CleanAtlantic

Tackling Marine Litter in the Atlantic Area

DELIVERABLE 4.3.1 – Review of Economic Sectors Impacted by Marine Litter in the Atlantic Area: Literature Review

WP 4: Marine Litter in the Atlantic Area

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1. Introduction

Since the 1950's, the volume of plastics in the environment has increased significantly (UNEP, 2016). It is estimated that around 8 million items enter the sea every day and this trend is increasing despite the measures already in place to reduce marine litter (McIlgorm et al., 2008). More than 10 million tonnes of plastic reach the world's oceans each year (Jambeck et al. 2015). Despite marine litter is nowadays identified as a major global environmental problem (Sutherland et al., 2010), Almroth and Egger (2019) state that environmental economics studies on marine plastic pollution are still scarce, which is something that concerns them as marine plastic pollution might potentially be of serious harm to human health (GESAMP 2015). UNEP (2016) note as well that marine litter is not only a threat to marine species and ecosystems but there is a growing concern about the potential danger to human health and the considerable negative impacts to human welfare. From an economic standpoint, industries such as tourism, fisheries, aquaculture and shipping are all negatively affected; resulting in individuals, enterprises and communities suffering substantial economic losses (Werner et al., 2016). While there have not been many studies on the economic costs of marine litter, it was estimated that in the Asia-Pacific region the cost was around €1.26 billion per year to marine industries (including such losses from tourism, entangled ship propellers and lost fishing time). However, this estimate did not take into account the costs that arise from the loss of ecosystem service provision or other non-market values, and is therefore likely to be an underestimate. With regards to its accumulation and dissemination, marine litter could well be one of the fastest rising threats to the health and productivity of the world's oceans (McIlgorm et al., 2008) (from endangering wildlife to loss of tourism and even introducing toxins into the human food chain). In this report we review the different forms of marine litter, and we explore their impacts on different economic sectors making use of an ecosystem services approach.

2. Marine Litter: What is it?

2.1. Defining Marine Litter

Marine litter (also named marine debris) is defined as "any solid material which has been deliberately discarded, or unintentionally lost on beaches and on shores or at sea, including materials transported into the marine environment from land by rivers, draining or sewage systems or winds" (OSPAR, 2017). Therefore, marine litter originates from numerous land and ocean-based sources and includes different types of litter consisting of a variety of materials, however, plastic dominates accounting for around 80% of marine debris found on beaches in the OSPAR area (OSPAR, 2017). Marine litter can be carried vast distances by ocean currents and can be discovered in all marine environments, even in the most isolated areas (Werner et al., 2016).

2.1. Marine Litter 'Hot Spots' in the OSPAR region

Macro and microplastics can be found in various "hot spots" throughout world's oceans; be it on the shoreline, nearby coastal water, or floating mid-ocean. One particular 'hot spot' for shoreline marine litter that is frequently cited within the literature is the Skagerrak coast, in Sweden, which accumulates litter from the whole North-East Atlantic (Marlin, 2013). Furthermore, it has been noted that higher amounts of litter were found in the eastern Bay of Biscay, southern Celtic Sea and English Channel than in the northern Greater North Sea and Celtic Seas (OSPAR, 2017). Previous studies have highlighted that the Bay of Biscay receives a high volume of litter from local rivers and transport (OSPAR, 2017).

2.2. Types of Marine Litter

Marine litter is comprised of a range of different materials which are commonly classified into several categories:

- **Plastics** including moulded, soft, foam, nets, ropes, buoys, monofilament line and other fisheries related equipment, cigarette butts or lighters, and microplastic particles
- **Metal** including drink cans, aerosol cans, foil wrappers and disposable barbeques
- **Glass** including buoys, light globes, fluorescent globes and bottles
- **Processed timber** including pallets, crates and particle board
- **Paper and cardboard** including cartons, cups and bags
- **Rubber** including tyres, balloons and gloves
- **Clothing and textiles** including shoes, furnishings and towels
- **Sewage related debris (SRD)** including cotton bud sticks, nappies, condoms and sanitary products (Beachwatch, 2009 cited in Mouat et al., 2010).

2.2.1. Plastics

Plastic accounts for the majority of marine litter (Sheavly, 2007), posing a significant threat to the marine environment due to its abundance, longevity in the marine environment (some items can take up to 600 years to degrade in the ocean (Cho, 2011)) and ability to travel long distances (Mouat et al., 2010). Plastics are relatively cheap to produce and have become extremely important in modern society, which has led to an increase in items being discarded (Derraik 2002). Almroth and Egger (2019), for example, report that plastic can enable innovation in the medical sector, and enhance food safety through food packaging, as well as help to save energy consumption and greenhouse gas emissions thanks to their characteristics and light weight. As they are lightweight and long lasting though, plastic items can travel lengthy distances and remain in the ocean for long periods of time; for example, a plastic bottle is said to take 450 years to degrade in the sea (Cho, 2011). Although accounting for 10% of all waste produced (Thompson et al., 2009a), plastics comprise approximately 50-80% of marine litter (Barnes et al 2009) and this is expected to continue to grow for the foreseeable future (Thompson et al 2009b). Worldwide it is estimated that 4.8 to 12.7 million tonnes of plastic enter the oceans every year due to mismanaged waste at coastlines (Jambeck et al. 2015).

Worryingly, when exposed to sunlight plastics may also deteriorate and fragment in the environment. This breakdown of larger plastics results in large amounts of tiny plastic fragments, which, when smaller than 5mm are referred to as secondary micro plastics (OSPAR, 2014). Other micro plastics that can be found in the marine environment are categorised as primary micro plastics, because they are produced either for direct use, such as for industrial abrasives or cosmetics, or for indirect use, such as pre-production pellets or nurdles (OSPAR, 2014).

Furthermore, Almroth and Egger (2019) highlight that the chemical additives used in plastic materials (e.g. plastic food containers and cutlery) can contaminate both food through packaging, having an impact on the life of humans, as well as the marine ecosystems where they are found, impacting the life of, for example, fish and marine mammals.

2.3. Sources of Marine Litter

Marine litter researchers typically classify debris sources into two categories: land- or ocean/waterway based, contingent on where the debris enters the water. The United Nations Joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP) discovered that land-based sources account for up to 80% of the world's marine pollution (GESAMP, 1991), although there are regional fluctuations, for example, in the Northeast Atlantic, shipping and fishing are very significant litter sources (E.U. Commission, 2017). Due to the fact that litter can travel long distances, it can be hard to determine where the debris originated.

2.3.1. Land-based sources of marine litter

Marine litter can be produced on land either in coastal areas such as beaches, piers, harbours, marinas and docks (Allsopp et al., 2006), or many miles inland, attributable to the lengthy distances litter can travel in the environment (Ten Brink et al 2009). Litter is both deliberately and unintentionally discarded into the environment and can result from a wide range of activities including coastal tourism, fly-tipping, local businesses and poorly managed waste disposal sites (UNEP, 2016).

Land-based sources of marine litter include (Allsopp et al., 2006):

- **Public littering** – A diverse range of litter items are discharged (purposefully or inadvertently), by the public at the beach, coast, or into rivers, and therefore entering the marine environment. Tourist and recreational visitors are a key source of litter with public littering accounting for 42% of all debris found during the 2009 UK Beachwatch survey (Beachwatch 2009 cited in Mouat et al., 2010).
- **Poor waste management practices** – Poor waste management practices can cause debris from waste collection, transportation and disposal sites to enter the marine environment. Although litter has the potential to originate inland, poorly managed coastal and riverine landfill sites, as well as fly tipping are of primary concerns.
- **Industrial activities** – Industrial products can enter the marine environment when they are inadequately thrown away or mistakenly lost during transport, both on land and at sea. Examples of this include small plastic resin pellets, the feedstock for plastic production, and are often discovered during marine litter monitoring surveys.
- **Sewage related debris (SRD)** – Sewage related debris (SRD) is a consequence of the release of untreated sewage into the marine environment, as a result of an absence of waste treatment facilities or from combined sewer overflows during storm events. SRD constitutes a small proportion of the overall litter problem,

accounting for only 5.4% of marine litter found during the 2009 UK Beachwatch survey (Beachwatch 2009 cited in Mouat et al., 2010).

• **Storm water discharges** – Litter can collect in storm drains and subsequently be discharged into the marine environment during storm events.

2.3.2. Ocean-based sources of marine litter

Ocean-based litter is introduced into the environment due to either accidentally or deliberately discarding items, ranging from galley waste to cargo containers (Allsopp et al., 2006).

Ocean-based litter is generated by (Allsopp et al., 2006):

• **The fishing industry** – Nets, ropes and other fishing debris are some of the most noticeable components of marine litter and arise from: a failure to remove gear, accidental loss of gear or the deliberate dumping of nets, ropes and other waste by fishing crews.

• **Shipping** – Although international legislation prohibits the disposal of manufactured items at sea, these are still inadvertently discharged, stored inappropriately or released intentionally by shipping vessels, particularly on long journeys. One of the major issues noted is the recurrent loss of cargo containers from commercial shipping, around 10,000 of these containers are lost internationally each year.

• **The leisure industry** – Recreational boat owners and operators unintentionally or deliberately discard waste and other manufactured items into the marine environment such as food containers, plastic bottles and recreational fishing gear.

• **Offshore oil and gas platform exploration** – Off shore oil and gas activities can result in the discharge, both accidental and deliberate, of a range of items into the marine environment (such as gloves and hard hats as well as waste generated from exploration and resource extraction).

2.4. Fate of marine debris

Approximately 70% of litter entering the ocean sinks to the seabed while 15% floats on the surface of the sea, with a further 15% remaining in the water column (UNEP, 2016). Floating debris mostly comprises of plastic bags, plastic items and woody debris, and it may be carried by winds and currents for sizable distances before sinking or being cast ashore (McIlgorm et al., 2008). Additionally, much of land-based litter stays on beaches, and in coastal habitats. Heavier types of litter may sink when disposed of and either lies on the seabed or becomes incorporated into soft sediments. Seabed debris is mostly derelict fishing gear, metal, cans and plastics, mainly from vessels and fishing activity (Moore and Allen, 2000).

3. The potential impact of marine litter on coastal and marine ecosystem services and related economic sectors

3.1. Potential impacts of marine litter on economic activities: overview

Marine debris has extensive negative social, economic and ecological impacts. There is now a growing recognition that marine litter has substantial economic impacts on industries such as commercial fishing, shipping, aquaculture and tourism, caused wholly or partly by various types of marine debris. However, the large variety of impacts contributes to the complexity of measuring the total economic cost that arise from marine litter. Principally, this is because some impacts are more easily estimated in economic terms than others (Mouat et al., 2010).

It is important to distinguish actual economic costs related to expenditure (e.g. beach clean-up costs; costs linked with loss or damaged fishing gear) from economic costs of loss of output or revenue (e.g. loss of returns from fish or tourism) and welfare loss valuations in economic terms (e.g. effects on health; assessing the economic value of loss of cultural values such as recreation or landscape aesthetics) (Bergmann, Gutow and Klages, 2015). Some approaches intend to establish the economic value of ecosystem goods and services which considers the full spectrum of impacts, both direct and intangible. Yet, there is a lack of studies that have adopted this type of methodology in a marine and coastal context, and more specifically, to determine the economic cost of marine litter on ecosystem service provision (Mouat et al., 2010). Nevertheless, valuations on marine ecosystem services suggest that even slight deterioration in provision would signify a large cost (Beaumont et al. 2007; Galparsoro et al. 2014). In this report we propose an ecosystem services approach that allows the analysis to identify whether an ecosystem service or a good/benefit is impacted by marine litter, and therefore take the most appropriate action.

3.2. Ecosystem services and the potential impacts of marine litter on economic activities

Ecosystem services are defined as “the benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services such as nutrient cycling that maintain the conditions for life on Earth” (UKNEA, 2011). Ecosystem services have been classified into four main categories (provisioning, supporting, regulating and cultural) by the Millennium Ecosystem Assessment (MEA) in 2005. Provisioning services are classified as the products obtained from ecosystems such as food, fibre and fuel; regulating services are the benefits acquired from the regulation of ecosystem functions such as water purification and natural hazard protection from storms, floods etc.; cultural services are the nonmaterial benefits that individuals attain through recreation, spiritual enrichment etc.; supporting services are those that are required for the production of all other ecosystem services such as primary production, nutrient cycling and soil formation (MEA, 2005). This report follows the UK National Ecosystem Assessment ecosystem framework in that there is a distinction between final services, which directly contribute goods and values to human well-being, and intermediate services, which are the ecological processes that underpin the outputs of final ecosystem services (UKNEA, 2011). When final ecosystem services (e.g. fish and shellfish) are combined with human, built and social capital, people derive goods and benefits (e.g. fish for food consumption, which can be valued economically) and other values (e.g. spiritual experiences which have a non-economic value). Those receiving the benefits (private or public) are named 'beneficiaries'. When contemplating the link between ecosystem services and economic activities, it is useful to differentiate between beneficiaries that directly 'consume' ecosystem services (e.g. individuals that breath fresh air) and commercial producers who utilise ecosystem services as inputs to their production processes (e.g. fisherman who depend on a healthy fish stock) (SEQ Ecosystem Services, 2005). Recognising the association between ecosystem services and economic sectors can help better understand the economic impacts that result from a change in ecosystem services (UKNEA, 2014). While there has been no comprehensive research into the impact of marine litter on ecosystem services, it is worth noting the potential impacts to justify how problematic marine litter may be to essential ecological processes as well as human welfare.

The following section presents an ecosystem services approach to the impact of marine litter on the tourism, fisheries, aquaculture and shipping industries. Each figure (1, 2 and 3) highlights (through the blue solid line arrows) the direct impacts that marine litter has on intermediate and final ecosystem services. This impact has wider implications (be it through impacting other ecosystem services, goods/benefits that are derived from the ecosystem services, or the related economic activities) that are displayed by the dotted blue arrows to represent the indirect impact of marine litter. Furthermore, there is also a feedback loop between the industries that are impacted by marine litter and those that act as sources (represented by the green arrow).

The ecosystem services approach highlights to policy makers the relationship between human well-being and the services provided by ecosystems. By doing this, it encourages decision makers to respect how society depends upon ecosystem services and consider the impact of marine litter on the future supply of different ecosystem services (Hancock, 2010). As ecosystem services are directly impacted by marine litter – decision makers should look to policy solutions to prevent and reduce in order to avoid ecosystem service degradation and economic loss. Furthermore, the presence of a feedback loop from the economic sectors would suggest that actions have to be taken by each economic activity directly – it is in each sector own interest to prevent and reduce marine litter as each is indirectly impacted through loss of ecosystem provision. It is within this context that Extended Producer Responsibility (EPR) is developing. With the EPR policy, the responsibility of a product is extended from production to the product's postconsumer stage. EPR provides incentives to producers at the design stage of a product for its collection, recycling or safe disposal (Almroth and Egger, 2019).

3.2.1. Tourism

The impact of marine litter on beach visitors' recreational experience is expected to constitute a significant share of the total economic costs to society (Brouwer et al., 2017). As shown in Figure 1, marine litter has a direct impact (shown by the solid blue arrow) on final cultural ecosystem services (landscapes and seascapes), which, through human and built capital has an indirect impact on ecosystem goods and benefits such as nature watching (represented by the dotted blue arrow). Marine litter such as ropes, plastics and derelict fishing gear can end up on the seabed, on beaches and along the coastline. This negatively impacts the aesthetic values of the coastline and beaches for marine tourism visitors and residents, and entanglement with ghost gear could cause distress for recreational water users (Surfer Against Sewage, 2014). Also, glass, metals and shards of hard plastics can potentially be dangerous to beach visitors. This can result in a decrease in the amenity value of beaches (an ecosystem service good/benefit) for tourists and may mean that tourists will be less willing to pay to go to a polluted tourist location by the sea (McIlgorm et al., 2008). Figure 1 helps to express at what level intervention should be carried out – if the impact is indirect on final ecosystem services (landscapes and seascapes), then, it is there that an action or policy should be taken.

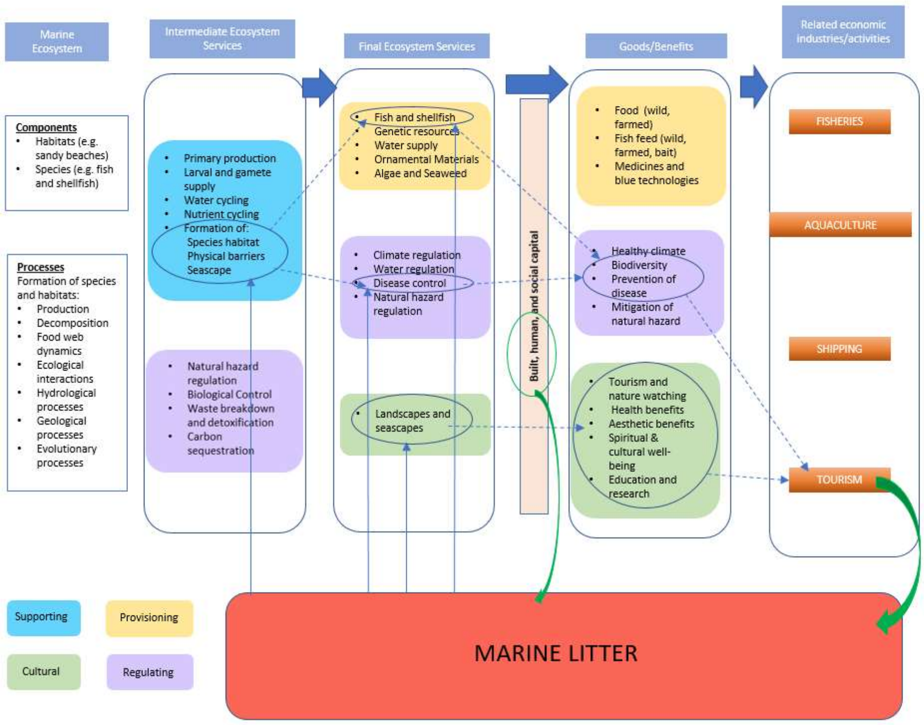

Figure 1 Impact of Marine Litter on Tourism – An Ecosystem Services Approach. The Blue solid line arrows show the direct impacts of marine litter; the dotted blue arrows to represent the indirect impact of marine litter; the green arrows represent feedback loop between the industries that are impacted by marine litter and those that act as sources.

The non-market impacts of beach litter on social welfare can be evaluated using surveys and questioning beach visitors about their perception of marine litter and preferences for clean beaches (Brouwer et al., 2017). Brower et al. (2017) conducted a survey on 785 visitors to 6 urban beaches in Bulgaria, Greece and the Netherlands along the coastlines of the Black Sea, Mediterranean Sea and the North Sea. Individuals were interviewed in person, and asked the same questions on their perception of beach litter, how beach litter affected their beach experience, and whether they would be willing to volunteer in beach clean-up actions or pay local entry fees and municipality taxes for beach clean-up (Brower et al., 2017). The study is the first to estimate the social costs of marine litter washed ashore as well as litter discarded by beach users along different European coast lines. It was found that Willingness To Pay (WTP) is greater for litter disposed by beach visitors than for litter washed on to land for which they are less likely to feel responsible, and for plastic bags and bottles than for glass bottles and cigarette butts (Brower at al., 2017). While individuals had the least WTP for fishnets and ropes. This would suggest that although cigarette butts were stated as the most recurrent beach litter in all three countries, beach users prioritize the clean-up of larger plastic bags and bottles over smaller cigarette butts (Brower et al., 2017).

Furthermore, Figure 1 indicates that marine litter directly affects the intermediate ecosystem service (displayed by the solid blue arrow) formation of species habitats (e.g. through smothering) as well as the final ecosystem service fish and shellfish (e.g. through loss of marine charismatic species by derelict fishing gear). This indirectly impacts tourism, through loss of biodiversity (an ecosystem good/benefit) that draw in tourists to a specific area. While there have been no estimates of these impacts in the North East Atlantic, there have been studies conducted in the U.S. For example, many communities in California depend on wildlife and bird-watching as a means of income. Although an exact estimate is not possible, a 2006 study found that "the non-market value of coastal wildlife viewing in the state could easily be in the tens or hundreds of millions of dollars annually" (Stickel et al., 2012). Therefore, the impact of debris on the health of ecosystems can and does significantly reduce tourism – action should be taken at the intermediate ecosystem services level (formation of species habitats) as well as on the final ecosystem service (fish and shellfish) that are impacted directly too.

Figure 1 also shows how marine litter directly impacts the final ecosystem service disease control through the introduction of harmful pathogens (highlighted by the solid blue arrow), which impacts ecosystem service goods and benefits (biodiversity and disease prevention), and their associated economic activity (tourism). For example, Goldstein et al. (2014) documented that the pathogen *Halofolliculina* (which causes skeletal eroding band disease in corals) was present on floating litter in the western Pacific and noted that the spread of this disease to Caribbean and Hawaiian corals may be due to the large quantities of marine litter recorded in these areas. Increase in coral death or the introduction of pathogens via marine litter could severely affect tourism – a sector which relies on the health of these crucial ecosystems. Interventions should thus target the final ecosystem service disease control.

3.2.2. Fisheries and aquaculture

There are also potential costs related with the loss of value of fisheries resources (food for human consumption) as shown in Figure 2; marine litter impacts the final ecosystem service fish and shellfish directly (solid blue line arrows). Reductions in fish and shellfish numbers can result from 'ghost fishing'[1] or reduced value due to impacts on quality of fish and shellfish (e.g. through ingested plastics or contamination with persistent organic pollutants, POPs) (Newman et al., 2015). From Figure 2, we can see that actions to prevent reduction in food consumption should be carried out for the protection of the final ecosystem service (fish and shellfish). The body of literature describing the contamination of commercially exploited fish and shellfish by microplastic ingestion is growing rapidly, as is the literature analysing the consequences of this and the health of individuals and populations (Galloway, 2015; Lusher, 2015). However, as yet there have been no economic assessments to estimate the costs of these impacts.

Additionally, as shown in Figure 2, marine litter directly impacts the intermediate ecosystem service formation of species habitats, which has indirect impacts (dotted blue arrow) on the final ecosystem services (fish and shellfish and disease control), thus (indirectly) affecting the fishing and aquaculture industries. Marine litter also directly impacts the final ecosystem service disease control through the transfer of pathogens and alien species (OSPAR, 2014). Marine litter provides additional opportunities for marine organisms to travel (including alien invasive species) up to threefold (Barnes, 2002). The introduction of alien invasive species can have harmful effects on marine ecosystems and biodiversity (Kiessling et al., 2015) and can cause serious economic losses to the fishing and aquaculture sector. Therefore, any estimates, which fail to include such ecological impacts, will inevitably fall seriously short of the true cost of the marine litter problem. Figure 2 demonstrates how marine litter directly impacts these intermediate and final ecosystem services which has wider impacts on other ecosystem services and goods and benefits, which the fishing and aquaculture industry utilise. Therefore, interventions must be stressed on the ecosystem services that are directly impacted by marine litter here (formation of species habitats, fish and shellfish and disease control).

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[1] Due to their design, Derelict Fishing Gear can still trap marine life after they have been lost (known as ghost fishing).

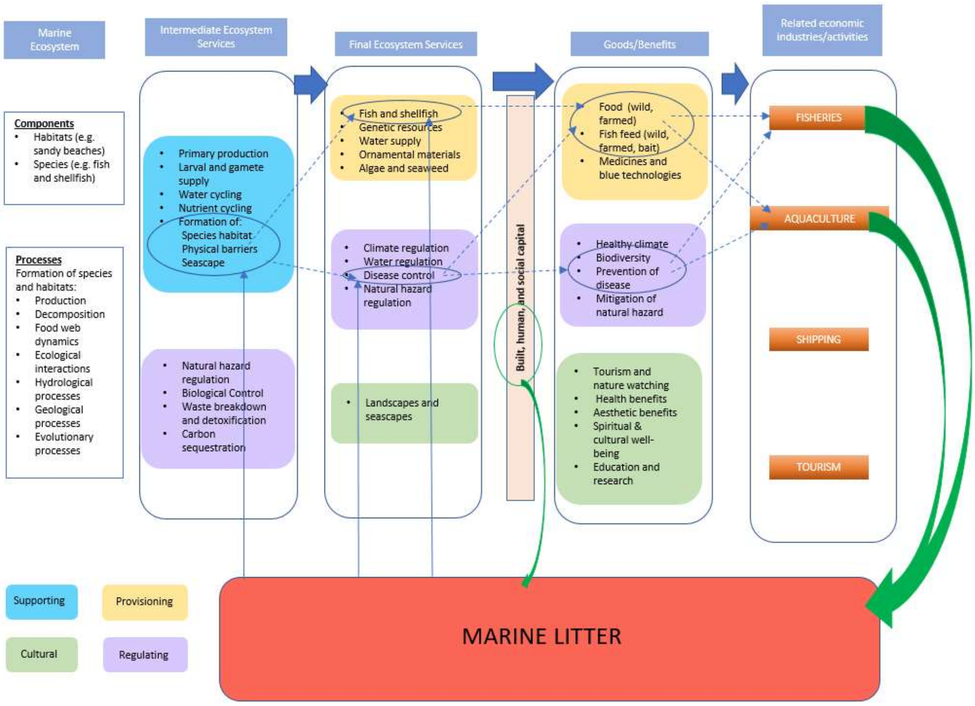

Figure 2 Impact of Marine Litter on Fisheries and Aquaculture – An Ecosystem Services Approach. The Blue solid line arrows show the direct impacts of marine litter; the dotted blue arrows to represent the indirect impact of marine litter; the green arrows represent feedback loop between the industries that are impacted by marine litter and those that act as sources.

3.2.3. Shipping

From Figure 3, it can be observed that shipping is not directly related to either intermediate or final ecosystem services, but marine litter impacts shipping directly (represented via the solid blue arrow). Shipping is an activity that takes place on the water, however it is not related directly to the change in human welfare (provided by a change in ecosystem services provision) but is worth noting as it is an important human activity that is impacted by marine litter. There is a risk of collision with litter that could severely damage engines or propellers. Furthermore, derelict fishing gear could entangle vessels resulting in economic losses. This would suggest that action or policy should be taken to prevent direct impacts on the activity. However, shipping is also a source of marine litter, providing a feedback loop as highlighted in Figure 3.

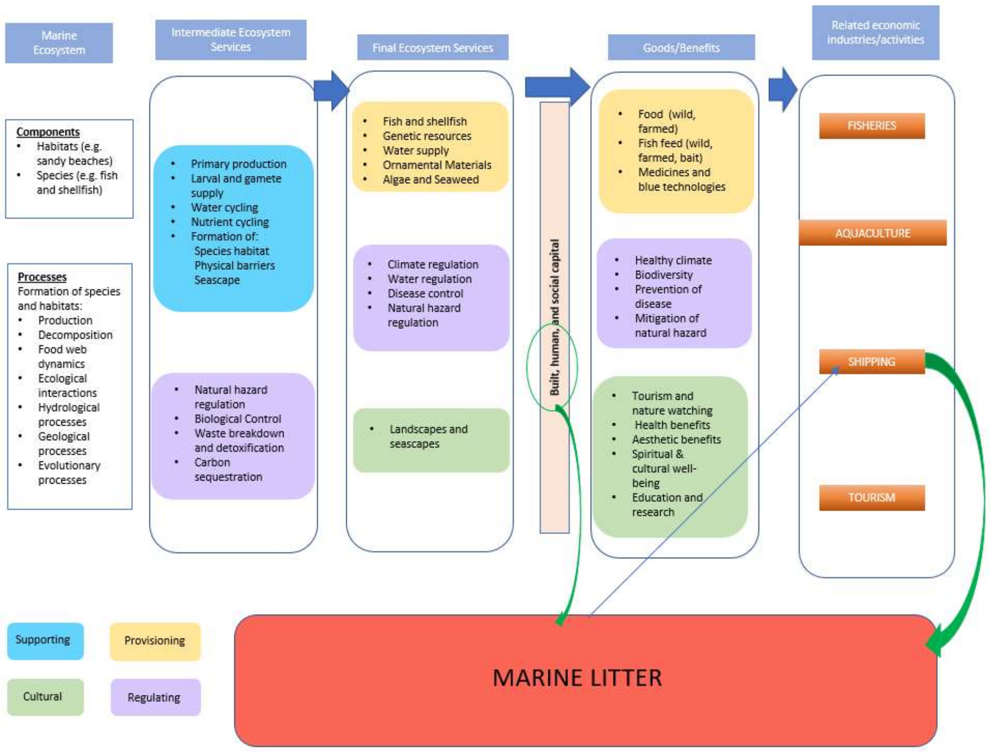

Figure 3 Impact of Marine Litter on Shipping – An Ecosystem Services Approach. The Blue solid line arrows show the direct impacts of marine litter; the dotted blue arrows to represent the indirect impact of marine litter; the green arrows represent feedback loop.

The measures presented in this section, however, should be considered temporary measures as they are dedicated to reducing the impacts of marine litter once these become evident. More effective worldwide policy measures would be actions looking at reducing the sources of litter and improving waste management (Abbott and Sumaila, 2019).

4. Methods of evaluating the economic impacts of marine litter

The most commonly used methods to evaluate the socio-economic impact of marine litter focus on assessing the economic cost of maintaining the provision of certain human activities that rely on the environment and how this can be affected by various factors, including marine litter (Mouat et al., 2010). While they offer only a fractional insight, because they do not consider the economic cost of intangible social and ecological impacts that are highlighted through an ecosystem services approach, they do emphasise to policy makers the impact of marine litter on industries such as tourism, fisheries, aquaculture and shipping (Mouat et al., 2010).

4.1. Tourism

Coastal region economies are impacted by marine litter predominantly through the direct cost of clearing beaches of litter and its wider implications for tourism and recreation. Direct costs include the collection, transportation and disposal of litter, as well as administrative costs such as contract management (Newman et al., 2015). Municipalities give precedence to removing litter to guarantee beaches are clean, safe and attractive for visitors when the economic case for protecting the local economy is justified by the cost of removing the litter (Newman et al., 2015). In regions where coastlines add a substantial proportion to the local economy, the costs incurred through marine litter can be considerable (Newman et al., 2015).

4.1.1. Expenditure on the removal of marine litter

Mouat et al. (2010) distributed surveys within North East Atlantic countries to try and quantify the direct costs of marine litter to the tourism industry (a summary of his findings can be found in table 1). In the U.K., beach litter removal in coastal boroughs is estimated to cost approximately €18–19 million (Mouat et al. 2010). Resulting in an average cost per borough of €146,000 (Mouat et al. 2010). A large proportion of this cost was accounted for by labour costs (Newman et al., 2010). Moreover, the average cost of litter removal was around €7,000 and €7,300 per kilometre per year, with costs ranging from €171 to €82,000 per km per year (Mouat et al. 2010). Higher costs were associated with larger clean-up operations on small areas of coastline, especially in areas with high numbers of tourists. In Belgium and The Netherlands, the cost of removing litter from beaches was estimated to be €10.4 million annually, with an average of €200,000 per municipality per year (Mouat et al. 2010). Per km, the cleaning costs came to €34,000 per year on average, again with great variation (e.g. from €600 to €97,300 in Den Haag) (Mouat et al. 2010). This average is higher than that projected for the U.K. because litter was removed from a greater proportion of coastline in Belgium and The Netherlands (because it is more densely populated) (Newman et al., 2015). The large variation in money spent by municipalities on different beaches signifies the differences in importance of different expanses of coastline to the tourism industry. Not surprisingly, many stretches of coastline in the world do not have anything spent on them to provide a litter clean-up service (Newman et al., 2015).

However, beach litter removal is not solely conducted by municipalities, but, many voluntary organisations tend to play a large role in removing litter (see Hidalgo-Ruz and Thiel 2015). The economic impact on society that stems from this consists of operational costs, financial aid or “in kind” assistance such as materials or insurance, and the value of volunteers’ time. Furthermore, there may be an opportunity cost where time spent volunteering could be used to service the community in other ways (Newman et al., 2015). Mouat et al. (2010) approximated the value of volunteers’ time in two annual beach clean operations in the U.K. where a considerable amount of litter from the U.K. coastline was gathered to be around €131,000. This approximation does not account for financial assistance or operational management costs, and therefore, it is probable that it significantly underestimates the value (Newman et al., 2015).

Country	Denmark	Ireland	Portugal	Spain	Sweden
No. of Responses	1	1	3	2	2
Reasons why beach litter removed	• Protect and maintain tourist areas • Pursue Blue Flag Awards • Public health risks • Maintain easily accessible beaches	• Protect and maintain tourist areas • Pursue Blue Flag Awards • Coastline known to have a marine debris problem	• Protect and maintain tourist areas • Pursue Blue Flag Awards • Statutory requirement • Public health risks • Maintain easily accessible beaches	• Protect and maintain tourist areas • Pursue Blue Flag Awards • Protect wildlife reserves	• Protect and maintain tourist areas • Pursue Blue Flag Awards • Statutory requirement • Coastline known to have a marine debris problem
Total distance where beach litter is removed	18km	8km	15km (2 municipalities)	12km	157km
Total cost of beach litter removal per year	€6,701.59	€89,950 - €102,800	€318,169.65	€655,518	€64,114
Cost of beach litter removal per km per year	€ 372.31	€11,243.75 - €12,850	€8,277.78 - €31,768.49	€38,189.75 - €87,500	€213.71 - €4,579.59
Increased costs over the past few years	Yes	Yes	Yes	Yes	Yes
Reasons behind increased costs		• Inflation • Increasing public expectations and therefore a greater frequency of clean ups	• More people using beaches resulting in more litter • Increasing cost of meeting the requirements for Blue Flag Awards • Increased disposal costs, particularly related to a higher demand for recycling	• Inflation • Increasing public expectations	• Increased amount of litter

Table 1 Direct costs of beach litter removal calculated by Mouat et al. (2010).

4.1.2. Wider Implications

In coastal municipalities, particularly those where beaches contribute significantly to the local economy, the indirect economic impacts of marine litter are more important. A few studies have attempted to calculate the costs incurred to coastal areas as a result of marine litter. The perceived loss of amenity can instigate consumers to visit other beaches and coastal regions with a reduction in expenditure in the area (Newman et al., 2015). The economic loss to the whole economy considers the relative change in values by consumers using a substitute beach. Marine litter, is therefore, a problem for municipalities when tourists choose to go somewhere else, exhibiting as a loss to the local economy (if not the national economy) (Newman et al., 2015).

Although beach users frequently stress the importance of cleanliness as a factor when choosing where to visit (Ballance et al., 2000), determining the extent to which marine litter affects tourist revenue is challenging, especially as it is unknown at what density litter begins to discourage tourists (Ballance et al., 2000). Examples of how marine litter has impacted tourist revenue are thus scarce but research from Sweden proposes that marine litter hinders tourism there by approximately 1-5% (Ten Brink et al., 2009). Tourism (one of Sweden's largest industries) on the Skagerrak coast of Bohuslan in West Sweden is worth 3 billion SEK (approximately £260 million). Assuming a "worst-case scenario", this would result in an annual loss to the local community of approximately £15 million. In addition, local clean-up campaigns have been approximated to cost around £937,000 per year[2]. The total cost of coastal littering to the Bohuslan local economy is therefore more in the region of around £16 million per year.

[2] However, only around 30% of the litter is actually recovered (Newman et al., 2010).

4.2. Fisheries

Sea fisheries are significant income and employment sources to many coastal communities throughout the Northeast Atlantic region, particularly in areas where other economic opportunities are scarce (Mouat et al., 2010). Although the fishing sector is usually perceived as a source of marine litter, it is also subject to economic costs itself. The direct costs faced by fisheries sector result from the need to repair or replace gear that has been damaged or lost due to encounters with marine litter; repairing vessels with tangled propellers, anchors, rudders, blocked intake pipes, etc.; loss of earnings due to time diverted to deal with marine litter encounters; and loss of earnings from reduced or contaminated catches resulting from marine litter encounters including ghost fishing (Newman et al., 2015). Furthermore, the industry also suffers indirect losses of income because of the effect of loss and abandoned fishing gear on fish stocks (MacFayden et al., 2009 cited in Newman et al., 2015).

Derelict fishing gear (DFG) comprises a large proportion of marine litter and can result in economic losses for fisheries. DFG includes any equipment, which can catch (shell-)fish, which is lost by fisheries, including trawl nets, gill nets, traps, cages and pots (National Research Council 2008). The durable materials used in fishing equipment means that it can continue to ghost fish for long periods of time; in this way it presents challenges as marine waste. Fisheries incur costs, firstly in having to replace the fishing gear they have lost at sea (as well as monitoring, clean-up and disposal costs), and secondly in a reduction in their potential harvestable catch of commercial and non-target species, and indeed the sustainability of that catch (Newman et al., 2015).

Mouat et al. (2010) approximated that the direct economic impact of marine litter on Scottish fishing vessels (i.e. costs of repairs and direct losses in earnings, not indirect losses due to ghost fishing) and estimated that on average marine litter costs each fishing vessel between €17,000 and €19,000 per year. The time lost clearing litter from nets[3] accounted for much of this cost (€12,000). Collectively, this costs the Scottish fishing sector as a whole between €11.7 and 13 million every year (Mouat et al., 2010). Therefore, marine litter reduces the fleets' total annual revenue by 5%. This is clearly a substantial cost to an industry that is already under high pressure and important in coastal communities.

Additionally, Mouat et al. (2010) estimated the economic impact of marine litter on Portuguese vessels, and noted that it was on average relatively low, particularly in comparison to the costs incurred by the Scottish vessels. Marine litter cost each Portuguese vessel €2,930 on average per year and more than 80% of these costs were associated with fouled propellers. Indeed, fouled propellers could cost as much as €15,000 per incident. Although repairing nets makes up only 18% of the average cost, this is relatively high as most of the Portuguese vessels surveyed used long-lines rather than nets. Despite high costs for individual vessels, the average cost of marine litter appears quite low, as these problems seem to affect only a small proportion of the Portuguese fleet.

4.2.1. Fishing for Litter

There are several 'Fishing-for-Litter' schemes conducted whereby fishermen voluntarily agree to collect the litter which they catch in their nets during their normal fishing activity and dispose of this safely on the

[3] Calculated using the average value of 1 hour fishing time as estimated by vessels in the survey (Mouat et al., 2010).

quayside at designated waste disposal sites. These arrangements are at present running in the U.K., Sweden, Denmark, The Netherlands, Belgium and Germany, and potentially other EU countries as there is EU support to fund such operations (Newman et al., 2015).

The fishermen gain from being involved as they lessen the amount of litter gathering in the oceans and beaches, and therefore lessen the amount of time they use untangling litter from nets and reduce the risks of other marine litter related costs described above. However, there are costs associated with the implementation and running of these schemes, and there are of course costs associated with waste disposal (OSPAR, 2007).

4.3. Aquaculture

The aquaculture industry is also negatively impacted by marine litter, through entangling propellers and blocking intake pipes, and time spent removing debris from and around fish farm operations. Mouat et al. (2010) conducted a questionnaire for finfish and shellfish aquaculture producers in Scotland and approximated that marine litter costs the industry €156,000 per year on average; which was around €580 per year per producer. Most of this cost (90%) originated from the time spent untangling fouled propellers on workboats and repairs. Clearing marine litter from aquaculture sites was generally less problematic, however this was not always the case, and in some areas, it was a regular problem. These figures highlight that in contrast to other sectors such as fisheries, the direct cost inflicted by marine litter on aquaculture is relatively low (Mouat et al., 2010).

4.4. Shipping

The shipping and yachting industries also suffer economic losses due to marine litter pollution. Harbours and marinas encounter costs for the removal of marine litter from their facilities so they are not dangerous and unattractive to users, and vessels experience interference with propellers, anchors, rudders and blocked intake pipes and valves (Mouat et al., 2010). Sometimes, few of these vessel encounters present navigational hazards, resulting in the need for the involvement of rescue services, thus substantially raising the costs (Newman et al., 2010). Mouat et al. (2010) approximated that U.K. ports and harbours incur average costs of €2.4 million per year for the removal of marine litter. However, this can range from €0 (as not all harbours surveyed in this study proceeded to remove marine litter, and thereby incurred no direct costs) to nearly €73,000 annually for individual harbours (Mouat et al., 2010). It was noted that higher costs were associated with larger and busier harbours. Most of the costs entailed were due to the disposal and manual removal of floating debris, as dredging to remove items off the seabed, although expensive, is not performed very commonly. While there is no official estimate for the cost of removing marine litter to the U.K. marina industry as a whole, data from a small sample indicate that it could be costly, with one marina reporting an annual bill of €39,000 (Mouat et al., 2010).

Additionally, when including the cost of undertaking rescue operations, the cost of marine litter to shipping and yachting rises further. An estimate for the U.K. Royal National Lifeboat Institution (RNLI) in 2008 calculated that 286 rescue operations to vessels with tangled propellers cost between €830,000 and €2,189,000 (Mouat et al., 2010). In many cases the lifeboat is run entirely by volunteers, leading to costs not only to direct rescue costs, but also costs to the employers of the volunteers in lost time.

5. International Strategies to support marine litter actions

With the growing concern and now, recognition, of the potential detrimental impacts of marine litter, preventative measures and policies are beginning to come to light around the world. Marine litter has been acknowledged as a significant issue at an international level by UN institutions since the 1980's. At the G7 in 2015, leaders pledged to deliver an action plan on marine litter, as well as embracing UN ocean sustainable development goal (SDG 14), in order to prevent and considerably reduce marine litter by 2025 (Löhr, 2017).

At the level of the EU, the EU Water Framework Directive and EU Marine Strategy Framework Directive include provisions on reducing pollution and marine litter respectively. Moreover, with the launch of the Circular Economy Action Plan, the European Commission committed to "adopt a strategy on plastics in the circular economy, addressing issues such as recyclability, biodegradability, the presence of hazardous substances of concern in certain plastics, and marine litter" (European Commission, 2015). Extended producer responsibility (EPR) is an essential element of the EU policy on circular economy (Almroth and Egger, 2019). Marine litter represents a resource inefficient economy. Valuable materials are polluting our beaches and causing harm to the environment instead of being redistributed back into our economy. Thus, a circular economy framework which stresses the prevention of waste as well as recycling and reusing materials and products in the first place has been cited as the best approach to tackle the marine litter problem (European Commission, 2017). In 2018, the EU announced its "Strategy for Plastics in a Circular Economy." The Strategy adds to previous EU plans to reduce plastic waste, such as the Plastic Bags Directive, which has considerably decreased plastic bag use throughout several Member States. However, in order to support the Commission's "vision for Europe's new plastics economy," the Strategy sets several more comprehensive and ambitious targets. Under the new plans, "all plastic packaging on the EU market will be recyclable by 2030, the consumption of single-use plastics will be reduced and the intentional use of microplastics will be restricted" (European Commission, 2018). Yet, for goals to be achieved there will be much investment required. The European Commission has pledged to invest €350 million in plastics production research. There are no exact estimates on the economic costs of preventative measures within European countries, therefore, further research is required.

Almroth and Egger (2019) also suggests considering how to influence behavioural change both at the consumer and the producer level investigating further norms and nudges in the realm of marine plastic pollution.

6. Global Impacts

As marine litter is a global problem, it is worth noting impacts found elsewhere in the world that may be of relevance to the OSPAR region. For example, in 2013, a study of 31 beaches in Orange County (California, USA) investigated the impact of marine litter on individuals' decision to go to the beach, and at what expense (Leggett et al., 2014). Using a travel cost model, they were able to approximate the value people obtain from recreation at a particular site based on the utility they expect to experience in relation to alternative sites. It was found that marine litter had a substantial impact on residents' beach choices, and that a 75% reduction in marine litter at six popular beaches generated over €40 million in additional benefits to Orange County residents over just 3 months. Another study estimated the costs of marine litter waste management in the Hudson-Raritan Estuary area. In total, these municipalities spend $59,063,285 million dollars a year on marine debris waste management activities. This translates to a per capita cost of $6.16, and $75,407 per square mile (Kim et al., 2015). This accounted for activities such as: beach clean-up, street sweeping, storm drain cleaning and maintenance, storm water and runoff capture devices, manual debris clean-up and public education (Kim et al., 2015).

Furthermore, with regards to the fishing industry, negative impacts of ghost fishing on commercial and recreational fish stocks are not always considered during fisheries management and stock assessment but may be significant for some fisheries (Newman et al., 2015). Recent estimates in the U.S. imply that approximately 3 to 4.5 per cent of the annual harvest of Dungeness crabs in fisheries along the west coast is lost due to ghost fishing, with an estimated loss of almost US$ 75 million for the Puget Sound fishery (Newman et al., 2015). Moreover, in the U.S. Virgin Islands fish mortality in fish traps was approximated to cost US$ 190,000 per year, which is likely to be an underestimate, given that the total number of traps in use is not well known (Newman et al., 2015).

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