CleanAtlantic

Tackling Marine Litter in the Atlantic Area

Characterisation of the fishing gear materials flows in the Autonomous Region of Madeira

WP 7: Monitoring and data management

WP 7.3: Reducing abandoned lost and otherwise discarded fishing gears (ALDFG).

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DISCLAIMER

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EXECUTIVE SUMMARY

To minimise the potential impact of fishing gear on marine ecosystems, it is necessary to implement public policies. This requires assessing the quantities involved, their origins and potential destinations. Accounting the consumption of products and the production of waste makes it possible to define more efficient strategies for their management in economic and environmental terms. Accounting the waste that is being produced today makes it possible to assess alternative destinations that avoid landfill. Knowing and accounting which products are being purchased today allows us to scale waste management systems and investigate new ways to keep materials circulating in the economy after the end of life of the products.

To frame and guide the policies of the Autonomous Region of Madeira (RAM) in this matter, the Regional Directorate of Environment and Climate Change (DRAAC), promoted the development of a detailed study to assess the flow of materials from fishing gear in the Region, identifying quantities, typologies, origins, and destinations of these products. The study's goal is to contribute to the development of a more sustainable and circular model for fishing gear in the ARM and the development of basic knowledge on this subject.

The accounting of fishing gear material flows involved two phases: information gathering and estimation of flows. In the first phase, the system boundaries were defined (in this case, in geographical terms, the Autonomous Region of Madeira and, in economic terms, the fisheries and aquaculture sector) and the actors of the value chain were inventoried. To estimate the flows, we used information collected directly from the actors in the value chain and sources available in literature and websites.

The agents of the value chain were contacted to learn about their practices and to obtain information that would allow estimates of flows associated with fishing gear in the Region. Due to the pandemic situation, contacts were made by email, telephone, and online interviews.

The estimated values of material flows point to a stock of polyamide, associated with angling and seine fishing, ranging from a minimum of 33.5 tonnes to a maximum of 132.5 tonnes. Associated to these gears we have to account also about 20 thousand buoys (Polyethylene, Polyurethane, Expanded Polystyrene (for filling)).

The stocks of equipment associated to aquaculture amount about 26,200 m^2 of nets to which we need to add all the associated components - floating structures (polyethylene and PVC), cables and buoys.

Although there is no information on the current production of gear waste in the Autonomous Region of Madeira, it was assumed that the quantities of yarn sold in the Region are replacement needs and therefore the production of polyamide waste associated with angling will be around 3100 kg per year. In some years this amount will be higher due to the end of life of the purse seine nets of some vessels.

The most common constraint in material flow studies is the scarcity of information on imports/consumables (usually associated with trade or sales), and on exports and waste generation. Among the mentioned categories, the lack of information on waste generation was the most relevant, mainly due to the lack of characterization or disaggregation of information. In the present study this lack of information was almost total, involving a strong constraint to results.

A more accurate knowledge of the quantities involved will require measures to trace the annual quantities of gear sold in the Region, on the one hand, and, on the other hand, the waste generated. The development of a scheme for extended producer responsibility for fishing gear, as determined by EU Directive/2019/904, will provide an opportunity in this regard, as it will require a record (whose templates are drawn in the Commission Implementing Decision (EU) 2021/958) of the quantities of gear entering the market and the waste produced. The first reporting reference period under that Directive is calendar year 2022.

The tracking of the waste generated will be easier if users of the gear are made aware and trained in order to avoid non-proper disposition (namely in the ocean) and, at the same time, if it is facilitated the disposal of waste in proper places - the OceanLit project which one of the goals is placing a dedicated container in each port in the Region will be an added value.

Polyamide waste, due to its economic value, may see its correct forwarding facilitated (namely for material recovery). But other waste, such as polyethylene or polypropylene, and the whole mixture of waste collected on beaches, will most likely constitute a burden for which a compensation may have to be provided under the extended producer responsibility regime. This will also include waste from aquaculture equipment containing algaecide impregnating agents.

The strategy for the management of fishing gears in the Region from a circular economy perspective should consider an integrated approach with the implementation of different sets of measures, complementary to each other:

- prevention measures - awareness raising campaigns, promotion of continuous improvement ideas, labelling, reconditioning and reuse;
- measures for recording and measuring - development of a recording and reporting platform
- measures for innovation - eco-design
- measures for waste recovery - selective collection and recovery.

INTRODUCTION

1. LEGAL FRAMEWORK

Directive 2019/904/EU 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 sets out measures to prevent and reduce the impact of certain plastic products on the environment, more particularly on the aquatic environment and human health, and to promote the transition to a circular economy with innovative and sustainable business models, products and materials. This Directive sets out new rules for EU Member States that aim to impose solutions for ten single-use plastic products that are frequently found on European beaches and at sea and for products made of oxy-degradable plastics, as well as solutions for fishing gear containing plastics.

In relation to fishing gear the Directive highlights that:

1. "A significant proportion of the fishing gear placed on the market is not collected for treatment. Single-use plastic products and fishing gear containing plastic are therefore a particularly serious problem in the context of marine litter, pose a severe risk to marine ecosystems, to biodiversity and to human health and damage activities such as tourism, fisheries and shipping."

2. "The large percentage of plastic stemming from discarded fishing gear, including abandoned and lost fishing gear, in marine litter indicates that the existing legal requirements laid down in Regulation (EC) No 1224/2009, Directive 2000/59/EC and Directive 2008/98/EC do not provide sufficient incentives to return such fishing gear to shore for collection and treatment. The indirect fee system set up under Directive (EU) 2019/883 of the European Parliament and of the Council (18) provides a system for removing the incentive for ships to discharge their waste at sea, and ensures a right of delivery. That system should, however, be supplemented by further financial incentives for fishermen to bring their waste fishing gear on shore to avoid any potential increase in the indirect waste fee to be paid."

Also acknowledging that plastic components of fishing gear have a high recycling potential, the Directive provides that Member States will have until 31 December 2024 to introduce extended producer responsibility (EPR) for fishing gear and gear components containing plastic to ensure separate collection of this waste and in the expectation that proper management, including recycling, can be financed.

Under this scheme, producers of fishing gear containing plastic must contribute to covering the costs of collection and its shipping and subsequent treatment. Typically, this type of scheme also places the responsibility to invest or cover costs of awareness-raising on the producers.

The directive also provides that the Commission shall request the European Standardisation Organisation to develop harmonised standards for circular design of fishing gears.

In most Member States, including Portugal, there are no specific policies for fishing gear waste. The closest instruments to cover this type of waste are the PERSU 2020 and the PNGR (both under revision at the time of this report), and the Action Plan for the Circular Economy. However, none of these refer specifically to fishing gear.

In May 2021, **Commission implementing Decision (EU) 2021/958** was published, setting out templates for reporting data and information on fishing gear placed on the market and waste fishing gear collected in Member States. The Decision determines the need to declare the total plastics, the total metals and the total rubber contained in the fishing gear placed on the market and the waste fishing gear collected. The information on plastics and metals shall however be disaggregated into types of plastics and types of metals according to the typologies detailed in Table 1.

According to Directive 2019/904/EU **the first reporting reference period is the calendar year 2022**. Data and information **must be reported electronically within 18 months of the end of the reference year** in which they were collected, which means that the deadline for reporting for the first reference period is June 2024.

Table 1 - Typologies of plastics and metals to be reported under Implementing Decision (EU) 2021/958

Typology	Description
Plastics	Polypropylene (PP)
	Polyethylene (PE)
	Ultra-high-molecular-weight polyethylene (UHMWPE))
	Nylon
	Others (PET, PVC, HDPE, EVA etc.)
	Mixture of polymers
Metals	Steel
	Aluminium
	Lead
	Other metals or mixtures of metals

The data and information reported by Member States will also have to be accompanied by a quality control report to ensure that the information and data reported provide a sufficient basis to verify the accuracy, reliability and comparability between Member States.

The information will have to be submitted electronically within one and a half years from the end of the reference year in which it was collected.

More than just a reporting element, the recording of this information is a strong support to the management of fishing gear waste.

2. FLOW ACCOUNTING OF FISHING GEARS

Accounting for flows from fishing gears is justified first and foremost by the urgency of addressing an environmental problem of alarming proportions, marine pollution. More than 80% of marine waste in Europe consists of plastics of different types and it is estimated that 27% (11 000 tonnes) originates from fishing gear (e.g. nets, lines, traps.) (EC, 2019). Sources include commercial and recreational fishing activities and aquaculture facilities.

Counting the consumption of products and the production of waste makes it possible to define more efficient strategies in economic and environmental terms for their management. Knowing and accounting for waste that is being produced today allows us to evaluate possible destinations that avoid landfill. Knowing and accounting for the products being purchased today allows us to scale waste management systems and investigate new ways to keep materials circulating in the economy after the end of life of the products of which they are part.

In this context, the regional authorities of regions like ARM, where there is a proximity or direct dependence on the state of marine ecosystems, have a key role in preventing marine litter, in order to reduce it and minimize its impact on the degradation of ecosystems and consequent loss of biodiversity. The recovery of fishing gear is foreseen as an obligation in the Fisheries Control Regulations (EC, 2009) under the Common Fisheries Policy. The revision of the Regulations requires marking devices to carry recovery equipment on board.

The collection and recovery of fishing gear by reintroducing it into production processes is also a vector for the transition to a circular economy, generating employment and wealth.

3. OBJECTIVES AND SCOPE

Aware of the challenge that this flow represents, the Regional Directorate for the Environment and Climate Change, promoted the development of a detailed study to assess the flow of materials from fishing gear in the Autonomous Region of Madeira, identifying quantities, typologies, origins and destinations of these products. The study, named RePesca, has as ultimate goal to contribute to the development of a more sustainable and circular model for fishing gear in the ARM and to the development of basic knowledge on this subject.

This work is part of a larger project, CleanAtlantic, which aims to protect biodiversity and ecosystem services in the Atlantic Area by increasing capacity to monitor, prevent and remove marine litter. Additionally, it aims to raise awareness and change among stakeholders and to improve marine litter management systems.

Although it is not a region where fishing gears are produced, ARM is a place par excellence of commercial and recreational fishing and aquaculture, so the authorities associated with fisheries (Regional Directorate for Fisheries) and the environment (Regional Directorate for the Environment and Climate Change) are stakeholders in the management of logistics associated with fishing gear waste and, consequently, will be agents of the fishing gear EPR system in the region.

4. METHODOLOGY

To achieve the identified objectives, the work was carried out in five phases, presented in Figure 1. These activities are detailed individually in the following paragraphs.

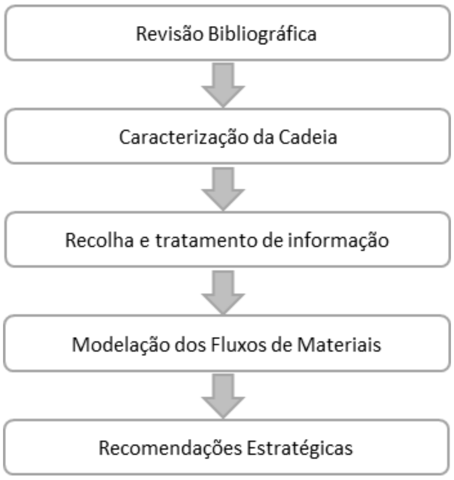


Figure 1 - Methodological approach

[IMAGE: Literature Review | Characterization of the Chain | Information Gathering and Processing | Modelling Material Flows | Strategic Recommendations]

4.1. Literature review

A desk research on the internet was carried out with a survey of national and international studies, published and accessible, where analyses on sustainability and circular economy in the fisheries industry have been carried out, namely addressing:

- The manufacture of fishing gear;
- The market and consumption of fishing gear;
- Production of fishing gear waste;
- Eco-design of fishing gear;
- Recovery of fishing gear waste.

4.2. Characterisation of the supply and consumption chain

The characterization of the value chain of fishing gears and aquaculture in the region was first carried out using the available literature. After defining the stages and players of a generic value chain, the Regional Secretariat for the Environment and the Regional Directorate for Fisheries were used to identify the players of this chain in the ARM. Simultaneously, a typification of the fishing gears used in the region was carried out using desktop research and the regional entities mentioned.

4.3. Information gathering and processing

The collection of quantitative and qualitative information regarding the acquisition - use - disposal of fishing gear materials was carried out on three fronts:

a. Different agents were contacted to characterise the value chain of fishing gear, learn about their practices and to obtain information that would allow estimates of flows associated with fishing gear in the region. Contacts were made by email, telephone and online interview (Table 2).

b. Data from campaigns to characterise fishing associated materials collected in the scope of the clean-up of remote areas - provided by SRAAC;

c. Estimates based on information gathered from the literature review.

In order to collect information in the ARM and obtain data to make the estimates, the following players in the value chain of these equipment were contacted.

Table 2 - Inventory of contacts established for the collection of information within the scope of RePesca

Name	Type of contact (E - email; TEL - telephone; M - meeting)	Topics covered
DRAAC/SRAAC	M + E + TEL	Entities and people to contact; Contacts; Study boundaries; Options to be taken in the development of the work; Data regarding waste and access infrastructures to the sea in the Autonomous Region of Madeira; Collection of fishing gear waste in the scope of cleaning actions on remote accumulation sites.

RDF	E+TEL	Professional fishing gears practised in the region (which ones and how many fish are caught according to each gear); Suppliers of fishing gear in the region (manufacturers, importers, traders); Practitioners of fishing gear - number of ship-owners, number and capacity of vessels for each gear
Funchal City Hall (Environment Department)	E+TEL	Waste fishing gear collected
DRMar (CMC)	E	Information on aquaculture in the ARM and contact details for aquaculture companies
ARM	E+TEL	Fishing gear waste collected and treated
MadeiraCartão	E	Fishing gear waste collected and treated
Aquabaía (Aquaculture)	E	Technologies used, dimensions, and respective production capacities and quantities of fish produced, according to each technology; Equipment suppliers (manufacturers, importers, dealers) and equipment repairers (maintenance) Waste generated by this industry related to end-of-life equipment.
Marismar (Aquaculture)	E+TEL	*idem*
Coopesca Madeira	EM+E	Quantities and sizes of fishing gear sold; Quantities and sizes of gear per vessel size; Average life times of gears. Ship-owners' contacts.
Ship owners	TEL	Characterisation and quantities of gear
Fishing tackle shop “A Canoa”	E+TEL	Quantities and sizes of fishing gear sold
Fishing tackle shop “Artes e Pesca”	E+TEL	Quantities and sizes of fishing gear sold
MARE – Madeira	RE+E	Centre's support to the RePesca project
ARDITI	C	Characterisation of fishing gear
Econyl (Italy), Plastix (Denmark), Nofir (Norway), Antex (Spain) Companies	C	Conditions for receiving materials from fishing gear for recovery
Ambibérica Company (Portugal)	E+TEL	*idem*

A summary description of the meetings, contacts made and information gathered is provided in Annex 1.

4.4. Material flow model for fishing gear

In order to develop a global model of this material flow, the information collected was extrapolated for the ARM. The extrapolation was carried out taking into account the characterisation of the composition of the products of the fishing gear and the characterisation of the players in the chain according to different parameters: number of vessels, vessels per gear, number of gears per vessel, among others.

The most common constraint in material flow studies is the scarce information on imports/consumables (usually associated with trade or sales), as far as input flows are concerned, and on exports and waste generation, as far as outputs are concerned. Among the categories mentioned, waste generation is generally the most relevant aspect, mainly due to the lack of characterisation or disaggregation of information on waste generation. In the case of the present study, this information gap was particularly pronounced, limiting the robustness of the study's results.

Another strong constraint observed in this type of study refers to the units of information available, which do not always correspond to the needs of the study. The analysis of material flows can serve, for example, to support the decision regarding the selection of materials and products with lower impact (in particular to meet sustainable consumption objectives) or, to support the selection of the best solutions in terms of waste management. In both cases it is important to produce estimates of values in units of mass. In the first case, because many life cycle databases (from which environmental impacts are calculated) need data in units of mass and, in the second case, because all logistics are mainly assessed in terms of the mass values of waste (e.g. capacity needed for shipping or capacity needed for treatment equipment). This constraint was also observed in the present study: most players in the fishing gear value chain in the region have information mainly on the amount of equipment at their disposal, rather than the weight they have. It was necessary to rely to some extent on the players' sensitivity on their estimates of the weight of the equipment and, at the same time, on the limited information on specific weights existing in some gear producers' websites.

4.5. Strategic recommendations

The bibliographical review, characterisation, information processing and construction of the flow model served as a basis for the definition of proposals for strategic recommendations for action throughout the life cycle of fishing gear materials.

Among the proposals were management issues at the various stages of the cycle such as the importance of registering the gear sold and discarded, or an incentive system that induces a decrease in the abandonment of waste in the marine environment or coastal areas.

LITERATURE REVIEW

1. FISHING GEAR AND MARINE POLLUTION

The fisheries industry is particularly dependent on plastics (for fishing gear, aquaculture equipment, fish boxes, packaging, among others). Fishing gear (such as nets, lines or traps) is designed to catch marine organisms, but in many cases it continues to influence marine life even after its end of life. Gear is designed to be durable and therefore takes many years to degrade (for example, it is estimated that monofilament fishing lines take 600 years to degrade).

Table 3 - Properties and types of materials commonly used in fishing nets and ropes (based on Hunt and Charter 2016)

Name	Polyamide	Polyester	Polyethylene	Polypropylene	Aramyd	High density polyethylene
Abbreviations	PA	PES	PET	PP		HDPE
Examples of trade names	Nylon, Perlon	Terylene, Dacron, Tetoron, Trevira	Nymplex, Courlene	Danaflex, Mulfiflex, Ulstron	Kevlar	Dyneema, Spektra, Dynex
Ease of handling	Good	Excellent	Good	Good	Excellent	Excellent
Durability	Good	Excellent	Acceptable	Good	Excellent	Excellent
Resistance to rot, fungal decay and moisture	Good	Excellent	Excellent	Excellent	Excellent	Excellent
Resistance to UV radiation	Acceptable	Excellent	Acceptable	Weak	Acceptabl e	Acceptable
Resistance to acids	Good	Excellent	Excellent	Excellent	Good	Excellent
Alkaline impact	Excellent	Excellent	Excellent	Excellent	Good	Excellent
Wear resistance	Excellent	Excellent	Acceptable	Acceptable	Weak	Excellent
Buoyancy (density)	Submerge (1.14)	Submerge (1.38)	Hardly fluctuates (0.95)	Floats (0.91)	Submerge (1.44)	Floats (0.97)
Melting point	Approx. 250°C	Approx. 245°C	Approx. 128°C	Approx. 150°C	Approx. 427°C	Approx. 147°C

The plastic used in professional fishing gear is of high quality, but the proportion recycled is small because only 1.5% of the equipment is, on average, actually recycled.

It is estimated that **in Europe 27% (11 000 tonnes) of marine litter originates from fishing gear** (e.g. nets, lines, traps.) (EC, 2019). Sources include commercial and recreational fishing activities and aquaculture facilities and the reasons for this loss vary, from accidents, storms and entanglements to intentional abandonment. These figures indicate that **in the EU, 20% of equipment is lost at sea**. Global figures advanced by a Greenpeace study (2019) point to an estimated 640 000 tonnes of fishing gear lost, abandoned or discarded annually on the planet.

Regarding gear losses in the ocean globally, Richardson et al. (2019) analysed 68 publications from the period between 1975 and 2017 that contained two types of quantitative information: (1) Percentage (proportion) of gear lost and (b) the number of gear units lost per vessel per year (count).

Estimates of net losses reported by the studies varied widely, at an annual rate of loss ranging from 0% to 79.8%. From traps there was a loss of equipment ranging from 0% to 88% and the studies relating to angling identified equipment loss rates in the range of 0.1% to 79.2%.

From these estimates a meta-analysis was carried out, using statistical methods, obtaining estimates of global fishing gear losses. Thus, it was estimated that, per year, 6% of all fishing nets, 9% of all traps and 29% of all lines are lost worldwide.

In another study by Richardson et al. (2018) conducted with approximately 50 Australian and Indonesian seine and trawl fishermen, 78% of fishermen identified that net loss is mainly due to obstructions on the seabed (approximately 41% for trawl nets and 79% for seine nets). Loss of equipment due to storms and bad weather was reported by 12% of gillnet fishermen from Indonesia.

The study sought to inventory all the possible situations observed on board the vessels that could constitute a reason for losses, and sought to identify the gaps in organisation and activity that could lead to these losses (Table 4).

Table 4 - Identification of possible causes of fishing gear losses in the ocean (Adapted from Richardson et al. 2018)

Consequences	Events	Potential causes
Losses of equipment stored on ships	Bad weather conditions	Risks assumed by the command Inadequate training Resource limitation
	Structural damage to the vessel	Inadequate maintenance
	Breakage of mooring ropes	Inadequate maintenance Inadequate training
	Inappropriately stored gear	Inadequate training Non dedicated storage
Gear lost or abandoned during the operation	Working in inadequate conditions	Limited resources (tools/technologies) Inadequate training Overcrowding in the marine area Inadequate legislation Lack of legal enforcement
	Operational problems	Insufficient training and experience Immersion period too long Inadequate maintenance
	Conflict with third parties	Risks assumed by the command Inadequately marked gear Over-allocation of allowances
Worn-out gear and/or the remains of repairs discarded at sea		Inadequate crew training: ignorance of impacts
		Inadequate training of the crew: lack of knowledge about the alternatives

Table 4 is a fraction of one of the results of the study, a tool to identify the chain of events resulting in abandoned fishing gear waste. The analysis of this chain of events (Annex 2) provides recommendations and improvements in regional fisheries management to reduce fishing gear loss in different contexts.

In an equivalent analysis carried out for the North East Atlantic context by OSPAR (2020), abandoned, lost or discarded fishing gear (ALDFG) can be understood as an accumulation of:

- Losses due to wear and tear during operational use;
- Losses due to hydrographic, meteorological conditions and sea currents;
- Accidental loss of appliances and appliance parts that cannot be recovered or are too risky and/or too expensive to recover (including due to severe weather conditions);
- Loss due to conflict with other fishing gear, for example in mixed fisheries;
- Losses from stretching the limits of what the fishing gear can handle;
- Intentional or accidental discarding of gear (or parts thereof) due to poor handling practice (e.g. netting patch cuttings) or lack of storage facilities; and
- Intentional loss due to illegality, deregulation and unreported fishing and vandalism/theft.

Although there are similarities, the pathways of marine litter resulting from aquaculture are different, the main ones being:

- Extreme weather conditions (e.g. loss of feed pipes or other PVC pipes used to construct the cages);
- Poor management and disposal (e.g. loss of gloves, glove packs, cut pieces of rope, cut pieces of tubing, water bottles used by teams, etc.);
- Wear and tear (e.g. loss of ropes, floats and weights, rubbing or peeling of ropes releasing microfibers).

Discarded or lost fishing equipment containing plastic materials degrade very slowly, remaining in the marine environment for decades if not collected. On the other hand, nets made of low density plastic continue to float on the surface and remain dangerous for marine animals as well as posing safety risks for vessels.

2. CIRCULAR ECONOMY OF FISHING GEAR

Technological innovation associated with improved fishing gear alone does not solve all the problems related to environmental impacts, so we should also focus on changing practices and avoiding the loss of gear in the ocean. Furthermore, although some fishing gears and techniques have less impact on ecosystems than others (for example, passive versus towed gears), this does not mean that fishing techniques with less impact cannot be improved.

Regardless of the type of equipment, the main plastic materials used in the OSPAR region are polypropylene (PP), polyethylene (PE) and polyamide (nylon / PA6). However, they can also include simple and mixed materials such as metals, PVC, polystyrene, rubber, foams and various hazardous materials (e.g. lead weights, copper coatings).

In general, raw materials for fishing gear production as well as final gear products are predominantly sourced from outside the OSPAR region, with final assembly carried out locally. Such assembly is often carried out in specialised facilities (e.g. fishing cooperative). Sometimes the fishermen carry out the assembly or repairs themselves. Overall, the fishing gear supply chain is complex and country-specific, with many different parties involved at various stages.

Currently in the OSPAR maritime area, only a small proportion of fishing gear is recycled at end of life. In Europe, the recycling of plastics from fishing gears is predominantly done by two companies, both highly specialised in the material they can process and with high standards and requirements for accepting waste fishing gear. Now, fishing gear can contain various types of (mixed) polymers, which require a high level of processing (sorting and dismantling) to be recycled, with high costs and time involved. This is notably because before the materials are transported to the recycling facilities, all contaminants such as lead, among others, must be removed from the materials. The fishing gear must also be relatively clean, with no sediment, sand or organic materials.

OSPAR found that currently available facilities for collection and recycling are limited, requiring high effort and costs to pre-process and shipping the material to recyclers, resulting in a high ecological footprint of recycling at present. Similar to what was pointed out in the Norway study, OSPAR identified that regions still greatly lack facilities for collection of fishing equipment at ports, there is a lack of available space to store used equipment and there is poor coordination in the process of cleaning and separation of waste.

Finally, recycled materials from fishing gear generally have a lower quality or there is a perception of lower quality by the market, which implies a lower market value than comparable primary polymers.

2.1. Reparability

Durability and extending the life of products are central to the concept of the Circular Economy model, but re-use, repair and remanufacturing activities have received limited policy attention compared to recycling . Yet these strategies generally offer greater savings in energy and materials and can create more economic value.

Repair needs rigorous organisation if it is to become widespread enough to change our consumption - and therefore production - habits. Fisheries authorities can help local stakeholders work together to build systems that make repair a common activity. In this way, they can help create a culture where product life is maximised, improve resource efficiency and reduce pressure on the environment.

There are different types of repairs, but any system will depend on collecting and transporting the damaged goods to a place where they can be sorted, stored and repaired. This may involve the creation of physical spaces, for example in port areas, where old equipment is collected.

In addition, the development of new businesses associated with the repair of fishing gear should be encouraged.

2.2. Reuse

Creating systems to redistribute goods for reuse is an important part of the circular economy, also helping to avoid waste such as building socially inclusive models that make goods available at reduced prices. This can help young people join the fishing or aquaculture profession as well as help other members of the community who may need help.

2.2.1. A second life for equipment and machinery

The investments required to get started as a young fisherman or aquaculture producer are high and often prohibitive. Therefore, it would be important to create conditions for fishing communities to set up systems to facilitate the transfer of equipment and machinery still usable to young or simply neighbouring fishermen who could still use a product that another would like to replace. As a complement to the repair system conditions should be created to organise, re-condition and make gear available for re-use, either through sale, loan, rental or leasing systems.

2.3. Valuing

Where gear cannot be repaired or refurbished for re-use, its constituents should be recovered, avoiding waste through dumping or potential impacts resulting from its burning (incineration).

Table 5 presents several cases of companies that recycle plastics from fishing gear and transform them into different products.

Table 5 - Examples of products manufactured using recovered fishing gear materials

Company Name	Description	Website
Fil&Fab	A company created in Brittany in 2015 by three designers, Fil & Fab is now the first French company to regenerate used fishing nets. In 2020, they acquired machines to transform the collected waste. The material resulting from the recycled nets is called Nylo®, and is made of 100% recycled polyamide granules that can be used in the manufacture of different products.	https://www.fil-et-fab.fr/
Aquafil	Aquafil produces among other materials the nylon Econyl ®, using for its production ocean nets rescued by volunteer divers and nets from aquaculture and fishing industries. Additionally old carpets destined for landfill sites are used. Econyl is used by different brands to produce clothing (e.g. swimwear), fashion accessories (purses, bags etc.), automotive textiles, curtains or carpets and rugs.	https://www.aquafil.com/
Bureo	Bureo produces NetPlus® from discarded fishing nets. Discarded fishing nets are collected from coastal communities in South America. The nets are then cleaned, separated by material type and sorted for transportation. The prepared materials are crushed and melted into NetPlus® recycled pellets. Finally, the pellets are transformed into quality products, such as rods for glasses or skateboards or clothing (Patagonia brand).	https://bureo.co/
Fishy filaments	Fishy filaments produces filaments for 3D printers from used fishing nets. This is possible because the nylon used by commercial fishing is made to very high standards in order to meet the demands of an extremely tough industry.	https://fishyfilaments.com/
Kettle Cove	Kettle Cove produces bicycle baskets from used lobster fishing traps.	https://kettlecoveenterprises.com/
Fishpond	Fishpond produces backpacks and waistcoats that are made from 40-100% recycled nylon from commercial fishing nets.	https://fishpondusa.com/about/corporate-responsibility

3. MATERIAL FLOW ACCOUNTING

Deshpande et al. (2020) developed the first comprehensive study of material flows from fishing gears, in this case concerning commercial fishing in Norway. Based on data provided by gear producers, suppliers, fishermen and waste managers, the flows of the polymers polypropylene, polyethylene and polyamide, used in the production of fishing gear in that country, were modelled.

The accounting has made it possible to estimate that there are about 18 400t of fishing gear in use in Norway and that about 2 600t of new fishing gear are purchased each year. Additionally, about 1 700t of replacement parts or components are purchased for maintenance of the gear in use.

Estimates also put the value of plastic and fishing gear lost at sea in that country at around 380t/year, with gillnets, longlines and traps being the main contributors to fishing gear abandoned, lost or discarded in the ocean (ALDFG). These figures imply that since 2007, approximately 4 000t of ALDFG have been accumulated in the ocean by the Norwegian fishing fleet.

About 4000 tonnes is also the estimated annual amount of fishing gear waste collected in Norway, of which 24% is landfilled, 21% is incinerated and 55% is separated for recycling, which takes place outside Norway.

The study also concludes that Norway is far from complying with the provisions of Directive 2000/59/EC which requires all ports to provide reception facilities for used fishing gear (only 1500 out of about 4400 ports complied with this requirement).

CHARACTERISATION OF FISHING GEAR FLOWS IN THE AUTONOMOUS REGION OF MADEIRA

1. CHARACTERISATION OF THE FISHING GEAR VALUE CHAIN

Figure 2 shows the value chain of fishing gears in the ARM. Up in the chain are the gear manufacturers located outside the region and the suppliers (distributors/traders) already located in the territory. The use phase of the gear includes the owners and fishermen and the repairers (who ensure the extension of the life time of the gear and who are usually the fishermen themselves). At the end of life of the gears, they are collected by waste managers who take them to their final destination.

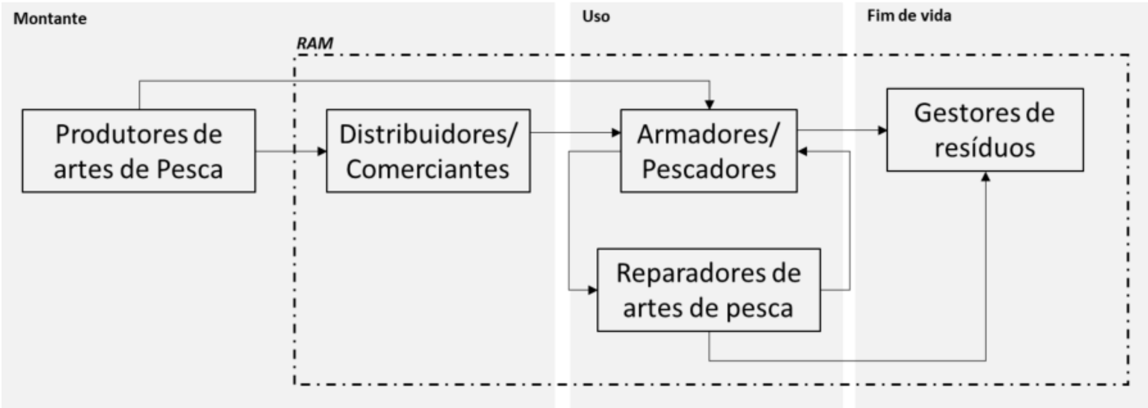


Figure 2 - Madeira's fishing gear value chain

[IMAGE: Amount | ARM | Use | End-of-life | Fishing gear producers | Distributors/Traders | Ship-owners/Fishermen | Fishing gear repairers | Waste managers]

The information provided by the Regional Directorate for Fisheries (RDF) allowed characterizing the players of the value chain in the ARM.

The main suppliers of fishing gear in the region are:

- COOPESCA MADEIRA Fishing Cooperative of Madeira Archipelago
- A CANOA - Electronic and fishing tackle shop (Machico)
- ARTES & PESCA - Fishing shop (Caniçal)

In 2020 it is estimated that these intermediaries supply 88 vessel owners and a total of 93 vessels. These vessels, which belong to the local and coastal fleet, are divided into two main groups according to the fishing gear they use, MGP and HOK.

HOK refers to the set of vessels using hook-and-line gear. The total number of vessels in this segment represents around 90% of the licensed fleet. In terms of capacity they represent approximately 92% of the tonnage and 89% of the engine power of the active fleet in 2019. They operate mainly in Sub-area 2 of the

EEZ-Madeira, with vessels operating at certain times of the year in the waters of the Azores and Canary Islands.

The most representative species caught by these vessels are tuna, black scabbardfish and various demersal species, especially snapper and forkbeard.

MGP refers to vessels using multipurpose active gear (such as seines). The total number of vessels included in this gear, represents only around 10% of the licensed fleet. In terms of capacity they represent around 8% of the tonnage and 11% of the engine power of the active fleet in 2018. The most commonly caught species are small pelagic fishes (mackerel and horse mackerel), up to 1 mile from the coast (coastal fishing), followed by shellfish harvesting (limpets) with a boat, carried out near the coast (local fishing).

Annex 3 describes the different fishing gear used by ship-owners and fishermen in the Autonomous Region of Madeira, particularly the equipment used and the species caught with each equipment.

According to the Fisheries Statistics 2019 (INE), the ARM had, in 2011 (date of the last CENSUS), 639 people resident and employed in fishing, which compares with 1715 in the autonomous region of the Azores (ARA) and 10 802 in mainland Portugal.

The fishing gear waste is managed by two entities, depending on the fishing port: ARM - Águas e Resíduos da Madeira, S.A. and Madeira Cartão, Sociedade de Triagem Lda.

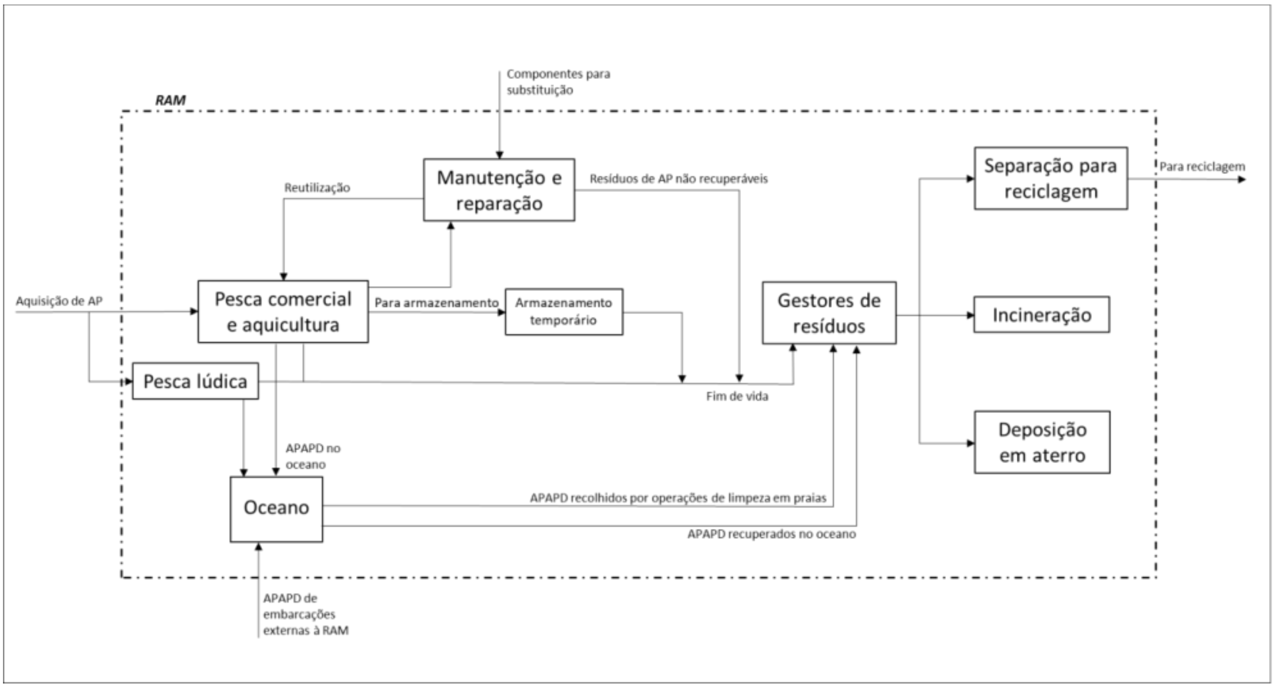
- Caniçal Fishing Harbour - has a recycling bin and collection is carried out by ARM, S.A.;

- Câmara de Lobos Fishing Harbour - Harbour with a shipyard next to the Socorridos Bridge has various undifferentiated waste containers collected by ARM. There are no collection points at the Câmara de Lobos Islet (Fishermen's Wharf);

- Funchal Port - Managed by the Madeira Ports Administration. Waste from fishing boats and urban waste from the Market (House of rubbish) are collected in an undifferentiated container, whose collection is carried out by the Municipality of Funchal.

- Porto Santo Harbour - Managed by the Madeira Ports Authority. Waste from the recycling bins is collected by ARM.

Figure 3 shows the flows associated with fishing and aquaculture in the ARM.



Note: ALDFG - Abandoned, lost or discarded fishing gear

Figure 3 – Flows associated with fishing and aquaculture in the ARM (adapted from Paritosh, 2020).

[IMAGE: ARM | Purchase of FG | Commercial fishing and aquaculture | Reuse | Maintenance and repair | Components for replacement | Non-recoverable FG waste | End-of-life | Waste managers | Separation for recycling | For recycling | Incineration | Landfill | ALDFG in the ocean | Recreational fishing | Ocean | ALDFG collected by beach cleaning operations | ALDFG recovered in the ocean | ALDFG from vessels outside the ARM]

At the top of the chain are the gear manufacturers located outside the region and the suppliers (distributors/traders) located in the territory (except for aquaculture equipment whose suppliers are also external). The latter supply commercial fishing and recreational fishing.

The use phase includes producers, ship owners and fishermen, who are also responsible for maintenance and repair (ensuring the extension of the life of the gear). At the end of life of the gear, it is collected by waste managers who take it to its final destination. Some unserviceable equipment may be subject to temporary storage before being repaired or before being sent to its final destination, for example for possible recovery of components. In some cases, gear that is no longer useful for larger vessels is donated for use by smaller vessels (e.g. longlines).

A fraction of the ALDFG results from vessels fishing in Madeira waters, but which come from outside the region. Another fraction comes from fishing carried out miles away from Madeira waters, but which are routed to this region by sea currents. Part of this waste ends up on the region's beaches, mainly on the north coast (oriented to the dominant Northeast current), becoming waste to which an appropriate destination must be given.

Currently, fishing gear waste is landfilled and a small fraction, other than nets and wires, can integrate the waste mixture that is subject to incineration. Under the OceanLit project , in an initiative led by the RDF, the collection of used fishing gear has started in the Port of Funchal with the placement of a dedicated container.

The RDF plans to install dedicated containers in all ports of the region, fulfilling the provisions of DL No. 102/2020.

At the time of drafting this report, the gear collected in this way is being stored until an appropriate destination is defined for it, namely forwarding it to a licensed operator.

1.1. Aquaculture

The structure of the aquaculture value chain is equivalent to that of commercial fishing, with equipment being supplied from outside the region and waste going to the same destinations as commercial fishing gear.

According to information from the Regional Directorate for the Sea, there are currently 3 aquaculture companies in the region:

- Ilhapeixe Lda. cage fattening company;
- Marismar Lda. cage fattening company;
- Marisland Lda. juveniles producer company.

The aquaculture production in Madeira closed the year 2020 with a production close to 1500 tonnes of fish, exceeding the 1075 tonnes recorded in 2019.

In the Autonomous Region of Madeira, the open sea culture system (Annex 3), for fish culture, is the indicated due to the limited space on land and the environmental conditions of the sea (DGRM, 2014). Marine waters are oligotrophic and do not support the growth of bivalves. The average temperature of the sea water in winter, being above 17ºC, allows the growth of farmed fish and the realisation of fattening cycles about 2 to 4 months lower than on the Atlantic coast of Europe.

2. QUALITATIVE CHARACTERISATION OF MATERIAL FLOWS ASSOCIATED WITH FISHERIES AND AQUACULTURE

According to EU Directive/2019/904 fishing gear refers to "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".

In the particular case of fisheries, gears are divided into two categories: active and passive. Active devices (nets) dynamically hunt the targeted species, while passive gears (lines, gillnets and traps/pots) are fixed gears designed to catch active fish.

According to the Regional Directorate for Fisheries of the ARM, the fishing gears used in the region are the following:

Table 6 - Materials making up the fishing gear used in the ARM (adapted from OSPAR 2020)

Type of art		Types of species caught
Angling	Drifting longline	Deep-sea species
	Bottom longline	Demersal species
	Surface longline	Pelagic species (including swordfish)
	Pole and Pole Jumping	Tunas
	Troll line	Pelagic species
	Cane and hand line	Demersal species
		Demersal or pelagic species
	Hand line	Demersal species
Traps	Caged	>= 15 mm (shrimp)
		>= 30 mm (crustaceans)
		>= 30 mm (demersal)
Encircling	On board	American type
Lifting gear	Sieve	Winged to edge (chestnut)
Angling	Tearing tool	Jigging line
You catch	Hand utensils	Giant limpets

Annex 3 presents the catches by species and by fishing gear in the year 2020.

Table 7 shows the usual constituents of the fishing gear used by producers, ship-owners and fishermen in Madeira.

Table 7 – Materials making up the fishing gear used in the ARM (adapted from OSPAR 2020)

Fishing Gear		Equipment	Material
Angling	LLD Drifting Longline	Snoods	Polyamide, Polyethylene
		Streamer lines	Polyamide
		Hooks	Steel
		Buoys	Polyethylene, Polyurethane, Expanded polystyrene (filling)
	LLS Depth longline	Snoods	Polyamide, Polyethylene
		Streamer lines	Polyamide
		Hooks	Steel
		Buoys	Polyethylene, Polyurethane, Expanded polystyrene (filling)
	LHP Pole and Hump	Thread	Polyamide
		Hooks	Steel
		Buoys	Polyethylene, Polyurethane, Expanded polystyrene (filling)
	LHP Hand line Cane	Thread	Polyamide
		Hooks	Steel
		Buoys	Polyethylene, Polyurethane, Expanded polystyrene (filling)
Encircling		Net	Polyamide
		Cables	Polyethylene, Polypropylene
		Buoys	Polyethylene, Polyurethane, Expanded polystyrene (filling)
Aquaculture		Floating structures	HDPE, PVC
		Strings	Polyethylene, Polypropylene
		Net	Polyethylene, Polyamide
		Buoys	Polyethylene, Polyurethane, Expanded polystyrene (filling)

The characteristics of these materials vary, notably in buoyancy (Table 8).

Table 8 - Properties of constituent polymers of fishing gear (Source: Circular Ocean 2016)

Chemical name	Abbreviations	Handling	Durability	Resistance to rot, fungal decay and moisture	Resistance to UV radiation	Wear resistance	Buoyancy (density)	Melting point
Polyamide (Nylon)	PA	Good	Good	Good	Acceptable	Excellent	Submerge (1.14)	Approx. 250°C
Polyethylene	PET	Good	Acceptable	Excellent	Acceptable	Acceptable	Hardly floats (0.95)	Approx. 128°C
Polypropylene	PP	Good	Good	Excellent	Weak	Acceptable	Float (0.91)	Approx. 150°C
High density polyethylene	HDPE	Excellent	Excellent	Excellent	Acceptable	Excellent	Float (0.97)	Approx. 147°C

Non buoyancy, a necessary property for single lines and nets, entails the risk of sinking when broken. In the case of monofilament (line fishing) this sinking is very frequent and is a waste product that is deposited on the seabed.

Additionally, most nets and ropes used in aquaculture in Europe manufactured before 2019 have algaecides impregnated into them. In 2019 the EU banned the use of these algaecides due to their potential effects on the marine environment. Thus, the algaecide-impregnated nets are now considered a hazardous waste, which has also become a strong constraint to their recovery.

Another case is that of polypropylene, whose recycled products have a market value that is currently too low to offset the costs of transporting and treating the waste.

3. QUANTITATIVE CHARACTERISATION OF MATERIAL FLOWS ASSOCIATED WITH FISHERIES AND AQUACULTURE

Currently, the equipment that constitutes fishing gear is very difficult to trace, making it difficult to analyse the flow of associated materials. Quantities therefore have to be estimated according to the scarce information provided by suppliers (in the case of commercial fishing) and users (in the case of aquaculture).

Information provided by the Regional Directorate for Fisheries made it possible to quantify the number of vessels practicing the main fishing gear (and involving larger equipment) and to disaggregate the information by vessel size. The quantity and size of fishing gear will be associated with the size of the vessels.

Table 9 - Number of boats by fishing gear in the ARM (Source: RDF)

(Dimensions, length overall, cff (m): I - [<=8 cff]; II - [8<=cff<=13.5]; III - [13.5<=cff<=20]; IV - [cff>= 20])

Fishing Gear		Boat dimensions	No. of boats by size	Number of vessels by gear
Angling	LLD Drifting Longline	I	56	88
		II	25	
		III	4	
		IV	3	
	LLS Depth longline	I	50	64
		II	12	
		III	2	
	LHP Pole and Hump	I	35	52
		II	9	
		III	3	
		IV	5	
	LHP Hand line Cane	I	63	86
		II	17	
		III	3	
		IV	3	
Encircling		I	1	5
		II	1	
		III	3	

CoopescaMadeira is the main supplier of equipment for commercial fishing in the region, providing about 80% of the equipment purchased by ship-owners in the region. Due to the degree of knowledge of the reality of commercial fishing in the region by the management of this cooperative, information was collected from them regarding quantities and average dimensions of the gear used by size of vessel.

Table 10 - Average quantity and size of fishing gear by vessel size (source: CoopescaMadeira)

Art		Size of the vessel	Average number of appliances* per vessel	Average length of the snoods (m)	Average number of monofilament per snoods	Average length of monofilament (m)
Longline	Drift (depth)	I	10	4000	90	500
		II	20	8000	90	500
		III	35	8000	90	500
		IV	40	16 000	90	500
	Surface	I	1	3000	120	25
		II	1	6000	250	25
		III	2	10 000	400	25
Art		Size of the vessel	Average number of nets per vessel	Average net size (L x H)		
Encircling		**I, II, III**	1	400x120		

* snoods + its monofilament

The total length of wire used by ship-owners in Madeira can then be estimated from these figures.

Table 11 - Overall dimensions of angling yarns

Art		Size of the vessel	Total length of snoods on all vessels by vessel size (m)	Total length of monofilament for all vessels (m)
Longline	Derivative (depth)	**I**	2 240 000	25 200 000
		II	4 000 000	22 500 000
		III	1 120 000	6 300 000
		IV	1 920 000	5 400 000
	Surface	**I**	15 000	150 000
		II	72 000	75 000
		III	40 000	40 000
		TOTAL	9 542 000	59 665 000

Considering an average distance of 500 metres between buoys on the drifting longline and 200 metres on the surface longline, then vessel owners will use in total around 20,000 buoys in their fishing activities.

Estimates of total weights were made from values of the length/weight ratio of different diameters of polyamide yarn contained in data sheets from a supplier of that product (Annex 5).

Taking into account the number and size of vessels operating in the ARM, as well as the mentioned characteristics of polyamide yarn, the total quantity of snood line varies between 17 and 80 tons and the total quantity of monofilament varies between 14 and 50 tons. Considering the average weight value of one purse seine provided by CoopescaMadeira, the total weight of nets of vessels operating in the ARM will total 2.5 tons.

In summary, the estimated values of material flows associated with longline and seine fishing in the ARM point to a stock that may vary between a minimum value of 33.5t and a maximum value of 132.5t of polyamide. To these gears are also associated about 20 thousand buoys (Polyethylene, Polyurethane, Expanded Polystyrene (filling)).

According to information from CoopescaMadeira, a purse seine, with annual maintenance, can last up to 10 years, a snood can last up to 4 years, but monofilament is generally replaced every month (especially that used for tuna fishing).

Although CoopescaMadeira does not commercialize nets, its management estimates that around 1500kg of new nets are acquired per year in the region. This figure is notably excessive when compared to the 2500kg of nets used by vessels in the ARM, assuming that each of the five vessels uses only one net and that each net can last up to 10 years. Several reasons may be given for this apparent discrepancy in values:

- Overvaluation of the quantity of nets sold per year in the region;
- Underestimation of the amount of nets held by each vessel;
- Combination of the three previous factors.

Thus, we point to the hypothesis that the amount of net sold annually is less than 1.5t and the amount of net held by each seiner is greater than one.

Regarding monofilament the cooperative sells about 3 000kg of it per year and the fishing tackle shop “A Canoa” reported sales of about 90kg of monofilament in 2019.

If the figures presented were assumed, by default, to be replacement needs (and assuming the size of the fleet does not change significantly), then the production of polyamide waste associated with fishing gear in the region would be, at most, 4,600kg per year - 3,100kg of monofilament and 1,500kg of net. As noted, this is considered to be excessive, but these materials are in addition to:

- Damaged hooks, buoys and cables;
- Damaged and replaced aquaculture nets and cables;
- Materials collected in remote areas.

For the latter, the Regional Secretariat for the Environment, Natural Resources and Climate Change provided data on the collection of fishing gear waste carried out under the Clean-up of Remote Areas and also under the OSPAR monitoring of beach cleaning (Table 12).

Table 12 - Volumes of materials associated to fishing collected within the scope of the cleaning of remote areas in the ARM (source: SRAAC)

Period	Type	Subtype	Class	Units	Number bags	Volume (m^3)	Weight (Kg)
set/19	Plastic		Shipping boxes	N/A		3,64	N/A
	Plastic		Small packages	N/A	14	2,772	N/A
	Plastic		Jerricans/industrial jerricans	N/A		6,336	N/A
	Plastic		Nets/meshes/traps/ropes	N/A	N/A	3,80	N/A
	Plastic		Buoys/defenders	N/A	3	0,57	N/A
	Plastic		Other fishing gear (bait boxes, etc.)	N/A	2	0,38	N/A
set/20	Plastic	Fishing	Shipping/Bait Boxes			1,53	
	Plastic	Navigation	Small industrial packaging	129	2	0,63	
	Plastic	Navigation	Jerricans/industrial jerricans	51		2,70	N/A
	Plastic	Fishing	Nets / Lines / Cables		3	0,95	N/A
	Plastic	Navigation	Buoys/defenders	159	7	2,21	N/A
	Plastic		Other fishing gear (bait boxes, etc.)				
abr/21	Plastic	Fishing	Shipping/Bait Boxes	N/A	0,1	0,02	N/A
	Plastic	Navigation	Small industrial packaging	N/A	5	0,75	23
	Plastic	Navigation	Jerricans/industrial jerricans	N/A	0,5	0,075	N/A
	Plastic	Fishing	Nets / Lines / Cables	N/A	2	0,3	44
	Plastic	Navigation	Buoys/defenders	400	10	1,5	79
	Plastic		Other fishing gear (bait boxes, etc.)	N/A	N/A		
jun/21	Plastic	Fishing	Shipping/Bait Boxes		1		8
	Plastic	Navigation	Small industrial packaging		0,50		3
	Plastic	Navigation	Jerricans/industrial jerricans		3		33
	Plastic	Fishing	Networks	20	N/A		314*
	Metal	Navigation	Buoys/defenders	2			4
	Plastic	Fishing	Styrofoam	N/A	3		23
	Plastic	Navigation	Cables/ropes/strands/mixtures		5		133
	Plastic	navigation	badly broken plastics		4		64

***includes 3 nets with a total weight of 81 kg that do not have the same characteristics as those used by ARM ship-owners**

The records of materials associated with fishing collected in the ARM remote areas confirm that fishing gear waste is a problem in the region, either by the pollution of beaches or by the risks to marine biodiversity. The 2021 campaigns collected in the first half of the year more than 700kg, which may mean that even over a year may give the coast more than 1.5t of materials. It should be noted that part of these materials are not generated by ship-owners in the region, making the prevention strategy more difficult.

3.1. Aquaculture

Aquaculture producers also provided information on their activity. Aquabaía currently has 20 cages, six for pre-fattening and 14 for fattening, and Marismar has 12 fattening cages. From the characteristics disclosed by the managers of the companies in relation to the perimeters of the nets and the maximum depths of the nets it was possible to estimate the maximum total area of the nets.

Table 13 - Estimated aquaculture net areas in the ARM

Company	Type of cages	Quantity	Perimeter (m)	Maximum depth of the net (m)	Maximum area per net (sqm)	Maximum total net area (sqm)
Aquabaía	Pre-fattening cages	6	35	8	276	1659
	Fattening cages	14	63	17	1068	14 954
Marismar	Fattening cages	12	80	10	800	9600

The total area of aquaculture nets used in Madeira is currently around 26 200 sqm. According to company officials these nets are made of polyamide.

The nets are suspended on floating high-density polyethylene and PVC structures and are also anchored by cables and buoys.

INTEGRATED STRATEGY - LINES OF ACTION

The estimated values of material flows associated with fishing gear in the ARM point to a stock that may vary between a minimum value of 33.5t and a maximum value of 132.5t of polyamide associated with angling and seine fishing. To these gears are also associated about 20 thousand buoys (Polyethylene, Polyurethane, Expanded Polystyrene (filling)).

The stock of equipment associated with aquaculture totals some 26 200 sqm of nets, plus all associated components - floating structures (polyethylene and PVC), cables and buoys.

Currently there is practically no information about the production of fishing gear waste in the ARM, but it can be considered that the quantities of yarn sold are replacement needs, so the production of polyamide waste associated with angling in the region will be about 3 100 kg per year. In some years the amount of polyamide waste will be higher due to the end of life of some vessels' purse seines.

The need to have more accurate knowledge of the quantities involved will require measures to trace, on the one hand, the annual quantities of gear sold in the region and, on the other, the waste generated. The imposition of a scheme involving extended producer responsibility for fishing gear, provided for in EU Directive/2019/904, will provide an opportunity in this regard, insofar as it will require a record to be kept of the quantities of gear entering the market and the waste produced, as determined in Implementing Decision (EU) 2021/958.

Tracking the waste generated will be made easier the more the users of the gear are made aware and trained to prevent it from being disposed of in the wrong place (namely the ocean) and, at the same time, to facilitate the disposal of waste in the right places. The OceanLit project and the objective of placing a dedicated container in each port will be an asset in this sense.

However, while on the one hand, waste consisting of polyamide may find it easier to dispose of correctly (namely for material recovery) due to its economic value, the management of other waste, such as polyethylene, and all the mixed waste collected on beaches will most likely constitute a burden for which compensation needs to be provided under the extended responsibility scheme.

This would also include waste aquaculture equipment containing algaecide impregnation agents.

Following the analysis carried out in this study, four sets of measures are proposed for implementation in the region: prevention measures, measures for recording and measuring, measures for innovation and measures for waste recovery. The region's strategy for the management of fishing gears in a circular economy perspective should consider an integrated approach with the implementation of these different sets of measures, which are complementary to each other.

The measures are shown in Figure 4 and are described in the following paragraphs.

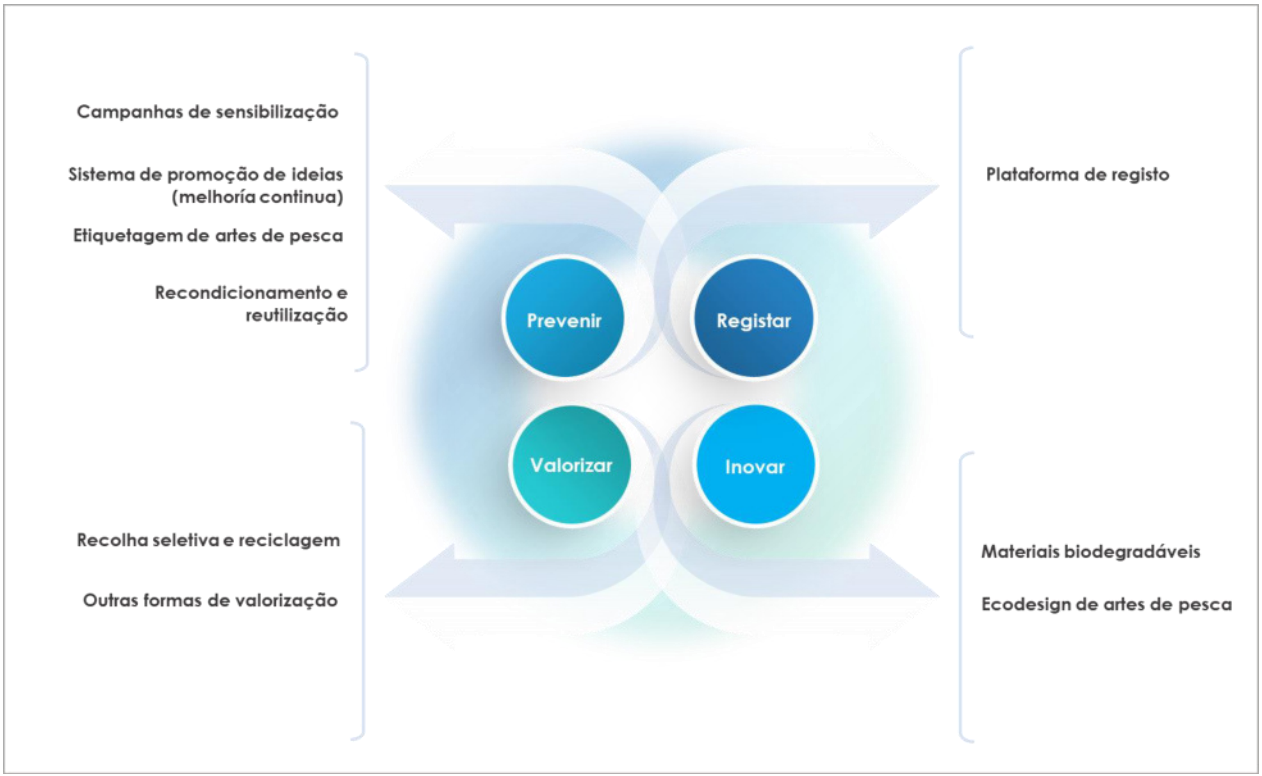


Figure 4 - Lines of action and gear management measures for the ARM

[IMAGE: Prevent: Awareness campaigns | Ideas promotion system (continuous improvement) | Fishing gear labelling | Reconditioning and reuse. Register: Registration platform. Value: Selective collection and recycling | Other forms of valuation. Innovate: Biodegradable materials | Eco-design of fishing gear].

1. PREVENT

1.1. Awareness campaigns

1.1.1. Description

The success of a strategy to prevent marine pollution by fishing gear and the proper management of its waste depends heavily on the adherence of ship-owners and fishermen. As it happens in relation to the generality of waste, this type of strategy has to be associated with a focus on raising the awareness of the players in the value chain and, in the first instance, the waste producers. This work has been practiced in the region under various projects coordinated by the regional authorities, such as, for example, the OceanLit project.

Awareness raising actions have to be accompanied by the creation, by the regional authorities, of conditions that expedite and simplify the correct separation and forwarding of waste, showing to ship owners and fishermen a joint effort. The intention, also under the OceanLit project, to dispense bags for collection on vessels and place a dedicated container for fishing gear in each port of the region is a critical contribution to this goal.

Awareness-raising should include on the one hand demonstrating the consequences of abandoning gear in the ocean, whenever possible using local cases, to ensure a greater sense of identification. On the other hand, it is important to make known the entire logistics chain associated with waste management from the moment it is discarded by ship owners and fishermen. In this sense it is important that awareness-raising initiatives are also guided by positive messages and incentives. This includes demonstrating the possible destinations for waste (e.g. products made from recycled polymers) and the value that waste can have.

An initial way of raising awareness may be to create incentives for ship-owners and fishermen to deliver end-of-life fishing gear, gear caught at sea and other waste also collected at sea. Incentives could take the form of annual awards, even if symbolic (e.g. "Sustainable ship-owner"), but which would give visibility to those who make the greatest effort to ensure separation.

1.1.2. Potential constraints:

The fact that a considerable fraction of the fishing gear used in the ARM is made of a submersible polymer (polyamide) strongly conditions the recovery of that material when the monofilament breaks or the net becomes entangled in an obstacle in the ocean and has to be cut. Their recovery potential is therefore more limited and requires a precautionary approach by fishermen.

1.1.3. Example:

Examples of awareness campaigns for fishermen and ship owners on the collection of marine litter are already common in several regions in Europe. FARNET, Fisheries Areas Network supports and publicises local European initiatives to promote sustainable fisheries, including a number of projects on the recovery of derelict fishing gear, such as Fishing for Litter in the UK.

1.1.4. References:

https://webgate.ec.europa.eu/fpfis/cms/farnet2/

http://www.fishingforlitter.org.uk/

1.2. Feedback and promotion of ideas system

1.2.1. Description

In parallel to awareness-raising actions, it is important to receive testimonies from the main players dealing with fishing gear - the fishermen and the gear suppliers. Activities to promote sustainability in fisheries will be all the more effective if they take into account the know-how of the players involved in fishing. As with continuous improvement systems in companies or other entities, developing ways to facilitate regular feedback from fishermen on the effectiveness of the fishing gear management system used is critical.

The system could include the collection of eco-design ideas, such as making the gear easier to handle, reducing breakage and rupture and facilitating the recovery of the gear in the ocean, and include a communication channel with suppliers for them to forward ideas submitted by fishermen and vessel owners to manufacturers. The creation of communication channels and incentives, together with suppliers and manufacturers, can leverage the adherence of fishermen to this type of initiative.

1.2.2. Potential constraints

If mechanisms for dialogue between manufacturers and fishermen are not created, the adherence of the latter to this type of initiative may be compromised from the outset, due to the idea that fishermen and ship owners may be providing ideas to others who may be the only ones to profit from them.

1.3. Labelling of fishing gear

1.3.1. Description

There is a need to identify the origin of fishing gear or its components whenever they are lost or entangled in marine animals. If all commercial fishing nets were marked, crews would have an added incentive to avoid losing their nets and retrieve them when they are lost.

With various methods of fishing gear tagging already available and new technologies on the horizon, tagging fishing gear is a realistic option to prevent losses and ultimately protect marine animals. Many options already exist for tagging gear, and emerging technologies aim to make it easier and less costly in the future.

Current options include:

- physical labelling;
- chemical marking;
- colour coding;
- radio frequency identification (RFID);
- radio beacons;
- satellite buoys.

1.3.2. Potential constraints

The adoption of fishing gear labelling may be resisted by vessel owners and fishermen for two main reasons: mistrust and cost.

On the one hand, vessel owners and fishermen may consider that their performance is now tracked and that they can more easily be held responsible for losses in the ocean if their gear is tagged.

On the other hand, technologies for lost gear identification, which are widely used in the offshore oil and gas industries, and for ocean exploration, are generally too expensive for fisheries applications, which determines their still low adoption by ship-owners.

It is important to develop solutions that facilitate the identification (or even the location) of the gear, but that do not represent a considerable cost for ship-owners and fishermen. The solution may be, in a first phase, a programme of offer of fishing gear markers by the regional authorities, enhancing the creation of new habits, making more evident the advantages of this technology and eliminating mistrust, so that in the future there is no resistance to its mandatory use.

1.3.3. Example

The Interdisciplinary Centre for Marine and Environmental Research of the University of Porto (CIIMAR-UP) leads the NetTag project focused on the prevention and reduction of marine litter produced by the fishing industry.

The project has two components: on the one hand, reducing the loss of nets and other fishing gear by applying acoustic locators on this equipment and adapting autonomous vehicles to make their recovery feasible and, on the other hand, promoting good practices on board vessels to manage the waste produced and caught during fishing activity.

The technology involved in this project comprises the construction of an innovative type of tag, a low-cost, customisable and easy-to-use acoustic device activated only by the source vessel. The equipment, developed by the team at the University of New Castle, will allow active gear tracking without compromising the privacy of the equipment and the performance zones of the respective vessels.

These tags, which will be tested and validated in the laboratory and then in real conditions, in a demonstration carried out with the fishermen's participation, will also be combined with collection robots to reduce the time of search and recovery of lost nets. The robots will be developed by INESC TEC's team.

The goal is that only the fisherman has access to the locator signal and activates it to know precisely where the lost net is and thus be able to recover it. The second phase of the process involves the robots that will be adapted to submerge and recover the nets while controlled by the fishermen.

1.3.4. Reference:

https://www2.ciimar.up.pt/projects.php?id=125

1.4. Reconditioning and reuse

1.4.1. Description

Setting up systems to redistribute goods for reuse is an important part of the circular economy, also helping to avoid waste.

The investments needed to get started as a young fisherman or aquaculture producer can be prohibitive. It would be important to create conditions for fishing communities to set up systems to facilitate the transfer of equipment and machinery still usable to young or simply neighbouring fishermen who could still use a product that another would like to replace.

To this end, in addition to the repair system, conditions should be created to organise, re-condition and make the gear available for re-use, either through sale, loan, rental or leasing systems.

To some extent this is already a practice in the ARM. One vessel owner contacted in the scope of the RePesca project reported that sometimes when the longline of larger vessels is damaged, reducing their size, this equipment is donated to fishermen with smaller vessels.

Eventually this example can be extended to other gear, enhancing the emergence of a future business or cooperative activity, with the aim of extending the life span of various components of the gear.

1.4.2. Potential constraints:

The negative charge still associated with the use of used products may condition the adherence of some fishermen to accept using used gear.

The amount of gear available for reconditioning (due to the size of the industry in the region, or due to the low willingness of ship-owners to make used gear available) may constrain the potential for creating a business associated with gear recovery for resale or rent.

2. REGISTER

2.1. Development of registration platform

2.1.1. Description

Although the Extended Producer Responsibility (EPR) model for fishing gear has not yet been defined for the country, the Implementing Decision (EU) 2021/958 clarifies the information that Member States will have to report on fishing gear placed on the market and on fishing gear waste collected. This Decision also does not determine the date of entry into force of the Decision, which may be linked to the date of entry into force of the system for the management of this waste in accordance with the EPR model.

The Autonomous Region of Madeira may thus become a pilot in the collection and processing of this information, insofar as it has a number of operators in the value chain of fishing gear that may allow this information to be collected in a more agile manner.

The necessary information will require a characterisation of the gear in order to quantify the different types of materials that make up the gear. The gears practised in the region have been identified and are relatively strict, so it will be possible to define a methodology with composition factors that will allow the information to be processed more quickly.

Regular recording of inputs (placing on the market) and outputs (waste) of fishing gear makes it possible to monitor the lifespan distributions of the different gears, which makes it possible, on the basis of history, to estimate annual waste production for different time horizons.

2.1.2. Potential constraints:

All the potential inherent in information collection for sustainable management of fishing gears can be hampered if the system for collecting and processing the information is developed incorrectly. This can happen for example if there is not the necessary communication between the future users and the development team during the process, and if there is not a sufficiently long period of testing and correction to fine-tune and adjust the system.

3. INNOVATE

3.1. Biodegradable materials

3.1.1. Description

The durability of synthetic polymers explains their widespread use, but it also represents a considerable drawback. Despite the possible fragmentation of polymers, they can remain for several hundred years in the marine environment.

The development of biodegradable polymers has been the target of several research projects where a new generation of monofilaments, resistant and biodegradable, has been developed.

In 2016, researchers from Korea's National Institute of Fisheries Science, in collaboration with the FAO, developed an alternative biodegradable material for gillnets. These nets are degraded by microbes after only two years in seawater, radically reducing the duration of ghost-fishing. The material ensures catch rates similar to those of conventional nylon nets.

Marine environment experts warn, however, that this solution should not be seen as a panacea to combat ghost fishing. In fact, according to existing solutions the potential for biodegradable nets to break or get lost is greater than that of normal nets.

In general, in the first instance, cheaper preventive measures should be implemented to reduce the amount of gear that is discarded. However, if integrated into a wider management framework that includes strategies to tag nets, reduce losses and improve recovery, biodegradable materials could play an important role in reducing the impact of discarded fishing gear, thus reducing socio-economic and conservation costs.

3.1.2. Potential constraints:

Existing solutions on the market are still in their infancy and are likely to be more costly and, as a result, fishermen are less inclined to adopt them.

3.1.3. Example

The E-Redes Project consists of a pilot study proposed for the marine protected area of the Marine Park on the North Coast of Portugal.

This study will involve the provision of biodegradable gillnets and trammel nets to the local fishing community, for further evaluation of the contribution of this initiative in reducing both ghost-fishing and the introduction of synthetic plastic material into the ocean. The study will involve assessing the physical properties and durability of innovative monofilaments, the feasibility of manufacturing gear with the biodegradable monofilaments, and the fishing efficiency of nets constructed from biodegradable monofilaments when compared to conventional nets. The sustainability of the use of biodegradable materials compared to synthetic conventional materials will also be assessed from an economic (costs and local economy), environmental (protection of the marine ecosystem and preservation of biodiversity) and social (local traditions and practices) point of view to conclude if the use of biodegradable nets could be a viable alternative to conventional nets considering its cost and fishing efficiency.

3.1.4. Reference:

https://www.e-redes.esposende.pt/

3.2. Other eco-design strategies

3.2.1. Description

There are other aspects related to more sustainable gear design, in addition to the potential of using biodegradable polymers. These include ease of dismantling, recyclability of the gear and traceability.

One of the most important strategies for making gear more recyclable is to reduce the number of different materials used in its manufacture, without compromising its functionality. This reduction of different types of materials should be accompanied by the development of marking systems for easy identification of the materials and correct routing after separation. Ease of separation is another critical requirement for making the value chain associated with the gear more circular.

More research is needed on the lifetime of nets, the frequency and detail of repairs needed, and the potential to use part of the nets with additional add-ons, extending their lifetime.

The wealth of knowledge and solutions that exist in research centres and companies developing eco-design projects is considerable, but these are not yet accessed by the fishing gear industry, so it is of the utmost importance to connect the different stakeholders in order to raise awareness of what exists in terms of innovation, research and knowledge.

As mentioned, it is also crucial to address and incorporate the needs of the end users of fishing gear (fishermen), and involve them in the development of alternative, more sustainable and functional products.

A significant proportion of the waste gear collected or sorted for treatment is not recyclable under existing technologies because of its degree of contamination with marine organisms. The development of new recycling processes and technologies are critical elements for the circularity of materials associated with gear.

3.2.2. Potential constraints:

New systems, new materials, new products, new technologies are generally associated with higher costs, at least at an early stage of market introduction. This fact constitutes a strong constraint to their adoption, delaying the introduction of more sustainable practices.

3.2.3. Example:

The DollyRopeFree project aims to replace the monofilament strands used to protect trawl nets with another type of solution or another material for the monofilament. The monofilament that forms these strands comes loose and pollutes the sea and beaches, so the project aims to find a solution to reduce or eliminate this pollution.

The project is coordinated by the Wageningen Economic Research Institute and is a partnership between the Dutch fishermen's organisation VISNED, the North Sea Foundation, the Dutch government, materials experts and scientists.

3.2.4. Reference

http://www.dollyropefree.com/

4. VALUE

4.1. Selective collection and recycling of fishing gear

4.1.1. Description

When fishing gear can no longer be repaired or refurbished for re-use, its components should be recovered through recycling, avoiding waste through dumping.

Polyamide is currently the most recycled constituent polymer of fishing gear, as it has the highest market value. This is mainly due to the fact that the resulting recycled products have a high quality material, unlike recycled products from other polymers such as polypropylene.

Some fishing gear, such as that associated with aquaculture, cannot enter the recycling loop because it contains algaecide substances, making this waste hazardous. The EU has been banning the use of these substances, but much of the equipment in use today still contains them.

Despite the limitations presented to the recycling of polymers used in fishing gear, the fact that fishing gear in the ARM (seine, longline and spearfishing lines) has a high percentage of polyamide incorporated, may constitute an added value for the recovery of fishing gear waste in the region.

The system currently being implemented for collecting used fishing gear in the ARM is a strong point for the success of this measure. The placement of dedicated containers in the markets and ports can allow the collection of quantities of polyamide that allow its forwarding for recycling, without costs or even with positive return.

4.1.2. Potential constraints:

A significant fraction of fishing gear is lost in the ocean, namely through entanglement or tangle on rocks, and is inevitably subject to discarding. This fact may condition the volume of collected gear and, therefore, its valorisation potential. In addition to implementing the collection system on land, the potential to set up a collection system in the ocean could be assessed (see next measure).

The fact that a good part of the polymers used in fishing gear have a low market value, either because the resulting recycled material is of low quality or because it incorporates substances that make its treatment unfeasible, strongly conditions the implementation of an extended producer responsibility system that respects the circular economy strategies, namely the extension of the usefulness of those materials in the economy).

4.1.3. Example

Ambibérica is a Portuguese waste management company that trades fishing gear waste (mainly nylon) with 12 companies worldwide (Europe, Asia, North America). Ambibérica receives the waste and treats it according to the client's needs.

For example, in the case of Aquafil, one of the world's leading producers of nylon, the company only receives waste nets made with Nylon 6, without any mixture of other polymers or added organic matter. Aquafil only receives defined quantities of waste, well sorted and packaged.

4.1.4. Reference

https://ambiberica.pt/

4.2. Collection of fishing gear waste in the ocean

4.2.1. Description

There are now a number of organisations working to clean up the oceans, notably by collecting abandoned fishing nets. These organisations range from small groups of local volunteers to large international programmes. They range from one-off beach clean-ups or involve entire fishing communities that regularly collect abandoned gear. They are usually non-profit organisations, which have often established partnerships with companies that recycle the collected plastic.

In addition to raising awareness among fishermen and ship owners of the need to send end-of-life nets and lines to dedicated containers, reporting of losses in the ocean should be encouraged (with an incentive model to be defined), if possible using geolocation (GPS).

The collection of this information allows assessing the technical and economic potential for collecting lost gears in the seas of the ARM. This assessment may determine the opportunity to develop a pilot project involving organizations that practice the collection, for example through periodic collection campaigns or by establishing a partnership with a team permanently in the region, with regular collection campaigns.

4.2.2. Potential constraints:

The costs associated with the development of campaigns to collect waste from fishing gear in the ocean may make them unviable, even on a regular basis. This issue may be associated with facts such as the spatial dispersion of waste, insufficient quantities of waste or the depth at which the waste is located.

4.2.3. Example

SEAQUAL INITIATIVE is a community of people, organisations and businesses working together to help clean up the oceans, raise awareness of marine litter and shine a spotlight on those who help combat the problem.

Ocean clean-ups conducted by SEAQUAL partners collect all types of waste: plastics, metals, glass, rubber and mixed material items. Because mixed waste is expensive to recycle, in the past much of this waste went to landfill or incineration. SEAQUAL is dedicated to giving this material a second life. Mixed waste is separated into different types of materials. Metals and glass are recycled through traditional routes, while organic material and other non-plastics are recycled or disposed of responsibly. Marine plastics are more difficult to recycle. Although plastics can survive in the ocean for hundreds of years, UV rays, salt water and friction mean they can degrade quickly. Plastics are cleaned and processed into Reclaimed Marine Plastics at SEAQUAL INITIATIVE approved facilities and then returned to industry to be made into new products.

4.2.4. Reference

https://www.seaqual.org/

4.3. Other ways of valuing plastics

4.3.1. Description

Complementary to the recovery of used gear and the recycling of polymers with commercial value, there are other ways to enhance the recovery of plastics from used fishing gear.

The processing of plastics does not always require complex, large-scale machinery and industrial facilities, and commercial or not-for-profit solutions are emerging that enable the milling, injection and moulding of plastics enabling small-scale or “do-it-yourself” production of products.

The creation of incentives and/or logistical conditions for the installation of equipment for the recovery of plastic waste from used fishing gear can boost the development of new locally or regionally based businesses.

4.3.2. Potential constraints

The creation of new businesses dependent on the contribution of fishing gear waste carries a high level of risk and this may determine the failure of its promotion initiative.

Polymers taken from the ocean or beaches have an associated cargo of debris (e.g. salt and marine organisms) that can make them difficult to reuse. In addition, the natural irregularity of raw material availability can make it difficult to leverage a business dependent on it. Finally, the shipping costs of raw materials may constitute an added disincentive.

4.3.3. Example

Precious Plastic is an organisation whose aim is to “provide a global solution to the problem of plastic waste”. For this purpose the organisation has developed an online platform where they provide machine plans, product designs, knowledge about plastics and the plastics industry, business models and a complete system that can be adopted by anyone who wants it. Everything that is published online is free and open to anyone who wishes to use and adapt it.

4.3.4. Reference

https://community.preciousplastic.com/academy/intro.html

IMPLEMENTATION PLAN

Following and complementing the proactive attitude of the ARM's authorities regarding the collection of used fishing gear, namely under the OceanLit project, with the installation of dedicated collection containers in the various markets, the different measures presented can be adopted in the region, in the short and medium term. However, there are external factors that will influence the effective implementation, such as, for example, the availability of biodegradable monofilament solutions.

The measures presented are perfectly complementary and can cover the different types of plastic waste generated in the region, whether generated by local vessels, or that washed up on beaches or collected at sea.

Some of the measures may be the target of incentives (financial or of other nature) created by the Regional Government, such as labelling, or where the Government is a partner to support the start-up of the projects, such as the creation of a community workshop with equipment to process the used plastics and create parts or products from them. However, in any of the measures, the regional government will have to constitute itself as promoter, leveraging the actions, and, eventually, assigning its management to other entities in more advanced stages of implementation.

Table 14 presents the suggested allocation of responsibilities and potential partnerships to implement the plan to make fishing and aquaculture activity more sustainable in the ARM.

Table 14 - Responsibilities and partnerships for implementing the measures

Lines of action	Measures	Promoter(s)	Partner(s)
Prevent	Awareness-raising campaigns	SRAAC, SRMar	CoopescaMadeira, Ship-owners, Fishermen
	Ideas promotion system	SRAAC, ARDITI	CoopescaMadeira, Ship-owners, Fishermen
	Labelling of fishing gear	ARDITI, SRMAr	- "-Atlantic Colab, Ship-owners, Fishermen
	Reconditioning and reuse	SRAAC, SREM	Ship-owners, fishermen, ARDITI
Register	Registration platform	SRAAC, ARDITI	SRMAr, CoopescaMadeira
Innovate	Biodegradable materials	ARDITI	Scientific partner (research centre), technological partner (biotechnology), ship owners, fishermen
	Other eco-design strategies	ARDITI	Scientific partner (research centre), industrial partner (fishing gear manufacturer), vessel owners, fishermen
Value	Selective collection and recycling	SRAAC, SRMAr	Industrial partner (recycling preparation company), associative partner (deep sea waste collection organisation), ship owners, fishermen
	Other forms of valuing	SRAAC, SREM	Associative partner (NGO, Business accelerator)

In the future, with the expected increased interest by European and national authorities, potential sources of funding for these measures should be identified. At the date of this report there is no framework defined to support projects of this nature, which may soon change with the entry into force of the Recovery and Resilience Plan.

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ANNEXES

1. ANNEX 1

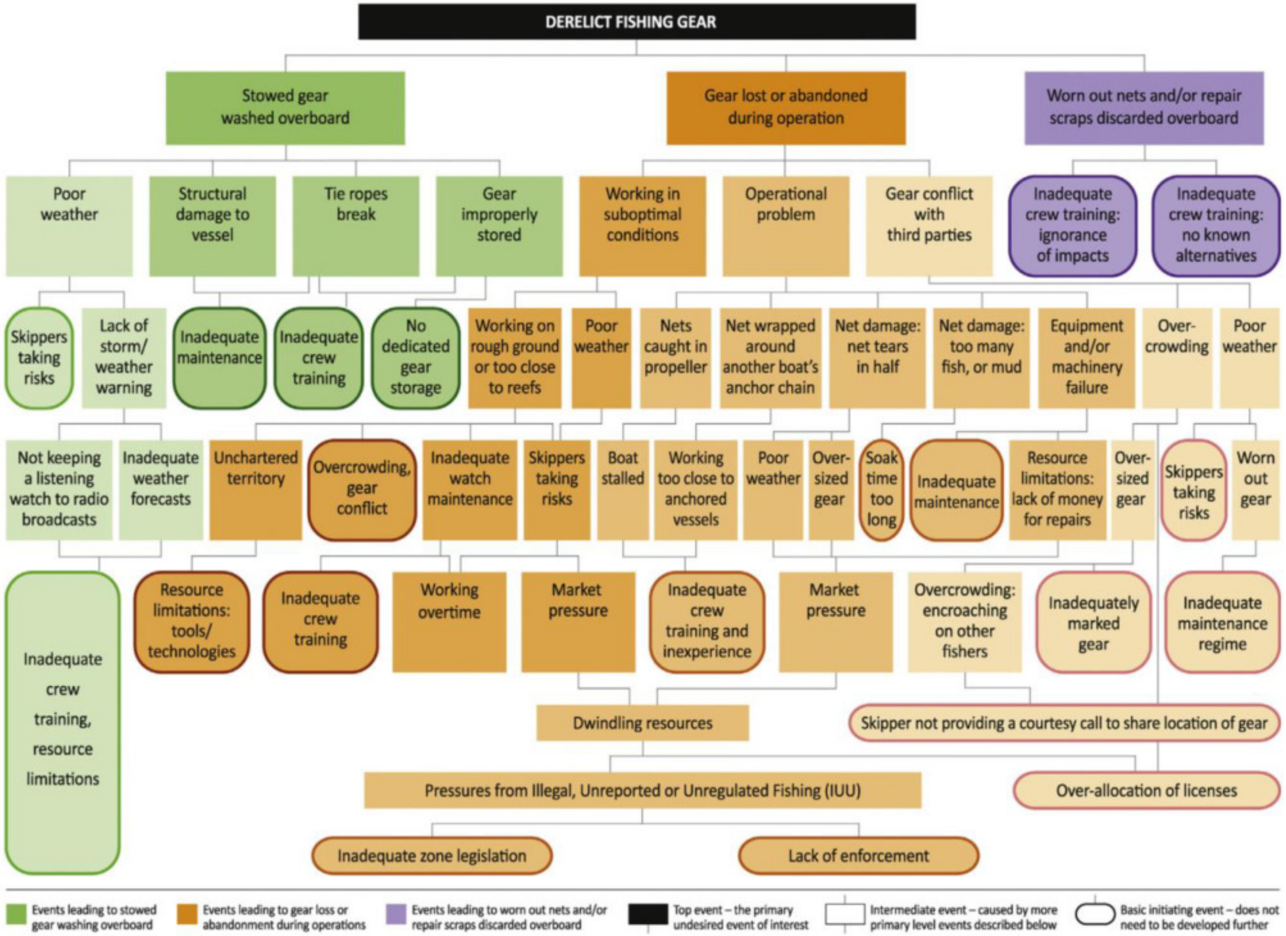


Figure 5 - Causes of trawl, gillnet and seine losses (Source: Richardson et al. 2018).

2. ANNEX 2

Brief description of offshore fishing and aquaculture gear

Fishing Gear

Angling

According to the Directorate General for Natural Resources, Security and Maritime Services, DGRM, angling is one of the most practiced fishing methods in the ARM and represents more than half of the catches made in the region. The line may be held in the fisherman's hand, it may be attached to a rod, with or without a reel, or it may be a thin line or cable called a snood (line), of variable length, from which lines (streamer lines or trotlines) with hooks are set. Generally the hooks are natural baits (like pieces of fish, shrimp or squid, or worms), or artificial baits, plastic or metal, shaped like the prey of the fish species to be caught. This gear can be used in a variety of ways: surface longline, pole and line, trolling, pole and hand line.

Longline Surface [1]

This type of line fishing gear consists of a strong and long main line, on which other shorter and numerous secondary lines depend at regular intervals, each one ending in a hook. There are also floats (buoys) and ballast (sinkers), which are responsible respectively for buoyancy and sinking, depending on the gear needs. This type of gear is considered to be one of the most selective fishing gear.

Logline surface in Madeira is used for tuna and swordfish fishing.

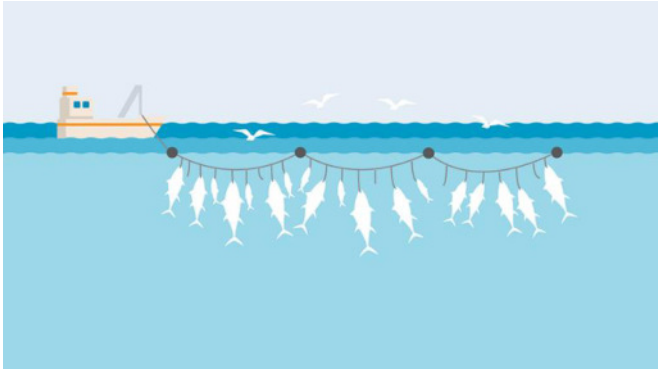


Figure 6 - Line fishing - Surface longline[2]

Drifting long-lining

This is similar to longline surface, but it cannot be considered surface because it is used at 800-1200m depth. In the Madeira region, this fishing gear is mostly used for hunting black scabbardfish.

Its socio-economic importance is very high, representing about 50% of the fishing catches landed in the Region.

[1] https://www.dgrm.mm.gov.pt/web/guest/anzol
[2] https://www.msc.org/what-we-are-doing/our-approach/fishing-methods-and-gear-types/longlines

Bottom longline[3]

This is a device with many hooks, formed by a line or cable called a snood, of variable length, from which branch lines or baited lines with hooks are fixed to the seabed.

Jumping and Pole Vaulting [4]

The art of jumping and pole-and-line with live bait, as the name implies, involves a pole and the technique of jumping, which consists of pulling the fish (tuna) on board with a single movement, making them jump. This art is a seasonal activity according to the target species of the tuna fleet and availability in the waters of the region. These oscillations are influenced by the variability of the oceanic conditions that determine the typical migratory routes of these species and abundance in the fishing grounds of the Autonomous Region of Madeira (ARM). The dominant tuna species in the fishery of the ARM in recent years are bigeye tuna with 58% of the catches (average of 1,490 tons/year) and skipjack tuna with 26% (average of 673 tons/year) of the total landings of this group of species. During the first half of each year, the catches of bigeye are more frequent and significantly higher, while in the second half, skipjack lead the catches in the area.

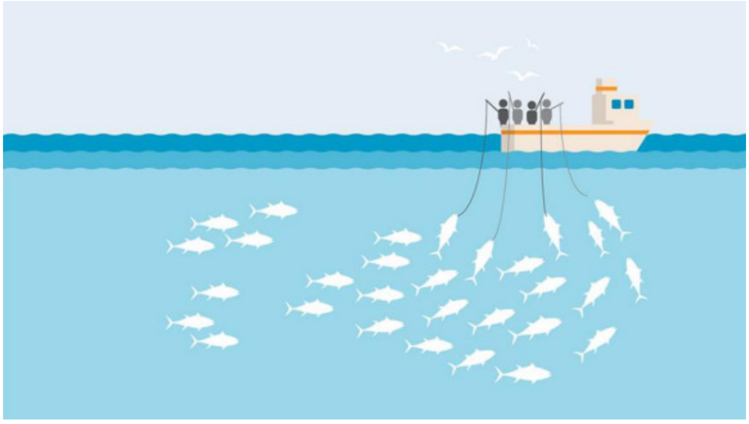


Figure 7 - Line fishing - Jumping and Pole[5]

Hand Line

This is a device, with a maximum of sixty hooks, which works attached to the fisherman's hand, with or without the aid of a line hauler. The following gear is considered within the group of hand lines:

Troll Lines [6]

This gear is used in the ARM to catch fish such as bass, mackerel, needlefish, among others. Trolling consists of throwing a natural bait to a certain area and then retrieving it, waiting for some fish to attack it. It is

[3] http://collab-keywords.snimar.pt/detail/180/
[4] https://dica.madeira.gov.pt/index.php/outros-temas/pescas/1059-breve-nota-sobre-a-pesca-do-atum-na-madeira
[5] https://www.msc.org/what-we-are-doing/our-approach/fishing-methods-and-gear-types/pole-and-line
[6] https://www.pesca-pt.com/pesca-corrico

performed with the movement of the boat: the rods are fixed in the boat and the movement of the bait is effected by the movement of the boat and not by action of the fisherman.

Cage traps [7]

Trap fishing is a passive fishing gear practiced in Madeira to capture crustaceans and molluscs. This gear consists of luring the prey or leading it into the device that will make it impossible for it to escape. Depending on the species to be caught, certain mesh size classes may be used: 8 mm to 29 mm, 30 mm to 50 mm, and > 50 mm. Certain parts of the trap may have a smaller mesh size. Lobster and spiny lobster may be caught in traps made of wooden strips at least 40 mm apart.

Encircling [8]

The so-called encircling gear consists of a rectangular-shaped encircling net, which may consist of several panels linked together. As they are surface nets the float line has numerous buoys or floats. The fishing is carried out at night and the shoal detection is made by means of sounders. The nets that operate in Madeira, have a closing method, which means that in the lower part there is a cable that, when pulled, closes the net like a bag, retaining the encircled fish. The purse seine is operated by two boats, the main boat and the support boat. The encirclement is completed when the main boat meets the support boat and the net is immediately closed by the purse seine. The nets can be up to 500 metres long and 90 metres high, with a minimum mesh size of 16mm, in accordance with the legislation in force. In the Madeira region, the species captured by this type of gear are represented by small pelagic fishes such as blue jack mackerel (Trachurus picturatus) and mackerel (Scomber colias). Other species like bogue (Boops boops) and sardine (Sardina pilchardus) are also part of this group, although with a smaller weight.

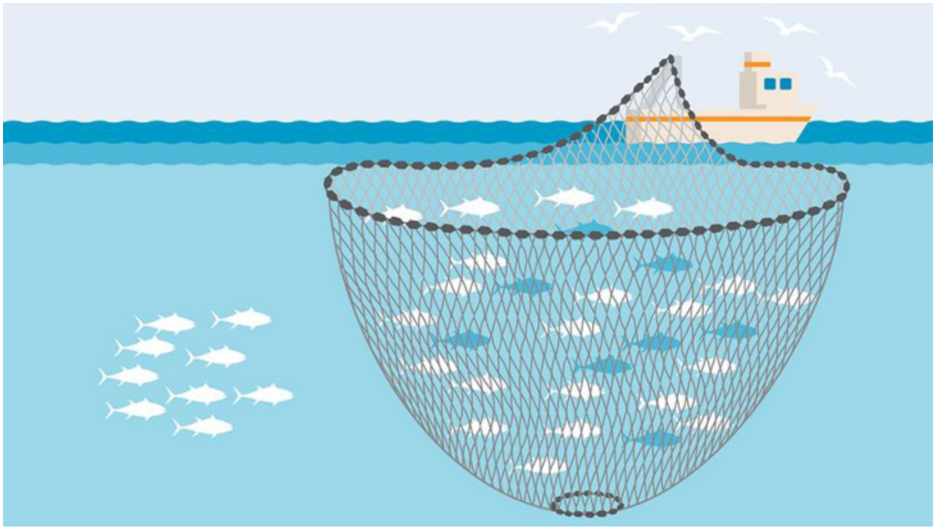


Figure 8 - Purse seine gear

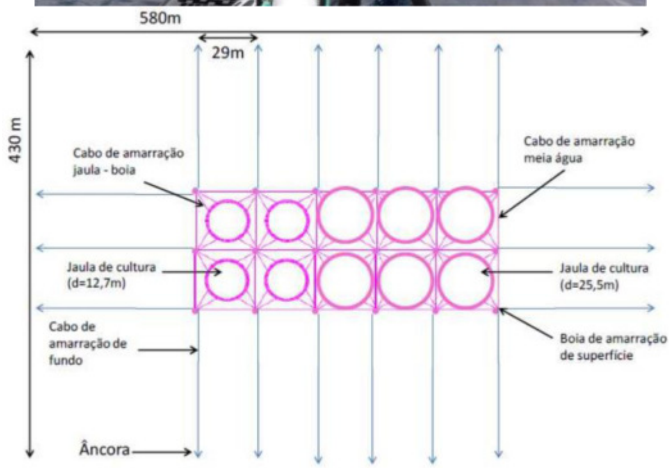
[7] https://www.dgrm.mm.gov.pt/web/guest/armadilhas-de-gaiola
[8] https://www.dgrm.mm.gov.pt/web/guest/cerco

Lifting and catching gear[9]

Fishing by lifting gear is defined as any fishing method using net structures that are used to catch fish with vertical movements. The instruments often used are sieves, which are large sieves. Catching is an individual fishing method, characterised by the non-use of specially made tools, not causing serious injuries to the catch. Various tools may be used, such as the shellfish knife, the short-handled grab, the cockle and the scraper.

Offshore aquaculture

Aquaculture carried out in the Madeira region is an offshore aquaculture (open sea), using floating rafts with a closed net structure, inserted in a body of water. In these structures, the fish are fed with rations developed in accordance with the nutritional requirements of the species.



[IMAGE: Cage - buoy mooring cable | Half-water mooring cable | Culturing Cage (d=12.7m) | Culturing Cage (d=25.5m) | Funnel mooring cable | Surface mooring buoy | Anchor]

[9] https://www.dgrm.mm.gov.pt/web/guest/apanha

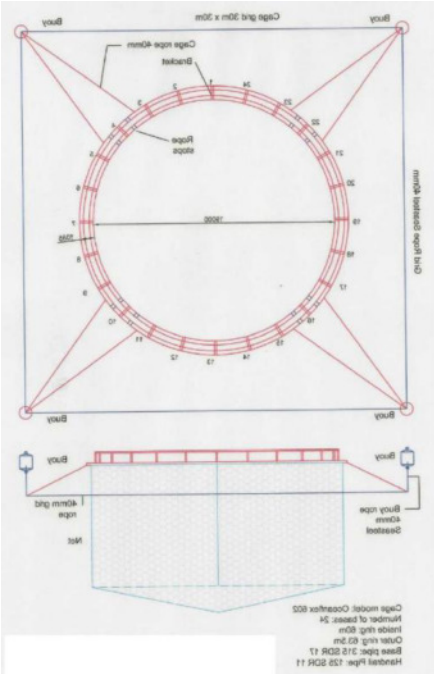


Figure 9 - Offshore aquaculture structures [10]

[10] https://www.wavec.org/contents/files/pedro-diniz--marismar--compressed.pdf

3. ANNEX 3

Catches of the fishing fleet in the ARM, 2020 (Source: RDF)

Species	kg at market 2020	GEAR
Black Scabbardfish	2.135.517	DRIFTING LONGLINE
Bigeye Tuna	1.087.964	SURFACE LONGLINE. POLE AND LINE
Flying Fish	902.420	SURFACE LONGLINE, POLE AND LINE
Skipjack Tuna	174.424	SIEVE LONGLINE, POLE AND LINE
Horse Mackerel	138.858	FENCING NETS
Bluefin Tuna	111.110	SURFACE LONGLINE, POLE AND LINE
Gastropod	100.251	HAND TOOLS (LIMPETS KNIFE)
Mackerel	87.662	FENCING NETWORKS
Albacore	21.129	SURFACE LONGLINE, POLE AND LINE
Dentex Gibbosus	15.820	BOTTOM LONGLINE/HAND LINES AND HOOKS
Red Porgy	10.819	BOTTOM LONGLINE/HAND LINES AND HOOKS
Leafscale Gulper Shark	8.265	DRIFTING LONGLINE
Needlefish	7.526	SURFACE LONGLINE/RAIL
Greater Amberjack	6.566	HEEL AND POLE/HAND LINE AND HOOKS
Guachanche Barracuda	5.113	POLE VAULTING/RACING
Forkbeard	4.985	BOTTOM LONGLINE
Triggerfish	3.868	BOTTOM LONGLINE
Oilfish	3.612	DRIFTING LONGLINE
Grouper	2.791	BOTTOM LONGLINE
Atlantic Bonito	2.754	SURFACE LONGLINE, POLE AND LINE
Mediterranean Moray	2.257	LONGLINES AND POTS OR TRAPS
Ommastrephidae	2.147	HAND NAIL WITH TONER
Blackbelly Rosefish	1.961	BOTTOM LONGLINE
Porbeagle	1.814	SURFACE LONGLINE
Conger	1.625	BOTTOM LONGLINE
Southern Red Snapper	1.537	HAND NAIL WITH TONER
Wrasse	1.360	LONGLINES AND POTS OR TRAPS
Prickly Puffer	1.239	DRIFTING LONGLINE
Common Two-Banded Sea Bream	1.185	BOTTOM LONGLINE
Whiting	1.096	BOTTOM LONGLINE
Dogfish	1.023	BOTTOM LONGLINE
Sheepshead	987	BOTTOM LONGLINE/LINES AND HAND
Sardines	982	FENCING NETS
Sergeant Major	856	LAYING CAGES OR TRAPS, sieve
White Sergeant Major	848	LAYING CAGES OR TRAPS, sieve
Blue Marlin	729	SURFACE LONGLINE/RAIL
Oilfish	669	DRIFTING LONGLINE
Blackspot Seabream	543	BOTTOM LONGLINE/HAND LINES
Dourado	533	POLE AND LINE/TROLLING LINE
Goliath Grouper	527	BOTTOM LONGLINE/HAND LINE
Sargo	509	DEEP LONGLINE /LAYING CAGES OR TRAPS
White Trevally	500	DRIFTING LONGLINE
Wahoo	489	SURFACE LONGLINE/RAIL
Big-Scale Pomfret	467	DRIFTING LONGLINE
Atlantic Wreckfish	463	DRIFTING LONGLINE/HAND WEDGE
Black Gemfish	437	DRIFTING LONGLINE
Brama	426	DRIFTING LONGLINE
Bermuda Sea Chub	378	DRIFTING LONGLINE/ LAYING CAGES OR TRAPS
Black Cardinal Fish	365	DRIFTING LONGLINE
Wrasses	360	DERIVED LONGLINE/HAND LINE
Salema	311	DRIFTING LONGLINE/ LAYING CAGES OR TRAPS
Morays	284	DRIFTING LONGLINE/ LAYING CAGES OR TRAPS
Blackbelly Rosefish	228	DRIFTING LONGLINE/HAND WEDGE
Stout Beardfish	188	DRIFTING LONGLINE
Smooth-Hound	186	DRIFTING LONGLINE
Sharktooth Moray	176	DRIFTING LONGLINE/ LAYING CAGES OR TRAPS
Ray	162	DRIFTING LONGLINE
Octopus	162	LAYING CAGES OR TRAPS/JIG
Frigate Tuna	144	SURFACE LONGLINE, POLE AND LINE
Atlantic Herring	137	PURSE SEINES
Cardinal Fish	116	DRIFTING LONGLINE
Saddled Seabream	98	HAND LINE AND LAYING CAGES OR TRAPS
Axillary Seabream	96	DRIFTING LONGLINE
Gulper Shark	87	DRIFTING LONGLINE
Bluefish	81	FINGERNAIL/TROLLING LINE
Flathead Grey Mullet	70	DRIFTING LONGLINE
Bogue	59	PURSE SEINES, SIEVES
Common Mora	51	DRIFTING LONGLINE
Dogfish	46	DRIFTING LONGLINE
Pompano	44	HAND LINE / PURSE SEINE
Kitefin Shark	40	DRIFTING LONGLINE
Longfin Yellowtail	37	BOTTOM LONGLINE
Bigeye Grunt	36	BOTTOM LONGLINE
Canary Damsel	29	BOTTOM LONGLINE
Blue Shark	23	SURFACE LONGLINE
Brown Moray	19	LONGLINES AND LAYING CAGES OR TRAPS
Surmullet	15	LONGLINES AND LAYING CAGES OR TRAPS
Alfonsino	13	BOTTOM LONGLINE
Splendid Alfonsino	12	BOTTOM LONGLINE
Lobster	9	LAYING CAGES OR TRAPS
Common Squid Nei	7	HAND LINE WITH JIG
Sargo Breams Nei	6	BOTTOM LONGLINE/ LAYING CAGES OR TRAPS
Black Seabream	6	BOTTOM LONGLINE
Sea Trout	5	BOTTOM LONGLINE
Common Dolphinfish	3	BOTTOM LONGLINE / HAND LINE
John Dory	3	BOTTOM LONGLINE
Glasseye	2	BOTTOM LONGLINE
Mediterranean Slipper Lobster	0	LAYING CAGES OR TRAPS

4. ANNEX 4

Table 15 - Values assumed for the estimation of equipment weights

Equipment	Material	d min(mm)*	d máx(mm)*	m/kg min*	m/kg máx*	Weight (kg)
Snood	Polyamide	1,4	3,0	575	120	
Monofilament	Polyamide	0,5	1,0	4300	1203	
Purse Seine	Polyamide					500**

*http://filkemp.com/pt/pesca-industrial/ e https://www.cadilhe-santos.pt/pt/monofilamentos-moncad%C2%AE/pesca/palangre-fundo.html

**Coopesca Madeira

Table 16 - Estimates of the total weights of longline gears operating in the ARM

					Snood					Monofilament				
Gear		Size of the vessel	Number of vessels using the gear	**Number of pieces of equipment** (purse seine + monofilament) per vessel	Average length of snoods	Average total length of snoods on each vessel (m)	Length in all vessels	minimum weight (kg)	maximum weight (kg)	Average number of monofilament per snood	Average length of monofilament	Average total length of monofilaments for all vessels (m)	minimum weight	maximum weight
Longline	Drift (depth)	**I**	56	10	4000	40000	2240000	3895,65	18666,67	90	500	25200000	5860,47	20947,63
		II	25	20	8000	160000	4000000	6956,52	33333,33	90	500	22500000	5232,56	18703,24
		III	4	35	8000	280000	1120000	1947,83	9333,33	90	500	6300000	1465,12	5236,91
		IV	3	40	16000	640000	1920000	3339,13	16000,00	90	500	5400000	1255,81	4488,78
	Surface	**I**	50	1	3000	3000	150000	260,87	1250,00	120	25	150000	34,88	124,69
		II	12	1	6000	6000	72000	125,22	600,00	250	25	75000	17,44	62,34
		III	2	2	10000	20000	40000	69,57	333,33	400	25	40000	9,30	33,25
							Total (kg)	16595	79517			**Total (kg)**	13876	49597
							Total (t)	17	80			**Total (t)**	14	50