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Study on Circular Design of the Fishing Gear for Reduction of Environmental Impacts

EASME/EMFF/2018/011 Specific Contract No.1

Final Report

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LIST OF ABBREVIATIONS

Term	Description
ALDFG	Abandoned, Lost or otherwise Discarded Fishing Gear
BASF	Badische Anilin und Soda Fabrik
BIM	Bord Iascaigh Mhara
CE	Circular Economy
DG MARE	Directorate-General for Maritime Affairs and Fisheries
EASME	Executive Agency for Small and Medium Sized Enterprises
ECD	Environmentally Conscious Design
ECHA	European Chemicals Agency
EMFF	European Maritime and Fisheries Fund
EOL	End-of-Life
EPR	Extended Producer Responsibility
ePS	Expanded Polystyrene
ESO	European Standards Organisation
EU	European Union
FNRs	Fishing Nets and Ropes
GGGI	Global Ghost Gear Initiative
HDPE	High-density Polyethylene
HMPE	High Modulus Polyethylene
IMO	International Maritime Organization
ISO	International Organization for Standardization
KIMO	Kommunenes Internasjonale Miljøorganisasjon
NGOs	Non-Governmental Organisations
OSPAR	Oslo/Paris convention (for the Protection of the Marine Environment of the North-East Atlantic)
PA	Polyamide
PE	Polyester
PET	Polyethylene terephthalate
PP	Polypropylene
PRF	Port Reception Facilities
PS	Polystyrene
PVC	Polyvinyl Chloride
PVDF	Polyvinylidene fluoride
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
ROSES	RepOrting standards for Systematic Evidence Syntheses
SMEs	Small and Medium-sized Enterprises
SUP	Single Use Plastics
SVHC	Substance of Very High Concern

SUMMARY

Within this project we have collated and assessed the range of challenges and solutions in the circular design of fishing gear, while also developing and validating the Technical, Circularity and Environmental Recommendations needed to support the development of guidance standards for the circular design of fishing gear. The guidance standards will provide European organizations with an opportunity to establish, implement and maintain circular design of fishing gear as an integral part of design and development of fishing gear, by integrating corresponding recommendations into their related organizational procedures and instructions.

This project encapsulated 4 Tasks to comprehensively build an understanding of the challenges and solutions to the circular design of fishing gear, and advance recommendations for the development of guidance standards. These tasks firstly encapsulated a substantial literature review, stakeholder engagement and expert stakeholder workshop, to identify the existing challenges and solutions to development of circular design of fishing gears. This project then utilised these learnings to propose a range of draft recommendations for development of a guidance standard, examining potential logistic and technical issues that may facilitate or constrain the utility of such recommendations. This work then involved collating the main elements comprising these recommendations, and validated the utility of such elements. Lastly, this project provided final results, with particular attention to development of future recommendations on circular design of the fishing gear, including the framework to develop a request for guidance standards relating to the circular design of fishing gear. In addition, to aid the future development of guidance standards, this project also collates and assesses the range of future research and training needs.

Although there was clear utility for the use of a literature review to build a baseline of information on circular design of fishing gear, there was a paucity of information available using this method. This was likely associated with the relatively low amount of work being undertaken by institutes on the circular design of fishing gears. Although this project showed that particular institutes (e.g., predominantly within northern Europe and the United Kingdom) had groups dedicated to examining aspects of circular design, there was not a strong impetus within institutes to focus research time and funding to this topic. To facilitate further research therefore, we have provided within the final section of this report a detailed and relatively comprehensive list of potential research topics that may encourage further work within Europe, and globally on this topic.

The lack of published material available on the circular design of fishing gears was also due to the relatively high degree of work being undertaken by private companies (e.g., gear manufacturers, recyclers, and those within the wider fishing industry), and therefore a lack of public dissemination of (what was predominantly) on-going trials of new gear design and gear development. Therefore, to build a comprehensive baseline of information on circular design of fishing gear, this project devoted a substantial amount of time to undertaking interviews with key stakeholders, while also developing publicly disseminating and analysing a detailed questionnaire. This project found that the use of such methods was vital in developing a baseline of information, but also in furthering the wider range of tasks within the project (e.g., development of an expert stakeholder group to be involved with stakeholder consultation). We would argue that further development of circular design of fishing gear within Europe must inherently utilise expert stakeholder engagement. This project has shown that without such engagement, the majority of up-to-date and therefore important information to facilitate the development of recommendations is not available.

Interviews with key stakeholders and analysis of the outcome of the detailed questionnaire showed that the main challenges for the circular design of fishing gears

was associated with (i) low utility of current materials, and the high level of mixing of different materials reducing effective reuse/recycling; (ii) lack of legal obligation or lack of support for local obligations from environmental authorities; (iii) lack of support for development of alternatives and high cost of alternatives; (iv) low use of (or lack of suitable) collection points in ports; (v) High organic contamination of materials reducing ability to recycle; and (vi) logistical issues associated with the full value chain of recycling within Europe. The obstacles to overcome such challenges were found to encompass the (i) lack of regulations and legal structure to enforce recycling; and (ii) lack of financial incentives and high cost of recycling. However, most importantly, there was a clear understanding that the design of fishing gears did not facilitate complete re-use or recycling of fishing gears.

Therefore, this work, through stakeholder engagement and discussions within an expert workshop were able to assess and collate the main outcomes that are needed to facilitate the development of guidance standards for circular design of fishing gear. Such outcomes included the need to have a clear understanding of the environmental and economic costs of fishing gears across their full lifecycle. Such understandings would then allow gear designers and manufacturers to decide on which materials used in fishing gear design are most important to reduce or completely discard to enable a circular design. In this respect, there was a broad consensus for a reduction and eventual elimination of hazardous and non-recyclable materials within fishing gears. In addition, further development of fishing gear that encompass circularity in their designs must reduce the economic costs to manufacture and repair/maintain, and also reduce costs for pre-processing at end-of-life.

There was broad consensus that one of the most important mechanisms to enhance circularity in fishing gear design was to use a less diverse range of material types and materials comprising of a mix of materials. Mixed materials within fishing gear (whether associated with different components, or where two materials are interweaved together) inherently reduce the likelihood of the material being re-used and/or recycled. However, any reduction or elimination of such materials (and therefore use of alternative non-mixed materials) must not reduce the utility of the material (e.g., durability, performance) and the component they are used in.

The re-design of fishing gears within a circular economy must be associated with a high (or complete) use of recycled/reused materials, with the gradual elimination of virgin plastics within new gear. However, importantly there must also be continual research and development to assess and critique further development of materials that are partially (or wholly) manufactured with recyclates. Such research and development will be vital, as the current project showed that there is an inherent distrust within the fishing industry in the use of recyclates in the development of new fishing gears. The main issue discussed was a proposed reduction in the utility of the material comprising high recyclates, including reduced performance, durability and product lifetime. In this respect, to facilitate the uptake of newly re-designed fishing gears by the industry, there is a clear need to work closely within this industry in innovation and development of new technologies.

The success of this project has been the close working relationship between the Commission, the consortium undertaking the work, as well as the industry stakeholders. This has been a vital way of working within the project, as it provided the platform to requesting expert opinion, but also enabled all relevant stakeholders to debate and recommend the factors that are important in developing guidance standards in circular design. This also allowed the project to effectively develop a range of recommendations, but importantly disassemble such recommendations into their elements and have such elements validated. Such validation was vital to enable input of stakeholders already invested in the project, but also the wider audience of stakeholders that either were not aware, or had not been able to engage with the project. The final development of guidance standards for circular design of fishing gear will inherently need to be

supported by this wider industry of stakeholders, potentially providing a much more robust development of such guidance standards.

This study has been important as it identified relevant stakeholders for development of guidance standards. These included organizations that are designing and developing fishing gear (directly concerned by the standards) and organizations that are indirectly concerned by fishing gear design stage e.g. producers, manufacturers, importers, repairers, performers of preventive maintenance, assemblers, recyclers and/or users of fishing gear in real life conditions (fishing and aquaculture). Importantly, this work has also identified the role of stakeholders that are concerned by negative environmental impacts of fishing gear lost at sea or mismanaged at end of life. Such identification has also provided an understanding of the main experts to engage with in development of a technical committee to work with the European Standards Organisation in developing guidance standards. In this respect, this project has supported the development of Eurocords (European Association of Rope, Twine and Netting manufacturers, their suppliers and their affiliate industries) Technical Committee 3 (Life Cycle Management & Circular Design of Fishing Gear). This committee has been developed within the industry to enhance understanding of the potential impacts of the EU Directive on Plastic waste (June 2019) on the fisheries industry within Europe; this committee is now supporting the development of a request to the European Standards Organisation (ESO) for development of a guidance standards for circular design of fishing gear. In addition, as the writing of the guidance standard is undertaken and supported by technical experts with knowledge on the content (who sit within a technical committee (TC) for development of such guidance standards), the workshop and wider discussions between stakeholders associated with the workshop will provide a range of stakeholders that will be part of that process.

Of the main outcomes of this work, there is a clear need to further the research and development to support the circular design of fishing gears. In this respect, this project has been able to effectively collate, assess and report the range of research programmes that will be needed to support guidance standards development. This work has shown the need to undertake further research on product requirements at the design and development stage, while also evaluating the consequent positive impact on gear performance and on the environment at any life cycle stage. Such impacts could include legal requirements, technical standards, voluntary agreements, customer requirements and specifications, and requirements from internal functions (e.g. logistics, production/service/maintenance, sales, procurement etc.). Such research programmes will be vital in furthering the development of such guidance standards, but also in highlighting the need within the wider industry to focus and utilise resources to effectively redesign, manufacture and have on the market viable alternatives to fishing gears so that fishing gear in future never becomes a waste.

1 INTRODUCTION

Plastics are synthetic organic polymers that can be easily moulded into different shapes and products for a large variety of uses. Invented only 110 years ago, plastics are now the most widely used man-made material and have become omnipresent in every aspect of our lives. From medical supplies and water bottles to food packaging, clothing, and construction materials, every person now disposes an average of 52 kg of plastic waste every year[1]. Geologists are now considering a plastic horizon in the world's soils and sediments as one of the key indicators marking the current geological epoch, the Anthropocene[2].

[1] Jambeck JR, Geyer R, Wilcox C, Siegler TR, Perryman M, et al. 2015. Plastic waste inputs from land into the ocean. Science 347:768–71
[2] Waters CN, Zalasiewicz J, Summerhayes C, Barnosky AD, Poirier C, et al. 2016. The Anthropocene is functionally and stratigraphically distinct from the Holocene. Science 351:137

Concerns about plastic release into the environment were at first non-existent. The material was seen as benign, due to its inertness and perceived lack of toxicity. As a result, an estimated sum total of 5Biot tonnes of plastic has been discarded into landfills and the environment since 1950[3]. This led to increasing concerns about pollution, particularly in the oceans, with some actions by governments to stem the growing tide of plastic debris. The International Convention for the Prevention of Pollution from Ships (MARPOL) was signed in 1973, although a complete ban on the disposal of plastics at sea was not enacted until the end of 1988[4]. At the same time, waste disposal practices and recycling capacities improved, particularly in highly industrialized countries, leading to better waste management and lower release of plastic waste into the environment.

Plastic pollution has now become widely recognized as a major global environmental burden[5,6] particularly in the oceans where the biophysical breakdown of plastics is prolonged,[7,8] effects on wildlife are severe[9,10] and options for removal are very limited[11,12].

There has been a recent shift in strategy within the EU regarding plastics, with the development of initiatives within the European industry towards a more circular plastics economy. In support of this, in 2019 the European Parliament and Council adopted two Directives that will make a significant contribution to the reduction of marine litter from sea-based sources. First, the revised Port Reception Facilities (PRF) Directive[13]. Up until now, ports have been able to charge fishermen for bringing retrieved abandoned, lost or otherwise discarded fishing gear (ALDFG) ashore over and above their normal fee. The revised PFR Directive introduces indirect fee and consequently removes this disincentive. Second is the Single Use Plastics (SUP) Directive[14], which addresses 10 most common single use plastic items found on European beaches as well as end-of-life fishing gear and ALDFG, foresee introduction of the Extended Producer Responsibility (EPR) for fishing gear as from 31/12/2024. Within this Directive producers of fishing gear containing plastic will have to take on the responsibility (and costs) for separate collection, transport, treatment and awareness raising measures of fishing gear. This has been brought in to reduce port costs for fishers, particularly in small fishing ports, and potentially accelerate the development of a dedicated waste stream for fishing gear waste.

In support of the PRF and SUP Directives, there are several challenges that need to be examined. The majority of producers of ropes and netting for the fishing industry are dominated by Small and Medium Sized Enterprises (SMEs), with a small number of large producers of fishing gear. In addition, there are substantial logistic issues across the entire value chain of fishing gear, from collection and retrieval at sea by fishermen (or other groups), to bringing and unloading in ports, collecting in ports, transporting to recycling facilities, performing mechanical and chemical recycling, and producing new products from recycled fishing gear. To date, all of the available work that has examined the issues surrounding logistics have focused solely on End-Of-Life (EOL) fishing gears - there are no successful efforts globally to recycle ALDFG, with all material incinerated

[3] Geyer R, Jambeck JR, Law KL, 2017. Production, use, and fate of all plastics ever made. Scientific Advances 3(7):e1700782
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[5] Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP), ed. 2016. Sources, Fate and Effects of Microplastics in the Marine Environment: Part Two of a Global Assessment. London: Int. Mar. Org
[6] Rochman CM, Browne MA, Halpern BS, Hentschel BT, Hoh E, et al. 2013. Classify plastic waste as hazardous. Nature 494:169–71
[7] Derraik JG 2002. The pollution of the marine environment by plastic debris: a review. Marine Pollution Bulletin 44:842–52
[8] Wilcox C, van Sebille E, Hardesty BD, 2015. Threat of plastic pollution to seabirds is global, pervasive and increasing. Proceedings of the National Academy of Sciences 38:11899–904
[9] Kaiser J 2010. The dirt on ocean garbage patches. Science 328:1506
[10] Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP), ed. 2016. Sources, Fate and Effects of Microplastics in the Marine Environment: Part Two of a Global Assessment. London: Int. Mar. Org
[11] Thompson RC, Olsen Y, Mitchell RP, Davis A, Rowland SJ, et al. 2004. Lost at sea: Where is all the plastic? Science 304:838
[12] Jambeck JR, Geyer R, Wilcox C, Siegler TR, Perryman M, et al. 2015. Plastic waste inputs from land into the ocean. Science 347:768–71
[13] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019L0883&from=IT
[14] DIRECTIVE (EU) 2019/904 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 5 June 2019 on the reduction of the impact of certain plastic products on the environment. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019L0904&from=EN

or dumped in landfills. Lastly, there are substantial problems with the current design of fishing gear in terms of environmental impact at end-of-life.

At present, six raw polymer types are utilised to manufacture the majority of nets within Europe: Polyamide (PA), Polyester (PES), Polyethylene (PET), Polypropylene (PP), Aramid, and High-density polyethylene (HDPE). However, within the current design of fishing nets within Europe, there is up to 700 different combinations of these polymers and other materials. Such mixing of different raw materials, although potentially important for the use of the fishing gear, makes it nearly impossible to recycle as a single unit. Furthermore, there is a range of other factors that reduce the likelihood of fishing gear being recycled, including the use of materials within nets that are toxic or unrecyclable (i.e., lead shot in sink lines), the likelihood that collected gear may have been contaminated (i.e. sand, salt) or other man-made material mixed, the small number of recyclers within Europe (two predominate; Plastix and Aquafil) and the need to provide to these recyclers cleaned and sorted gears, as well as the lack of agreed standards for circular design of fishing gear.

This Specific Contract forms part of a wider array of work undertaken by the EU in the development of the Circular Economy[15], and supports the recent EU Strategy for Plastics in a Circular Economy[16]. This is the first EU-wide policy framework adopting a material-specific lifecycle approach to integrate circular design, use, reuse and recycling activities into plastics value chains. The strategy sets out a clear vision with quantified objectives at EU level, so that amongst other things, by 2030 all plastic packaging placed on the EU market is reusable or recyclable.

1.1 Aims and objectives

This project has two main aims:

- To better understand the recyclability of ALDFG and end-of-life fishing gear by identifying existing challenges (legal, practical) to collect, redesign, reuse and/or recycle ALDFG and end-of-life fishing gear, best available practices and technologies, voluntary commitments and certification processes (International Organization for Standardization (ISO) etc)

- To propose recommendations for effective, useful and harmonized standard on circular design of fishing gear.

The objective of this work is to provide the background and information necessary in supporting the European Commission in requesting the European standardisation organisations to develop a harmonised standard and guidance relating to the circular design of fishing gear to encourage preparation for reuse and facilitate recyclability at EOL (this standard request is provided in more detail in Annex 1).

1.2 Approach

This project was encapsulated within 4 Tasks (see Annex 2 for detailed methods). Task 1 was to utilise a comprehensive literature review, stakeholder engagement (online questionnaire) and expert stakeholder workshop to identify the existing challenges and solutions to development of circular design of fishing gears. Task 2 then utilised the learnings from Task 1, especially those associated with the stakeholder engagement workshop, and proposed a range of recommendations for circular design of fishing gear. Within this section we discuss the potential logistic and technical issues that may facilitate or constrain the utility of such recommendations. Within Task 3 we then

[15] Circular economy is 'restorative and regenerative by design, and it aims to keep products, components and materials at their biggest utility and value at all times, distinguishing between technical and biological cycles" (Ellen MacArthur's Foundation)
[16] 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 COM/2018/028 final

collated the main elements comprising the recommendations, and then utilising a second online survey questionnaire, validated the utility of such elements for development of guidance standards for circular design of fishing gears. Task 4 developed to provide the final results of the project, with particular attention to the development of future recommendations on circular design of the fishing gear as well as (in addition to that originally stated in the Terms of Reference), providing the framework to develop a request for guidance standards relating to the circular design of fishing gear.

To further support the development of a standard and guidance for circular design of fishing gears, throughout this project we have collated and assessed the range of future research and training needs that stakeholders have argued are necessary. Such collation of research questions occurred within both the 1st (Task 1) and 2nd (Task 3) online questionnaires, as well as within the substantial workshop (Task 1). Therefore, within this project we have developed a further task (Task 5) that has collated and synthesised the range of research questions posed throughout the project. This is provided at the end of the report, and is a substantial and informative baseline of the future research needs in supporting the development of guidance standards for the circular design of fishing gears.

1.3 Structure of the report

Section 2

This section outlines a brief methodology, and then describes the outcomes of a substantial literature review and expert stakeholder questionnaire that examined all key legal and practical challenges and solutions for the development of harmonised standards for circular design of fishing gears.

Section 3

This section provides a full description of the proposed recommendations for the circular design of fishing gears following a substantial stakeholder engagement. Within this section we also draw on discussions with expert stakeholders and provide an assessment of the utility of each recommendation (where possible), as well as the likely factors that may facilitate or constrain the usefulness of the recommendation proposed.

Section 4

This section provides the outcomes of a critical assessment of the main elements comprising each of the proposed recommendation, assessing their validity and likelihood to form an important component for the development of a guidance standard for circular design of fishing gears.

Section 5

This section outlines and discusses the learnings from all three previous tasks to provide a synopsis of the main aspects needed to be encompassed to facilitate the development of harmonized standards for the circular design of fishing gear.

Section 6

This last section of the report collates and assesses the range of future research and training needs that stakeholders have stated are necessary to support development of such standards.

2 TASK 1: IDENTIFICATION OF EXISTING CHALLENGES AND SOLUTIONS

Within this section we utilise a substantial literature review and expert stakeholder questionnaire to determine and assess all key legal and practical challenges and solutions for the development of harmonised standards for circular design of fishing gears. Detailed methods for all three aspects of this task are listed in Annex 2; a brief synopsis of the methods and a detailed discussion of results are provided below.

2.1 Sub-task 1.1 Literature Review

This sub-task encompassed collating and reviewing all available primary, secondary and grey literature globally to determine and assess all legal and practical 'challenges' and potential solutions in the collection, redesign, reuse, recycling and/or monitoring of recycling of ALDFG and EOL fishing gear, as well as determining best available practices and technologies addressing all challenges, including those associated with voluntary commitments to practices and any certification processes utilised globally for recycling. In detail we examined the literature to answer three questions:

- **Primary question:** What are the legal and practical 'challenges' and best available practice/technologies for the collection, redesign, reuse, recycling and/or monitoring of recycling of ALDFG and EOL fishing gear?

- **Secondary question:** What voluntary commitments have been undertaken to address challenges in the collection, the collection, redesign, reuse, recycling and/or monitoring of recycling of ALDFG and EOL fishing gear and what have been their effect?

- **Secondary question:** What certification processes have been undertaken to address challenges, and what have been their effect?

Forty-six relevant publications were assessed, encapsulating papers from 2010 to 2019. We found that there was a relatively global distribution of interest in understanding challenges and potential solutions, with literature encompassing work within Africa, Australia, Belgium, Brazil, Canada, Caribbean, Germany, Iceland, India, Indonesia, Kenya, Korea, Macedonia, Netherlands, New Zealand, Norway, Portugal, South Korea, Spain, Taiwan, Turkey, UK and USA.

Of the available literature, the vast majority was based solely on examining factors associated with ALDFG, including collection, monitoring, redesign, recycling and reuse. Of these papers, the predominant topic was associated with understanding how best to collect and/or monitor ALDFG (i.e., associated with reactive management). Proactive management of ALDFG (i.e., papers encapsulating redesign to reduce ALDFG) was only examined in 9 publications, while of the small number of papers examining EOL (i.e., either ALDFG and EOL, or EOL only), only 1 discussed factor associated with the redesign of fishing gears.

Primary question: What are the legal and practical 'challenges' and best available practice/technologies for the collection, redesign, reuse, recycling and/or monitoring of recycling of ALDFG and EOL fishing gear?

Of the publications that discussed issues with recycling of materials as a possible means to reduce ALDFG and/or EOL, the majority were not written as technical proposals to develop recycling, but discussed the factors that may enhance recycling, and the need to establish policy and regulatory frameworks to support such activities. Of the publications that did mention technical aspects of recycling (i.e., solutions to enhance recycling), especially associated with the design of fishing gear, only two ideas were proposed. These have been summarised below:

Thermomechanical recycling: One publication[17] discussed the possibility of thermomechanical recycling of polyamide 6 (PA6) from waste fishing nets. This work suggests that for purse seine nets and for particular material within those nets (i.e., PA 6), thermomechanical recycling resulted in recycled pellets that could be reused. Such work showed that thermomechanical processing after commercial marine use did not greatly affected the final properties of the plastic, showing similar characteristics to virgin plastic and the potential to reuse such plastic in similar applications to those of pristine PA-6.

Recycling of material for secondary products: One study, although not circular in designation, discussed the use of synthetic fibres coming from fishing gear in the reinforcement of mortar and other material for building purposes.

Of the publications mentioning redesign of fishing gear, the majority were not written as technical proposals to develop redesign, but merely discussed the potential for design to facilitate recycling, reuse etc., and the need to establish policy and regulatory frameworks to enhance such design. Of the publications that did mention technical aspects of design, only two ideas were proposed. These have been summarised below:

Use of biodegradable materials: Two studies discussed the potential use of biodegradable nets as a feasible solution to reducing ALDFG, though did not propose how this could occur or the potential impacts such materials would have on the wider environment (i.e., as biodegradable materials may degrade into macro- or micro-plastics).

Replacement of existing materials: Two studies proposed replacement of existing multifilament polyamide twine (e.g., in hoop nets, but could be utilised throughout any type of net) with alternative multi-monofilament and monofilament PA twines.

Secondary question: What voluntary commitments have been undertaken to address challenges and what have been their effect?

Seventeen relevant publications were assessed which examined voluntary commitments, encapsulating papers from 2013 to 2019. We found that there was a relatively global distribution of voluntary commitments, with the literature encompassing work within Australia, Canada, the European Union, Iceland, India, Korea, Macedonia, Taiwan, the UK, the USA (Hawaii, Massachusetts) and globally.

Of the available literature, the majority were based around voluntary commitments associated with ALDFG, or ALDFG and EOL, with only two studies focusing entirely on EOL. Of this work, the predominant studies examined voluntary commitments to enhance the collection and/or monitoring of ALDFG and/or EOL.

Of the two publications that examined voluntary commitments encapsulating recycling, one examined the need to promote the collection, disposal and recycling of used gear, with no technical aspects associated with how to enhance such mechanisms. The other publication discussed a project where regional people from several communities engaged in traveling through districts during a fishing season to buy old nets from fishermen for recycling – again, no technical discussion of the process in recycling was provided.

Of the five publications identified that had examined voluntary commitments in terms of redesigning, one was solely discussing the utility in redesigning gear to increase recyclability (although no technical aspects were discussed), while three publications were solely associated with designs that could reduce potential ghost fishing, if the gear was discarded or lost (i.e., use of biodegradable gill nets, use of escape panels in gill

[17] https://onlinelibrary.wiley.com/doi/abs/10.1002/app.48442

nets, use of weak links to increase the likelihood of gill nets breaking down quickly). Only a single study examined voluntary commitments in redesigning fishing gear for reducing plastic waste, though was based on designs associated with biodegradable buoys and rafts on oyster farms.

Secondary question: What certification processes have been undertaken to address challenges, and what have been their effect?

Only two of the three publications collated on certification processes to address challenges were inherently useful for this project. Both publications focused on the development of certification processes for Styrofoam buoys, with the first describing the process for a certification system for environment friendly buoys, and the second discussing the potential importance of covering buoys with polyethylene or a plastic bag in certifying them as environmentally friendly.

2.2 Sub-task 1.2 Stakeholder engagement

To further understand the range of challenges and solutions to the development of circular design of fishing gear, a detailed questionnaire was developed and to answer three main themes of question (Annex 3):

- Challenges (legal and/or practical) that are linked to the reuse /design /recycling /manufacture of fishing gear
- Barriers associated with fishing gear recycling
- Understanding design standards for fishing gear

The objectives of this questionnaire were to collate up to date understanding of the challenges to the design and recycling of ALDFG and EOL fishing gear, while also gathering examples of best practice of design and recycling, as well as labelling and standardisation of design.

There were forty-one responses to the questionnaire (26% of stakeholders identified), which included fourteen key participants who were interviewed over the phone. Respondents answering the questionnaire encapsulated the majority of the sectors listed, with the only sector not covered by individuals within eco-labelling/ ISO certification/ standardization organisations (Figure 1). Of respondents, the majority listed their sector as non-governmental, while a relatively high percentage of respondents stated they were either within organisations that could be described as (i) fishing gear manufacturers/assemblers and/or suppliers, (ii) national or regional governments, or international organizations, or (iii) port authorities.

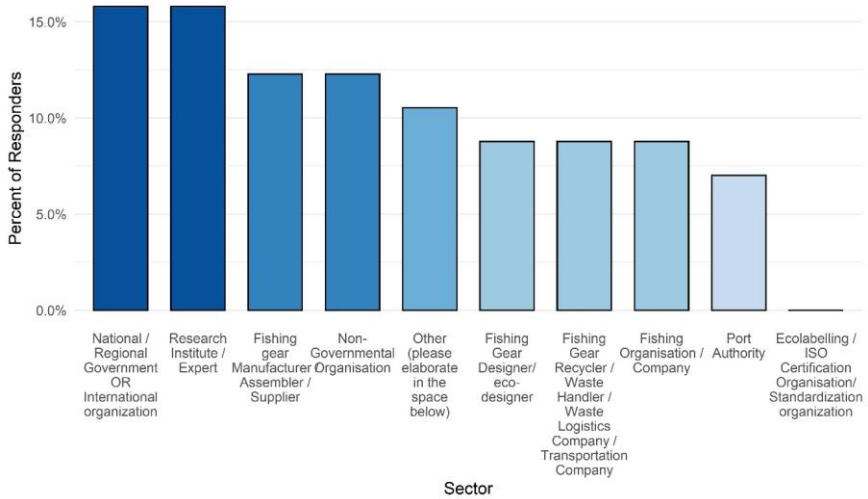

Figure 1: Sectors to which questionnaire respondents were aligned

Respondents were asked to state how their organisations were involved with fishing gear. Respondents represented companies that were involved with plastic materials, including processing and recycling of plastics. Specifically, one respondent was part of a company that was involved in developing alternatives for lead in recreational fishing, and producing fishing weights. This company supply alternatives to fishing weights based on iron and bio-degradable bio-polymers, while also being involved with the development of alternatives for dolly rope (called "pluis" in the Netherlands, and "spekking" in Belgium).

Several respondents represented NGOs or groups interested in the development of policy associated related to the SUP and PRF Directives, including inputting into stakeholder engagement sessions and providing technical expertise. Such respondents were active in international industries on the topics of shipping and marine litter, including IMO and OSPAR. Importantly, a range of respondents represented groups that were involved with European research groups (e.g., IPA-Adriatic DeFishGear project, Smart NET, MARELITT Baltic), which have been associated with targeted recovery of 'ghost nets' from the sea with the direct involvement of fishermen and divers; establishment of derelict fishing gear management schemes to collect and recycle lost or abandoned fishing nets and other gear.

Several respondents were associated with (or worked as) port authorities, dealing with the logistics associated with waste nets and marine litter. Such respondents were also part of a local organisation, which included those representing fisherman, net manufacturers, government agencies and recycling centres.

Several respondents were involved with local or regional projects to design, trial and implement more selective fishing gears for the purpose of reducing discards, as well as develop better methods to collect, recover and recycle fishing gear. Lastly, such respondents were predominantly also examining technological methods to reduce marine litter, and increase fishing gear recycling capacity.

Challenges (legal and/or practical) that are linked to the reuse / design / recycling / manufacture of fishing gear

There is a range of factors that respondents provided in understanding the challenges to the reuse / design / recycling / manufacture of fishing gear. Below we provide a brief summary of the major factors discussed.

Certain materials within fishing gear reduce likelihood of recycling

- A range of fishing gears utilise lead in sink lines (or as weights) that need to be removed to allow recycling of the fishing gear, as well as for incineration or communal landfill. As lead is on the Substance of Very High Concern (SVHC) list of the EU, if lead is not removed then such fishing gear is classified as a hazardous waste, and placed within open-air landfills. In addition, if the fishing gear is fouled with organic matter this may reduce the likelihood of recycling, due to the high economic costs needed to effectively clean the material before recycling. If cleaning of the material is not undertaken then the gear is prohibited from being disposed of within under-ground hazardous waste facilities.

No legal obligation or lack of support for local obligations from environmental authorities

- Respondents that identified as Gear designers and/or Gear manufacturers felt there was a lack of legal obligation or a lack of support from environmental authorities' in taking action to enhance recycling of fishing gear. For example, such respondents stated that authorities were not enforcing relevant environmental laws and accepting non-compliance with Registration, Evaluation,

Authorisation and Restriction of Chemicals (REACH) information obligations in the selling of lead products to consumers (i.e., within angling shops).

- Respondents that identified as representing NGOs also stated that in some Member States there are legislative issues related to the recovery and disposal of ALDFG, as these may be considered as a special category of waste, and thus there are special disposal obligations connected to these. There was also little legal responsibility for design of recyclable fishing gears, and the recovery of lost fishing gear.

Lack of support for development of alternatives and high cost of alternatives

- One respondent identified as representing NGOs stated that a lack of support for start-ups with proven technology providing alternatives to non-recyclable materials (i.e., lead) was hindering recycling of fishing gear. In addition, one respondent stated that alternatives for different materials were still costly, leading to less alternatives being utilised in fishing gear.
- There are smaller actors within Europe that deal with fishing gear e.g., *Fishy Filaments* in Cornwall, UK and other small and medium-sized enterprises (SMEs) looking at local remanufacturing options for fishing gear through the use of extruders and 3D printing. However, the development of such industries is needed to be supported by local, regional or national government grants and incentives.

Issues to do with logistics of fishing gear collection in port

- Several respondents identifying as representing NGOs and Gear recyclers stated that difficulties in setting up enough collection points for end-of-life fishing gear was a challenge. For example, in countries with extensive coastlines (e.g., Greece, Croatia) a lot of landing sites are remote from major ports, therefore reducing the likelihood that fishermen would go to these ports to dispose of their fishing gear. In addition, although not stated by respondents, DG MARE is aware that logistic difficulties in fishing gear collection in port is also associated with the new obligations for separate collection points for different types of waste fishing gear.

Issues with the variety and number of materials used in fishing gear and where these come from

- There was a range of respondents across the majority of stakeholders that stated that fishing gear containing multiple types of polymers and multiple parts make it difficult to disassemble, reuse and recycle. Specifically, many fishing gears are comprised of a range of different materials (e.g., trawl nets contain nylon, polypropylene, polyethylene, steel, rubber amongst others), which is exceptionally labour intensive to disassemble, and can be impractical with current technology to separate into individual recyclable streams. One respondent stated that it was difficult to disassemble Nephrops trawl gear, despite different parts of the gear becoming unusable over time (before wear and tear reduce the efficiency of the net). For example, different metal parts become corroded, while netting material in cod ends often becomes unusable due to net shrinkage and becoming too small to legally be used as a cod end.
- One respondent, identified as representing NGOs stated that most parts of fishing gear are produced outside of the EU and only get assembled within the EU. Eurocord had stated that approximately half of ropes and nets come from outside Europe. As a result, there is less control on the supply chain to regulate the quality of the fishing material (and the likely recyclability of it).

High organic contamination of gear reducing ability to recycle

- Several respondents (predominantly those representing NGOs and gear recyclers) stated that contamination of EOL or ALDFG with natural materials (e.g., sediments, water or biological particles) increased the difficulty to recycle, and therefore the likelihood of being recycled. In addition, recycling of contaminated fishing gear may also result in a low grade undesirable product, which cannot be reused in the human food chain of plastics. Lastly, fishing gear if not appropriately cleaned and prepared may also be categorised as hazardous biological waste (which will have impacts on storage, transport and recycling).

Logistics associated with the full value chain of recycling

- Organising the collection, cleaning, segregation and transportation of large volumes of nets presents unique challenges in each region and will influence the success of any recycling project. The process of identifying the material types and ascertaining the best method to undertake the labour-intensive task of separating and cleaning fishing nets before disposal is a critical component of the collection process prior to recycling. Installation of portside reception facilities, establishing partnerships with surrounding fishing syndicates, ensuring nets are appropriately cleaned and separated by material type, high transportation costs and the high volumes of nets required to make the numbers work are common themes across regions. Most of the current successful models focus on collecting the nets directly from the fishermen as soon as they meet their end-of-life, as opposed to seeking them for collection on beaches and waterways, as recovered ghost nets are usually heavily fouled and thus require an extra layer of labour (cleaning) before they can be reliably recycled. In addition, recycling can also come with a high environmental/health/economic cost (i.e., chemical recycling), while also resulting in recycled plastic that is more expensive than virgin plastic.

Low level of capability to recycle in Europe

- In Europe, there are only two companies working with the fishing industry and aquaculture to collect, dismantle and recycle fishing nets and other related products made from a range of source materials. Nofir AS is a Norwegian company that collects and recycles or repurposes discarded equipment from commercial fishing and fish farming around Europe and Turkey. Collected material is transported to the factory in Lithuania or Turkey, where it is dismantled and prepared for recycling. Nofir work in partnership with Aquafil in Slovenia to turn the recycled nets into regenerated polymers which are then used in products such as socks, swimwear, and carpet tile. Plastix Global has created a recyclate called OceanIX HDPE made from discarded fishing nets. They work with partners around the world to collect and recycle a range of fishing gears to create their OceanIX pellets. At their facility, they are able to handle the cleaning, separation, cutting and recycling of a variety of different net materials.

What are the main obstacles to addressing the identified challenges?

Respondents were asked to state the main obstacles to addressing the range of challenges to the reuse / design / recycling / manufacture of fishing gear. We summarise these below.

Logistics associated with the full value chain of recycling

- Respondents stated that complex portside logistics were major obstacles to addressing the range of challenges to the reuse / design / recycling / manufacture of fishing gear. These included: lack of available space to store old gear for collection, contamination of disposal / reception facilities by fly-tippers, poor portside coordination on the cleaning and separation process. In addition, there is still a lack of recycling centres to deal with fishing materials, including

available sorting and dismantling facilities (only known examples: Smögen Fisheries Association Norden, Nofir dismantling plant in Lithuania). Lastly, there were still substantial difficulties in separating materials for recycling and in places such material was hard to access at quaysides.

Lack of regulations and legal structure to enforce recycling

- Several respondents (predominantly NGO and gear manufacturers) stated a lack of willingness or commitment by environmental authorities to enforce applicable laws on substances of very high concern (i.e., lead) reduced the likelihood of fishing gears being recycled.

Lack of financial incentives and high cost

- Respondents (predominantly gear recyclers) stated that there was a lack of financial incentives to compel fishing vessels to deliver old or derelict fishing gear (i.e., lack of compensation for fishers engaging in good practice (in some areas) therefore disincentivising participation). In addition, the cost of dismantling (separation of different components of nets), available and easily accessible storage facilities, contaminated gear, recycling facilities and (sometimes long-distance) transport to recycling facilities were major obstacles. Such costs were also high as there was no company willing to pay for gear to be dismantled and transported, while no obvious or close by markets for the components from which the fishing gear is made to be sold into were high obstacles. Lastly, costs incurred by and availability of labour to whatever party is assigned the role of separating component materials were also obstacles.
- Respondents (predominantly NGOs and gear recyclers) also stated that the low cost of virgin plastic (PE and PP) material and the higher cost of recycled plastic material was a major obstacle. In addition, the quality of materials produced after recycling may be inferior to new materials.

Low awareness to current approaches and environmental impact of different materials

- Some respondents (mainly Government or International Organisations) stated that there was a lack of awareness about the possibility and approaches for collecting and recycling fishing gear, with a major obstacle being lack of awareness of waste managers of how to deal with fishing gear. There was also a lack of communication (and therefore understanding) of the issues associated with different components of fishing gear (i.e., lead), with fishers lacking awareness regarding lead as a hazardous waste, and therefore mixing these with household or commercial waste. In addition, fishermen are not aware that ALDFG may decompose into micro- and nano-plastics, and this can have a profound effect on the basis of the marine food chain through its impact on the plankton.

Technical aspects of fishing gear design

- Major obstacles to effectively designing new gear were the lack of standardised approaches to gear labelling, lack of standardised approaches to marking to ensure traceability of fishing gear, and low knowledge of component materials. In addition, one respondent stated that fishing gear is designed for functionality at present, with no waste management considerations. Lastly, respondents stated that there was currently no method available to recycle treated nets (treated with copper or antifouling), or long-term lost gear (ALDFG).

Voluntary actions being taken to reduce the impact of, or remove, challenges.

- Several projects were identified that supported voluntary actions. These included projects to enhance lead replacement in recreational angling (Green Deal Sportvisserij Loodvrij), as well as the development of biodegradable alternatives

for dolly rope (Een alternatief voor Pluis). The Global Ghost Gear Initiative (GGGI), which supports recreational divers collecting ghost gear was also stated, while the KIMO/OSPAR training programmes for fishers on waste management in Iceland, and recycling of fishing gear in Sweden were highlighted. Lastly, a number of programs (e.g., BIM net Recycling, Circular Ocean initiative) were stated where solutions to the practical problems of recycling have been explored.

- Respondents also mentioned several instances where fishers would voluntarily reuse different parts of fishing gear, including removing lead lines for reuse when sorting out nets, while individuals on small vessels re-using cod-ends that had previously been used on large vessels but where the mesh had now shrunk in size.
- One respondent (researcher) also stated that there were ongoing projects utilising waste fishing gear to produce new retail goods, for example SEA2SEE recycling fishing gear into fashion glasses[18].

Barriers associated with fishing gear recycling

This second theme of the questionnaire examined the range of issues associated with understanding the barriers to fishing gear recycling.

Respondents were firstly asked to provide details regarding the top barriers to implementation of fishing gear recycling. Respondents' answers showed that there was a broad range of obstacles to fishing gear recycling, with the most associated with logistical difficulties, while factors associated with gear design and lack of funding and costs associated with recycling were also highly cited (Figure 2). Interestingly, all of the other potential issues provided to respondents to rank were identified within the survey. Most importantly, following barriers associated with logistics, other issues such as gear design and funding, the contamination of fishing gear, challenges associated with the recycled product and technological challenges were all highlighted as important by respondents.

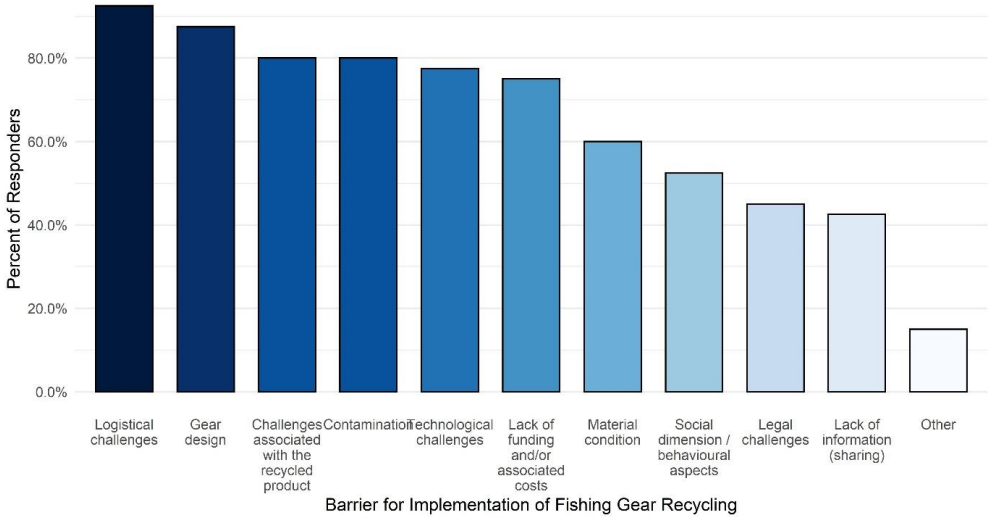

Figure 2: Top barriers to implementation of fishing gear recycling

Several respondents stated that there were other barriers (not listed in the questionnaire) that were important to understand. These were the fact that alternatives to the materials used in fishing gear (i.e., alternatives that were more likely to be recyclable than materials currently being utilised) were predominantly more expensive and sometimes not as good as the material they replace (Gear manufacturers). As users

[18] https://www.sea2see.org

were more than likely not prepared to pay an extra price for more recyclable materials, the likelihood of being used in fishing gear was low. Respondents also stated that although the use of lead in fishing gear has been banned in areas, as regional and or national environmental authorities may refuse to enforce the EU and national laws, the use of such materials has not reduced (Gear manufacturers and those representing NGOs). Lastly, respondents (Gear recyclers) stated that the annual volume of EOL nets was still too low to be economically viable for recycling companies to recycle such fishing gear.

Respondents were asked to identify the top three barriers to fishing gear recycling (Figure 3). Across respondents all barriers listed in the questionnaire were classified (by at least one respondent) as being a 'major' obstacle. Of all of the barrier, logistical difficulties, factors associated with gear design, and lack of funding and costs associated with recycling were the most likely to be identified as the top barrier. There was a reduced number of barriers that were systematically classified as second or third-most important by respondents. Gear design was highly likely to be identified as the second most important barriers, while both logistical difficulties and challenges associated with the recycled product were highly likely to be classified as the third most important barrier by respondents.

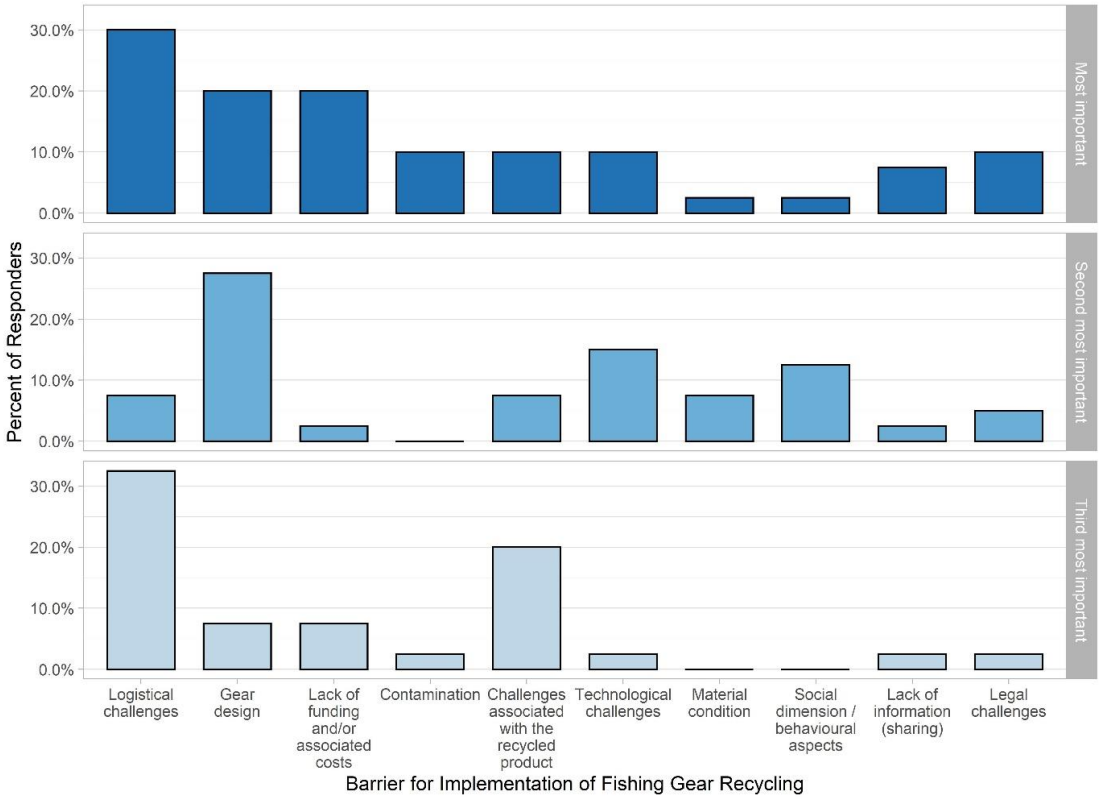

Figure 3: Top 3 most important barriers to recycling fishing gear

Respondents were asked which types of fishing gear were currently being recycled by them or others, and which they knew were not being recycled (Figure 4). This work showed that all of the materials listed in the questionnaire were being recycled (at least partly). However, respondents were more likely to state that particular materials were being recycled than others, with more respondents stating that net (trammel/gill/draft), ropes and bottom trawl nets were known to be recycled.

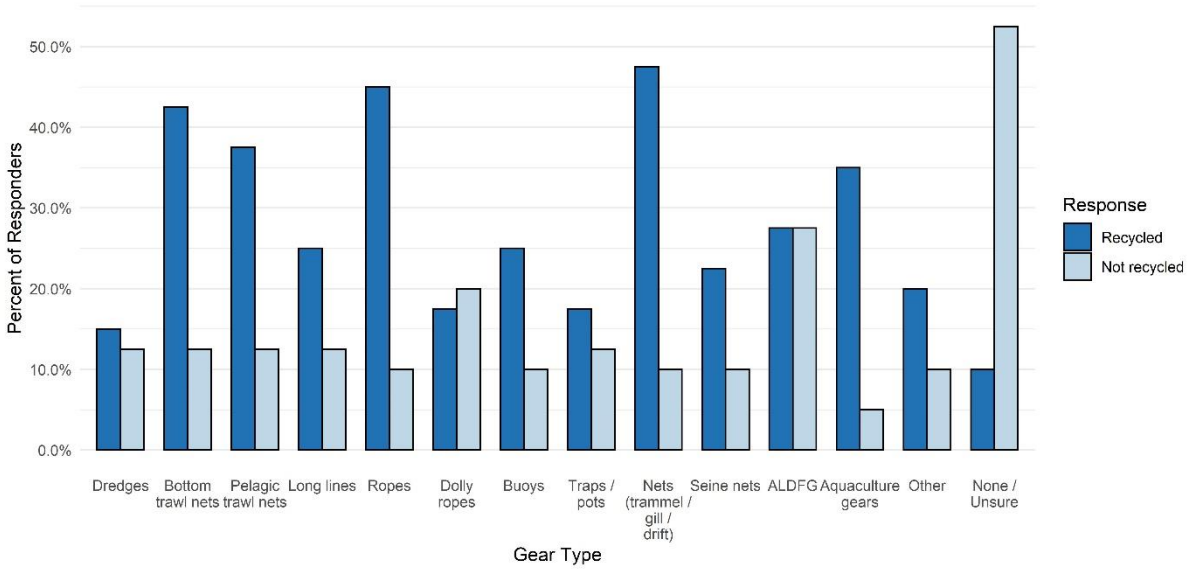

Figure 4: Types of fishing gear recycled

Respondents also showed that there were a range of regions (and companies within those regions) where fishing gear were being recycled (Table 1). Although this analysis showed that a range of fishing gears are recycled throughout Europe (and within the USA), the majority of gears were being sent to either of two companies: Plastix (Denmark) and Aquafil (Slovenia). However, Aquafil will only process nylon, while Plastix will process multiple polymer and gear types. In addition, respondents also stated that there was a variety of other materials utilised in fishing gears that remain after recycling. Although not stated, these materials are expected to include those not able to recycle easily (e.g., multi-polymer products).

Table 1: List of regions (and if provided, companies) currently recycling fishing gear

Region (company)	Type of fishing gear
Non-country specific – standard recycle bin	Buoys
Europe[19]	Longlines, Nets (trammel net / gill net / drift net)
Countries which were identified by stakeholders	
Belgium	Bottom trawl nets, Dolly ropes
Denmark (Plastix)	Dredges, Bottom trawl nets (test project), If PE or PP, Pelagic trawl nets, Ropes, Dolly ropes, Buoys, Traps/Pots, Nets (trammel net / gill net / drift net), Seine nets, Aquaculture gears (e.g. longlines, cages, rafts, tanks, bottom beds/poles/stakes), fish boxes
Ireland	Dredges (as scrap metal), trawl doors and steel components of any fishing gear (initial processing)
Norway	Longlines, Ropes, Aquaculture gears (e.g. longlines, cages, rafts, tanks, bottom beds/poles/stakes)[20]
Slovenia (Aquafil)	Bottom trawl nets (PA part), Nets (trammel net / gill net / drift net) if nylon/PA6, Seine nets, Abandoned, Lost or Discarded Fishing Gear (ALDFG)[21]
Sweden	Bottom trawl nets, Pelagic trawl nets, Longlines, Ropes, Buoys, Traps/Pots, Nets (trammel net / gill net / drift net), Abandoned, Lost or

[19] This category was utilized as stakeholders stated 'Europe' instead of listing a specific country
[20] Norway have some examples of the cages being recycled (Blue Circular Economy Project)
[21] Aquafil do collect abandoned / lost nylon fishing gear via their Healthy Seas programme and recycle it at their facility in Slovenia

	Discarded Fishing Gear (ALDFG), Aquaculture gears (e.g. longlines, cages, rafts, tanks, bottom beds/poles/stakes)
USA	Bottom trawl nets, Pelagic trawl nets

One respondent (identified as representing the fishing industry) stated that all of the products listed within the questionnaire were also reused in making of new gear (e.g., Dredges, Bottom trawl nets, Pelagic trawl nets, Long lines, Ropes, buoys, traps/pots, nets and aquaculture gears) (Table 1). Lastly, one respondent stated that recycling itself was not economically viable, and had to be funded by marketing budgets, subsidy.

Several respondents stated that there were several materials they knew were not being recycled, with respondents (identified as representing NGOs, Government or international organisation, and Gear manufacturers) overwhelmingly stating these were ALDFG and dolly ropes (Figure 4). Respondents (identified as representing Gear recyclers) stated that the lack of recycling of such materials were due to a range of factors, with the most common response being the contamination of the material, logistical challenges associated with recycling, and the design of the gear also being commonly stated.

Respondents provided further descriptions of why different materials are not able to be recycled (

Table 2). This work showed that there are a number of issues associated with each barrier to recycling, although natural fouling and entanglement in reducing the economic viability of recycling was mentioned several times, as well logistic issues associated with collection of material. Other issues stated were the several varieties of polymers utilised within the same gear, social issues associated with lack of awareness of the need to recycle material and lack of legal obligations to recycle.

Table 2: Reasons why certain materials cannot be recycled

Issue	Description	Number of respondents stating this issue
Logistical challenges (e.g., collection, storage, transport)	Challenges related to the coordination and availability of facilities for the collection and recycling of fishing gear and storage in port side where the gear will not be contaminated by either fly tipping or rodents	12
Technological challenges	*No further statements made by respondents*	10
Material condition (e.g., knot slippage)	Fouling	10
Contamination (e.g., biofouling, lead contamination)	Anti-foulant coating on aquaculture gear poses a challenge for recycling The longer ALDFG stays in the water the more difficult it is to recycle	14
Gear design (e.g., multiple materials used, increasing cost associated with pre-processing)	Recycling of pots and traps is often described as challenging due to the contamination and number of different materials used, as well as different designs. For other fishing gear design is a bit challenge due to mixing of polymer types, making separation and recycling incredibly challenging	12
Social dimension / behavioural aspects	Lack of awareness on behalf of fishers with regards to plastic pollution and the availability of recycling	7

	options. Logistical challenges disincentivise fisher engagement.	
Legal challenges	Lack of mandatory obligations and financial incentives on fishers to use recyclable fishing gear and ensure its delivery at end-of-life	4
Challenges associated with the recycled product (e.g. market value, quality)	Low value of recycled PE and PP and the reduced quality of the pellets has been cited as a challenge, also, challenges using the recycled plastics for food contact sometimes limits scope of application	9
Lack of funding and/or associated costs	Establishing pilot projects is costly and limited funding available for this, or complicated application process via EMFF	10
Other factors impacting recyclability	Degradation through saltwater and atmospheric factors (3 stakeholder's response) Low quantity of waste (1 stakeholder's response) Too entangled & too difficult to dismantle – mixed materials including sink lines with hazardous waste lead, mixed polymer types, metal items, other marine litter and organic matter – even hard to waste manage, not only to recycle (1 stakeholder's response)	5

In understanding the issues that may reduce the likelihood of materials being recycled, respondents were asked what they knew about any dangerous substances used in the design of fishing gear which made it unsuitable for recycling.

Are there dangerous substances used in the design of fishing gear which makes it unsuitable for recycling?

Lead, which is unrecyclable, is utilised in a number of ways in fishing gear, including as lead lines (weighted lines) and as separate sinkers. In addition, the inclusion of lead in fishing gear (especially in lead line, which is where lead is in a soft PVC tube) makes it impossible to recycle the PVC encapsulating the lead. Lastly, the anti-foul that is coated on aquaculture nets (copper coating) were also deemed dangerous.

Prior to the recycling of fishing gear, what forms of pre-processing may occur?

There are a number of different processes that were undertaken by respondents or others before recycling (Figure 5). Pre-processing by 'other parties' were the most likely response by respondents, with all types of pre-processing listed in the questionnaire being undertaken by other parties. Of the pre-processing being undertaken by the respondents, the most frequent response was of sorting and cutting and/or separating different types of material before recycling. Removal of parts for reuse and removal of parts to meet acceptance by waste handlers were also relatively frequently stated (Figure 5).

Work on the type of pre-processing which need to occur to increase the likelihood of recycling has been examined by the Circular Ocean project[22]. Within this project they have attempted to develop innovative solutions to 'end-of-life' problems associated with contaminated fishing nets and ropes. This work has developed methodology in examining the washing processes to remove anti-foulants and other chemical compounds impregnated into nylon fishing nets, ropes (FNRs) and cages, processes to decontaminate the waste water arising from the washing process, and the processes to extract copper compounds from fishing nets and ropes and cages for metals recycling.

[22] http://www.circularocean.eu/wpcontent/uploads/2017/12/CircularOcean_ChemHack_FINAL.pdf

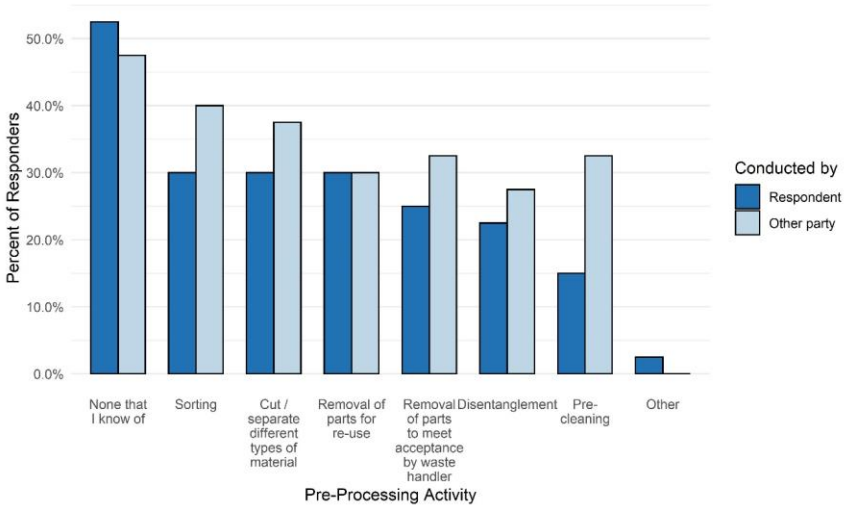

Figure 5: Form of pre-processing required prior to recycling of fishing gear

What output streams of recycling have a positive market value?

We asked respondents to state the range of materials associated with fishing gear that are already being reused and/or recycled. Metals and rubber were the most frequent materials stated to be reused in fishing gear, with small numbers of respondents also stating the majority of materials were reused (except Polyvinyl Chloride (PVC), Polyvinylidene fluoride (PVDF), Dacron, foams and Other). Interestingly, all of the materials listed within the questionnaire were also stated (by at least one, but no more than 3 respondents) as not being reused.

Respondents were also asked to state which of the listed materials were recycled. This list of material that is recycled was much smaller (n = 8) than those stated as being reused (n = 11). Of the materials which were stated as being recycled, metals were the most likely to be stated by respondents, while mixed plastics, Polypropylene (PP), Polyester (PE), Nylon – monofilament, Nylon – multifilament, Polyethylene (PET) and Dyneema were all deemed recyclable.

Both Aquafil (Slovenia) and Plastix (Denmark) are producing marketable products by recycling end-of-life fishing gear. In detail, the chemical recycling process used by Aquafil to return recycled nylon (Aquafil Econyl yarn, partially made with fractions of end-of-life fishing gear) has a positive market value. Respondents were less clear on the positive market value where PE and PP are recycled (mostly handled by Plastix), where the lower value and quality of the recycled material poses potentially greater concerns for the economic return of the new recyclate.

Only at a large scale (larger than at present) will recycling of fishing gear and ropes be an economically viable process (statement from Gear manufacturer, Gear recycler). For example, the prices of new material made from virgin plastic that recycled material has to compete with are: PE € 1.10/kg, PP € 1.20/kg, PET € 1.00/kg, PA €2.50/kg, while prices for recycled plastics (although fluctuating) are predominantly above these costs23. As obsolete gears and ropes needs to be collected, transported, separated, cleaned and re-processed into granules, it is not expected that such costs would lead to a product that was lower in cost than virgin plastic.

[23] https://www.spglobal.com/platts/plattscontent/_assets/_files/en/specialreports/petrochemicals/plastic-recycling-pet-europe.pdf

Which output streams of recycling cannot be marketed as a product (or used thereafter)?

A number of different materials are not able to be marketed, including a mix of lead, PP and soft PVC as used in muscle seed catch lines, while mixed plastics and in some cases steel (due to low market value) were also deemed likely not marketable. In addition, chain, warps, headlines and footropes are also not likely marketable. In addition, mixed polymers, including those with entangled debris, and/or organic matter that cannot be prepared and cleaned for recycling are unmarketable.

Understanding design standards for fishing gear

This last section questioned respondents on the range of mechanisms that may be important in developing new designs and design standards for fishing gear

Which fishing gear type is most suited to apply design modifications to increase its recyclability?

Respondents (identified as representing NGOs, Gear manufacturers and Gear recyclers) stated that gear comprised of mixed polymers were suited to apply design modifications to (e.g., trawl nets, ropes), with design modifications based on utilizing single polymer yarn/filament instead of mixed polymers. The re-design of fishing gear from mixed to single polymers would also increase the ease of disassembly of different fishing gear (at portside). In this respect, the other design modification (to enhance the use of single polymers in fishing gear design) would be to design monofilament to be stronger than it currently is.

One respondent (identified as representing Research) also stated that lead weights could be replaced by other inert materials (e.g., volcanic rock).

One respondent (identified as representing NGOs) stated that static gear such as crab and lobster pots were suited for design modification. These gears do not need to be as strong as towed gear, so there was more scope for investigating the use of other, more easily recycled materials in their manufacture.

Design innovations already developed / in development to reduce environmental impacts and/or enhance the circular design and/or increase the life of the fishing gear?

There was a balance between the number of respondents stating they were aware of design innovations and those that were not aware of design innovations already developed / in development to reduce environmental impacts and/or enhance the circular design and/or increase the life of the fishing gear.

Of the respondents that did have an awareness of innovations, several stated that there were alternatives to the use of lead, including the use of steel and rock (identified as representing Research, NGOs).

One respondent (identified as representing Gear manufacturers) stated that their company has a do-it-yourself system available for people to cast their own lead weights, therefore potentially reducing the use of new lead material when building nets. In addition, one respondent (identified as representing Gear manufacturers) stated that their company had changed gear design on trawl nets to reduce the need for abrasion protection on the bottom of the nets (e.g., dolly ropes), while two European projects were stated by respondents (predominantly those identified as representing NGOs and

Research) to also be looking at ways to replace dolly ropes with alternative materials (DRopS[24], DollyRopeFree[25]).

Examples where mixed materials in design have been replaced by monotype materials

Nearly all respondents stated that they were not aware of examples of mixed materials being replaced by monotype materials, although one respondent stated that pelagic nets consist predominantly of nylon, while bottom trawls nets consist mostly of all polyethylene

Barriers for (large-scale) implementation of design for recyclability of fishing gear

Respondents stated that there were a number of important barriers for (large-scale) implementation of design for recyclability of fishing gear. The most stated barrier was the cost, while the potential implications of redesign on the performance and efficiency of the gear (i.e., reduction of efficiency) and the technological/engineering challenges to development of gear were also important. Respondents also stated that the social dimension (i.e., behavioural aspects) of newly redesigned gear, as well as logistical challenges in developing gear and organisational aspects were also important barriers to design for recyclability of fishing gear.

One respondent (identified as representing Gear designers) stated that there were a range of barriers to implementation of design for recyclability. Firstly, the functional needs of fishing (i.e., which demands heavy, small weights in sink lines for gillnets) are not met by current recycling methods (i.e., recyclability demands moving away from lead). Secondly, systematic collection schemes (as requested in the revised PRF) would support the logistics of redesigned fishing gear, but such schemes are currently rarely in place (although the example of Smögen in Sweden was given).

Thirdly, different polymers have different functional properties that allow them to be used for different tasks (e.g., low-density (lighter than water) polymers are needed for floats, while high-density polymers are typically used to keep nets standing straight in the water column). However, moving towards fishing gear that potentially uses a smaller range of polymers (or only one polymer) will require innovative solutions to preserve functionality and performance. Currently, design innovation projects for revised fishing gear designs are rare although a design competition to replace dolly ropes in Germany (Thünen Institute) provided excellent, functional alternatives designed by the fishers themselves. Lastly, there is too little exchange/communication with the fishing sector and net manufacturers to result in a suitable development of materials and fishing gears for circular design.

[24] https://www.thuenen.de/de/of/projekte/fischerei-surveytechnik/verringerung-von-kunststoffmuell-aus-der-krabbenfischerei-durch-netzmodifikationen-drops/
[25] http://www.dollyropefree.com/

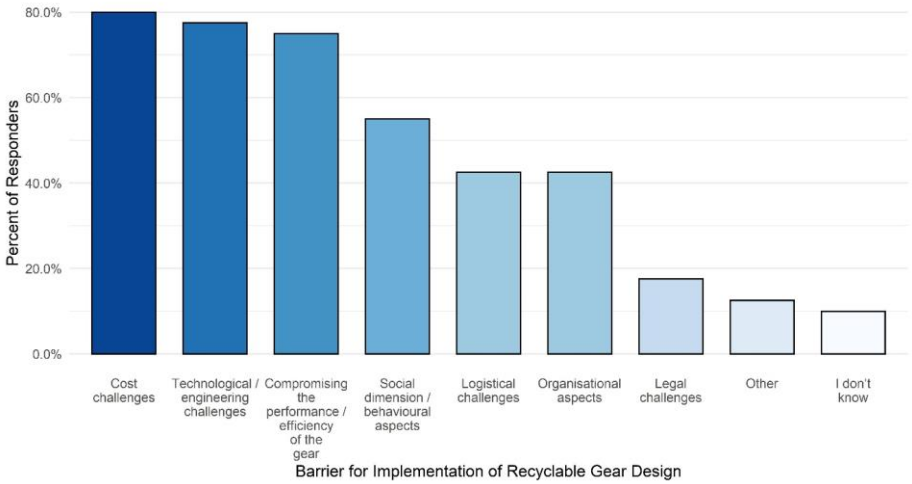

Figure 6: The most important barriers for (large-scale) implementation of design for recyclability of fishing gear

2.3 Subtask 1.3 Expert stakeholder workshop

To gather collective intelligence and useful input for the development of recommendations for circular design of fishing gears from relevant players, an international multi-stakeholder workshop was organized by MRAG in collaboration with Cefas and OSPAR on 19 and 20 February 2020 in Brussels (Annex 4). This workshop was developed to identify recommendations for effective, useful and harmonized standards for the circular design of fishing gear and to feed into the work of OSPAR on the design and recycling of fishing gear.

This workshop provided a stage in which to examine the range of challenges, solutions and potential recommendations that expert stakeholders deemed necessary to facilitate the development of standards for circular design of fishing gears. **Therefore, below we provide a synopsis of the Solutions and Draft Recommendations from these solutions that were developed and discussed within the expert stakeholder workshop.** To allow readers to understand how such solutions and recommendations were developed we also provide the full range of challenges identified within the stakeholder workshop (Annex 5).

1. Development of standards within the industry

Solutions

- Utilise and build on existing standards for design, materials used, manufacture and assembly where possible.
- Provide the opportunity for all relevant stakeholders to be part of the redesign of fishing gears, by inviting all to form part of expert working groups that will develop and finalise new standards in environmentally conscious (friendly) circular design of fishing gear.

Draft Recommendations

- Map potential needs/opportunities and existing standards to identify where the gaps are for environmentally conscious (friendly) circular design of fishing gear, including defining the scope of standards already there, e.g. standards on design, recycling, materials and very specific issues like design of ropes and design nets.
- Standards should be developed within expert working groups. Such groups should consist of a range of stakeholders from all parts of the industry, including experts on marine litter (including ALDFG) and environmental impact assessment

(ICES/FAO/GESAMP), as well as ICES/FAO working group on fishing technology and fish behaviour.

2. Legislation/Regulation should be supportive of measures to enhance environmentally conscious (friendly) circular design

Solutions

- Support regulation to enforce a certain percentage of recycled material (i.e., clean recyclates) within new gear to enhance the use of recycled content.
- Enforce reduction in the number of different materials used in single products (e.g. reduction in use of multipolymers in rope).
- Cease subsidies enhancing the use of virgin polymers, and increase tax incentives to utilise recycled materials.
- Enforce REACH restrictions on use of hazardous materials, while supporting R&D into sustainable alternatives, within fishing gears.

Draft Recommendations

- Member State governments should be driven to adopt measures to incentivise within fishing gears increased use of recycled materials and recycled content, increased product life extension, increased durability, increased use of environmentally friendly materials selection.
- The design, manufacture and use of fishing gears should have an environmental risk assessment undertaken, taking into account the EU commitments to tackle marine litter, climate change, ozone layer depletion, air pollution, loss of habitat and biodiversity, resource depletion.

3. Investments in research and design

Solutions

- To facilitate development and redesign of new gear and materials for new gears, there is a need for proper testing and money for research and innovation. Support is needed for tests and pilot studies to understand the costs and efforts for new technologies. There is a need for better understanding of who will pay for such R&D, while such R&D can be difficult to justify as a business case.

Draft Recommendations

- European Maritime and Fisheries Fund (EMFF) Blue Economy calls (or similar calls) for funding should include calls for (i) research and development of new materials and coatings for fishing gears; (ii) testing the utility of using high quality recyclates within new fishing gears; (iii) increased research and innovation (i.e. including running pilot projects with expert input and advice) to enhance the development and manufacture of 100% recyclable materials; (iv) further projects that develop methods to increase life of nets through design (extension strategy).
- Further training for manufacturers and/assemblers related to environmentally conscious (friendly) circular design, including product development that incorporates environmentally conscious (friendly) circular design.
- Research to develop a broadly acceptable gear marking/tagging or colour coding of materials and products, to facilitate reuse, recycling and disassembly.
- Disseminate broadly available best practices for redesigned materials and alternatives that are already in use.
- Increase transparency between manufacturers in providing accurate information on what materials have been used in the production of gear (including chemicals used in coatings).

4. Innovation in gear design

Solutions

- Future design should facilitate disassembly of fishing gears into their constituent parts, reducing manual labour time. To enhance dismantling of the product (and therefore recyclability) one solution may be to utilise colour schemes for different materials. There is also the need to explore re-use and repurpose of different materials currently used within fishing gears (e.g., rubber disks / hoppers). Lastly, the facilitation of repair, re-use and recycling could be accomplished by designing fishing gear that is modular in design.
- As mixing of different polymers within the same product may reduce the likelihood of recycling of the product, the solution could be to replace polymer mix with a single polymer with broader properties. Such replacement may then enhance the utility of chemical and mechanical recycling, although testing will be needed.
- Future gear design should have a focus on removing all materials/ substances/ elements that cause a strong negative impact on the marine environment.
- Focus on design that increases the durability and strength of the fishing gear, to reduce abrasion and breakage of material, and therefore extend the lifetime of the fishing gear. In this respect, increase the quality of the materials utilised within the fishing gear (i.e., replace PP/PE with nylon/PE), which will increase the value, lifetime of the product and consequently will increase the incentive to recycle the product. Moreover, use environmentally friendly coatings to extend the lifecycle of products.
- Increase the value of the fishing gear by using materials (e.g., Nylon 6), that have a higher value on the secondary market, and will therefore incentivise reuse and recycling.
- Identify key design principles that minimize physical interaction of fishing gears with the seafloor (to avoid contamination, abrasion), while maximizing functionality (e.g., redesign net to provide more clearance from the benthos, by using upward action, buoyancy aids).
- Utilise design to reduce the cost of transport and distribution

Draft Recommendations

- Terms and definitions for all standards should be well developed and agreed in principle by relevant experts in the field.
- Need for increased awareness of lifecycle thinking when designing fishing gears.
- Design should encompass innovation in maintenance, repair, remanufacturing, refurbishment (modification), recycling at 'end-of-life' and upcycling.
- Designs should have clear resource efficiency, including using less mixed materials, less diverse parts within a gear or its components, reduced energy and water consumption, reduced process waste, reduce emissions to air, water and soil during manufacture and increased use of internally recovered or recycled materials from process waste.
- Where possible reduce costs of transport and distribution by minimising product size and weight and optimising shape and volume for maximum packaging density.
- If mixing of materials within a product, or a range of parts are necessary for the use of the fishing gear, then there should be a clear, simple and resource efficient mechanism to separate different types of materials, and detach different parts.
- Further design should consider reducing environmental impact across lifecycle of product: within supply chain of material used and transport and distribution; by using extension strategy to enhance life of product; and during management of recycling at end-of-life.

5. Materials used in fishing gear

Solutions

- Develop an understanding of the total volume of gear made and utilized throughout Europe, and therefore where the best use of innovation should be focused (i.e., which gears to redesign first).
- Reduce non-performance relevant additives (e.g., colourants) and standardize required additives between different polymers (i.e., to give performance)
- Consider R&D into the use and utility of sustainable biodegradable materials in fishing gear. Specifically, to look into the entire lifecycle of biodegradable materials from sustainable production, throughout assurance of environmentally friendly biodegradation in marine environment until safe disposition at end-of-life. To consider differences between sea basins in environmental factors important for biodegradation (e.g., bacterial composition, water temperature, salinity).
- To consider increased use of natural materials. For example, instead of conventional dolly ropes (to protect abrasion of fishing nets), cow leather can be used (e.g., DollyRopeFree project). Traditional octopus pots were made from ceramic (now from plastic), mussel socks and lines that oysters are attached to PE ropes (in aquaculture) were originally produced out of more natural fibres, while lobster pots in Ireland were originally from wood (willow and hazel) and string (now made of plastic). Fishing gear design with biobased materials/natural fibres should consider natural waste products at the end-of-life.
- Polystyrene fish boxes are broadly used within the industry, but once they become litter, they gradually degrade into microplastics. To consider either more durable and longer life plastic boxes or eco-friendly cardboard instead.

Draft Recommendations

- To ensure environmentally conscious (friendly) circular design in all fishing gears, all materials utilised should be reusable[26] (following definition in ISO 18603:2013), recyclable[27], repairable or compostable[28].
- Further understanding of the supply chain for materials utilised within fishing gear and fishing gear products, including which are designed, manufactured and assembled in Europe. In addition, assess the total volume of gear being imported into, manufactured and sold within Europe
- Decouple the range of materials used in fishing gear from the use of finite virgin plastic resources (i.e., through a virgin reduction target). Such decoupling may involve complete elimination of the virgin plastic, increased use of recycled content, increased use of renewable materials, and/or substitution by other materials. Any virgin reduction target should focus as its underlying delivery mechanisms on both eliminating the plastics we don't need through innovation and reuse, and increasing recycled content for those plastics we do need.
- Any materials or components within a fishing gear should not contain (i.e., through plating or coating) nor have as a manufacturing requirement, hazardous chemicals that pose a significant risk to human health or to the environment. Such restrictions should be embedded through consultation with the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) regulation in partnership with the European Chemicals Agency (ECHA).

[26] Material which has been designed to accomplish or proves its ability to accomplish a minimum number of trips or rotations in a system for reuse. A system for reuse defined as established arrangements (organizational, technical or financial) which ensure the possibility of reuse, in closed-loop, open-loop or in a hybrid system

[27] Material is deemed recyclable if its successful post-consumer collection, sorting, and recycling is proven to work in practice and at scale. When taking into account the ability of materials to be recycled, such definition must take into account ISO 18604:2, which defines material recycling as: "Reprocessing, by means of a manufacturing process, of a used packaging material into a product, a component incorporated into a product, or a secondary (recycled) raw material; excluding energy recovery and the use of the product as a fuel." This includes both mechanical (maintaining polymer structure) and chemical (breaking down polymer structure into more basic building blocks, for example via chemical or enzymatic processes, that are then built up again into new materials) recycling processes. Recycling, as defined for the environmentally conscious (friendly) circular design of fishing gear explicitly excludes technologies that do not reprocess materials back into materials but instead into fuels or energy.

[28] Material is compostable if it is in compliance with relevant international composability standards and if its successful post-consumer collection, sorting, and composting is proven to work in practice and at scale.

- The feasibility, standards and environmental impact for biodegradable materials and non-polymer materials should be examined.
- Currently fishing gears are composed from materials that cannot be avoided (or replaced by a reuse model), while maintaining utility; utility may be associated with a specific weight, volume and/or shape of material or product. Therefore, future materials and products should not only take into account recyclability, reusability or composability, but should also be fit for use.
- Some materials should be designed out of any future fishing gear, with viable alternatives developed. As a priority, replacement of lead, copper coating and other metals (zinc, etc), as well as problematic plastics: polyvinyl chloride (PVC), polystyrene (PS), expanded polystyrene (ePS) and non-recyclable plastics (i.e., HMPE) should occur.
- Durability of the materials used, and the fishing gear as a whole should be inherent in any future design and development. Such durability should enhance performance as well as the likelihood of being reused, repaired and/or recycled.
- Further innovation and research are needed for the assessment and use of alternative materials/design for gear protection, including exploring feasibility of using sustainable traditional/natural materials.

3 TASK 2: PROPOSED RECOMMENDATIONS FOR CIRCULAR DESIGN OF THE FISHING GEAR

Within this Task we have built on the outcomes of Task 1, especially in the development of Draft Recommendations from the expert stakeholder engagement, and within the stakeholder workshop and **propose detailed recommendations for effective, useful and guidance standards on circular design of fishing gear**.

Recommendations examined and assessed within this section fall into the following three themes:

a. **Technical recommendations**: Specific to the product, to enhance circularity in design, manufacture and use.

b. **Circularity recommendations**: Aiming at optimising circular aspects including the product lifetime: reusability, upgradability, reparability, recycled content and recyclability.

c. **Environmental recommendations**: Aiming where possible to address the most significant environmental impacts throughout the lifecycle of products, while also exploiting environmentally conscious design potential and responsibility of manufacturers.

Importantly, drawing on discussions with Eurocord members (which are responsible for 70% of the trade in ropes within Europe) that had participated in the workshop within the project, **we provide an assessment of the utility of each recommendation (where possible), as well as the likely factors that may facilitate or constrain the usefulness of the recommendation proposed**. This further assessment of recommendations was deemed important to enable the Commission to better understand how the industry may view such recommendations, but also where they (or the elements comprising such recommendations) are already underway within the industry. Therefore, each recommendation is provided as a paragraph, with any expert stakeholder comment associated with this recommendation provided immediately below as a series of italicised bullet points.

3.1 Technical recommendations

Specific to the fishing gear, the technical recommendations to consider are:

Technical Recommendation 1: Durability, catchability and strength of the materials used, and of the fishing gear as a whole should be inherent in any future design and development. Gear durability enhances the performance as well as the likelihood of being reused, repaired and/or recycled and that all materials utilised are reusable (following definition in ISO 18603:2013), recyclable or repairable

Technical Recommendation 2: Future materials and products should not only take into account recyclability, reusability or composability, but should also be fit for use and maintain utility[29].

Technical Recommendation 3: There should be a mobilisation of the potential for digitalisation of product information (product and material type, composition, reuse/recyclability options etc.) for all components utilised in fishing gears, including solutions such as digital passports, tagging (e.g. QR or barcode) and watermarks, and exploring digital product design tools[30], while taking into consideration that digital literacy is uneven across the population.

Technical Recommendation 4: Design should encompass innovation in preventative maintenance, repair, remanufacturing, ability to refurbish[31], recycling at 'end-of-life' and upcycling.

Statements in assessment of Technical Recommendation 4 by Eurocord members

a. *There is high access to spare parts within the fishing industry, as this industry is focussed on service. For example, chain supply is already in place with stakeholders, including through distribution centres, net lofts, cooperatives etc.*

b. *Ease of maintenance is already part of the design of fishing gears, as the end user (fisherman) predominantly mends their equipment until it is deemed to be discarded. The complexity of fishing equipment in general is not such that mending of equipment is the major issue, given that the operator has the basic mending skills. Training sessions are organised with customers on how to repair and maintain new products/designs. Repair and maintenance instructions are given. Universal guidelines to rebuild/repair netting with twine and repair kit are available.*

c. *Any design that maximizes ease of reuse and disassembly will be complicated by the complexity of fishing gear, and how this varies greatly between gear types. For example, fish farming nets, gill nets and purse seines are not typically complex, while trawl nets may be a combination of a wide range of different materials.*

Technical Recommendation 5: Where possible, further reduce costs of transport and distribution by minimising product size and weight and optimizing shape and volume for maximum packaging density.

Statements in assessment of Technical Recommendation 5 by Eurocord members

a. *Reduction in the weight, size and volume of product is already ongoing within the industry. Recent developments include the use of enhanced synthetics (i.e., HDPE (instead of regular PE), HMPE's and aramids) that have higher strength with less diameter, as well as having a lighter weight, while also showing higher abrasion resistance and therefore higher lifetime. In addition, there has been*

[29] Currently fishing gear is composed from materials that cannot be avoided (or replaced by a reuse model), while maintaining utility. Utility may be associated with a specific weight, volume, shape of material, elongation, tensile strength, tenacity, and other specific characteristics/properties.
[30] E.g. https://recyclass.eu/
[31] Which can include modification, repairing and cleaning equipment so that its condition is like new

increasing work undertaken to improve mechanical fibre performance under new European regulations stipulating new polymer grades.

b. *Optimisation of the shape and volume of fishing gears for maximum packaging density is currently being worked on within the fishing industry. For example, the introduction of compacted netting packaging to reduce transport volume.*

c. *Efficient and optimised transport of fishing equipment is a high focus for the fishing industry, representing a considerable cost to be kept as low as possible.*

Technical Recommendation 6: Design should consider the need of mixing materials within a fishing gear and consider a clear, simple and resource efficient mechanism to separate different types of materials, and detach different parts.

Statement in assessment of Technical Recommendation 5 by Eurocord members

a. *Tagging of fishing gear components (and logging of that information within a materials composition database) are already occurring within the aquaculture industry (i.e., fish farms nets), easing the detection and therefore methods needed to separate different materials.*

Technical Recommendation 7: To consider materials that could be designed out of any future fishing gear, with viable alternatives developed. For example, to consider replacement of lead (e.g. by steel, tungsten, bismuth, volcanic rock etc.), copper coating and zinc, as well as problematic plastics: polyvinyl chloride (PVC), polystyrene (PS) and expanded polystyrene (EPS).

3.2 Circularity recommendations

Circularity recommendations aim at optimising the product lifetime, reusability, upgradability, reparability, recycled content and recyclability. The circularity recommendations to consider are:

Circularity Recommendation 1: To ensure environmentally conscious (friendly) circular design[32] in all fishing gears, there should be efforts to utilise identifiable materials that are reusable[33] (following definition in ISO 18603:2013), recyclable[34] or repairable to ensure the following circularity requirements: modification, reusability, end-of-life recycling and efficient dismantling of fishing gear.

Circularity Recommendation 2: There should be a decoupling of the range of materials used in fishing gear from the use of finite virgin plastic resources (i.e., through a virgin reduction target). Such decoupling may involve a gradual elimination of the virgin plastic (as long as this does not reduce performance), increased use of recycled content, increased use of renewable materials, and/or substitution by other materials. Any virgin reduction target should focus as its underlying delivery mechanisms on both eliminating the plastics we don't need through innovation and reuse, and increasing

[32] More up to date set of 'circular' definitions within BS8001:2017 and more detailed work will start in ISO TC323 (MC)

[33] Material which has been designed to accomplish or proves its ability to accomplish a minimum number of trips or rotations in a system for reuse. A system for reuse defined as established arrangements (organizational, technical or financial) which ensure the possibility of reuse, in closed-loop, open-loop or in a hybrid system

[34] Material is deemed recyclable if its successful post-consumer collection, sorting, and recycling is proven to work in practice and at scale. When taking into account the ability of materials to be recycled, such definition must take into account ISO 18604:2, which defines material recycling as: "Reprocessing, by means of a manufacturing process, of a used packaging material into a product, a component incorporated into a product, or a secondary (recycled) raw material; excluding energy recovery and the use of the product as a fuel." This includes both mechanical (maintaining polymer structure) and chemical (breaking down polymer structure into more basic building blocks, for example via chemical or enzymatic processes, that are then built up again into new materials) recycling processes. Recycling, as defined for the environmentally conscious (friendly) circular design of fishing gear explicitly excludes technologies that do not reprocess materials back into materials but instead into fuels or energy.

recycled content for those plastics we do need but should also be fit for use and maintain utility'.

Statements in assessment of Circularity Recommendation 2 by Eurocord members

a. *Producers are already using recycled material for non-high demanding applications, For example, steel items are already being reused/recycled for new products (e.g., linkages used in floats). While PA and PE are being used, for example fishing nets have been reused as fence netting in agriculture and for cargo netting.*

b. *The use of recycled materials is predominantly from clean material, with little use of material from dirty material, as the costs to utilise are prohibitive, and potentially has lower performance. To ensure further use of recycled materials, incentives (tax benefit, footprint certification or other economic tools) are needed.*

c. *The use of recycled materials greatly depends on the needed level of accuracy in predictability of material performance. Such materials must have similar performance for the end user (i.e., performance and operational).*

d. *Some materials should be designed out of any future fishing gear, with viable alternatives developed. As a priority, replacement of lead, copper coating and other metals (zinc etc.), as well as problematic plastics: polyvinyl chloride (PVC), polystyrene (PS), expanded polystyrene (ePS) should occur.*

Circularity Recommendation 3: There should be an avoidance of the use of mixed materials, the use of less diverse parts within a gear or its components, and an increase in the use of internally recovered or recycled materials from process waste.

Statement in assessment of Circularity Recommendation 3 by Eurocord members

a. *Reduction in the number of parts is part of the typical research and development in all products being manufactured, as lower numbers of parts results in reduced logistics and more efficient manufacturing. Despite this, performance of the end product normally has priority. Therefore, design should be optimized for performance, increase in lifetime and reduction in maintenance/repair.*

Circularity Recommendation 4: There should be an incentivisation of product-as-a-service or other models where producers keep the ownership of the product where possible (this will predominantly be associated with the use of the material in a predictable environment and a lifetime expectancy, e.g., aquaculture) or the responsibility for its performance throughout its lifecycle

Circularity Recommendation 5: There should be a standardised approach to gear/polymer labelling and marking (e.g. colour coding, electronic marking) to ensure traceability of fishing gear and enable material identification by recyclers.

3.3 Environmental recommendations

Environmental recommendations aim to address the most significant environmental impacts along the life cycle of fishing gear, by considering environmentally conscious circular design of fishing gear at the gear design stage. The environmental recommendations to consider are:

Environmental Recommendation 1: Any materials or components within a fishing gear should not contain (i.e., through plating or coating) nor have as a manufacturing requirement, hazardous chemicals that pose a significant risk to human health or to the environment. Such restrictions should be embedded through consultation with the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) regulation in partnership with the European Chemicals Agency (ECHA)

Environmental Recommendation 2: There should be rewards for products based on their different sustainability performance (including environmental, economic and social pillars) by linking high performance levels to incentives.

Environmental Recommendation 3: There should be an establishment of sustainability principles (environmental, economic and social), by reducing energy and water consumption, reducing process waste, emissions to air, water and soil during manufacture.

Statement in assessment of Environmental Recommendation 3 by Eurocord members

a. *The industry inherently strives for cost-effective solutions, including materials with lower embodied energy and/or water. For example, development of standards for manufacturing (under ISO 50001[35]) is the result of the industry working with suppliers (e.g., Dow, Repsol) committed to addressing their impact, conserving resources and improving the bottom line through efficient energy management.*

b. *Reduction of process waste is also part of the normal manufacturing process. For example, within production of raw materials (typically some form of extruding), the waste is recycled in-line, while during assembly of fishing equipment there are typically implemented gathering and recycling of cut-offs.*

c. *The use of internally recovered or recycled materials from process waste is already being undertaken by producers of filaments during the extrusion phase. The percentage of such materials is defined according the desired output for the final application, with lower performance products containing higher percentage, while materials that have a higher performance containing lower percentage of internally recovered or recycled materials.*

Environmental Recommendation 4: To consider reducing environmental impact across lifecycle of product: within supply chain of material used and transport and distribution; by using extension strategy to enhance life of product; and during management of recycling at end of life

4 TASK 3: VALIDATION OF ELEMENTS COMPRISING EACH OF THE PROPOSED RECOMMENDATIONS

Within this section we utilised the recommendations of Task 2, extracted the main elements comprising each recommendation, and developed an online survey to validate the utility of such elements in writing standards for circular design of fishing gear (Annex 6). This survey encompassed 3 key themes: Technical requirements; Circularity requirements; Environmental requirements.

190 stakeholders were identified and the questionnaire directly emailed to them. In addition, to engage with the largest range of stakeholders possible, the survey link was also advertised publicly.

[35] ISO 50001 is a company level certification based on a standard published by the International Organization for Standardization (ISO).

There were 86 full responses to the questionnaire, with a wide range of stakeholders completing the questionnaire (Figure 7). The number of responses were dominated by stakeholders in research organisations, those that represented the fishing industry, as well as stakeholders in national/regional governments or international organisations. The 'Other' category included stakeholders that operated EPR schemes, or were in consultancy or tourism.

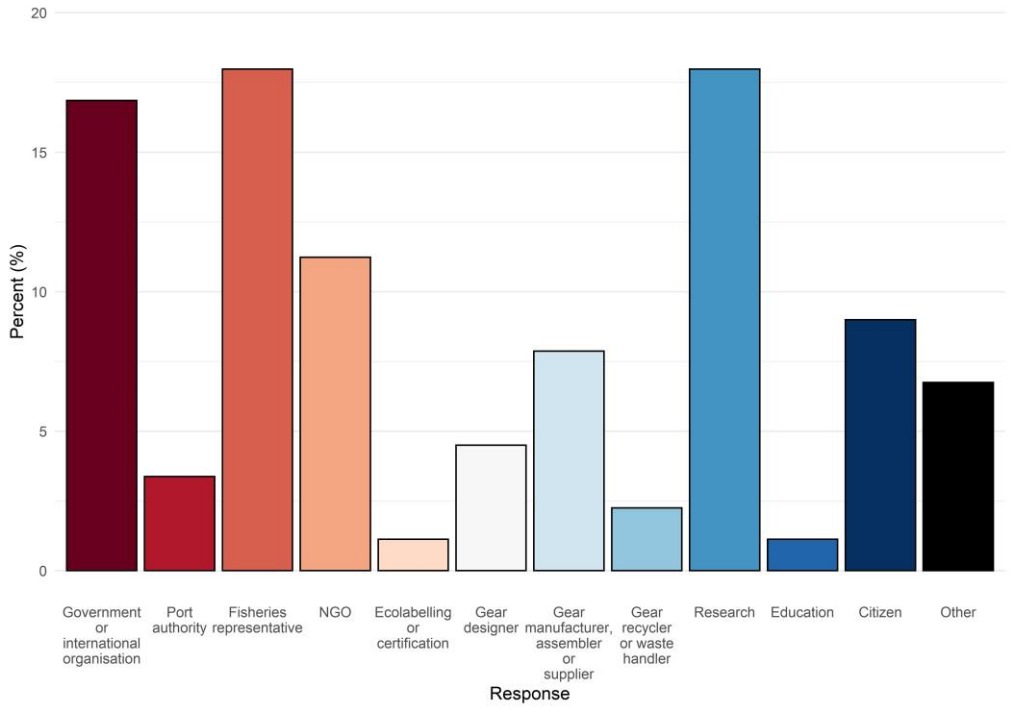

Figure 7 Composition of type of stakeholder completing validation survey

4.1 Technical requirements

Below we list each of the questions developed under 'Technical Requirements', provide a graph (where relevant) to show the main pattern in outcome, describe and assess the pattern, and then if relevant, provide any further comments from stakeholders.

Q1. Which are the most important technical requirements for fishing gear (and its components)?[36]

Durability, catchability and the strength were deemed the most important technical requirements of fishing gears (Figure 8). Importantly there was relatively no difference in the ranked importance of factors across stakeholders.

[36] Please note, here stakeholders were asked to choose 2 of the 4 possible categories

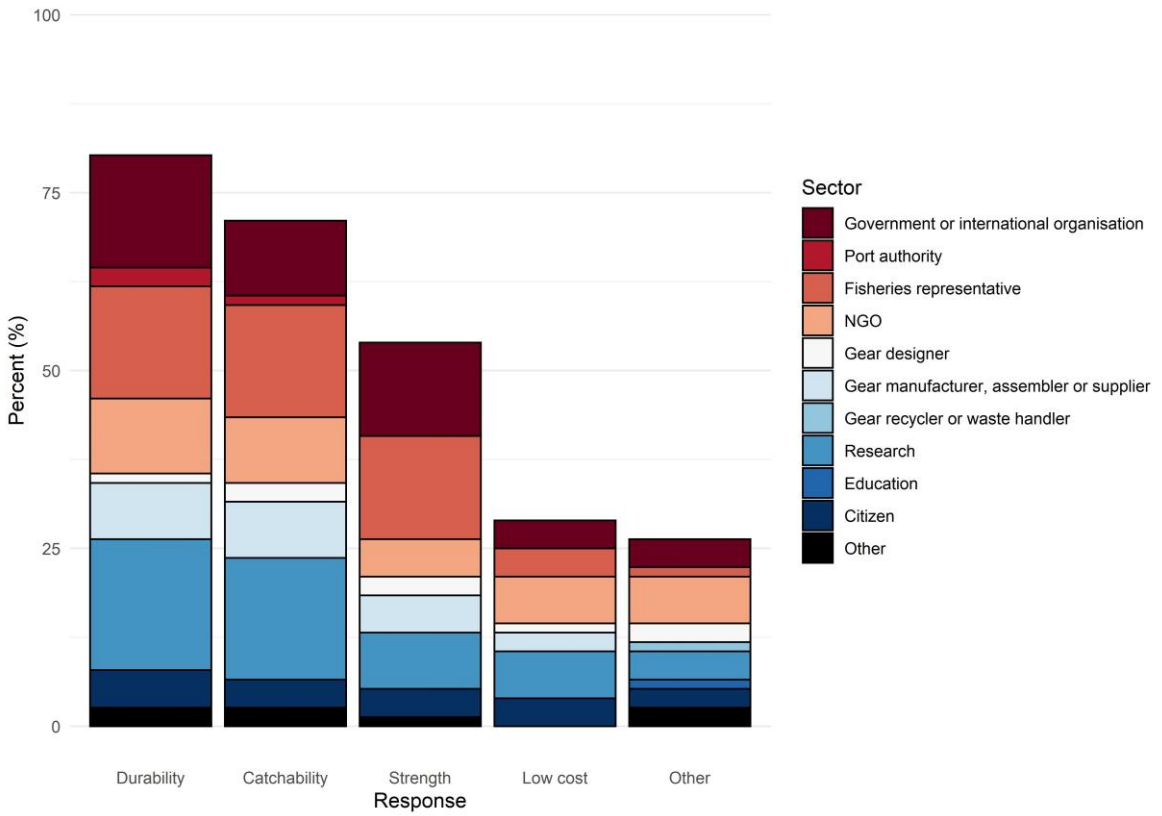

Figure 8: Importance of technical requirements for fishing gear

There was a range of other factors that stakeholders stated were important in terms of technical requirements. Of these, ease of repair and recyclability (Citizen, NGO, Government or international organization), biodegradability (Fishing Gear designer/eco-designer, Government or international organization), efficiency and selectivity (Government or international organization, NGO, Research), and low environmental impact (Government or international organization, NGO) were stated across stakeholders. The ability to track the vessel origin in case of loss was stated as important by NGOs, while simplicity in material used was stated by a fishing gear designer/eco-designer stakeholder.

Q2. How important is it to reduce the costs of transport and distribution of fishing gears, by minimising product size and weight and optimizing shape and volume for maximum packaging density?

There were mixed responses across stakeholders in quantifying the importance of reducing costs by changing design (Figure 9). The majority of stakeholders thought that it was 'slightly important' or 'important', while relatively fewer stakeholders felt it was 'very important'. Differences in response were also apparent between stakeholders, with those in research being the only stakeholder that thought reducing costs by design 'very important', whereas fisheries representatives, government or international organisations and NGOs stating that such a technical change was only 'slightly important'.

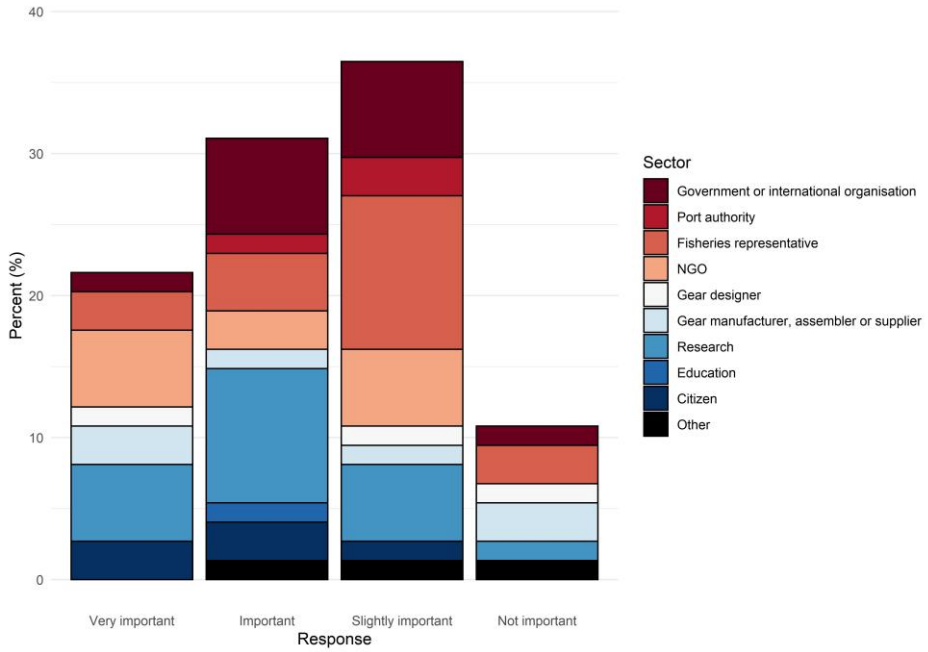

Figure 9: Importance of reducing costs of transport and distribution of fishing gears

Q3 Do you consider a mixture of polymers within a product necessary if a single polymer provides the same functionality and performance?

The majority of stakeholders stated that fishing gears comprised of a single polymer was much more preferred over one comprised of multiple polymers, as long as functionality and performance is maintained (Figure 10). However, stakeholders that are gear manufacturers, assemblers or suppliers stated that a mixture is always required, while stakeholders within government or international organisations and gear recycler or waste handler, stated that a single polymer should always be used.

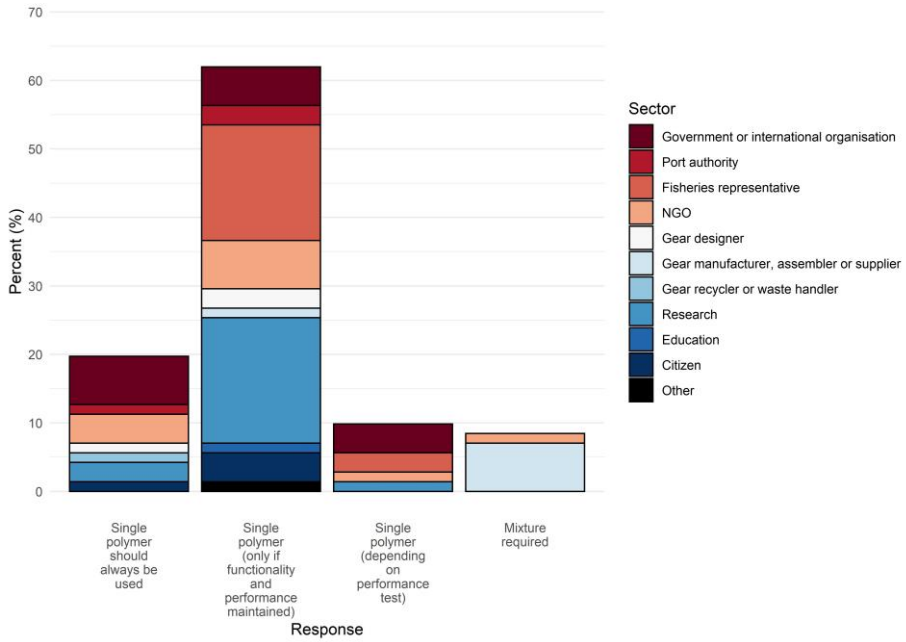

Figure 10: Single polymer versus multipolymer in comprising fishing gears

Where stakeholders stated that they needed a mixture, there were several responses to why this was important, with the majority of statements coming from gear manufacturers, assemblers or suppliers. These statements were predominantly associated with the utility of different types of polymers, and the understanding that different polymers represent different properties in the equipment, associated with differences in weight (specific gravity), strength (dimensioning), material stability, and ability to withstand abrasion/wear. For example, one stakeholder stated that it was 'not possible to mount PE nets with PE twine, because the knots will not be fixed. Elasticity in different parts of the nets must be different to get a good catchability with less material'.

4.2 Circularity requirements

Q4. What are the key circularity aspects to consider at the design and manufacturing stages for the circular design of fishing gear?[37]

Of the key circularity aspects to consider at the design and manufacturing stages, stakeholders stated that modification, reusability, end-of-life recycling and efficient dismantling were the most important aspects (Figure 11). Interestingly, although important, the use of recycled or recovered materials and the avoidance of mixed materials were not as important aspects, while there was little interest in the use of biodegradable materials, the remanufacturing of gears and the avoidance of diverse parts.

Other aspects identified by the stakeholders as important in design and manufacturing were: clear labelling (Citizen, Government or international organisation), the use of bio-based materials, although dependent on their strength and durability (Gear designer, Research, Government or international organisation), locations for end-of-life reprocessing (Gear designer), and proper polymer marking that would enable material identification by recyclers (Other)

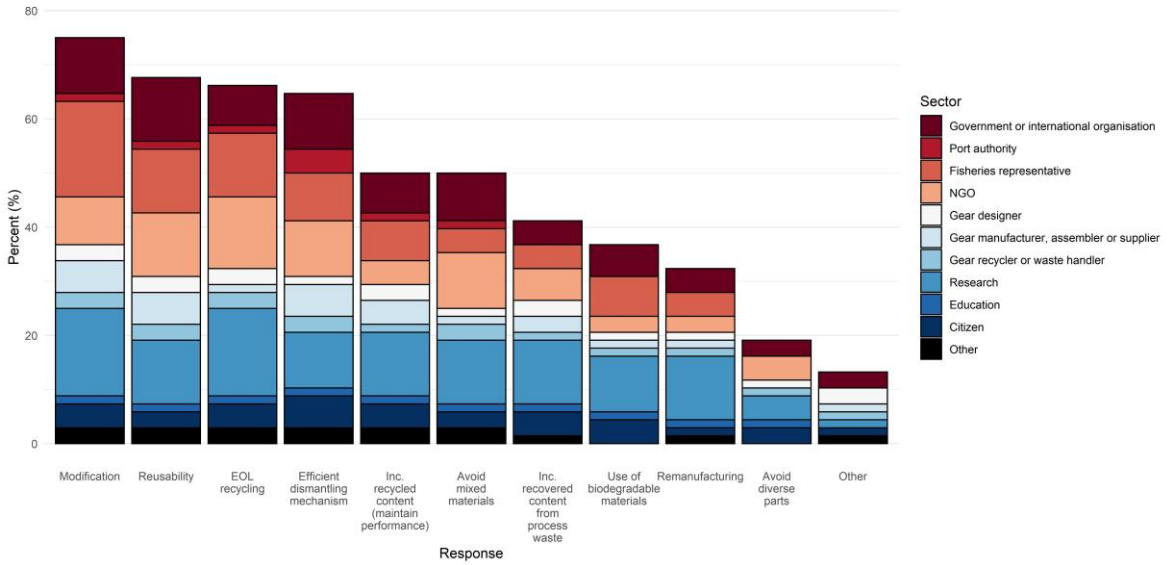

Figure 11: Key circularity aspects to consider at the design and manufacturing stages

[37] Please note, stakeholders were asked to tick 'all that apply'

Q5. For manufacturers/producers and users of fishing gear - would you agree to a system where producers retain ownership of the fishing gear, and/or the responsibility for its performance throughout its lifecycle?

There was near consensus across most stakeholder categories for the utility of producers retaining ownership of the fishing gear, and/or the responsibility for its performance throughout its lifecycle. On the contrary, fisheries representatives and gear manufacturers, assemblers or suppliers more likely would not support this statement.

As regards other opinions, producers disagreed to retain ownership or the responsibility for gear performance, but the utility to develop a partnership between producers and users was stated as potentially important.

Q6. Is there a need to increase transparency between manufacturers in providing accurate information on what materials have been used in the production of gear (including chemicals used in coatings)?

There was an overwhelming majority of stakeholders that stated the need for increased transparency in the use of different materials within fishing gear. However, fisheries representatives, gear manufacturers, assemblers or suppliers as well as a small percentage of researchers surveyed disagreed with this statement.

Q7a. Should the high sustainability performance of fishing gear be rewarded by incentives for manufacturers?

Overwhelmingly, there was a near complete agreement that incentives should be awarded to manufacturers that provide high sustainability in fishing gear.

Q7b. If incentives are deemed relevant, what kind of incentives should those be?

Within the range of incentives provided to stakeholders, the majority stated that lower taxes were the most likely incentive to enhance the development of sustainable fishing gear (Figure 12). However, stakeholders were also provided the opportunity to state other incentives that might also be utilised. Such incentives were those associated with lowered fees or economic incentives (Gear manufacturer, assembler or supplier) especially associated with the development of the Extended Producer Responsibility (EPR) scheme (Gear recycler or waste handler). In addition, the accreditation or a sustainability stamp/label (Government or international organisation), while increased support for research and development from the European Marine and Fisheries Fund (EMFF) (NGO) were also stated. Lastly, stakeholders stated that attaching the end-of-life costs to product instead of the manufacturer having to pay for these (NGO, Port Authority), and subsidising the circular manufacture of, where possible, biobased materials for use in fishing gear with carbon credits for exchange within a capped carbon trading system (Research) were all suggested incentives.

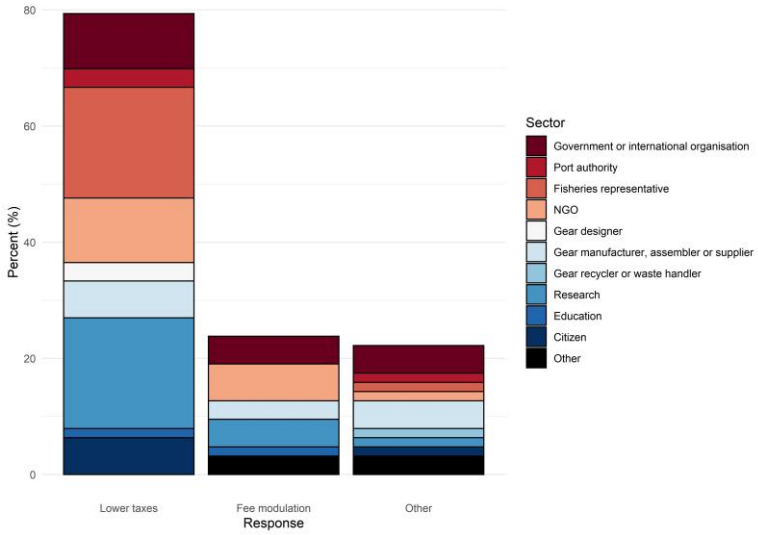

Figure 12: Incentives to develop highly sustainable fishing gear

4.3 Environmental requirements

Q8. At what lifecycle stage of fishing gear do you see in the future the highest potential for reduction in environmental impact?[38]

Stakeholders stated the product design stage and recycling at the end-of-life are the likely lifecycle stages for a fishing gear where the highest potential for reduction in environmental impact would occur. Importantly, the majority of stakeholders stated that there was little to no likely potential reduction in environmental impact during both transport and manufacturing of fishing gear.

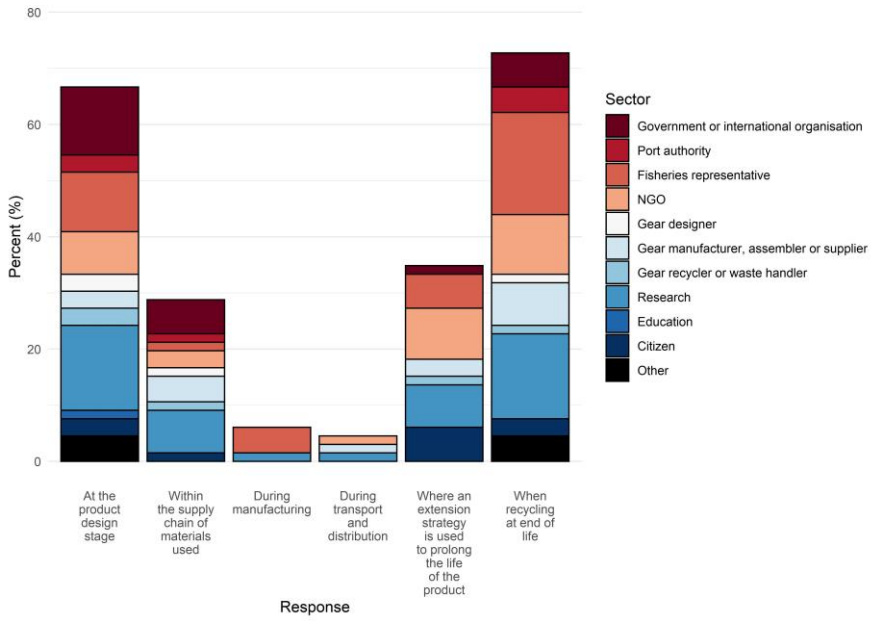

Figure 13: Lifecycle stage of fishing gear with the highest potential to reduce environmental impact

[38] Please note: Stakeholders were asked to choose 2 options in this question.

Q9a. Should fishing gear producers and users be aware of the environmental impacts throughout the life cycle of the product?

All stakeholders stated that fishing gear producers and users should be aware of environmental impacts, with no difference in statement between stakeholders.

Q9b. If fishing gear producers and users be aware of the environmental impacts throughout the life cycle of the product, which environmental impacts are most important?[39]

The environmental impacts deemed most important by stakeholders were the environmental impact during gear use and the environmental impact at the end-of-life of the fishing gear (Figure 14). Despite this, generation of waste during production were also important to be aware (Government or international organisation, NGO, Fisheries representatives, Research), while energy and water consumption were also deemed important (Research).

Where stakeholders were asked to list any further environmental impacts, analysis of the full range of emissions by using a full lifecycle assessment were deemed important (Gear designer, Research), while the social impact throughout the supply chain (Gear recycler or waste handler), as well as the impact of lost gear (i.e. ghost fishing) (Government or international organisation) were also deemed important.

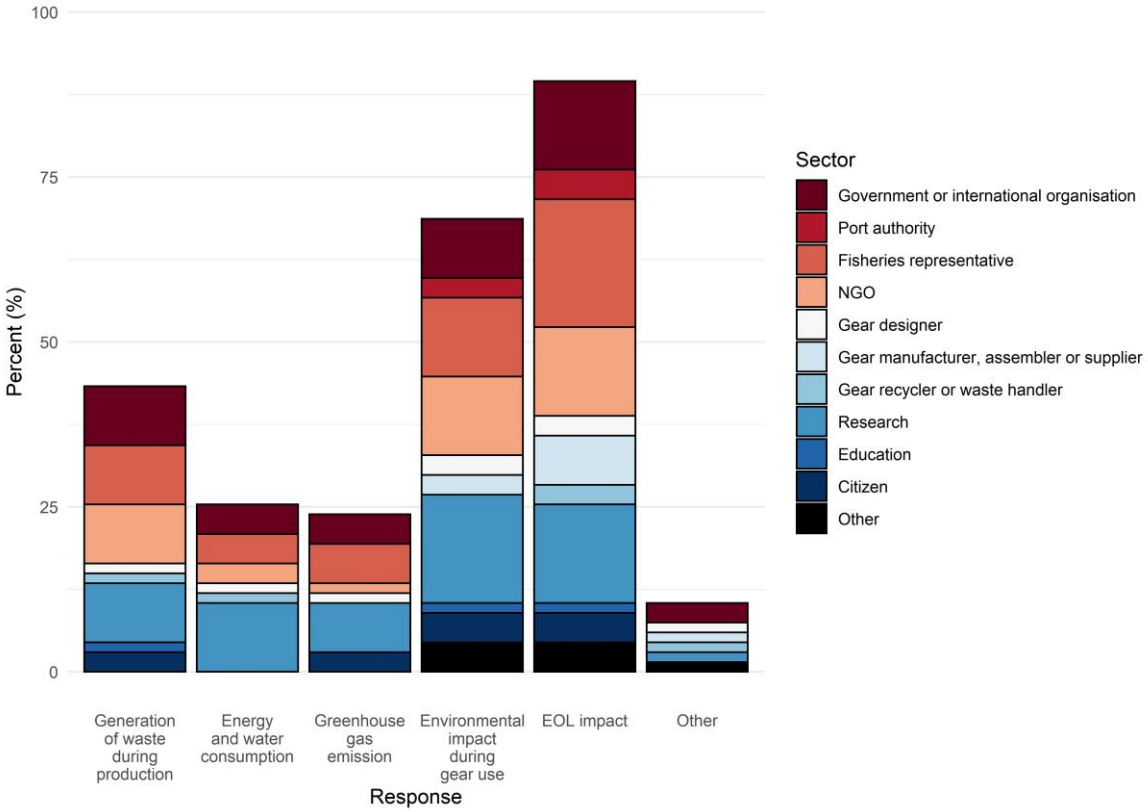

Figure 14: Environmental impact most important to determine

Q10. Are there any materials that fishing gear should not contain (i.e., through plating or coating) nor have as a manufacturing requirement?[40]

[39] Please note: Stakeholders were asked to choose 2 options in this question
[40] Please note: Stakeholders were asked to tick 'all that apply'

There was a broad consensus across all stakeholders that all materials identified in the survey should not be part of a fishing gear product or form part of its manufacturing process, with the highest number of responses for the removal of lead and non-recyclable plastics (Figure 15). Importantly, there was little difference in the response between stakeholders, although fisheries representatives and research stakeholders stated that the removal of copper coatings was important, while the removal of polyvinyl chloride was also deemed important by fisheries representatives.

Where stakeholders were asked to list other materials that should be removed, the broad consensus was that all listed materials, as well as any toxic or non-recyclable material should be removed (Gear manufacturer, assembler or supplier, Government or international organisation, NGO, Research), while any materials that inhibit high value reuse (Gear recycler or waste handler), as well as any and all materials with a proven negative environmental impact that hinder improved gear design for improved circularity (Government or international organisation).

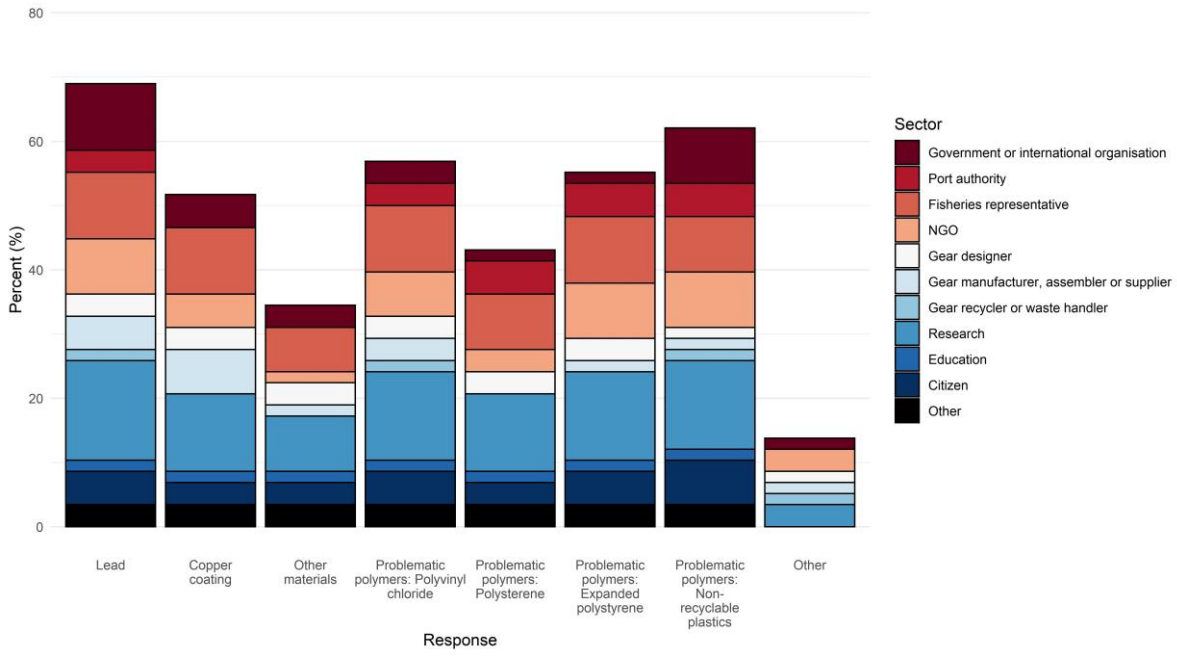

Figure 15: Materials that should not be part of a fishing gear product or form part of its manufacturing process

5 TASK 4: FRAMEWORK TO DEVELOP A REQUEST FOR GUIDANCE STANDARDS RELATING TO THE CIRCULAR DESIGN OF FISHING GEAR

Within this work we have been able to determine the main challenges and solutions to the circular design of fishing gear (Task 1; section 2), which provided us a platform for developing draft recommendations for the development of a guidance standard for circular design of fishing gear (Task 2; section 0). To support the final development of such recommendations, this work then utilised an online survey format to assess and understand the importance of the elements comprising each recommendation (Task 3; section 4). Within this section, we utilise the learnings from all three previous tasks to provide a synopsis of the main aspects needed to be encompassed to facilitate the development of harmonized standards for the circular design of fishing gear.

To support the development of a guidance standard for circular design of fishing gears, there must be a clear understanding of the environmental and economic costs of fishing gears across their full lifecycle. This must encompass all types of fishing gears and all

types of fishing practices. Without such an assessment, there will be little understanding of where within the lifecycle of fishing gears the likelihood of being recycled/reused/maintained versus being abandoned will occur.

This work has shown that one of the primary recommendations for a guidance standard is one that results in a reduction and eventual elimination of hazardous and non-recyclable materials within fishing gears. Indeed, the results of the literature review, workshop outcomes and both stakeholder questionnaires showed that most(?) stakeholders are aware of the environmental impacts of certain hazardous materials (e.g., lead, copper) as well as non-recyclable plastics. The reduction and elimination of such materials would however, need to be supported with research and development to find viable alternatives (e.g., lead alternatives), including substances or materials that reduce the need for toxic coatings and materials that reduce biofouling within non-active fishing gears.

The re-design of fishing gears must also be associated with the use of less diverse or mixed materials. However, there is broad consensus among stakeholders that such re-design needs to be mindful of the utility and performance of using different types of materials within fishing gears (i.e., durability, catchability of the fishing gears and the strength of that fishing gear) were deemed the most important technical requirements of fishing gears. Importantly, at present for range of different fishing gears (e.g., trawl nets) the performance of the nets is completely associated with the use of a range of different materials. Therefore, to support the likelihood that redesign of fishing gears occurs with less diverse mixtures, new innovations in the range of materials utilised in fishing gears, including the development of material that have a range of different properties and that can replace various different materials are needed.

The re-design of fishing gears within a circular economy must also be associated with a high (or complete) use of recycled/reused materials, with the complete gradual elimination of virgin plastics within new gear. There was a strong impetus throughout stakeholders for new innovation and development to enhance the likelihood of the use of recyclates in new fishing gears. However, there is a perception in stakeholders within the fishing industry (predominantly gear manufacturers) that the quality (including performance, strength, durability) of materials that contain recyclates will be lower than those made completely of virgin plastics. However, to date (June 2020) there has not been any uptake of post-consumer fishing gear recyclates in the fibre industry[41]. Therefore, to use recyclates within newly designed fishing gears, there must be further testing of the performance of materials comprising certain levels of recyclates and further developments of innovative technologies to enhance the quality of such materials.

Within the redesign of fishing gears for a circular economy there must be a much stronger impetus to mark / tag the components within the fishing gear. According to the majority of stakeholders, developing effective, simple and universally accepted marking / tagging technology was thought to be exceptionally important aspect in circular design and enhancement of recycling. Although the utilisation of a colour coding was thought of as more likely a technology to facilitate identification of fishing gears, stakeholders also stated that electronic marking / tagging would also be an important innovation. Marking / tagging of fishing gear components would then facilitate dismantling at the recycling stage, and therefore have positive economic impacts on the costs of recycling of materials.

The fishing industry, especially within large industrial fishing operations, utilise a reuse/recycling/modification and repair system to allow the continual use of their fishing gears (until they reach end-of-life and disposal is necessary). Therefore, the development of guidance standards must support such a model, but also facilitate

[41] Personal communication with B. Mercx

guidance in best practice for such a system which also engages with smaller fishing operations. Such development will be vital in fishing operations where fishing gears are replaced on a regular basis (i.e., gill netting, hand lines) and the end-of-life fishing gears are potentially discarded or abandoned.

This project has highlighted that there is a substantial amount of information held, but also a range of practices undertaken, that are already occurring within the fishing industry (e.g., maintenance and reusing of old materials, manufacturing processes that reduce waste products, research and development to increase the durability and performance of materials). Therefore, in development of a guidance standard for circular design of fishing gears, there is a need to work directly with the industry to utilise such information and practices.

To facilitate the uptake of newly re-designed fishing gears by the industry, there is a clear need to work closely within this industry in innovation and development of new technologies. This will be important, as any new technology must not only be developed to enhance circularity in its lifecycle, but must also have a high utility, durability, performance and be economically feasible for the industry to use.

The development of a guidance standard for circular design of fishing gears must acknowledge the need for continual research and development. However, such research and development must not be born entirely by the industry, but also be supported by substantial and long-term external funding support. Such funding support would be expected to come from EMFF (or equivalent funding), but must be made available across the entire market chain and encompass the broadest array of stakeholders, to ensure consensus in development goals, and continual collaboration between different parts of the industry.

Throughout the present study, and across the majority of relevant stakeholders there is little interest to include biodegradability in any development of guidance standards for circular design of fishing gears. Stakeholders, especially from the fishing industry felt that utilising resources to develop technology based on biodegradability (e.g. biodegradable material for use in a range of fishing gears), should not be supported. This does not preclude supporting ongoing research into examining biodegradability of fishing gears, though the industry felt that the immediate utility of biodegradable technology was not viable for fishing practices at present.

Development of a guidance standard for circular design of fishing gears must inherently reduce the economic costs to manufacture and repair/maintain, and also - reduce costs for pre-processing at end-of-life. The economic costs to dismantle, clean, recycle, and (if needed) chemically/mechanically render materials to their constituent chemical parts must be reduced where possible. Such factors were deemed substantial impediments for effective recycling and/or re-using fishing gear components for further use.

6 TASK 5: RESEARCH, TRAINING AND STUDY NEEDS

To further support the development of guidance standards for circular design of fishing gears, this section collates and assesses the range of future research and training needs that stakeholders have stated are necessary to support development of such standards. This section encompasses three themes under which the main research need has been stated:

- Management of circular design development
- Design and manufacture of fishing gears
- Support for end-of-life mechanisms

6.1 Management of circular design development

Training and stakeholder engagement

- Further training for manufacturers and/assemblers related to environmentally conscious (friendly) circular design, including product development that incorporates environmentally conscious (friendly) circular design.

- Development of further outreach programs to enhance understanding (within users) of what fishing gears can be recycled, where end-of-life gear can be taken, and what processes may facilitate such recycling (Citizen, Gear manufacturer, assembler or supplier).

- Facilitate collation of best available practices and make available for product designers and manufacturers to enhance their own research and development (Gear manufacturer, assembler or supplier).

Mapping and increasing the transparency of the development of fishing gears

- Develop understanding of the supply chain for materials utilised within fishing gear and its components, including those which are designed, manufactured and assembled in Europe. In addition, assess the total volume of gear being imported into, manufactured and sold within Europe.

Development of baseline understanding of standards already developed

- Undertake desk analysis to define the scope of standards already existing that might be relevant for awareness/understanding of circular design of fishing gears (e.g., TC323, BS8001 and CEN/CENELEC resource efficiency standards related to energy-related products), and identify the gaps for development of the environmentally conscious (friendly) circular design of fishing gear.

Funding needs

- Examine the fees and incentives that facilitate or constrain use of recyclable or renewable materials (Government or international organisation).

- European Maritime and Fisheries Fund (EMFF) Blue Economy calls (or similar calls) for funding should include calls for (i) research and development of new materials and coatings for fishing gear; (ii) testing the utility of using high quality recyclates within new fishing gears; (iii) increased research and innovation (i.e. including running pilot projects with expert input and advice) to enhance the development and manufacture of materials which are recyclable and/or reusable after modification; (iv) further projects that develop methods to increase life of nets through design (extension strategy); (v) further understanding of design for dismantlability; (vi) further understanding on the environmental impacts of different parts and types of fishing gear.

- Innovation in EU funding to subsidise public-private partnerships (e.g. BBI-JU) to introduce new technologies, identify complementary actors and develop collaborative mechanisms to ensure circularity in manufacturing processes (Research).

Legislation to support circular design

- Further understanding of the impact of implementing changes in technical regulations (e.g., increasing mesh sizes), on the extent of equipment becoming obsolete before end-of-life (Fisheries representative, Port Authority).

- Legislation to facilitate use of high performance and high durability materials (Research).

- Incentives on reduction, or overt bans, on the use of non-environmentally friendly materials (Gear manufacturer, assembler or supplier, Government or international organisation).

6.2 Design and manufacture of fishing gears

Development and assessment of new and existing materials and technologies

- Increase the quality/performance of recycled material, and establish trials to determine loss of performance of products containing recycled material, especially for "high" content of recycled material (Fisheries representative, Gear manufacturer, assembler or supplier, Gear designer, Government or international organisation).

- Development of new materials in nets (e.g., nanotechnology on fibres) (Citizen, Education, Fisheries representative, Gear manufacturer, assembler or supplier, Government or international organisation).

- Research to find a long lived single polymer product which maintains catchability and strength (Government or international organisation).

- Explore the use of novel recycling technologies from outside the sector e.g. new enzyme based recycling solution that can be applied to PET.

- Research to develop a broadly acceptable gear marking/tagging or colour coding of materials and products, to facilitate reuse, recycling and disassembly. In support of this, to develop a central database to hold all tagging information.

Determining the utility of using biodegradable materials

- Despite no biodegradable materials existing at present, research is needed to understand the potential utility and environmental impact of biodegradable materials if developed, either as components within a fishing gear or the complete fishing gear (Fisheries representative, Gear designer, Research).

- Further research to determine the likelihood of biodegradable materials degrading in cold sea water.

Assessment of environmental impact of existing versus new technology

- Examine the environmental impacts across the full life cycle for all components utilised within fishing gear.

- Examine the economic and environmental feasibility of utilising alternative materials/design for gear protection, including sustainable traditional/natural materials.

- Better understanding of the process of plastic degradation within the environment, and how plastics accumulate organic pollutants that could reduce the lifespan of the gear (NGO).

- The feasibility, standards and environmental impact for biodegradable materials and non-polymer materials should be examined.

Replacement of hazardous coatings in fishing gears

- Understanding the impacts of different levels of coatings (including no coating) on the life of fishing gears (Citizen, Gear manufacturer, Assembler or supplier, Government or international organisation, NGO).

- Further research and development into non-toxic alternatives (Fisheries representative, Education, Government or international organisation, NGO, Research), including materials that shed instead of poisoning (citizen), and the use of more natural-based materials (Gear designer, Research) or development of materials that do not require hazardous coatings (NGO, Research).

6.3 Support for end-of-life mechanisms

- Develop support programs, increase incentivisation for returning nets for repair/ refurbishment at reduced cost (Citizen, Gear designer, NGO, Research).

- Development of outreach programs to enhance understanding (within users) of the availability of resources to reuse/repairability or return fishing gears (Fisheries representative, Research).

- Determine the economic utility in developing potential market for return, repair and renting nets (Government or international organisation).

- Development of further facilities to enhance the capacity to recycle fishing gear within Europe (Fisheries representative), including further development to reduce costs of recycling fishing gears (NGO) and developing methods to reduce accumulated matter in end-of-life nets to facilitate recycling (NGO).

- Development of modular elements for fishing gear that make for easier repair with less mixture of materials (NGO).

- Develop good practice guidelines for use and storage of fishing gears (Research).

- To develop methodology to differentiate precise types of plastic used in netting (NGO).

- Determining the economic utility and usefulness of products that are recycled back to basic or near basic materials (Fisheries representative).

- Identification of fast growing biomass to provide appropriate chemical building blocks for manufacture of high tensile strength polymers.

- Building on existing technology to advance development of more efficient and sustainable primary production technologies i.e., to ensure consistent supply of biomass chemical feedstocks.

- Assessing the likelihood that end-of-life fishing gears are brought back to a port where recycling facilities are available (i.e., not left in a third country with no suitable facilities).

Annex 1 Requirements concerning the content of standard(-s) for circular design of fishing gear

The overall objective of the development of a standard for circular design of fishing gear is to achieve the aim that fishing gear never becomes a waste. Therefore, the development of standards shall cover fishing gear and its assembling elements and shall take into account the generally acknowledged state of the art. The standard shall describe the technical specifications for fishing gear containing plastic to facilitate its reuse and recycling at the end-of-life according to the requirements of Article 8(9) of Directive 2019/904.

The standard shall describe principles, specify requirements and provide guidance for organizations intending to integrate environmental aspects into the design and development in order to minimize the adverse environmental impacts of their products

The product solution resulting from design and development should achieve a balance between the various environmental aspects including relevant stakeholder requirements and other requirements such as function, technical requirements, quality, performance, safety, economic aspects, ethical and social value, and technical and business risks.

Definitions

Environmentally conscious design systemic approach, which considers environmental aspects in the design and development with the aim to reduce adverse environmental impacts throughout the life cycle of a product

The definitions of plastic, fishing gear, waste fishing gear and producer are laid down in the Article 3 of Directive (EU) 2019/904. The definitions of environmentally conscious design, environment and environmental impact are laid down in the ISO 14006:2020.

The Commission defines sustainable development as development that "meets the needs of the present without compromising the ability of future generations to meet their own needs." The principles of sustainability are the foundations of what this concept represents. Therefore, sustainability is made up of three pillars: economic, social and environment. These principles are also informally used as profit, people and planet.

WHO are the relevant stakeholders?

The standard will be relevant for organizations that deal with designing, manufacturing, assembling and importing to the EU fishing gear and its assembling elements, as well as fishermen that produce their own gears.

The standard will be developed in a collaborative manner, with full engagement of relevant experts and stakeholders that produce, manufacture (both raw materials and components), assemble, repair, perform preventive maintenance on, and reuse fishing gear components, as well as recycle fishing gear and its assembling elements, use gear in real life conditions (fishing and aquaculture), and that are concerned and manage (including Fish Producers Organizations / EU Advisory Councils) the environmental impact of fishing gear lost at sea or mismanaged at end-of-life.

WHY develop a standard?

There is currently no standard for the circular design of fishing gear and often no sustainable circular economy or full life-cycle thinking in fishing gear design and manufacture. The lack of such standards may then lead to end-of-life fishing gear having relatively limited value, resulting in substantial environmental impacts including

development of ALDFG and high disposal of gears in landfill. The product design phase has a major influence on the total environmental impact[42].

HOW would such a standard be developed?

By developing an environmentally conscious circular design of functional fishing gear containing a maximum amount of plastic for subsequent reuse and high recyclability at end-of-life while maintaining and possibly improving the gear components full functionalities, durability and catchability, and overall ecological footprint of the fishing activity.

The standard will provide to the organizations the opportunity to establish, implement, and maintain environmentally conscious design (ECD) as an integral part of design and development of fishing gear and its components by integrating corresponding requirements into the related procedures and instructions. ECD to be reflected in the policy and strategy of the organization. If an organization has a management system which includes design and development, the ECD shall be a part of that management system[43].

The organization shall determine the scope of ECD for a particular product or product group. This scope shall consider the relevant stakeholder requirements, and environmental aspects relevant to the product (or product group, as applicable) and the environmental sphere of influence of the organization.

The standard will be voluntary for the organizations to implement.

WHAT to consider?

Circular economy is 'restorative and regenerative by design, and it aims to keep products, components and materials at their biggest utility and value at all times, distinguishing between technical and biological cycles" (Ellen MacArthur's Foundation)

Considering the 'closed-loop, closed-source' concept, requires fishing gear component designers to plan and design for a product's entire lifetime, with the product repeatedly cycling through the Circular economy (CE) in different states of integrity. The challenge for designers is to create fit for use, economically viable, and robust products with extensive adaptive possibilities that also can be repaired or remanufactured.

In the open-loop, open-source concept product integrity is seen as a collective responsibility involving all stakeholders from producers to end users, product designers have to prioritize reuse (reparability, remanufacturing), upgradeability (e.g. through modular designs) and recycling.

Circular fishing gear (and its assembling elements) design aims to reduce (or avoid) raw material input and generate less waste while maintaining and possibly improving gear components functionalities. Design for circularity eliminates waste as part of the design process and replaces the idea of a product's 'end-of-life' with 'the end of its period of primary use'.

As such, design in the sense of the choice of materials is a key facilitating factor in the implementation of a circular economy[44].

Further it has been recognized that the design stage benefits from its position early in the product development process, at which point there exists the most potential for

[42] Ulrich K, Eppinger S, 2000. Product Design and Development. Irwin McGraw-Hill, Boston
[43] Management systems are described, for example, in ISO 9001 and ISO 14001. ISO 14006 provides guidelines for incorporating ECD into a management system.
[44] Andrews D 2015. The circular economy, design thinking and education for sustainability. Local Economy, 30:305–315.

radical innovation before considerable time and resources have been committed to any particular design or direction[45]. However, within the current industrial system, design for a circular economy faces a number of challenges, including those related to designer awareness and education[46], the availability and provision of product and material data[47], consumer expectations[48] and technical and economic feasibility[49] (Preston, 2012).

Design for recyclability is an important principle to enable product disassembly and subsequent reuse and recycling of the product's inherent materials and components.

[45] Bocken NMP, de Pauw I, Bakker C, van der Grinten B, 2016. Product design and business model strategies for a circular economy, Journal of Industrial and Production Engineering, 33 :308-320
[46] Andrews D 2015. The circular economy, design thinking and education for sustainability. Local Economy, 30:305–315.
[47] Winans K, Kendall A, Deng H, 2017. The history and current applications of the circular economy concept. Renewable and Sustainable Energy Reviews. 68:825-833.
[48] Tukker A 2015. Product services for a resource-efficient and circular economy – a review. Journal of Cleaner Production 9:76-91
[49] Preston F 2012. A Global Redesign? Shaping the Circular Economy. Chatham House Briefing Paper

Annex 2 Detailed methodology utilised to complete Tasks

Task 1: Identify existing challenges and solutions

Sub-task 1.1 Literature review

This sub-task encompassed collating and reviewing all available primary, secondary and grey literature globally to determine and assess all legal and practical 'challenges' and potential solutions in the collection, redesign, reuse, recycling and/or monitoring of recycling of ALDFG and end-of-life fishing gear, as well as determining best available practices and technologies addressing all challenges, including those associated with voluntary commitments to practices and any certification processes utilised globally for recycling. In detail we examined the literature to answer three questions:

Primary question: What are the legal and practical 'challenges' and best available practice/technologies for the collection, redesign, reuse, recycling and/or monitoring of recycling of ALDFG and EOL fishing gear?

Secondary question: What voluntary commitments have been undertaken to address challenges in the collection, the collection, redesign, reuse, recycling and/or monitoring of recycling of ALDFG and end-of-life fishing gear and what have been their effect?

Secondary question: What certification processes have been undertaken to address challenges, and what have been their effect?

We searched for literature in Science Direct, Web of Science and within Google Scholar between 2015 and 2019 (Science Direct) and 2010 to 2019 (Web of Science, Google Scholar). Searches were performed using English language search terms across all bibliographic databases. The following search string were used in bibliographic databases:

("abandoned, lost, discarded fishing gear" OR ALDFG OR "derelict fishing gear" OR GGGI OR "ghost fishing" OR "ghost gear" OR "ghost nets" OR "Global Ghost Gear Initiative" OR "marine debris" OR "marine litter" OR "ocean plastics" OR "plastic litter" OR "end-of-life fishing gear" OR "EOL fishing gear" OR "fishing nets" OR "separate collection" OR "fishing for litter" OR "aquaculture gear") AND ("harbour dumping" OR "port infrastructure" OR collection OR collecting OR collect OR design OR redesigning OR recycle* OR "point of sale" OR, "mechanical recycling" OR "chemical recycling" OR re-use OR "preparation for re-use" OR reprocessing) AND (legal OR "best practice" OR policy OR management OR "single use" OR "extended producer responsibility" OR "circular design" OR "Atlantic Western Waters" OR "circular economy" OR "extended responsibility scheme" OR "eco-innovation" OR "eco-design").

Where review papers were found within the literature review, the bibliography of the paper was also searched for relevant papers.

Organisational websites

We applied a case study approach for searching for grey literature. Searches were performed across a set of relevant organisational websites that focus on fishing gear collection, redesign, reuse and recycling, as well as fishing gear certification (see table below). Each website was searched for relevant publications and screened for relevance before being combined with other records.

The following organisation websites were searched:

Organisation	Source

GGGI	http://globalghostgearportal.net/dp/usermanagement/
NOAA	https://marinedebris.noaa.gov/innovative-removal-projects
Norwegian University of Science and Technology	http://www.circularocean.eu/wp-content/uploads/2017/09/Barrier-assessment_FINAL.pdf
UNEP - IMO	https://wedocs.unep.org/bitstream/handle/20.500.11822/26253/fishing.pdf?sequence=1
Bertelsen_DTU Aqua	https://orbit.dtu.dk/files/128000846/Pages_from_Cold_region_engineering_conf_proceedings_2_2.pdf
Norwegian University of Science and Technology	https://ntnuopen.ntnu.no/ntnu-xmlui/handle/11250/2433857
WWF	http://wwf.panda.org/wwf_news/?259916/Removal-of-derelict-fishing-gear-lost-or-discarded-by-fishermen-in-the-Baltic-Sea
DeFishGear project	https://www.defishgear.net/images/Outputs/WP6DFGFFLguidelines.pdf
Kimo	http://www.kimointernational.org/news/exploring-extended-producer-responsibility-schemes-for-fishing-gear/
Green Enterprise	https://www.netmap.ie/wp-content/uploads/2018/07/Netmap_Report.pdf
European Commission	http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=home.showFile&rep=file&fil=3R-FISH_Informe_tecnologico_redes.pdf
Marelitt	http://www.marelitt.eu/files/14259815070.pdf

Testing comprehensiveness

A benchmark list of 10 articles of known relevance to the review were screened against scoping search results to examine whether searches are able to locate relevant evidence. All the 10 articles were found during scoping and therefore the search criteria were determined to be valid for this analysis.

Sub-task 1.2 Stakeholder engagement

Existing information on challenges, best practices, technologies, voluntary commitments and certification processes were supplemented and developed through questionnaires to a wide audience of experts, and interviews with key stakeholders. A stakeholder engagement strategy was developed to make clear how the engagement and interviews would deliver the information and data across Task 1 in a coordinated way and to minimise respondent fatigue.

A set of interview guidelines were developed and shared with EASME/DG MARE before translation and dissemination in both English and Spanish. The questionnaire was developed to answer three main themes of question:

- Challenges (legal and/or practical) that are linked to the re-use / design / recycling / manufacture of fishing gear
- Factors associated with fishing gear recycling
- Understanding design standards for fishing gear

This questionnaire was sent to 159 key stakeholders.

Subtask 1.3 Expert stakeholder workshop

Building on the review of available literature, and interviews with key stakeholders, a 2-day workshop was organised to validate the findings of sub-tasks 1.1 and 1.2, and to further gather collective intelligence on practical solutions to address any potential challenges identified.

The workshop was developed in collaboration with OSPAR colleagues, as a connected study has been undertaken by OSPAR to examine best practices for circular design of fishing gear. Workshop development was led by Cefas, and comprised plenary sessions in which the organisers presented information from sub-tasks 1.1 and 1.2, and various breakout or 'focus group' sessions were undertaken that had been tailored to stakeholder sectors and key challenges identified in sub-tasks 1.1 and 1.2.

Task 2: Recommendations for circular design of the fishing gear

Building on the results of Task 1 (literature review, stakeholder engagement and key stakeholder workshop), this task provides a detailed and thorough description, summary and then lists out broad recommendations for the circular design of the fishing gear. The development of this task draws heavily from the results of sub-tasks 1, 2 and 3 (Task 1), including the discussion and recommendations from the key stakeholder workshop.

Task 3: Validation of recommendations

Building on the outcomes from Task 2, this task (Task 3) was developed to seek feedback from key individuals (identified and utilised within sub-task 1.2) on the draft findings and recommendations on circular design of fishing gear and classification of fishing gear for point of sale and port collection, to validate and increase the quality of the findings and recommendations.

Task 4: Final Report

Building on the outcomes of Tasks 1, 2 and 3, the objective of Task 4 has been to collate all validated recommendations, to better understand ALDFG and EOL fishing gear recyclability, by collating all information on existing challenges (both legal and practical) collection, redesign, reuse and/or recycling of ALDFG and EOL fishing gear and providing substantial and effective solutions to overcome such challenges. In addition, we quantify and report on the best available practices and technologies, voluntary commitments and certification processes known for ALDFG and EOL, proposing recommendations for harmonized standards for the circular design of fishing gear.

Annex 3 Questionnaire on circular design of the fishing gear for reduction of environmental impacts

Name, First name	Date:
Organisation, title:	
Location (Country):	
Sector (please highlight):	National / Regional Government OR International organization Fishing Organisation / Company Port Authority Fishing Gear Designer/eco-designer Fishing gear Manufacturer / Assembler / Supplier Fishing Gear Recycler / Waste Handler / Waste Logistics Company / Transportation Company Non-Governmental Organisation Research Institute / Expert Ecolabelling / ISO Certification Organisation/Standardization organization Other (please elaborate in the space below)
Consent given to use this information for the purposes of this study (please delete which is not applicable). Your response will be treated in full confidence, and will be grouped in the report, so that it cannot be traced back.	Y / N
Telephone:	Email:

Please note: Within this study we follow the SUP directive (Article 3(4)), which defines fishing gear as "any item or piece of equipment that is used in fishing and aquaculture to target or capture or rear marine biological resources or that is floating on the sea surface and is deployed with the objective of attracting and capturing or rearing such marine biological resources".

1. Please briefly describe how your organisation is involved in the re-use / design / recycling / manufacture or certification of fishing gear?

2. Challenges

2.1 Are you aware of any challenges (legal and/or practical) that are linked to the re-use / design / recycling / manufacture of fishing gear?

No (please skip to section 3)

Yes (please provide details below)

For example, where gear contains hazardous materials (i.e., lead) that local/regional or national laws render that gear unrecyclable

2.2 If there are challenges, are you aware of any voluntary action being taken to reduce the impact of, or remove, these challenges?

No (please skip to Question 2.3)

Yes (please provide details below)

What are the main obstacles to addressing these challenges?

For example, low levels of awareness of challenge, low understanding of effects on not addressing challenge, low level of commitment or actions from organisations (e.g., local government), high level of obstacles to addressing challenge

3. Recycling

3.1 What are the most important barriers for implementation of fishing gear recycling? Please tick all that apply, then rank the top three barriers (1 = highest, 3 = lowest)

	Tick all barriers that apply	Top 3 ranked barriers
Logistical challenges (e.g., Collection, storage, transport etc)		
Technological challenges		
Material condition (e.g. knot slippage)		
Contamination (e.g., biofouling, lead contamination, etc)		
Gear design (e.g., multiple materials used, increasing cost associated with pre-processing)		
Social dimension / behavioural aspects		
Legal challenges		
Challenges associated with the recycled product (e.g. market value, quality, etc)		
Lack of information (sharing)		
Lack of funding and/or associated costs		
Other (please elaborate below)		

3.2 Which types of fishing gear are currently recycled by yourself or others, and which do you know are not (please tick)?

Fishing gear type	Recycled, if so where (e.g., Europe, Asia etc)?	Not recycled?
Dredges		
Bottom trawl nets		
Pelagic trawl nets		
Long lines		
Ropes		
Dolly ropes		
Buoys		
Traps / pots		
Nets (trammel net / gill net / drift net)		
Seine nets		
Abandoned, Lost or Discarded Fishing Gear (ALDFG)		
Aquaculture gears (e.g. longlines, cages, rafts, tanks, bottom beds/poles/stakes)		
None / I don't know		
Other (please provide details below)		

3.3 If you have indicated any fishing gear that is not recycled (by you or others), can you indicate why this is not recycled?

Please tick

- Logistical challenges (e.g., Collection, storage, transport etc)
- Technological challenges
- Material condition (e.g. knot slippage)
- Contamination (e.g., biofouling, lead contamination, etc)
- Gear design (e.g., multiple materials used, increasing cost associated with pre-processing)
- Social dimension / behavioural aspects
- Legal challenges
- Challenges associated with the recycled product (e.g. market value, quality, etc)
- Lack of information (sharing)
- Lack of funding and/or associated costs
- Other (please elaborate below)

3.4 Do you know of any dangerous substances (lead, copper coatings, Substances of Very High Concern or POP's) used in the design of fishing gear which makes it unsuitable for recycling?

- No
- Yes (please indicate which material types and which type of fishing gear these apply)

For example, lead within sinker lines

3.5 Prior to the recycling of fishing gear, is there any form of pre-processing required that you would complete yourself or that others complete for you?

Please tick all that apply

	Pre-processing you complete	Pre-processing others complete
Pre-cleaning		
Disentanglement		
Sorting		
Cut / separate different types of material (e.g., polypropylene ropes from nylon nets)		
Removal of parts for re-use (e.g., metals, buoys etc)		
Removal of parts to meet acceptance by waste handler (e.g., lead-lines, etc)		
Other – (please describe below)		
None that I know of		

3.6 Which different material streams from fishing gear are re-used and or recycled, and which technologies are used?

Type of material stream	Re-used (yes/no)?	Recycled (yes/no)?	If recycled, which technology used to recycle (mechanical/chemical)?
Metals			

Mixed plastics
Polyvinyl Chloride (PVC)
Polypropylene (PP)
Polyester (PE)
Polystyrene (PS)
Nylon - monofilament
Nylon - multifilament
Polyvinylidene fluoride (PVDF)
Polyethylene (PE)
Dacron
Dyneema
Rubber
Foams
Hazardous waste
Other (please elaborate below)

3.7 Which output streams of recycling have a positive market value? Which cannot be marketed as a product (or used thereafter)?

3.7 Which output streams of recycling cannot be marketed as a product (or used thereafter)?

4. Design of Standards for fishing gear

4.1 What are the most important barriers for (large-scale) implementation of design for recyclability of fishing gear? Please tick all that apply, then rank the top three barriers (1= highest, 3 = lowest)

	Tick all barriers that apply	Top 3 ranked barriers
Technological / engineering challenges		
Social dimension / behavioural aspects		
Organisational aspects		
Logistical challenges		
Cost challenges		
Compromising the performance / efficiency of the gear		
Legal challenges		
Other (please provide detail below)		
I don't know		

4.2 Which fishing gear type is most suited to apply design modifications to increase its recyclability? Please provide detail of any such modifications

4.3 Are you aware of any design innovations already developed / in development to reduce environmental impacts and/or enhance the circular design and/or increase the life of the fishing gear?

No

Yes (please provide details below)

4.4 Do you know of any examples where mixed materials in design have been replaced by monotype materials?

No

Yes (please indicate which material types and which type of fishing gear these apply)

4.5 Do you know of any examples where design has been adapted to facilitate future disassembly of fishing gear?

No

Yes (please indicate which material types and which type of fishing gear these apply)

Annex 4 Workshop Agenda: Study on circular design of the fishing gear for reduction of environmental impacts

19th February. Day one: Gear design, recycling and challenges	
Time	Activity
08:30 09:20	Registration, networking & coffee
09:20 09:40	Introduction from DG MARE
09:40 09:50	Can you recognise the materials from which this gear is made? Are they recyclable?
09:50 10:00	Introduction to MRAG Europe/ Commission project & workshop aims and objectives. Introduction to validation exercise post-workshop
10:00 10:10	Introduction of OSPAR project and objectives of workshop; Summary of design and recycling of fishing gear
10:10 10:30	Key findings from scoping (OSPAR & Commission) study on design and recycling of fishing gear
10:30 11:00	Coffee break
11:00 11:15	Gears and ropes going circular-still some hurdles to take
11:15 12:45	Discussion 1: Challenges and barriers (legal and practical), and solutions and best practices: - Collection and logistics for recycling - Practical recycling (EOL & ALDFG)
12:45 13:45	Catered lunch
13:45 14:00	Short summary of discussion 1
14:00 14:15	Eco-design and circular design of fishing gear
14:15 14:30	Circularity in design
14:30 15:15	Discussion 2: Challenges and barriers (legal and practical) and solutions and best practices; - Design for recyclability and reuse - Design to reduce impact on the marine environment
15:15 15:45	Coffee break
15:45 16:30	Discussion 2 continued…
16:30 17:00	Summary to whole group (Group leaders) – Main issues and recommendations
17:00 17:30	Wrap up

20th February. Day two: Solutions, recommendations and validation	
Time	Activity
08:45 09:00	Walk in & coffee

09:00 09:10	Recap & intro to day 2.
09:10 10:30	Discussion 3: Identify recommendations (legal and practical) and potential feasibility - Collection and logistics of recycling - Practical recycling - Design for recyclability and reuse - Design to reduce impact on the marine environment
10:45 11:00	Summary (5 min per moderator)
11:00 11:30	Coffee break
11:30 12:30	Discussion 4: Prioritisation of recommendations STEP 1: Individual & group recommendations STEP 2: Prioritisation of these recommendations STEP 3: Key issues of the priority to address, includes assessing feasibility of the recommendation.
13:00 13:45	Lunch break
13:45 15:20	Discussion 4: continuation of STEP 3, and STEP 4: Summary of prioritisation
15:20 16:00	Next steps and conclusions
16:00	End of the meeting

Annex 5 Challenges in the environmentally conscious (friendly) circular design of fishing gear

Knowledge and willingness

There is a lack of knowledge of how to develop new designs and limited research and development facilities that are working on redesign of fishing gear. Importantly, such further innovation of fishing gear will cost, and there is still little understanding of who should bear the costs for innovations, including the design of new materials, different gear structure, development, better end-of-life properties, etc. Additionally, a major challenge to any further development of the design of fishing gear is the potential low price of contemporary gear. Understanding the cost to reward in the design of new fishing gear is needed.

There is still an attitude within the fishing industry that economic development is more important than environmental impact in fishing gear design, therefore raising awareness and education is needed

Regional and cultural differences in the behaviour of fishers and fisheries will impact the uptake of new designs of fishing gear

Lack of understanding of fishing gear manufacture, assembly and market

There is still little knowledge of the total volume of gear made and utilized throughout Europe, and therefore where the best use of innovation should be focused (i.e., which gears to redesign first). In addition, there is still little knowledge transfer of gear development across the Member States. This is despite knowing who manufactures which product (through branding), and the technology to determine the chemical makeup. Lastly, fishing gear can consist of a heterogeneous range of materials and designs, each with different characteristics and properties. Such design will depend on the type of fisheries involved, the local circumstances, and individual preferences in design.

There is not a substantial interest in the development of materials utilised within fishing gear that are recyclable (i.e., no impetus from the market in providing such products). The request from the market is for high performance and low price in fishing gear. Therefore, there is a low ability to charge for recycled product, resulting in recycled products potentially having a lower worth on the market.

Current materials do not fit eco-design principles

There has been growing interest in plastics that are biodegradable in seawater. However, biodegradable materials are not yet of the same quality as high tenacity PA, and therefore are likely to not provide suitable materials for new fishing gears. Further economic incentives are needed to allow it to be competitive on cost. In addition, the rate of biodegradability depends on the 'aggressiveness' of the environment, with seawater considered less 'aggressive' than freshwater, soil or composting facilities. Therefore, materials will be relatively slower to degrade, with recent estimates of months to years for biodegradable fishing gears to degrade (Grimaldo et al. 2018a, 2018b). In addition, the use of biodegradable fishing gear may increase microplastic pollution, as the biodegradable gears break down. At present biodegradability is not a solution as it interferes with recycling, is environmentally dependent (i.e., what bacteria are in the water) and may add to microplastics. Lastly, marketing of a biodegradable fishing gear may increase risk of reverse incentive, as fishers feel they can throw away material as it will naturally degrade in the environment - this may lead to more waste being produced (and less recycling).

Within fishing there are still a number of materials that are substantially utilised, with no obvious alternative (e.g., tie wraps within aquaculture farms) and materials that will degrade and produce microplastics (e.g., polystyrene fish boxes, which will break down into pellets/beans).

There is a challenge to the use of natural fibres instead of synthetic fibres, as the manufacture of such fibres need water and pesticides to produce. Also, when natural fibres are used they require coatings to prevent decomposition and fouling.

There are challenges for using different materials for redesign, as alternatives aren't always like-for-like and therefore the market needs to be open to this (e.g., lead replacement may have a different weight and shape). Any new materials should meet demands of the client (especially in terms of quality).

Hazardous materials (e.g., lead, copper coating) are still widely utilised in a range of fishing gears. These are predominantly still utilised as there is not a suitable (and/or economically feasible) alternative that is available to manufacturers and gear assemblers.

Current design principles do not fit eco-design principles

Contemporary fishing gear is currently designed for efficiency and selectivity, with design also substantially impacted by legislation. In this respect, there is still little understanding of the range of materials that are used to produce fishing gears, and the reason why such materials have been used. This is expected to be because the range of materials used within fishing gears will differ depending on the type of fishing, (i.e., pelagic fishing, demersal fishing, aquaculture), where the fishing occurs (i.e., fishing grounds), and the fishing methods used (e.g., mechanical vs non-mechanical methods for hauling). These will all impact the types of material utilised within fishing gears, and therefore the range of materials that need to be examined in the circular design of fishing gear.

Increasing ability to easily dismantle fishing gears may reduce the durability of the product, and therefore such materials may be more prone to wear and tear. Also, any design that has separability as a specific constraint may then be impacted by post-use reconstruction of the fishing gear associated with fixing by the fisherman.

Future use of redesigned gear should be fit for purpose

All materials utilised within fishing gear may be impacted by actual use, and therefore should be taken into account when redesigning. This includes understanding how the materials weight, their elongation and abrasion, and how their flexibility is impacted by fishing activities. In addition, understanding how such properties will impact the recycling and further use (and reuse) of the materials will be important. For example, nylon is used when mounting netting to ropes (instead of PE, which slips), as well as when joining sections of nets during repair. This is because nylon will shrink when it gets wet, tightening any knots. Overall, there is little understanding of how gear will change in its behaviour with a change of materials that are more likely recyclable.

There is a need to understand the effect of using new materials on the environmental impact of such gears. For example, new materials may have more drag when used, resulting in more fuel being used and therefore a higher CO2 footprint. In this respect, changing the material in fishing gear to reduce environmental impact (e.g., microplastics), may then have another impact.

The suitability of different materials for undertaking economically feasible fishing activities should be examined if redesigning of gears is undertaken. Such factors include the need to replace existing materials that are being used for a particular purpose (e.g.,

antifouling and coatings for aquaculture cages) with products that work. In support of this, there is a clear need to undertake more research on alternatives to existing materials, as there is a lack of understanding of the material properties that are needed to design new fishing gears.

There is still a range of materials and mixtures of materials used in fishing gear design that reduce or negate its ability to be recycled. Fishing gears are still produced from a mix of materials that are difficult to dismantle (e.g., lead core rope), or from materials that are not recyclable (e.g., HMPE [Dyneema®]) or materials with low market value at their end-of-life (e.g. PE/PP, as opposed to PA).

Current legislation does not support environmentally conscious (friendly) circular design of fishing gear

There is a lack of EU legislation (and to our understanding, Internationally) to support the use of (and therefore development of) fishing gear that is more likely to be recycled and/or reused. The only driver at present is the costs associated with the recycling of gear. In addition, where policy exists there is no matching of engagement between different stakeholders across the Member States. For example, Denmark's statutory order on 1 Dec 2000 prohibited the import and marketing of products containing lead. Despite this, there has been no mirroring of such a ban in other EU countries.

Any redesign of fishing gears will need to comply with current fisheries legislation, which has not been developed to enhance eco-design. In addition, any development of legislation will be slow, reducing the likelihood of eco-design being incorporated.

There is still a high use of fishing gear that is imported from overseas (e.g., 100% of pots and traps from Asia). Depending on the country of origin legislation, such gears may not be designed to conform to future EU standards for fishing materials and therefore?? .

Annex 6 Questionnaire on the circular design of fishing gear[50]

The EU Commission has recently contracted MRAG Europe (partnering with Fundacion AZTI (AZTI), the Centre for Environment, Fisheries and Aquaculture Science (Cefas) and Danmarks Tekniske Universitet (DTU Aqua)) to assess the range of factors that are needed to develop a harmonised standard for the design and recycling of ALDFG and EOL fishing gear, while also gathering examples of best practice of design and recycling, as well as labelling and standardisation of design.

This questionnaire is an opportunity to contribute to the development of the European standard for circular design of fishing gear, which has the wider aim that fishing gear in the future never becomes waste. Your opinion is very important for making transparent and well informed decisions. This survey seeks for finding a balance in future design of fishing gear among economic, social and environmental considerations

Name, First name		**Date:**
Organisation, title:		
Location (Country):		
Sector (please highlight):		National / Regional Government OR International organization
		Fishing Representative (Company/Organisation/Advisory Council, etc.)
		Port Authority
		Fishing Gear Designer/eco-designer
		Fishing gear Manufacturer / Assembler / Supplier
		Fishing Gear Recycler / Waste Handler / Waste Logistics Company / Transportation Company
		Non-Governmental Organisation
		Research Institute / Expert
		Ecolabelling / ISO Certification Organisation/Standardization organization
		Education
		Citizen
		Other (please reply below)
I give my consent to use this information for the purposes of this study. Your response will be treated in full confidence, and will be grouped in the report, so that it cannot be traced back.		Y / N
Please note: Within this study we follow the SUP directive (Article 3(4)), which defines fishing gear as "any item or piece of equipment that is used in fishing and aquaculture to target or capture or rear marine biological resources".		

Section 1: Technical requirements

[50] 'Fishing gear' means any item or piece of equipment that is used in fishing or aquaculture to target, capture or rear marine biological resources or that is floating on the sea surface, and is deployed with the objective of attracting and capturing or of rearing such marine biological resources.

Specific to the product, to enhance circularity in design, manufacture and use.	
1.	Which are the most important technical requirements for fishing gear (and its components)? Tick all that apply
	Durability
	Strength
	Catchability
	Low cost
	Other, please comment
2.	How important is it to reduce the costs of transport and distribution of fishing gears, by minimising product size and weight and optimizing shape and volume for maximum packaging density? Tick one box
	Not important at all
	Slightly important
	Important
	Very important
3.	Do you consider a mixture of polymers51 within a product necessary if a single polymer provides the same functionality and performance? Tick one box
	Single polymer is fine, but I will need to test the performance of the product myself
	Single polymer is fine, if functionality and performance is kept
	Single polymer should always be used
	I need a mixture (please provide examples)

Section 2: Circularity requirements Aiming at optimising circular aspects including the product lifetime: reusability, upgradability, reparability, recycled content and recyclability.	
1	What are the key circularity aspects to consider at the design and manufacturing stages for the circular design of fishing gear? (Tick all that apply).
	Reusability
	Repair/Refurbishment (modification),
	Remanufacturing,
	Enabling high-quality recycling at 'end-of-life'
	Increasing recycled content in products, while ensuring performance and safety of the product
	Avoidance of mixed materials (e.g. mixture of polymers in ropes)
	Avoiding the use of diverse parts
	Increased use of recovered or recycled materials from process waste
	Clear, simple and resource efficient mechanism to dismantle different types of gear, materials, and detach different parts
	Use of biodegradable materials
	Other – comment

[51] Mixture of polymers/materials makes their recycling extremely difficult or even impossible

2	For manufacturers/producers and users of fishing gear - would you agree to a system where producers retain ownership of the fishing gear, and/or the responsibility for its performance throughout its lifecycle? Tick one box
	Yes
	No
	Other (please specify)
3	Is there a need to increase transparency between manufacturers in providing accurate information on what materials have been used in the production of gear (including chemicals used in coatings)? Tick one box
	Yes
	No
4	Should the high sustainability performance of fishing gear be rewarded by incentives for manufacturers? Tick one box
	Yes
	No
5	If 'Yes' to above, what kind of incentives should those be? (Tick all that apply and add text, if relevant)
	Fee modulation
	Lower taxes for more sustainable products
	Other incentive? Please list (free text)

Section 3: Environmental requirements Aiming where possible to address the most significant environmental impacts throughout the lifecycle of products, while also exploiting environmentally conscious design potential and responsibility of manufacturers.	
1	At what lifecycle stage of fishing gear do you see in the future the highest potential for reduction in environmental impact? (Tick 2 boxes where you see highest potential)
	At the product design stage
	Within the supply chain of materials used
	During manufacturing
	During transport and distribution
	Where an extension strategy is used to prolong the life of the product
	When recycling at end-of-life
2	Should fishing gear producers and users be aware of the environmental impacts throughout the life cycle of the product? (Tick either ''yes'' or ''no'')
	Yes
	No
3	If 'Yes' to above, which environmental impacts are most important (tick all that apply):
	Level of energy/water consumption
	Greenhouse gas emission
	Generation of waste during production cycle and assembly
	Environmental impact during the use of the fishing gear
	Impact at the end-of-life
	Other

4	Are there any materials that fishing gear should not contain (i.e., through plating or coating) nor have as a manufacturing requirement? Tick all that apply
	Lead
	Copper coating
	Other materials (e.g., Zinc)
	Problematic polymers: Polyvinyl chloride (PVC)
	Problematic polymers: Polystyrene (PS)
	Problematic polymers: Expanded polystyrene (ePS)
	Problematic polymers: Non-recyclable plastics (i.e., HMPE)
	Other

Section 4: What are the necessary research needs for circular design of fishing gear and its components?	
1	Is there a need to map the gaps for circular design of fishing gear? (Tick either ‘’yes’’ or ‘’no’’)
	Yes
	No
2	Is there a need to enhance sustainable design and manufacture of 100% recyclable materials? (Tick either ‘’yes’’ or ‘’no’’)
	Yes
	No
3	Is there a need to develop a broadly acceptable gear marking/tagging or colour coding of materials and products?
	Yes, electronic tagging
	Yes, colour coding
	No
	Other
4	What research and innovation is needed to enhance digitalisation of product information? (Tick all that apply and add comment, if relevant).
	Digital passports
	Tagging
	Watermarks
	Other
5	What research and innovation is needed to increase recycled content (i.e. recyclates) and renewable materials in twines, ropes and netting?
6	What research and innovation is needed to develop an extension strategy (i.e. extend lifespan) for nets?
7	What research and innovation is needed to replace hazardous coatings on fishing gears?

Section 5: Best practices, training needs & Managing process of standardisation	
1	Is there a need for training to be developed for manufacturers and/assemblers, related to environmentally conscious (friendly) circular design, including product development that incorporates environmentally conscious (friendly) circular design? (Tick either ‘’yes’’ or ‘’no’’)

	Yes
	No
2	Is there a need to collect and disseminate broadly available best practices for redesigned materials and alternatives that are already in use? (Tick either ‘’yes’’ or ‘’no’’ and add comment, if relevant)
	Yes
	No
3	If ‘’Yes’’ to above, then please provide detailed information on the best practices you are aware for redesigned and alternatives already in use
4	If ‘’No’’ to above, please provide other ways of cooperation and collaboration to work towards a harmonised design and manufacture in future

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