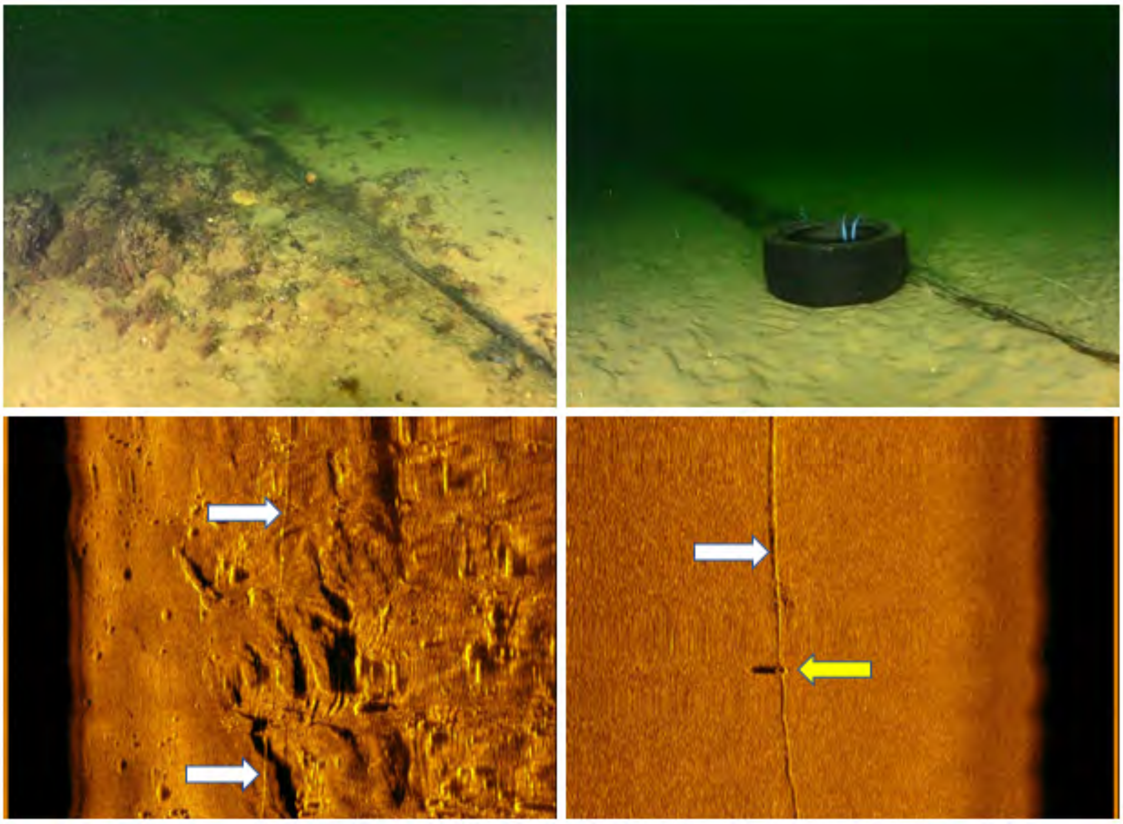


Figure 23. The two first photos show the deployed nets on hard bottom (up to the left) and on smooth/soft seabed (up to the right). To improve detectability of the nets, ordinary car tires were attached every 100 m. The nets can be clearly seen on the two lower images pointed out by the white arrows. In the photo down to right, the yellow arrow shows one of the attached tires.

10. Research related to the development of a new fishing gear marking technique based on passive radio-frequency identification markers

As stated in the chapter "*The main causes of fishing gear loss*", one of the factors causing the loss of fishing gears is related to conflicts between different sea users and between fishermen using different fishing methods, i.e. passive and active gears. Several primary factors of net loss due to such conflicts have been identified, including:

- lack of proper regulations or non-regulatory measures aimed at spatial management of different types of fishery;
- leaving passive gears unattended;
- increased competition for limited resources;
- lack of detailed spatial management plans for the Baltic Sea;
- insufficient requirements related to proper marking of fishing gears.

The outcomes of the search operations carried out under the MARELITT Baltic project prove that conflicts between the sea users is one of the main factors of fishing gear losses today, since most of the retrieved fishing gears were found in areas where passive and active fishing gear efforts overlap. Also in Germany, conflicts with sport boats and working vessels were reported by fishermen as the main reason for gear loss today. Nets accidentally run over by larger vessels will be displaced and cannot be recovered by the fishermen without proper marking technology.

One of the reasons of fishing gear loss in areas where passive and active fishing gear efforts overlap is related to inadequate marking of the fishing gears. Fishing vessels operating with trawls could unintendedly, especially under bad weather condition, break passive gears left unattended. In addition, a lack of proper and durable devices for the marking of fishing gears could be one of the reasons for the lack of compliance with Article 48 of the Council Regulation (EC) No. 1224/2009 of 20 November 2009, which legally requires fishermen to report lost gears. If the fishing gear is not marked in a way that allows to identify its owner after loss, the fishermen show less willingness to report the net loss. Fishermen fear that they would be charged with the costs of retrieval operations in case they cannot retrieve the nets themselves, and hence avoid reporting if possible. This also implies that the fisheries control authority or coast guard of the respective area cannot retrieve the gears that might cause a risk to other sea users.

With the aim to mitigate the impact of inadequate gear marking on the probability of fishing gear loss and reporting, a study of a new method of fishing gear marking was carried out under the MARELITT Baltic project by the Institute of Logistics and Warehousing (ILiM). The study focused on the development and testing of a new marking technology based on the passive Radio Frequency Identification technology (RFID), that uses radio waves to supply, read and identify of an electronic system (RFID tag) and an object marked with it. The scope of the study included an analysis of available solutions, development of RFID tag prototypes for mass applications as well as tests carried out both in laboratory and real-life conditions.

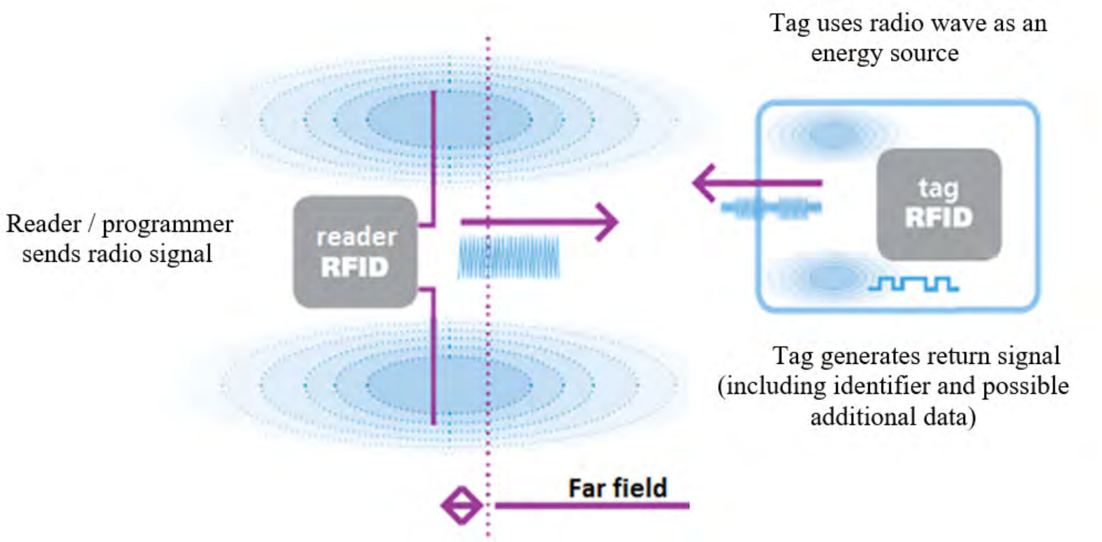


Figure 24. Transmission in RFID systems[81].

In the course of the study, ready-made solutions available on the market enabling the marking of gears used in difficult conditions (up to 100 m below sea level) in connection with existing net elements (floats of different types and sizes) were tested, however their cost had a significant impact on the price of the fishing gears. In consequence, in consultation with the project partners and experts cooperating with the project team, the Identification Technology Laboratory committed to develop prototypes enabling massive marking of fishing gears while maintaining low costs of such solution. During further laboratory work, the aforementioned prototypes were developed (both 3D projects as well as physical implementations of these projects using various techniques - 3D printing or polyurethane foam molding). Prepared prototypes had been subject to laboratory tests and after positive results, went through trials at sea during the fishing operations (both with the use of gillnets and trawl nets).[82]

[81] Grabia, M., Markowski, T., Sitarz, P., Kaczmarek, B., Borowiak, K. and Gruszka, P., 2019. Development and research of a technological solution for marking fishing nets based on passive RFID technology.
[82] *Ibidem*.

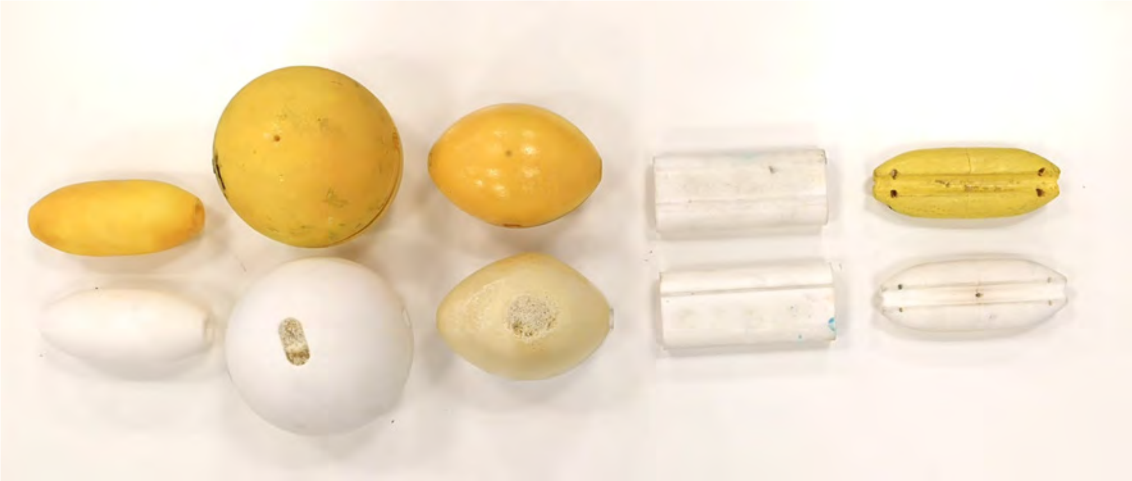


Figure 25. Tags subjected to laboratory tests[83].

The results of the study indicate that the developed markers are durable and could be used during standard fishing operations. According to the authors, further work is needed to develop an IT application which could be used in the harbours and other locations where fishing gears are handled. The outcomes of the project are promising. If the use of RFID markers becomes mandatory, the identification of fishing gears, including the lost ones, would be much simpler and quicker. The durability of markers would ensure the identification of the owner of the fishing gears even after a long period of their deposition in the marine environment. Furthermore, the newly developed markers could be used as an element of the regional register of fishing gears. Implementation of such a system could support the enforcement of regulations related to lost fishing gears reporting (Article 48 of the Council Regulation (EC) No. 1224/2009 of 20 November 2009).

During the works, the use of radio reading methods was also analysed in terms of their use of searching for lost nets, however due to the nature of radio waves propagation, it is not possible to read the tag under the water surface for a longer distance, which disqualifies radio identification technology in this application.

11. Identifying the trends of DFG deposition in the Baltic Sea & recommendations: POST-PROJECT PLAN

11.1 Identifying the trends of DFG deposition in the Baltic Sea

An attempt to assess the average amount of derelict fishing gears deposited in the three area types (Type A, B, C), the average time needed to search one square as well as the average cost of the retrieval of 1 kg of derelict fishing gear was estimated based on the outcomes of the retrieval activities carried out by fishermen in Poland in 2018. In this year, the categories were defined as follows:

[83] Grabia, M., Markowski, T., Sitarz, P., Kaczmarek, B., Borowiak, K. and Gruszka, P., 2019. Development and research of a technological solution for marking fishing nets based on passive RFID technology.

A. high density of bottom trawling – low probability of derelict fishing gear occurrence;
B. low density of bottom trawling - moderate probability of derelict fishing gear occurrence;
C. close to zero bottom trawling – high probability of derelict fishing gear occurrence.

It should be underlined that due to several factors the findings presented in this chapter should only be regarded as indicators of general trends. The reasons for such an approach are as follows:

1. The sample size is too low to determine the trends with appropriate accuracy. In total, 132 squares were searched for derelict fishing gears, which constitutes approximately 2.3% of the Polish EEZ.
2. 39% of searched areas were hot spot areas suggested by fishermen and 61% were randomly chosen areas – outcomes of the retrieval activities in hot spot areas could highly influence the average amounts, as the probability of derelict fishing gear occurrence in these areas was higher than in randomly chosen areas. At the same time, these areas were not excluded from the calculation and were also granted a category (A, B, C). Exclusion of these areas would lower the statistics and further reduce the accuracy of the calculation.
3. The coverage of each area type differs significantly. 66% of all searched areas were categorised as type B area.
4. The standard deviation for the calculation of the average amount of fishing gears found in each area type is very high.
5. The weather conditions could highly influence the outcome of each retrieval operation – this factor was not taken into account in the calculation as no information on weather conditions during the search operations had been reported.
6. The experience of the fishing vessel crew could highly influence the outcome of the retrieval operation - this factor was not taken into account.
7. The impact of the intensive retrieval operations carried out during the last three years by Polish fishermen could highly influence the outcome of retrieval operations under the MARELITT Baltic project - this factor was not taken into account as no detailed information on the areas of previous activities had been made available.

However, even though the findings presented in this chapter are characterised by very high statistical uncertainties, it was agreed among the MARELITT Baltic project Partners to present them as a general perception of the situation. The decision was driven by the fact that even though the findings have a relatively low statistical basis, they constitute the best known approximation of the actual state of DFG in the Baltic Sea. Further work to gain precise information for a proper statistical assessment is needed.

11.1.1 Average amounts of derelict fishing gears deposited in Polish waters in each of the categories A, B, and C

Three area categories were targeted in 2018 by the Polish fishermen:

- 18 squares located in type A area - high density of bottom trawling– low probability of derelict fishing gear occurrence;
- 88 squares located in type B area - low density of bottom trawling - moderate probability of derelict fishing gear occurrence;
- 26 squares located in type C area - close to zero trawling with a high intensity of the gill net fishery – high probability of derelict fishing gear occurrence.

Derelict fishing gears were found and retrieved from 56% of squares located in areas with high demersal trawl fishing effort (type A), 35% of squares located in areas with low demersal trawl fishing effort (type B) and 15% of areas with close to zero demersal trawl fishing effort (type C).

	Number of searched squares in 2018	**Number of squares where DFGs were found**	**% of squares where DFGs were found**
Type A area	18	10	56%
Type B area	88	28	32%
Type C area	26	4	15%

Table 17. % share of squares of each of the category in which derelict fishing gears were found during retrieval operations in Poland carried out in 2018.

The biggest amounts of derelict fishing gears were found in type B areas – 3109 kg, followed by type C and A areas. But it has to be highlighted that also the number of squares category B that were searched was significantly higher than two other categories. The biggest probability of derelict fishing gears occurrence was identified for area type A.

Area type according to the randomisation process carried out in 2018 in Poland	**Kg of retrieved fishing gears**
High density of bottom trawling – low probability of derelict fishing gear occurrence (type A)	224.5
Low density of bottom trawling - moderate probability of derelict fishing gear occurrence (type B)	3109
Close to zero trawling – high probability of derelict fishing gear occurrence (type C)	250

Table 18. Kg of retrieved fishing gears in Poland in 2018 in each of the category (several positions from reports were not included in the calculation due to insufficient information on the location of retrieved fishing gear).

The average amount of retrieved derelict fishing gears is the highest for type B areas even when taking into account the large number of squares where no fishing gear was found, followed by type A and C areas. However, given the high standard deviation and hence the large variation in the retrieved weight of DFG between individual squares, these results should be treated only as indicative. The standard deviation is strictly connected with the distribution of results of retrieval operations shown in Table 19 below. For example, in 60 squares located in type B areas, no nets were retrieved and at the same time in 8 of the squares the amount of nets was above 100 kg each. This large variation is reflected in the presented results.

	Average quantities of retrieved DFG per square [total retrieval divided by number of squares searched] [kg]	**Standard deviation**	**Median retrieval of DFG [kg]**
Type A area	12,47	15,42	10,00
Type B area	35,34	114,24	0,00
Type C area	9,62	28,07	0,00

Table 19. Average quantities of retrieved nets by square type with standard deviation and median retrieval amount of DFG in kg per square.

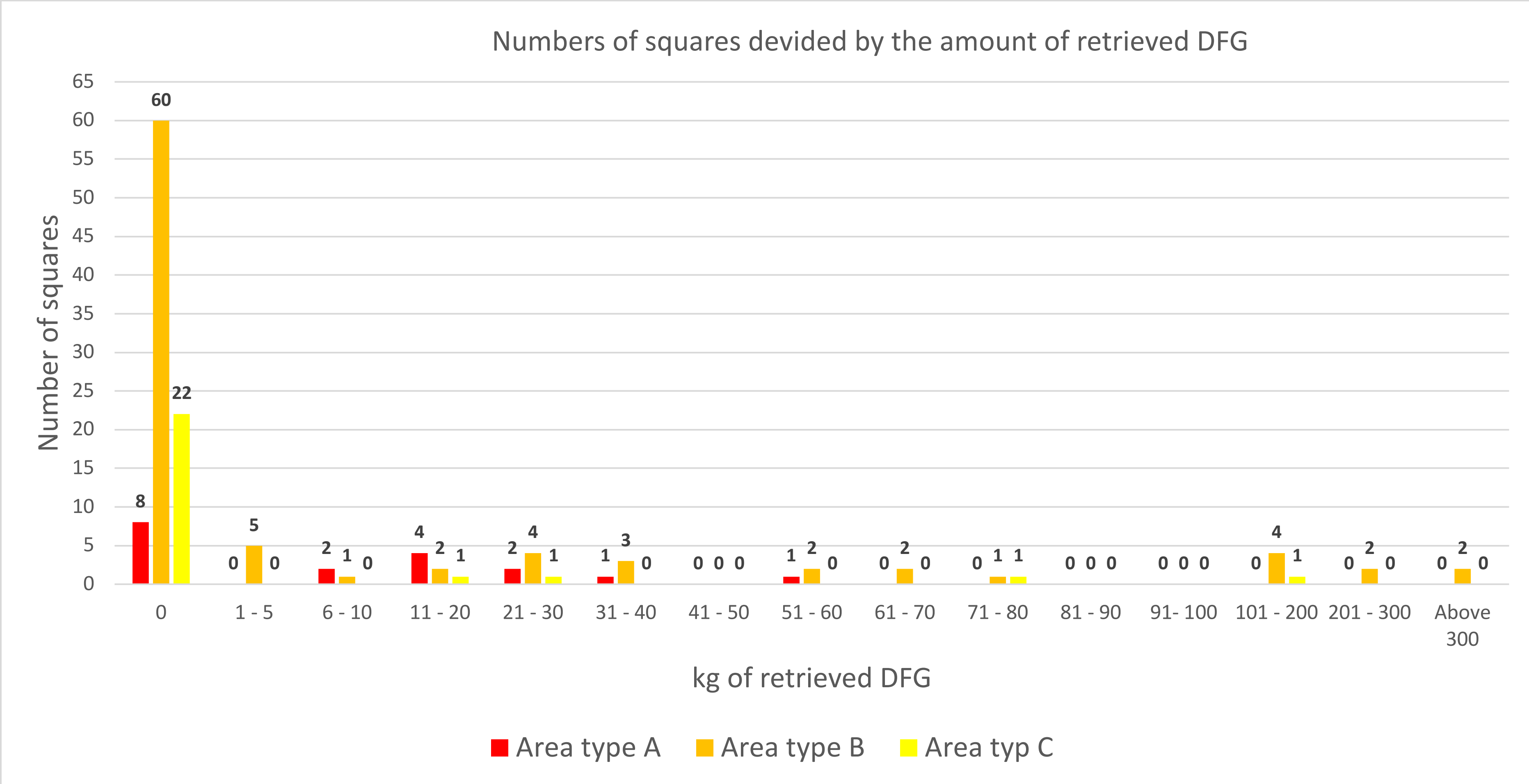


Figure 26. Number of areas in which the indicated weight of the fishing gears has been retrieved (based on the data from Poland from 2018).

11.1.2 Estimation of the amount and geographical distribution of DFG in the covered Swedish Sea area and how this information can be used during the post-project activities

Geographical distribution of the DFG in the study area

Thanks to the developed methodology, the study area could be divided into smaller, strategically more treatable entities (sub-areas) with clearly different preconditions to host DFG and thus different needs of required actions (Figure 27).

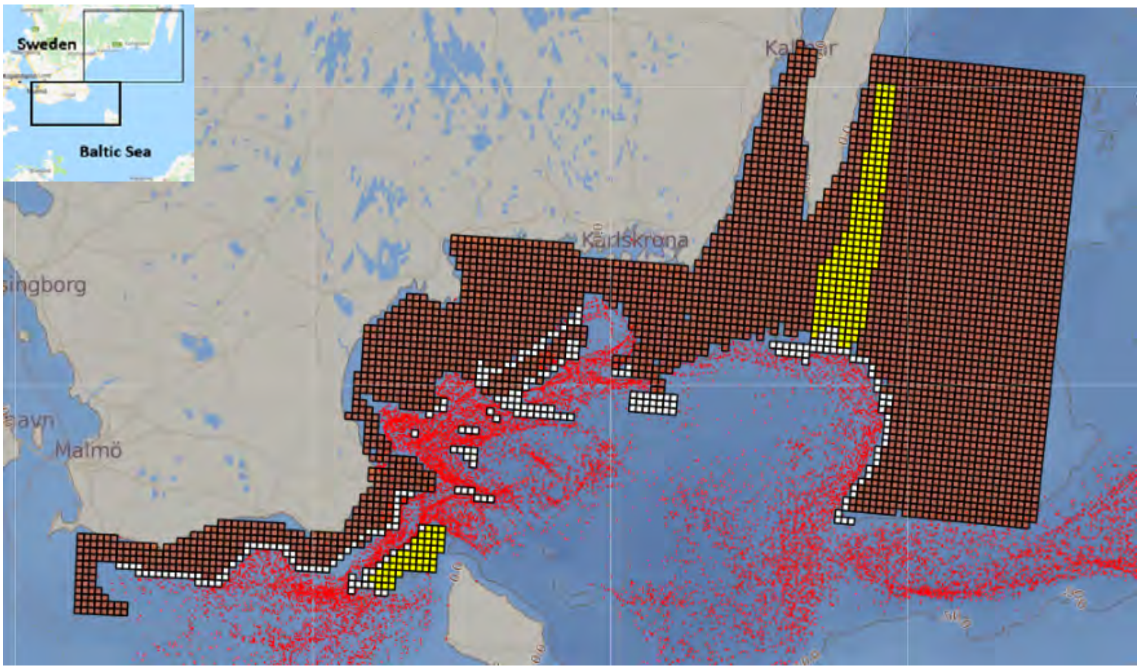


Figure 27. A map showing the size and geographical location of the defined three categories of sea areas, with varying probabilities to host DFG. The red marked areas are used by bottom trawlers (type A), the brown and yellow areas (yellow marking hot spots) are used by gillnet/passive fleet (type B) and the white squares show conflict areas (type C).

By studying more carefully the compiled DFG host area map (Figure 27) and in particular the way the different type of areas (A, B and C) are related to each other, we can confirm the assumed clearer distinction between fishing areas operated by passive and active gears in Sweden as presented earlier (Figure 2). Both in the western and eastern part of the studied area, the third area type (C=conflict area) runs as a one narrow strap between the two dominating areas A and B. Inside the Bay of Hanö, in centre of the map, we can distinguish another pattern. In this particular area, the three types of areas form a much more mixed pattern resembling the pattern more common in the studied Polish area. The logical reason for an exceptional pattern in how fishing fleets operate in centre of Bay of Hanö is the flatter seabed. In this part of the coast, we do not find the similar steep slopes as in western and eastern parts, that in practise become a natural border between trawling and gillnet fishing grounds.

The size of the entire covered and studied Swedish sea area was determined to over 29.000 km^2 (Table 20). Over 1/3 (8.500 km^2 corresponding to 35.5%) of the studied area comprise of fishing grounds used without exception by bottom trawlers (type A area).

This sub-area was excluded from the assessment based on the results from several national projects run during 2002 – 2004 confirming that trawling grounds deposit only very small quantities of DFG. The overwhelmingly largest sub-area, located between the coast and trawling areas, measuring 14.500 km^2 (60.4% of total area), comprise of fishing grounds only used by gillnetters or in general by the passive gear fleets (type B area). Within sub-area type B, our sampling activities revealed two larger locations (hot spots measuring 996 km^2 corresponding to 4.1% of total area). The third type of sub-area (type C; conflict area) was determined to be approximately 972 km^2 (4.0% of total studied area).

Area category	nr of squares	Area km2	% of total
Type A - Bottom trawl fishing	2 139	8 556	35,5
Type B - Gillnet/passive gear	3 635	14 540	60,4
B - Gillnet (low DFG density)	3 386	13 544	56,3
B - Gillnet (hot spot; high density)	249	996	4,1
Type C - Conflict	243	972	4,0
Total	9 652	24 068	

Table 20. A summary of total number squares per sub-area, calculated area in km^2 and the share of the sub-area of the total studies geographical area.

Due to a decision to exclude type A areas provided a possibility for concentration of the cleaning/dragging effort to the two remaining area types (B and C) and through that secure a higher sampling rate. This was a strategic decision due to the fact that in the application, cost of fields activities had to be restricted to roughly cover max. 30% of the total project budget. Based on the executed analyses by experts and fishermen, a general decision was made due to this restriction to focus more on verification of the DFG occurrence pattern in the two extreme cases area B/hot spots and C/conflict area (Table 20). 117 squares (3,5%) was sampled within sub-area B (low DFG density), whereas the sampling rate was 10 times higher within B (hot shot) and C (conflict area). The overall sampling rate on the entire studied area (sub-areas B and C) is 4,7%.

Area category	Total nr. squares	Nr. sampled squares	% sampled of total
Type A - Bottom trawl fishing	2 139	-	-
Type B - Gillnet/passive gear			
B - Gillnet (low DFG density)	3 386	117	3,5
B - Gillnet (hot spot; high density)	249	33	13,3
Type C - Conflict	243	33	13,6
Total (A excluded)	3 878	183	4,7

Table 21. A summary of total number of squares in the targeted areas, number of sampled and cleaned squares and % of squares sampled per given type of area; B/low DFG density area, B/high DFG density area and C/conflict area.

Following the hypothetical DFG occurrence pattern, most of the net findings and length of retrieved net per covered area were found in the assumed hot spot areas within area type B (Table 22). Over 50% of the sampled squares is this sub-area contained DFG, which is markedly higher than in the two other sub-areas. Due to a much lower sampling rate within area B/low density (3.5%), a possibility of smaller not detected hot spots cannot be totally excluded. Should smaller spots with higher DFG density exist, their effect on the overall DFG density estimate for this sub-area type would be small. Based on the fishermen knowledge of e.g. reasons for gear loss, environmental circumstances and morphology within area B/low density, a possibility of larger, undetected hot spots in the covered areas is considered rather low.

Area category	No sampled squares	No squares with DFG (%)	No clean squares (%)	Length of DFG (kg)
Type B - Gillnet (low density)	117	12 (10,3%)	105 (89,7%)	11,4
Type B - Gillnet (hot spot)	33	18 (54,5%)	15 (45,5%)	14,9
Type C - Conflict	33	7 (21,2%)	26 (78,8%)	3,5
Total	183			

Table 22. Result of the cleaning actions of the 183 sampled squares broken down by sub-area, if DFG was retrieved or alternatively the squares were observed clean. Total length of retrieved gill nets per sub-area is given in the last column.

Estimate of the total amount of DFG present in the studied area

A straightforward calculation based on the individual sampling results (average retrieval of netting per square and number squares with net findings) suggest that the total amount of netting in the covered area is 470 km or 181 ton (Table 23). The highest average amount of netting (950 m) per square is found in sub-area B (low density) which does not correspond to an expected lower retention probability. This unexpected result might be negatively influenced by the lower sampling rate (3,5%) and a couple of squares with exceptionally high retention rates of DFG.

Area category	Average DFG/square	No of squares with DFG	Estimated amount	Average per square
Type B - Gillnet (low density)	0,951	349	332	0,098
Type B - Gillnet (hot spot)	0,827	136	112	0,451
Type C - Conflict	0,500	52	26	0,106
Total (km)			**470**	
Type B - Gillnet (low density)	0,318	349	111	0,033
Type B - Gillnet (hot spot)	0,371	136	50	0,202
Type C - Conflict	0,391	52	20	0,083
Total (ton)			**181**	

Table 23. Result of a calculation of the estimated amount of DFG present in the studies sub-areas and in the entire covered study area. In the last column the estimated amount of DFG is related to the total size of the sub-area, which if fact reveals that the highest retention probability can be logically found in hot spots.

A more detailed statistical approach, based on the individual samples and the range of variation included, that an arithmetic mean length of a retrieved gillnet is somewhat shorter than a general calculation suggests (Table 24 compare with Table 23). Median values, are in all cases lower than the mean values, confirming of a distribution screwed toward smaller samples.

Area category	No of ind. net findings	Average (km) retrived net	Standard deviation	Median
Type B - Gillnet (low density)	14	0,815	1,002	0,350
Type B - Gillnet (hot spot)	21	0,709	0,699	0,400
Type C - Conflict	6	0,583	0,411	0,375

Table 24. Key statistics derived from the gained retrieval data.

The result presented in Table 24 suggest that the total amounts of DFG present in the studied area is likely to be lower than 470 km (Table 23). Even if the result would be a bit lower, it is still fairly close to an earlier estimate from a national project (2003) suggesting that the sampled area (not totally equal in size compared to the area in this study) would contain 520 km of netting.

Strategic approach for post-project cleaning activities

Despite of markedly improved overall knowledge on the characteristics of the ghost fishing problem, after completing the project, it is still difficult to advocate if the result of 470 km of netting is a low or high estimate. However, concerning the post-project plan how the work initiated by MARELITT Baltic project should be continued, the most important result is probably not an exact estimate of the total amount of netting deposited in the area, but the new knowledge on the distribution pattern and the size of the defined different types of host areas.

The revealed DFG occurrence pattern provides a more strategic approach to carry out cost-efficient retrieval campaigns in the future. The two identified hot spots provide relatively good preconditions to start systematic cleaning actions with guaranteed relatively high cost-efficiency.

Together with a higher retention probability, the developed grid with 2 km x 2 km squares provide a possibility for "*real-time*" steering of the applied dragging effort. By cleaning systematically one square at the time and constantly monitoring the unit result (retrieved netting km/km^2), it is possible to avoid cleaning of squares in areas with decreasing amount of retrieved netting. In case the unit result has been decreasing step by step, the cleaning activities can be moved back to the site where the retention rates have been verified to be higher.

Simultaneously while cleaning hot spots, surveys to map the larger areas (type B) e.g. by using side-scan sonars can be initiated. Gradually when the areas with more dispersed DFG occurrence pattern have been mapped, retrieval of the located DFG objects can be initiated using creepers and local fishermen (Figure 28).

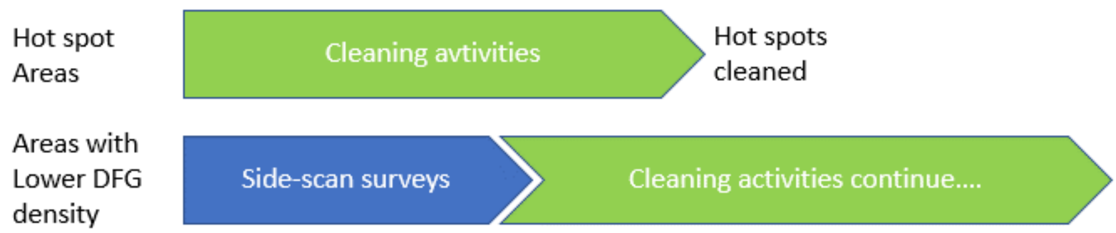


Figure 28. A schematic presentation of a suggested strategic plan with parallel activities in two type of DFG host area. While cost-efficient cleaning/dragging campaigns are started in hot spot areas, side-scan sonar surveys are initiated to produce more accurate DFG maps over the part of sea areas, with more dispersed DFG occurrence pattern.

Required effort and budget

With the realised dragging effort (2017-2018) in the Swedish sea area during the MARELITT Baltic project (1.400 hours), 183 squares equivalent to 732 km^2 of seabed were cleaned. In other words, it took on average 3.1 hour to clean one km^2. Roughly 60% of the applied effort was used for dragging and lifting of retrieved DFG onboard. The remaining effort (40%) was used for travelling between the targeted/sampled squares. In the future cleaning operations, a larger share of the effort is likely to be used for cleaning because the need to change areas will be smaller. Moreover, it is important to take into account, that in the Swedish waters the recovered DFG were mostly gillnets. The larger the share trawls in the retrieved DFG, the larger effort is needed. Logically, a larger dragging effort per km^2 effort is also needed if the nets are not fully stretched like in the Swedish waters.

Based on the above scenario, the estimated effort and total cost amounted to 6.700 hours and 13.8 million Euro (Table 25). The strategy proposed in Figure 29 might lower this total cost, however there is no data to estimate the cost for the needed side-scan sonar effort to cover a huge area (sub-area B) as shown on map (Figure 27).

Area category	No squares with DFG	Required effort (hours)	Cost of cleaning (€)
Type B - Gillnet (low density)	349	4 349	8 977 311
Type B - Gillnet (hot spot)	136	1 692	3 493 156
Type C - Conflict	52	642	1 326 063
Total	536	6 684	13 796 530

Table 25. An indicative estimation of the needed total effort and cost of dragging activities to clean the designated area (536 squares) of 2.100 km^2 located outside southern Swedish coastline.

11.1.3 Average time needed to clean one square (2 km x 2 km)

The average time needed to search one square, calculated on the basis of the data from Polish retrieval activities carried out in 2018, was 16 hours (standard deviation 9.1). The minimum recorded time spent in one square was 3 hours and the maximum 60 hours. There is no detailed information available related to the description of the cruise, therefore the presented average value should be treated with caution. In particular, the fishermen did not report the time purely spent on searching and the time spent for individual retrieval actions. This renders a comparison of required times per square difficult because the time effort for retrieval activities depends on the weight of the DFG, the efficiency of hooking and lifting the DFG with the search device, and storage capacity or required processing on board, which can differ dramatically. In addition, during the Polish cruises, several squares were searched by one vessel during one trip. The information on the duration of a particular trip covering several squares was reported as one value, therefore it is not possible to determine the exact time of the cleaning operation carried out in each square. For the purpose of this analysis, the total time of the trip was divided by the number of squares covered under the trip to obtain the time spent in one square.

At the same time, it should be noted that the assessed average time needed to search one square is realistic if we take into account the assumptions made in the beginning of the project. It was planned that each square (2 km x 2 km) would be covered by 10 parallel tracks at intervals of 200 meters. The towing speed was set at 1 knot (1.852 km/h). After completing each track, the vessel should move to the next track with the highest possible speed, to ensure the highest efficiency of the operation. If the time spend at searching according to the pattern described above is not fully used, additional perpendicular tracks should be completed.

It should take about one hour and five minutes to trawl a two-kilometer path with the speed of 1 knot. An operation covering ten paths should take approximately 11 hours. If other factors, such as the transfer to the next path, handling of the search device and the time needed for retrieval of derelict fishing gears are added, the operation might realistically last on average 16 hours. The differences in time allocated for search operations in different squares could also result from the weather conditions and seabed morphology. In some cases, if the net was found in a particular area, additional effort was taken to search the entire square with the highest resolution (more paths per square) to make sure no further DFG is missed.

11.1.4 Average cost of retrieval activities

In 2017 and 2018, during the retrieval activities carried out by the Polish fishermen, 4 320 kg of derelict fishing gears were collected. The total cost of the engagement of fishing vessels during the period 2017 – 2018 was 358.846.90 EUR (1.527.474 Polish zloty, VAT excluded). An average cost of retrieval of 1 kg of net is therefore 82.94 EUR (353 Polish zloty).

At the same time, it should be underlined that the presented numbers are just rough estimates. The real cost of retrieval activities and the time needed to clean one square are influenced by several factors not included in this assessment, among others:

- the technical characteristic of the fishing vessels (length, engine power, engine age which influences the fuel consumption);

- the experience of the crew (it was proven in the past projects that the experience of the crew has a high impact on the amount of retrieved fishing gears);
- number of the crew members needed to carry out the search operation;
- fuel costs;
- weather conditions affecting both fuel consumption and time needed for search operations;
- preparation of the retrieval activity (through an NGO or through a governmental agency;
- the effort of collecting the data for the host area map used to identify likely hot spots, the creation of the map;
- the effort in hiring the fishermen together with the staff costs.

However, this rough estimate could serve as the basis for planning future retrieval operations. Especially retrieval conducted by fishermen or the fisheries organisations under the EMFF funding scheme would have to expect similar costs for activities at sea. However, this requires that hot spot areas are already known or that the publicly available MARELITT Baltic project hot spot map is used by future search teams following the procedures for hot spot area identification described in this report.

11.2 Recommendations

The MARELITT Baltic project was the first initiative on such a scale in the Baltic Sea region. Nine partners from four countries: Estonia, Germany, Poland and Sweden cooperated jointly to develop and test methodologies for the location and retrieval of derelict fishing gears, and to mitigate the negative impact of derelict fishing gears on the Baltic Sea ecosystem. Two years of activities, including identification of areas with high probability of derelict fishing gear occurrence, search and retrieval operations carried out by fishermen as well as location, identification and cleaning of shipwrecks conducted by divers, resulted in many observations and lessons learned. These are provided below as recommendations from the MARELITT Baltic project.

11.2.1 Recommendations related to the activities at sea

1. One of the crucial elements of the MARELITT Baltic project was to develop a methodology consisting of two steps: 1) a model to define potential host areas for DFG and 2) a randomization process to verify the credibility of the predicted DFG occurrence pattern. The developed DFG prediction model was based on the fishing effort data related mostly to the fisheries using static and active fishing gears, water depth and morphologic data and fisherman knowledge on fishing patterns and environmental characteristics. It was assumed that the spatial distribution of the effort related to these two types of fisheries could serve as the basis for identifying the areas with the highest probability of retention of derelict fishing gears. The outcomes of the project clearly indicate that the DFG problem is multidimensional. Fishing effort can be used as basis for designation of potential host areas, however, fishing effort alone does not determine where the highest DFG densities can be found. In some cases, like in Poland, these areas are found where both passive and active fisheries are carried out simultaneously.

While in Swedish case, hot spots where without an exception found where only gillnet fleets are operating. At the same time, areas with low or no fishing effort should not be automatically excluded from being potential host areas, as other factors such as water currents may transport DFG long distances to areas with specific seabed morphology´ or underwater obstacles.

2. The outcomes of the retrieval operations clearly show that most of the retrieved fishing gears were older than 5 (Poland) and 10 (Sweden) years. Therefore, in the future, it is recommended to use in addition the historical fishing effort data to identify the areas with the probability of derelict fishing gear occurrence and at the same time to increase the accuracy of the selection process by improving resolution of fishing effort data, adding more relevant data or by using promising modern underwater survey technologies such as side-scan sonars.
3. The outcomes of the project also suggest that the larger the depth, the higher the probability of fishing gear occurrence. This observation is consistent with the observations from previous derelict fishing gear projects in Poland, showing that the probability of fishing gear loss increases with water depth. Therefore it is recommended in the future to allocate additional effort to search and retrieval operations also at larger depths.
4. In relation to shipwrecks, it was revealed that the exact location and monitoring of shipwrecks prior to the retrieval operations is of great importance. Several locations provided by national authorities were incorrect. This resulted in the loss of resources, which could be used for retrieval activities on other shipwrecks. Some shipwrecks recommended by divers also did not host DFG anymore. Within a few months, private diving teams or storm event might remove DFG from wrecks. Therefore, the identification of shipwrecks and confirmation of the presence of DFG with the use of modern techniques such as a beam or side scan sonar is recommended in the future before the engagement of a professional diving team.
5. Further work to improve the cooperation with fishermen is crucial. It was proven during the MARELITT Baltic project that fishermen have the knowledge and experience crucial for planning and proper execution of retrieval operations. Retrieval operations carried out by experienced fishermen were very efficient in terms of time, cost and amounts of retrieved DFG.
6. The exact information on the areas with the high possibility of occurrence of old munition from the Second Word War is needed for the designation of retrieval areas Within MARELITT Baltic project, an ammunition risk assessment was commissioned and is available through the MARELITT Baltic project webpage. Maps of ammunition hot spots in the project areas are presented in this study, and recommendations for avoidance and mitigation measures when encountering ammunitions are provided.
7. In many cases, shipwrecks and new discovered human settlements are or could become in the future national or regional cultural heritage and therefore any activities related to the retrieval of derelict fishing gears might be forbidden. It is recommended to engage to a larger extent an archaeologist-expert in future derelict fishing gear retrieval projects to develop a safe methodology of shipwreck cleaning which will ensure that no damage is made to the selected underwater objects. Consultation of the regional cultural heritage authorities is

highly recommended to avoid conflict between cultural heritage and DFG cleaning interests. The MARELITT Baltic project host area map, at least regarding the covered Polish and Swedish sea areas, will be a new tool to foresee any possible overlapping of interests and thus help in planning of cultural heritage and DFG retrieval activities.

11.2.2 Recommendations related to mitigation measures

1. Further work to identify the primary causes of derelict fishing gear occurrence should be carried out. The modified fault tree methodology applied in the Arafura Sea or a similar process could be applied. The cooperation with all professional sea users is of crucial importance in this process. Identification of primary factors is crucial for the development of remedial measures.
2. As described in this report, the legislation related to the responsibilities of fishermen with regard to the retrieval and reporting of derelict fishing gears is not properly enforced. Further engagement in the drafting process of the new EU control regulation is recommended to ensure that an effective reporting system related to fishing gear loss is developed and enforced. Cooperation with fishermen and fisheries associations is crucial to ensure high compliance as at present almost no reports on lost fishing gears are submitted to the relevant authorities.
3. Further work to develop a cost-efficient system of fishing gear marking is crucial to reduce the amount of net loss as well as to improve the compliance with the reporting requirements. The best available technologies should be used to allow effective positioning and retrieval of lost fishing gears. Technologies such as RFID should be further examined, on the basis of the outcome of the research made by the Institute of Logistics and Warehousing under this project.
4. Introduction of non-special fee schemes for waste reception in fishing harbours and extended producer responsibility with regard to fishing gears should be further discussed as possible legislative measures to improve the collection, recycling and, as a last-resort solution, energy recovery systems (see the MARELITT Baltic project report on recycling and waste management options available on the webpage).
5. The possibility to create a regional register of fishing gears should be discussed. Implementation of such a system could support the enforcement of regulations related to the reporting of lost fishing gears (Article 48 of the Council Regulation (EC) No. 1224/2009 of 20 November 2009). A bonus on the purchase of new gears for the fishermen who give back old fishing gears should be considered under this system. The use of the RFID system to mark fishing gears should be also considered.
6. Improvements in waste management strategies in harbours need to be considered to ensure proper recycling and waste management of fishing gear materials.
7. Further work on the development of biodegradable materials for fishing gears should be carried out. The new material should have the same strength as the one used at present, and at the same time decompose more rapidly in the water in the event of loss.

Annexes

Annex 1	Reporting sheet used in 2017 for searching and retrieval activities carried out by fishermen
Annex 2	Reporting sheet used in 2017 for searching and retrieval activities carried out by divers
Annex 3	Reporting sheet used in 2018 for searching and retrieval activities carried out by fishermen
Annex 4	Reporting sheet used in 2018 for searching and retrieval activities carried out by divers
Annex 5	Decision making tree related to the shipwrecks identification, verification and cleaning
Annex 6	Summary of the MARELITT Baltic project Sonar workshop in Simrishamn

Annex 1

Reporting sheet used in 2017 for searching and retrieval activities carried out by fishermen

		1	2	3	4
CRUISE	Survey number				
	Name/number of vessel				
	Name of searched area				
	Lenght of the vessel				
	Name of the Skipper				
	Dragging date/time START (yyyy-mm-dd hh:mm)				
	Dragging date/time STOP (yyyy-mm-dd hh:mm)				
	Number(s) of square(s) (unique grid number)				
	Coordinates Start (dragging)				
	Coordinates End (dragging)				
	Coordinates of the square - upper left				
	Coordinates of the square - lower left				
	Coordinates of the square - lower right				
	Coordinates of the square - upper right				
	Search and hook device (type and weight)				
	Substrat (Sand, stone…)				
NET	Net findings (0=no, 1=yes)				
	Depth [m]				
	If yes coordinates				
	Type of net				
	Mesh width [mm]				
	Material				
	Weight [kg]				
	Length [m]				
	Estimated age				
FISH	Fish: species, how many				
	Fish: species, dead or living [a scale of 1-5]				
	Other organisms: species, how many				
	Other organisms: species, dead or living [a scale of 1-5]				
OTHER	Other objects (what kind of object, how many [eg. litter])				
	Comments				

Annex 2

Reporting sheet used in 2017 for searching and retrieval activities carried out by divers

WRECK	Country	
	Survey number	
	Wreck's name	
	Coordinates (location)	
	Depth-bottom	
	Working depth of divers	
	Material which wreck is made of	
	Type od ship	
	Date of wreck construction	
	Date of wreck sank	
	Is it heritage place?	
	Estimated amount of DFG	
	Types of DFG	
	Is it N2000 site?	
	Is it natural reverve?	
	Is there munition?	
	Is there other hazardous substances? Which?	
	Is there fish/birds/mammals by-catch visible?	
	Is there other marine litter present?	
	Are there any other objects?	
	Are there video/photo materials from this wreck?	
	Are there any actions forbidden on this wreck?/ why?	
	Other comments	
CRUISE	Name/number of the vessel	
	Name of search area	
	Lenght of the vessel	
	Name of the Owner	
	Cleaning date/time START (yyyy-mm-dd hh:mm)	
	Cleaning date/time STOP (yyyy-mm-dd hh:mm)	
	Device used (type and weight)	
	Substrat (sand, stone, etc.)	
	Date of cleaning operation	
NETS	Net findings (0=no, 1=yes)	
	Depth [m]	

	If yes coordinates	
	Type of net	
	Mesh width [mm]	
	Material	
	Weight [kg]	
	Length [m]	
	Estimated age	
FISH	Fish: species, how many	
	Fish: species, dead or living [a scale of 1-5]	
	Other organisms: species, how many	
	Other organisms: species, dead or living [a scale of 1-5]	
OTHER	Other objects (what kind of object, how many [eg. litter])	
	Comments	

Annex 3

Reporting sheet used in 2018 for searching and retrieval activities carried out by fishermen

CRUISE	Survey number	
	Name/number of vessel	
	Name of search area	
	Lenght of the vessel	
	Name of the Skipper	
	Dragging date/time START (yyyy-mm-dd hh:mm)	
	Dragging date/time STOP (yyyy-mm-dd hh:mm)	
	Number(s) of square(s) (unique grid number)	
	Search and hook device (type and weight)	
	Substrat (sand, stone, etc.)	
NETS	Net findings (0=no, 1=yes)	
	Depth [m]	
	If yes coordinates	
	Type of net	
	Mesh width [mm]	
	Material	
	Weight [kg]	
	Lenght [m]	
	Estimated age [years]	
FISH	Fish: species, how many	
	Fish: species, dead or living [a scale of 1-5]	
	Other organisms: species, how many	
	Other organisms: species, dead or living [a scale of 1-5]	
OTHER	Other objects (what kind of object, how many [eg. litter])	
	Comments	

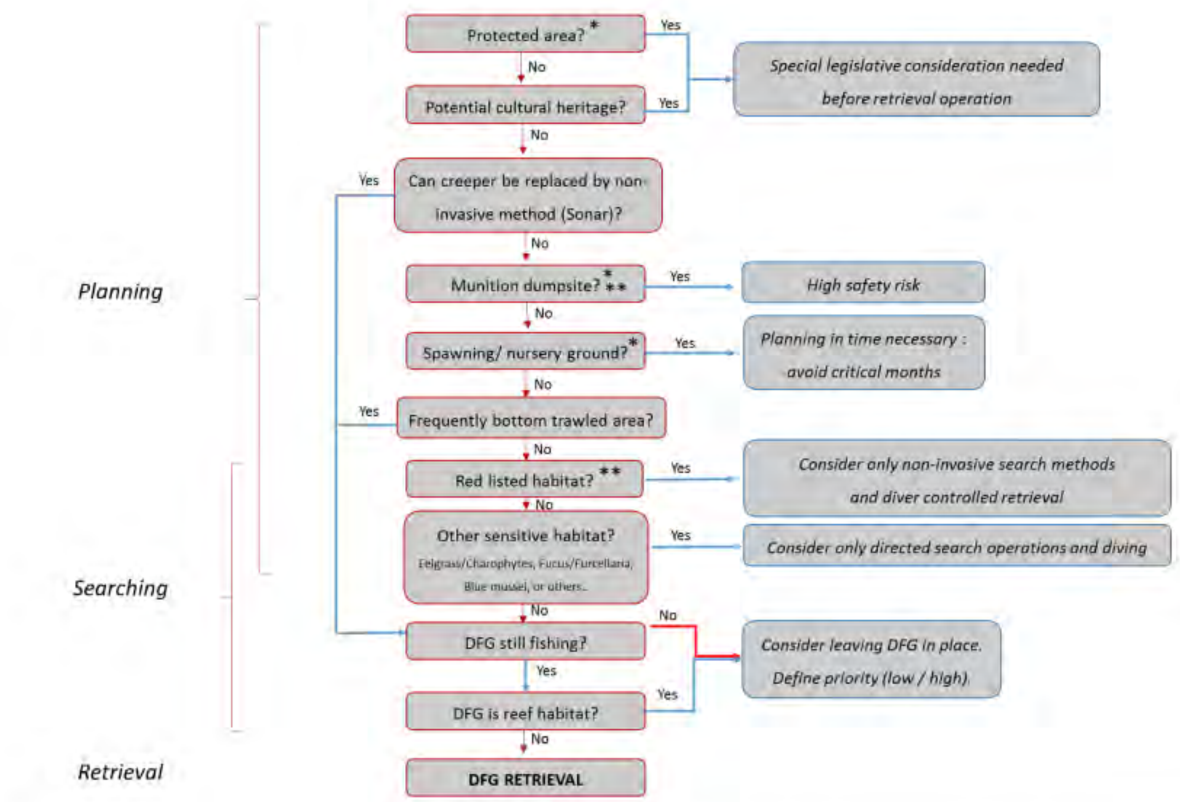
Annex 4

Reporting sheet used in 2018 for searching and retrieval activities carried out by divers

WRECK	Country	
	Survey number	
	Wreck's name	
	Coordinates (location)	
	Depth-bottom	
	Working depth of divers	
	Material which wreck is made of	
	Type od ship	
	Date of wreck construction	
	Date of wreck sank	
	Is it heritage place?	
	Estimated amount of DFG	
	Types of DFG	
	Is it N2000 site?	
	Is it natural reverve?	
	Is there munition?	
	Is there other hazardous substances? Which?	
	Is there fish/birds/mammals by-catch visible?	
	Is there other marine litter present?	
	Are there any other objects?	
	Are there video/photo materials from this wreck?	
	Are there any actions forbidden on this wreck?/ why?	
	Other comments	

Annex 5

Decision making tree related to the shipwrecks identification, verification and cleaning



*spatial information is available from HELCOM. For spawning sites only information regarding cod is available, but local environmental authorities or fishermen can have other information available.

** information available in HELCOM, 2013. Red List of Baltic Sea underwater biotopes, habitats and biotope complexes. BSEP No. 138.

Annex 6
Summary of the MARELITT Baltic project Sonar workshop in Simrishamn

MARELITT Baltic Sonar workshop in Simrishamn

Date/time September 6th 2018, 10-15

Participants

Crayton Fenn, Fenn Enterprices LTD, Seattle, USA
Gabriele Dederer, WWF Germany
Patrik Juhlin, P-Dyk, Ystad, Sweden
Leigh Boyd, Avalon Innovation, Stockholm, Sweden
Pontus Ekström, Swedish Coast Guard, Sweden
Johnny Nilsson, Johnny's Elektroniska, Sweden
Per Nilsson, Johnny's Elektroniska, Sweden
Arne Fjälling via Skype, Swedish University of Agriculture, Sweden
Vesa Tschernij, MARELITT Baltic, Simrishamn, Sweden
Camilla Witt, MARELITT Baltic, Simrishamn, Sweden
Madeleine Lundin, MARELITT Baltic, Simrishamn, Sweden

Welcoming, presentation of participants and the project

A short presentation of the people round the table.

Vesa held a short introduction about MARELITT Baltic (hereafter the *project*). He gave a rough overview of the project; partnership, plan/set-up and expected outcome which is improvement of the capacity in Baltic Sea Region (BSR) to work with ghost fishing problem. To achieve this overall result the project is developing both practical and policy tools and is contributing to increase the transparency of the ghost net problem in the BSR.

Objective of the workshop

The side-scan sonar experiment carried out in August-September and this workshop is part of the activities in the project to find more environmental friendly, cost-efficient and precise ghost net mapping/survey methodologies. Similar work has been carried out in Germany, Poland and Estonia.

Hydro-acoustic signal enhancement technologies

Project has ordered a literature study on different kinds of technologies to strengthen the respond/echo from sonars to assess the possibility to "*see better DFG in future*". Leigh Boyd, from Avalon presented the results. A report is published on www.marelittbaltic.eu in October beginning of November 2019.

Side-scan sonar experiment using a test bed

Vesa explained the experiment set-up. The plan & invitation document is given in appendix 1. Two companies, P-Dyk (Sweden) and Fenn Enterprises (USA) using two different "*tow-fish*" (transducers) has visited the test site. The two experimental net fleets were installed on seabed by P-Dyk.

Company 1: P-Dyk www.pdyk.se

Patrik showed some video shootage to visualize the two included seabed types (rocky/mixed and smooth/gravel) and described net characteristics. The experimental nets were authentic ghost nets retrieved in the project this May and kept moisty not to lose all the organic material. A set of hand-picked typical bottom gillnets (cod and flatfish) were assembled into fleets and divided into sections using car tires as markers, which are known to give a good bounce/echo. The nets were typically entangled and were mostly shot to lay flat/tightly against the seafloor. Some sections were rigged to stay at some distance (0.3 – 0.5 m) from seabed. The nets are twisted due to water currents (snapshots from film; appendix 2).

We towed our sonar in different angels (in relation to the targeted fleet) across but followed also along the net fleet. We experienced also some rougher weather, which immediately impact on the produced image. Two things are clearly important. A sonar transducer should be towed stable in the water and fly on the right depth above the bottom. We tested both 5 and 15 m above seabed using 50 m range (=distance that is covered is thereby 2x50=100m). The obvious difference between 5 and 15 m, which might in same cases also be decisive, was that 15 meters gave more shadow making it easier to see the net fleets.

Patrik is sometimes using a front-fish (an additional weight) made of stainless steel to both stabilize and, if needed, to pull down a smaller tow-fish (sonar transducer). This rigging efficiently sinks the tow fish and allows a shake absorbed movement with only little up and down motion. This is one/my way to make a sub-standard tow fish perform like a more, advanced and expensive one!

Our results verify clearly that it is possible to detect a typical twisted gill net fleet with a side-scan sonar! Obtained results are, actually, beyond my expectations of what

I thought was possible! A couple of sample images (observe they are screen dumps; lower resolution) are provided in appendix 3.

Company 2: Fenn Enterprises, www.fennent.com

Crayton Fenn assisted by Gabriele Dederer showed some side-scan sonar images with higher resolution using a 600 kHz optimized transducer. They are somewhat more accurate with higher resolution than P-Dyks images. Side-scan technique is basically a 360-degree instrument meaning that you could see the surface as bias if water depth is less than the operating range. Obviously, you want to maximize the operation range to cover a wider area with one track. In our equipment, we have cut of signals going up making operation possible in shallower water.

There were some rocks in the chosen test-site, however, they were relatively small. In a situation where you try to survey a sea area with larger rocks, slopes or even deeper cliffs, you might need to omit a double or even multi- pattern survey method to reduce the black zones (shadows)? This type of surveying can be much more time-consuming. Images produced using a ghost net optimized sonar transducer by Fenn Enterprises are given in appendix 4.

Gillnets without float- and lead-lines can be difficult to detect

In some cases, the task to detect ghost nets is more challenging. Crayton has operated e.g. in German waters where the nets do not look like the nets we can see in Swedish waters. We have bumped into nets that have nothing else left than the net panel (net sheet) often made of very thin twine (0.2 mm and less). Using post-processing which is based on a long experience, even this type of extreme case nets can be detected but it can take time thus money. Pictures of this type of ghost nets found in German coastal (shallow water >15m) were shown. Crayton and Gabriele said that it took 15 tours to get these pictures of monofilament net panels. According to Crayton, thanks to sand and shells covering them, we can see them with a good side-scan sonar.

Conclusions and lessons learned:

Signal strengthening

There are definitely a wide range of existing technics that can make future lost nets more visible. The two key questions are: 1) the size of transponders without becoming impractical in fishing operation and 2) the needed length of operation time?

A pinger (size of a banana) attached on gillnets, used today to warn harbor purposes of gillnets, could inhouse some of the technologies shown in the report. The obvious disadvantage of using pinger-type solution is that often nets get lost typically due to an interaction (conflict) with either a cargo or other vessels or bottom trawlers. In both cases the net fleet and nets are often torn into smaller sections or even pieces. All these net remnants will not carry a pinger because it is not possible to attach pingers every 5 m etc.

The group concludes the smaller, the less power needing the technic used, the more practical it is in fishing operation. Looking from this perspective, air bladders are the cheapest, most simple way to make something visible to side-scan sonars. Using 600 KHz, these bladders need not to be bigger than 2cm in diameter but the longer they are, the better you can see them. Unfortunately, modern floatlines manufactured for gillnets uses special "*ropes*" where its floating characteristic is based tiny air bubbles spread along and inside the entire rope. This makes a gillnet less visible. If the nets would instead be equipped with old-school, plastic hollow floaters with air inside, this solution would also guarantee a better hydro-acoustic visibility.

<u>Side-scan sonar technology for detection of DFG</u>

Higher resolution is needed. The optimum is 600-680 kHz.

Range of the scale 50 - 60 m perhaps up to 80 m but then a lower towing speed is required.

Speed 1.5 or 3 knots, 3 used during the experiment in Simrishamn.

4.3 knot is optimal with 50 m range.

Good weather gives better (more useful data) result but using a more complex rigging with stabilizer/weight you can operate in less good weather.

The optimal method would be to break down the task between a sonar survey and a diving survey to verify the identified potential objects. This is of course highly depth dependent but is a good option in less than 30 m depth. Probably a good method in shallow, rocky coastal or archipelago waters. In future a combination of side-scan sonar and submersible camera could be one solution.

Post-processing is important. Training people to interpret side-scan images takes time. You need to be exposed to a lot of material before you develop the capability of detect a net. All people do not have the "*eye*" for this job.

In case net fleets or nets physically form themselves in clear patterns like continuous lines or bundles, computers programs using specific algorithms can be used to detect potential objects. Every object on a side-scan image that you can bee with human eye, can be detected by a computer.

We can conclude that already today we can see sea objects like ghost nets with a sonar. This method is ready for implementation!

The project representatives agree that a logical next step would be to test and verify in real situation the usability of a combination of sonar and dragging survey. MARELITT Baltic has identified a number of sea areas with higher abundance of lost nets. These sites offer a perfect possibility to test this approach right away. Vesa will contact the national authorities to investigate in such a test could be run already this year.

What are the bottlenecks?

- Collection of the data, weather-dependent, seabed morphology
- Post-processing
- Money

APPENDIX 1. Experimental plan and invitation.

Welcome to become part of MARELITT Baltic and contribute to a ghost net free Baltic Sea

What is MARELITT Baltic?
MARELITT Baltic is an international three-year project with nine partners in four countries. Main objective of the project is to improve the capacity to mitigate ghost net problem primarily in the Baltic Sea Region but due to a groundbreaking approach, the methodology will be adaptable for any region. For more general information visit our homepage www.marelittbaltic.eu or read our short project description "*MARELITT Baltic brochure*".

More cost-efficient surveying tools for mapping of areas with lost fishing gear
One of the critical challenges of the project is to identify more cost-efficient technics enabling more environmental friendly, smoother and more accurate way to detect and locate lost fishing gears. One potential way is to use hydro-acoustic surveying. E.g. side-scan sonars are today used in a wide range of different surveys, but the question is – can it detect lost fishing gears.

Thanks to the systematic work within MARELITT Baltic where the ghost fishing phenomenon has been studied in different areas, we know much more about the nets that have been lost in to the Baltic Sea. Today this new knowledge provides us substantially better chances to foresee what we can expect to find on the seabed in different areas thus hopefully helps us e.g. to identify or develop more efficient and accurate methods to locate the nets.

How can *you* contribute?
To meet this challenge MARELITT Baltic has design an experiment by deploying two authentic ghost net fleets in coastal waters NNE of Simrishamn. These 400 m long net fleets were retrieved earlier this year during cleaning actions within the project. The nets where stored specifically to maintain their authenticity. In other word they are still covered with algae, containing plastic objects, dead fish, some sections are totally twisted whereas others have netting bundles or sheets sticking out from the fleets and even up from the seabed etc.

These two ghost net fleets are typical for areas along the Swedish coastline with more rockier and topographically more varying seabed. The net fleets are deployed on two types of seabed typical for actively used gillnet fishing grounds along the west coast of southern Baltic Sea. The fleets are deliberately located close to coast line to secure good weather conditions, which logically result in less typical water depth (for gillnetting it is 40-60m).

Through this experiment, we offer you and your institute a chance to test your hydro-acoustic instrument on *two verified and authentic objects*. You are free to enter the area and test as many equipment as you prefer and collect data. The fleets are anchored and are planned to be on place until week 36 (first week in September). If you wish to test your gear but the provided time window doesn't allow it, please contact us.

Here are the coordinates of the experimental net fleets:

1. **Net fleet on hard and rocky bottom (depth 20-23m)**
    a. Starting north at 55 38.5188 N / 014 19.5067 E
    b. Ending south at 55 38.2627 N / 014 19.7399 E
2. **Net fleet on soft bottom (depth 35-37m)**
    a. Starting north at 55 38.8952 N / 014 21.0079 E
    b. Ending south at 55 38.6355 N / 014 21.2659 E

You will also find gpx-files attached, which we hope your chart plotter can read. Using these files, you can easily add the net fleets on your electronic map.

The fleets are marked as well with black flags (typical fishing gear markers) one in each end of the fleet.

In the end of this document you will find some photographs, giving you some idea how the seabed but most of deployed net fleets look like.

The experiment will end with a workshop for experts only
Regardless if you have visited our experimental site and have some results (e.g. side-scan sonar or other type of images) or not, we would like to invite you to a workshop which we arrange in Marine center, Simrishamn September the 6th starting at 10.00. Aim of the workshop is by using your former experience and perhaps your results from our experiment, to evaluate the outcome and hopefully draw up some achievable future milestones.

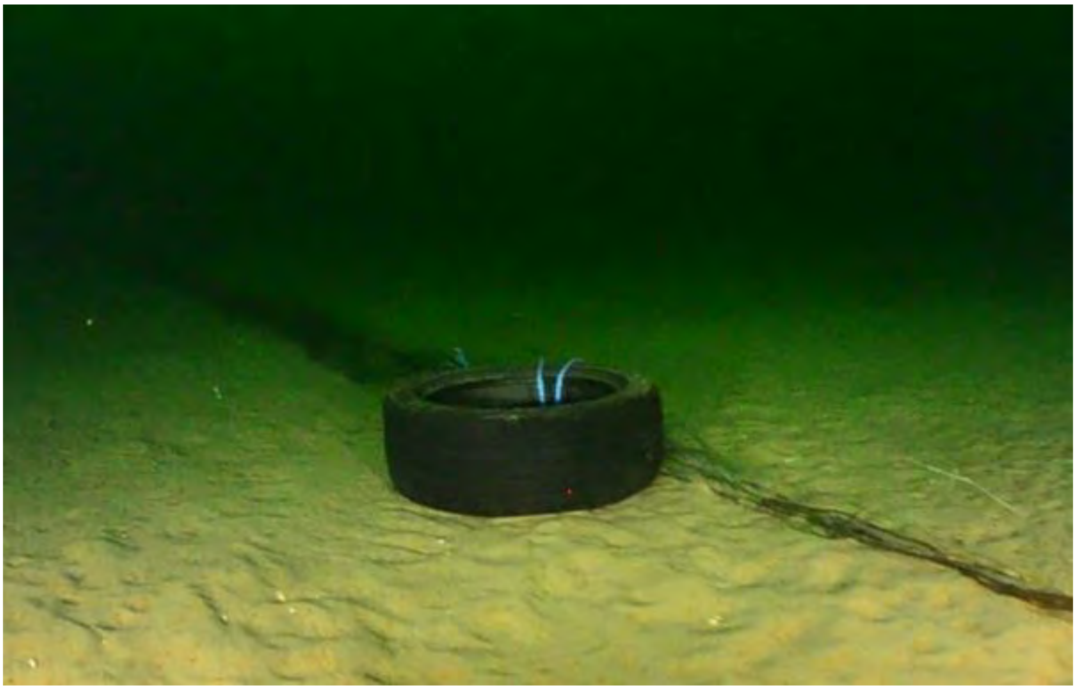
By inviting only experts and keeping the meeting reasonable small (max. around 10 people), we will hope to have a detailed and fruitful discussion on the critical issues concerning future use of hydro-acoustic as a survey technology.

We are also very happy and honored to have with us an experienced side-scan specialist Crayton Fenn from USA (www.fennent.com) who will bring with him his ghost-net-optimized survey gear.

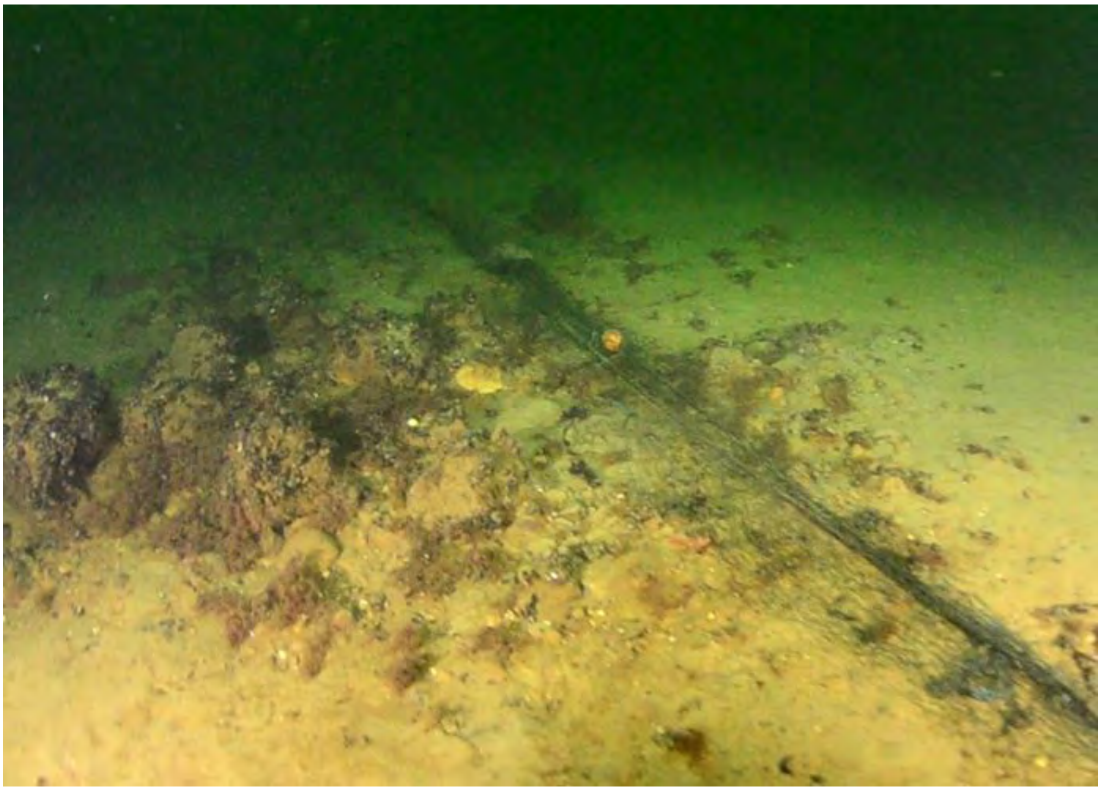
Don't hesitate to contact us if you have any questions concerning experiment or workshop:
Vesa Tschernij, project manager, 0414-819166 or vesa.tschernij@simrishamn.se
Camilla Witt, project assistant, 0414-819168 or camilla.witt@simrishamn.se

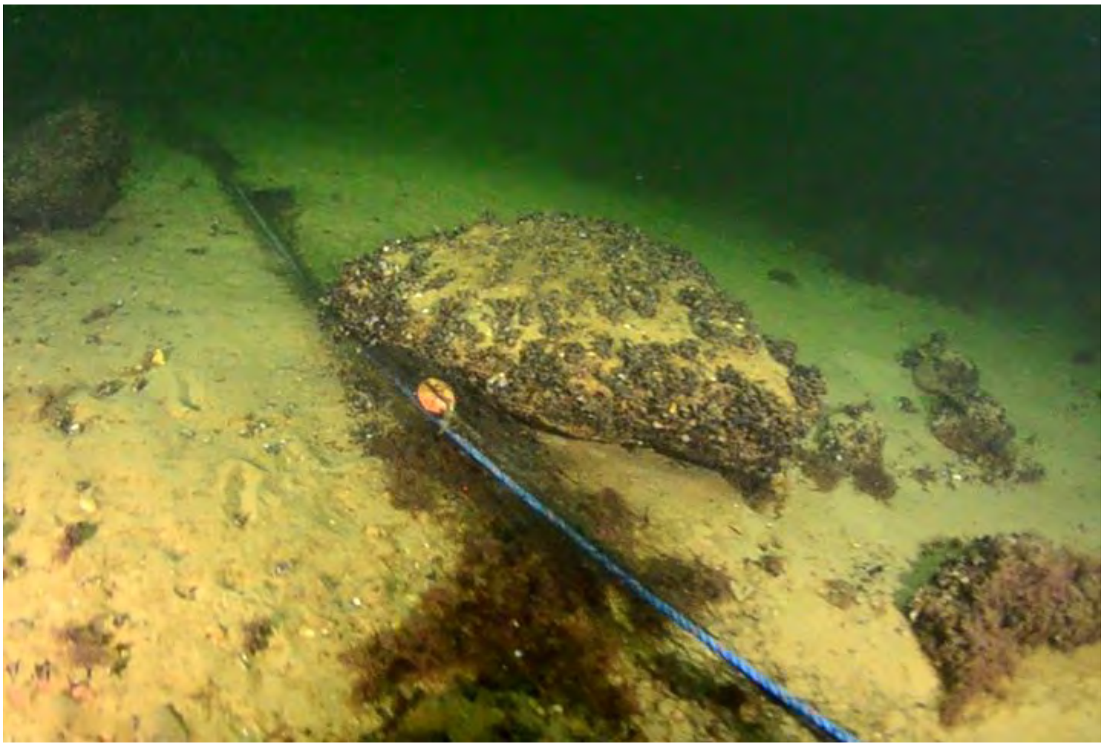
APPENDIX 2.
Snapshots from UW video film.

Net fleet located closer to the coastline on hard bottom in shallower water

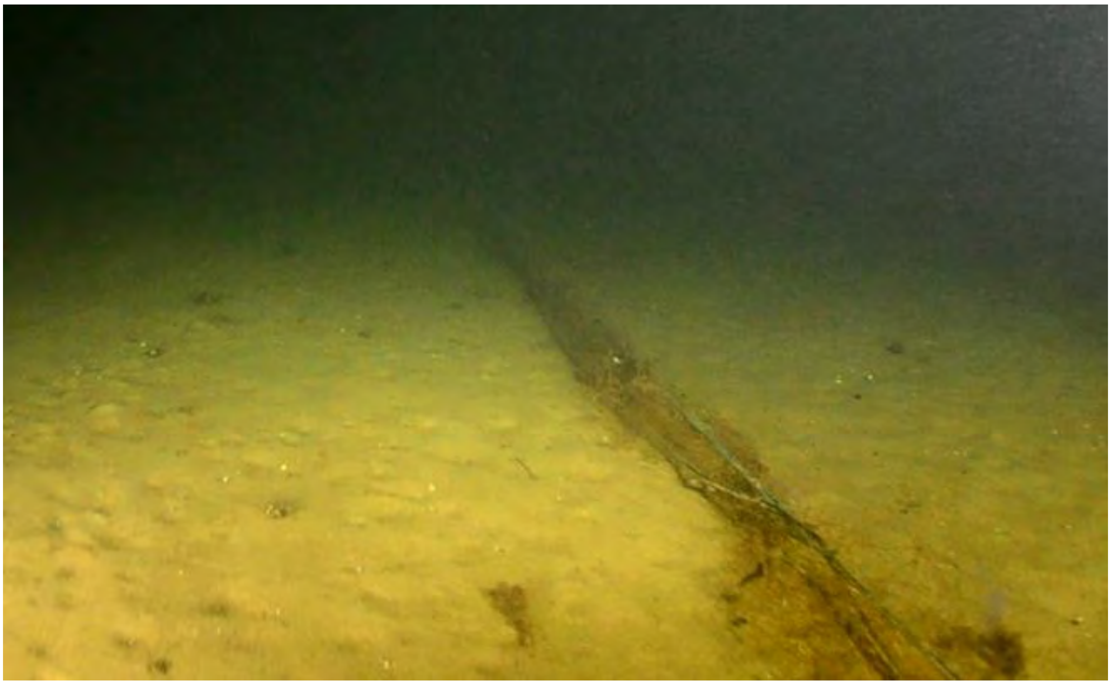


Net 400 m long fleets are "*marked*" every 100 m with a tire. Tires are attached between the four individual nets in the fleet. Nets in the fleets have different materials and varying mesh size etc.





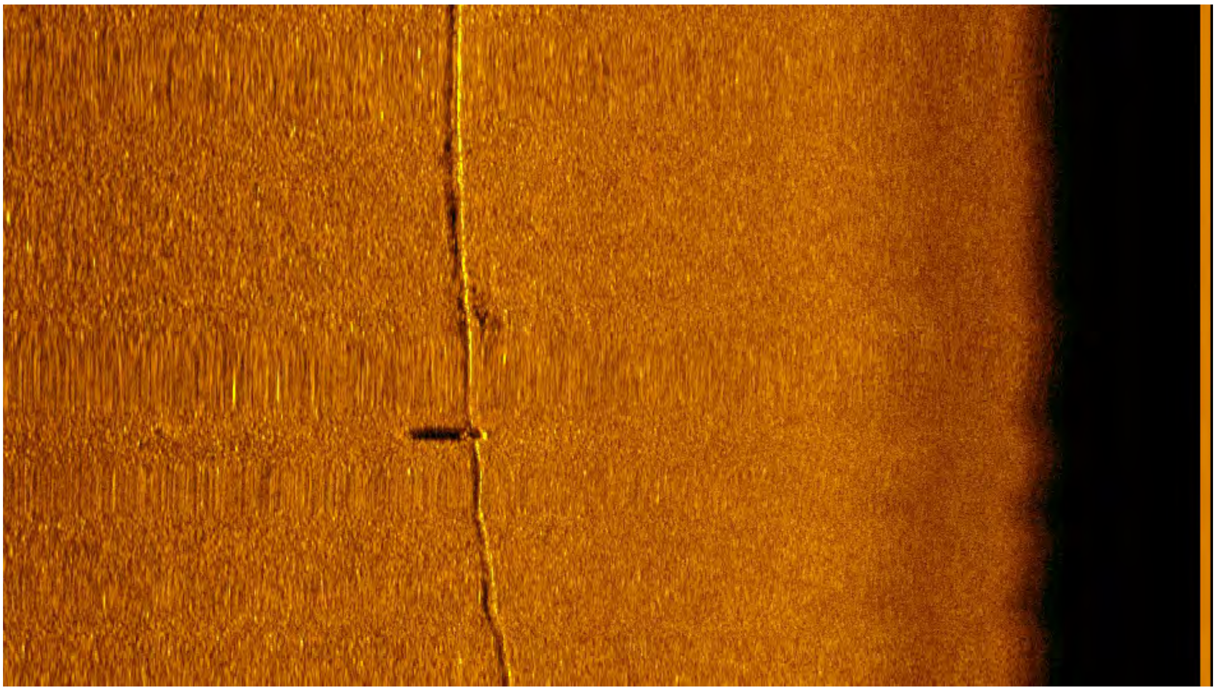
Net fleet in deeper water on a semi-hard/or mixed softer bottom



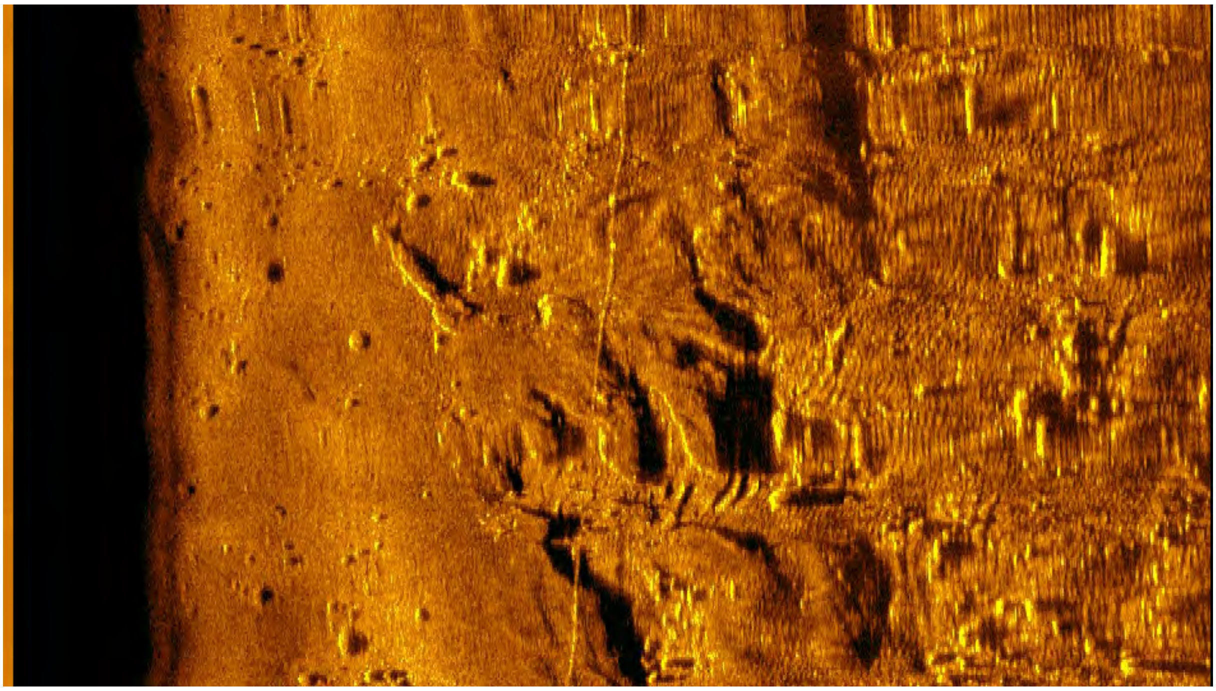
APPENDIX 3.

Two photographs from a monitor shows a net fleet clearly visible on a rocky seabed (picture to left) and on smooth soft seabed (picture to right).

APPENDIX 4.



An image (screen shot) showing the net fleet on the smooth seabed. A car deck (marker) is clearly visible as a circle on the image.



A net fleet seen running through a more rockier area but still it is easily reckonable.

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.

Project partners

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

More information

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