AQUA-LIT

Potential Future Impacts

Deliverable 2.4 (D2.4)

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

Project No.	S12.789391
Project acronym	AQUA-LIT
Project name	Preventive Measures for Averting the Discarding of Litter in the Marine Environment from the Aquaculture Industry.
Start date of the project	01.01.2019
Duration	24 months
Period covered	01.01.2019-31.12.2019
Document title	**D2.4** Potential Future Impacts
Due date of deliverable	M15
Lead beneficiary for this deliverable	Instituto Español de Oceanografía (IEO)

Please cite as:

Vidal M., Alomar C., Deudero S., Altvater S., Sandra M., De Raedemaecker F., Devriese L., Mata Lara M. (2020). *Potential Future Impacts*. D2.4 AQUA-LIT project. Palma, Spain. 77 pp.

Name	Organisation
Maria Vidal Rigo	*IEO*
Carme Alomar	*IEO*
Salud Deudero	*IEO*
Susanne Altvater	*s.Pro*
Matthias Sandra	*VLIZ*
Lisa Devriese	*VLIZ*
Fien De Raedemaecker	*VLIZ*
Mariana Mata Lara	*GEONARDO*

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

Dissemination level		
PU	Public	x
CO	Confidential, restricted under conditions set out in Model Grant Agreement	
CI	Classified, information as referred to in Commission Decision 2001/844/EC	

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

Contents

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

AQUA-LIT project

AQUA-LIT is an EASME-EMFF funded project that aims at providing the aquaculture sector with a sustainable **toolbox** of innovative ideas and methodologies to address the 3 main components of marine littering: **prevention & reduction, monitoring & quantification, and removal & recycling.**

To fulfill this mission, we will be working face-to-face with aquaculture farmers in three **regional Learning Labs**: at the **Mediterranean basin, the North Sea and the Baltic Sea regions.** In parallel, we will identify and cluster existing, upcoming and already implemented tools on marine littering, and we will further **develop a platform and an app** for providing the **'Tide against marine litter toolbox'.**

Lastly, we will **'scale up the tide'** by developing the '**policy for less litter'** set of recommendations, by showcasing the **'funding a wave of solutions'** available for the sector and by coming up with a **transferability plan for outermost regions.**

Through this, we expect to help all stakeholders from the aquaculture chain to increase the understanding, awareness and availability of solutions, so a potential **transformation of the aquaculture sector towards a less polluting sector** can become possible.

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

Project Consortium

Geonardo Environmental Technologies **(GEO)**

European Centre for Information on Marine Science and Technology **(EurOcean)**

Vlaams Instituut voor de Zee -Flanders Marine Institute **(VLIZ)**

Sustainable Projects GmbH **(s.Pro)**

Instituto Español de Oceanografía -Spanish Institute of Oceanography **(IEO)**

Société d'Exploitation du Centre National de la Mer - French National Sea Centre in Boulogne-sur-Mer **(Nausicaa)**

Fundo Regional para a Ciência e Tecnologia -Regional Fund for Science and Technology **(FRCT)**

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

Definitions

Globally, the term 'marine litter' is put forward in research and communication strategies in the context of anthropogenic debris and plastic waste in and towards the sea. In fact, 'litter' has a strong connotation pointing at carelessly discarded items; items that have been discarded incorrectly and/or deliberately at an unsuitable location.

The AQUA-LIT project cooperates with stakeholders from the aquaculture sector. This sector deals with exceptional offshore conditions, like storm events, and consequently has unintentional losses of materials or equipment. To better represent the context, the word 'debris' is used instead of 'litter' for those exceptional cases, if the distinction can be made correctly. Otherwise the authors stick to the term "litter" also due to the projects' name AquaLIT.

Litter: consists of (anthropogenic, manufactured, or processed solid) items that have been deliberately discarded, unintentionally lost or abandoned, or transported by winds and rivers, into the environment. The term 'litter' has the connotation of been discarded incorrectly and/or deliberately at an unsuitable location. The verb 'to litter' means to drop and leave fabricated objects in the environment.

Waste: any substance or material which is eliminated or discarded after primary use, or is worthless, defective and of no longer useful.

Debris: rubble, wreckage, scattered remains of something that has been destroyed, pieces of rubbish or unwanted materials.

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

Summary

The Potential Future Impacts report, developed under the AQUA-LIT project, is a preliminary approach for the evaluation of the potential impacts that the aquaculture sector might face by 2025 regarding the non-organic marine litter. Therefore, it provides a framework for the development of further investigations and forthcoming projects.

The main objective of this report, is foreseeing the potential increase and decrease of non-organic marine litter derived from the aquaculture activities in a short term future. This report is based on literature research and on the information that was gathered from the more than 120 aquaculture stakeholders during the four AQUA-LIT Learning Labs and interviews that were carried out in the Mediterranean Sea, North Sea and Baltic Sea regions.

With the aim to achieve the goal of the Potential Future Impacts report, two main bibliographical references have been used: Aquaculture Development 4. Ecosystem approach to Aquaculture (FAO, 2010) and The long-term economic and ecological impact of larger sustainable aquaculture (European Parliament, 2014). **In the context of this deliverable, the examination of the potential increase or decrease of marine litter has been based on the following steps:**

1. **Identification of the main external drivers of change from 2020 to 2025**. It includes: ensuring sustainable consumption and production pattern of aquaculture products in the European context, climate change, gear manufacturers' role, plastic producers' role, certification bodies' role, importance of the European policies and legislation, importance of the research priorities related to aquaculture marine litter management, and consumers' role.
2. **Creation of the schematic tree which contains the main factors to be considered for the issue identification**. The factors are categorised under the perspective of the aquaculture production process, that is to say:
    a. Inputs (including type and characteristics of the equipment);
    b. Resource use factors (related to decisions made by personnel);
    c. And outputs (considering the available waste management systems and the monitoring and cleaning up initiatives).
3. **Identification of the issues related to the aquaculture litter management and the derived and expected potential increase or decrease of marine litter by 2025**. This examination is performed taking into consideration the effects of the external drivers regarding the potential increase or decrease of marine litter. A preliminary framework

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

for the future analysis of the potential increase or decrease of marine litter by 2025 is forecasted by aquaculture type and by sea basin.

For the purpose of this report, the main conclusions are presented considering the aquaculture factors included in the previously schematic tree.

Most of the factors considered in this evaluation are related to a potential increase of the marine litter by 2025. The increasing weather events related to the climate change, the growing aquaculture industry, the plastic industry expansion, the substitution of traditional materials for plastic materials, and the fact that there are no current real alternatives to this material for most of the aquaculture gear (although lots of initiatives to develop suitable alternative materials are taking place) are strongly linked to an increase of the plastic marine litter by 2025. An increase of other marine litter materials (like metal, wood, or rubber) is also expected by 2025.

Regarding specifically to the plastic marine litter, the implementation of the European Single Use Plastic (SUP) Directive provisions plays a key role. This Directive is being transposed to national Member States legislation by 2021. This means that Extended Producer Responsibility schemes (including collection, recycling and upcycling initiatives and increasing awareness) are likely to be under development by 2025. In this context, it is probable that the accompanied needs of an aquaculture industry in expansion will not be completely covered in some European regions. As a consequence, an increase of the marine litter can be also expected related to this factor, although increasing rates will progressively disminish in parallel with the increase of disposal points and EPR systems put in place.

This potential reduction of the increasing rates of plastic marine litter from 2020 to 2025 is also a key consideration regarding the SUP elements, which are in general, and also in particular regarding the aquaculture activities, the most frequent items found on beaches. SUP elements are widely used in aquaculture due to the consideration that there are no current alternatives.

The substitution of traditional plastics for biodegradable plastics and biobased materials could lead to a decrease of the first ones and, therefore, to a reduction of the plastic marine litter, but only if their biodegradability characteristics are really adjusted for all environmental conditions and their resistance is improved in the next 5 years. Other factors which should be overcomed in order to reduce the potential marine litter are their current high prices and some farmers' reluctance to switch from traditional to alternative plastics.

On the other side, there are also factors to take into account that are likely to lead to a decrease of the marine litter by 2025, although most of them need more ambitious efforts due to most of the related initiatives are under development. These factors include:

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

- The attempts to increase the facilities robustness and fixing systems improvements (specially in the North Sea basin and the Baltic Sea basin).
- The efforts being currently done from innovative perspectives regarding the tracking of the valuable items from aquaculture (e.g. buoys and ropes),
- Increasing the aquaculture personnel awareness and knowledge through involving them in specific trainings and marine litter activities,
- Promotion of the good practices currently in place performed by the farmers by linking them to a motivating certification and/or economic benefit.
- And promotion of the cleaning up activities and monitoring programmes in order to:
    1. Better understand the marine litter issue and to fill in the current knowledge gaps related to the impact from the aquaculture sector;
    2. Help to rise the general concerns regarding the marine litter:
    3. Feeding the databases of the European policies and national legislations;
    4. And providing useful information to related research centers.

The applicability and potentiality of this report relies on **settling the path for future and more detailed studies. Despite these studies are beyond the scope of what was planned for AQUA-LIT, we would like to point out that further analysis** should be developed following a more scientific approach, which can include new data collection and an in-depth analysis. Thus, we want to guide these studies into amore complete analysis, for which we consider that the following criteria and parameters need to be taken into account:

1. Level of implementation of the SDG Agenda 2030 regarding the aquaculture activities.
2. A better knowledge of the climate change effects on the aquaculture activities is needed.
3. The effects of the transposition of the SUP European Directive by 2021 and its level of implementation at Member State and / or regional level, to better analyse the role of the gear manufacturers in the Extended Producer Responsibility schemes.
4. Effects of the ongoing waste and plastic management legislation at European and national levels.
5. Effects of the inclusion of waste management criteria by the Certification bodies, which are currently starting to be considered.
6. Analysis of the improvements on the biodegradable and biobased materials, in order to understand if they have achieved the needed characteristics to be used under marine conditions.
7. Consideration of the growing general concerns regarding food transparency and the consumer's role.

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

1. Introduction

The world population in 2015 was of 7.4 bilion people, while the estimation for 2020 is to reach 7.8 bilion people. By 2030, the population is expected to increase to 8.5 bilion people, and to 9.7 bilion people in 2050 (United Nations, 2019).

The population expansion, especially since mid-twentieth century, has raised concerns about the capacity to produce enough food at a worldwide level and particularly in the areas where populations grow fastest, i.e. Africa and Asia (United Nations, 2015). Regarding this concern, all the United Nations Member States adopted, in 2015, the 2030 Agenda for Sustainable Development. The aim of the 2030 Agenda is to provide a global guideline and framework to end poverty and other deprivations with sustainable strategies, which include multiple approaches, including health, education, economic growth, climate change, inequality reduction and protection of the environment. The core of the 2030 Agenda are the 17 Sustainable Development Goals (SDGs) (United Nations, 2020), urgent calls for action to be addressed by all countries - developed and developing - in a global partnership. Aquaculture, together with fisheries, is fully linked to the SDG 14-Life Below Water: Conserve and sustainably use the oceans, seas and marine resources for sustainable development; as both activities need to encourage a responsible use of ocean resources including a responsible use of coastal waters that prevents pollution and eutrophication. Further, both sectors are essential to reduce hunger, improve nutrition, mitigate poverty and promote economic growth (FAO, 2020).

Sustainable aquaculture is also linked to SDG 12: Ensure Sustainable Consumption and Production Patterns. The aim of the initiatives related to this SDG are to ensure that current material needs do not lead to the overextraction or degradation of the natural resources. To achieve it, policies that improve the resource efficiency, disminish waste and support sustainable practices should be implemented (United Nations, 2020).

All these enhancements should be performed by applying FAO's Blue Growth Initiative foundations: good governance principles, participatory decision-making activities and best environmental, social and economic practices regarding the aquatic resources (FAO, 2018a; FAO, 2020). Therefore, **fish hold an essential role in global food security, especially in lower-incoming countries, as it contains the vitamins and minerals needed to address the nutritional deficiencies** (FAO, 2018b). In 2015, the estimations were that more than 4.5 billion people ingest at least 15 % of their average per capita intake of animal protein from fish (Béné et al., 2015). Fish consumption has increased by an average rate of about 1.5% per year in per capita terms in the last 50 years at a global level. Moreover, the average annual increase of fish consumption at a worldwide level since 1961 is 3.2%, which has exceeded the population

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

growth rate of 1.6% (FAO, 2018b). In comparison with any other food industry, fish production has been the fastest developing sector over the course of the last 40 years (Béné et al., 2015) and, considering the population increase estimation, is expected to maintain this essential role.

Traditionally, fishery activities have been the main source of seafood. However, since the end of the 1970s, the percentage of fish stocks that are considered biologically sustainable has decreased from 67% to 90%, while the percentage of stocks which are fished at unsustainlable levels has increased from 10 to 33% (FAO, 2018b). Moreover, capture fishery production has not changed significantly since the late 1980s (FAO, 2018b).

On the contrary, since the 1980s aquaculture has become the world's fastest growing food production industry (FAO, 2018b). Between 1981 and 2011, the production continued expanding at an average annual rate of more than 8 percent, and the contribution to total food fish supply raised from 9% to 48% (The World Bank, 2013). Nonetheless, a reduction of the exponential growth rate is expected due to, among other reasons, the freshwater scarcity, reduction of optimal locations and high costs associated to fishmeal, fish oil and other feeds (Béné et al., 2015). In this context, it is expected that aquaculture will provide 60% of the fish available for human consumption by 2030 (FAO, 2018b).

In the European context, multiple estimations have been performed to forecast the growth of the sector in the next years. For example, the European Parliament (2014) highlighted the following expected trends:

1. For coldwater marine aquaculture, production is expected to increase by 4% per year until 2030. Atlantic salmon will remain the main species, although alternative species (e.g. cod, flatfish and large trout) will increase.
   Coldwater marine production growth will be parallel to technological improvements like increase of individual cage size and depth or productivity improvements strictly related to a better technological management. Besides that, an increase of the integrated systems (e.g. producing more than one species on the same time) and multi-functional targets (not just producing food) is expected. It is also probable that more farms will be located in areas that have higher water energy.
2. Warmwater marine aquaculture is also expected to increase by average of 4% per year until 2030. Sea bass and sea bream will continue being the most frequent species, although sole, meagre and turbot will also probably increase.
   Sea cages will be still the prefereably production technologies, although it is likely that there will be a development of land-based systems adapted to flatfish species production. Besides, it is probable that a diversification of the sector will occur. Larger cages located offshore are a growing tendency also in the Mediterranean.

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

3. Freshwater production is foreseen to increase 1.5% per year until 2030. Efforts will be made on diversification, higher survival rates and better food conversion rates.
4. Shellfish production is expected to increase 1.3% per year until 2030. Integrated and multifunctional technologies are expected to be developed, and production will move to offshore/deeper water areas.
   A continued domination of supported/suspended cultivation systems for shellfish production, with further decreases in bottom culture techniques is foreseen.
5. In the frame of the mentioned report, no growth scenario was developed for algae.
6. In general:
   a. A decline of the coastal pond aquaculture is expected because of the decrease in available space.
   b. An increase of multi-trophic aquaculture systems is also expected, combining species (e.g. salmon, seaweeds, mussels, etc) for a better use of space and a mitigated environmental impact.

In parallel to the aquaculture expansion, major disease outbreaks have happened at a national level (infectious myonecrotic virus in shrimp in Indonesia and Brazil; infectious salmon anemia virus in Chile; early mortality syndrome in China, Vietnam, Malaysia, and Thailand) and even global levels (white-spot syndrome virus in shrimp). These crises need to be considered a warning of the importance of applying good management practices (The World Bank, 2013). Concerns regarding other environmental impacts of the aquaculture development have also arised including, among others (Martínez-Porchas and Martínez-Córdova, 2012):

- Destruction of natural ecosystems.
- Salinization/acidification of soils.
- Pollution of water for human consumption.
- Eutrophication and nitrification of effluent receiving ecosystems.
- Ecological impact in natural ecosystems because of the introduction of exotic species.
- Ecological impacts caused by inadequate medication practices.
- Changes on landscape and hydrological patterns.
- Trapping and killing multiple organisms (entangled or trapped in the nets).
- Negative effect on fisheries (decline of the fishery caputures nearby aquaculture farms due to the associated pollution).

Consequently, marine litter is not usually included among the initial concerns related to aquaculture. In this frame, the impact of the non-organic litter that comes from the aquaculture activities has started to be widely considered in the recent years. In April 2019, the Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) established the Working Group 43 on sea-based sources of marine litter, with the aim to create a core knowledge on this topic, including the estimation of the contribution of

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

different sources, the analysis of plastic use and the extent of impacts from these activities in the marine environment (GESAMP, 2020).

Most of the aquaculture litter is made of plastic (apart from some items made of textiles, wood, (synthetic) rubber and metal). Plastic is resistant to abrasion, it is durable and resistant to rust, and it can be moulded into specific shapes, but it also can take 500 years to biodegrade in the Ocean. From the economic perspective, using plastic reduces the handling and associated costs due to its lightness (Luhser et al., 2017; Huntington, 2019). Moreover, its widespread use in the aquaculture sector reflects its popularity in all human activities. Plastic production has increased worldwide exponentially since 1950s, reaching 383 million tonnes in 2015 (including synthetic fibres), and is expected to continue incrementing by the doubling of the production levels by 2025 (Lusher et al., 2017). In 2010, between 4.8 and 12.7 million tonnes of plastic entered the marine environment (Lusher et al, 2017).

Abandoned, lost or discarded fishing gears (ALDG) are considered the main source that comes from fisheries and aquaculture (Lusher et al., 2017). In this context, marine litter coming from aquaculture activities can be classified by following item specific categories (Sandra et al., 2019):

- Ropes (plastic and natural textile);
- Nets (plastic);
- Pallets (wood);
- Floats and buoys (plastic, rubber);
- Collecting materials (plastic, natural textile and wood);
- Strapping material (plastic);
- Clothing (gloves, hard hats, safety boots, etc) (plastic, rubber);
- Structure items (pipes, containers, thimbles, stakes, etc) (plastic, metal, wood);
- Other, including plastic mesh filter tubes, jerry cans, plastic bottles.

The main ecological impacts that have been related to these litter items are (Deudero and Alomar, 2015; Werner et al., 2016):

1. Entanglement and physical damage;
2. Ingestion;
3. Ecotoxicological damage due to contaminats associated to plastics;
4. Habitat alteration: smothering, inhabitating gas exchange in seabed surface;
5. Colonization of litter and enhancing dispersion of invasive species;
6. Increase of micro-plastics as a result of the fragmentation of bigger plastic elements; this is the case of the microplastics made of Expandable Polystyrene (EPS) that can be found along the shorelines in Southern Korea, Japan and Chile which are strongly related to the EPS buoys widely used in the aquaculture installations in those areas (GESAMP, 2015).

Moreover, it has been proven that these litter items have negative impact in the aquaculture activities themselves including, among others (Werner et al., 2016):

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

- Costs associated to removing litter from the nets and other damaged fishing gear;
- Potential loss of 0.7% on annual income every year due to biological affects and reduction of the sales revenue linked to the ingestion of microplastics by cultured shellfish.

Nevertheless, **the role of aquaculture activities regarding the marine litter issue is still poorly understood.** This is due to mainly (Altvater et al., 2020; De Raedemaecker et al., 2020; Vidal et al., 2020):

1. **No knowledge on the amout (quantities) of plastic** waste derived from aquaculture activities;
2. The **lack of standardised monitoring protocols** including seafloor, floating and on-beaches litter at an international level;
3. The **lack of specific environmental policies** and related approval procedures which include the non-organic marine litter as a criterion;
4. And, finally, the **lack of networking and interaction among all the stakeholders** of the aquaculture chain.

In recent years, some estimations regarding the marine litter related to aquaculture activities have been performed. For example, Viool et al. (2018) estimated that **the loss of plastic waste from aquaculture in the European seas ranges between 5,933 tonnes/year and 19,622 tonnes/year**. A second estimation was done using the data from Sundt (2018) report. In Norway, 25,000 tonnes of plastic from aquaculture are discarded at sea annually, while the Norwegian aquaculture production is 1.4 million tonnes. In comparison, EU-28 produces 1.3 million tonnes (EUROSTAT 2018). Applying these Norwegian rates on **the EU-28 production**, it would mean that EU-28 **could be losing around 22,809 tonnes of plastic from aquaculture every year** (Viool et al., 2018).

In this context, considering the expected expansion of the aquaculture activities and, therefore, the possible increase of the use of plastic and other non-sustainable materials, **there is a need to forecast the potential aquaculture marine litter increase or decrease in the European framework and, therefore, identify the potential future impacts.** For the purpose of this report, the forecast will be performed considering a medium-term period of 5 years (2025).

This report will help to identify and link solutions to prevent marine non-organic littering from aquaculture activities in the near future. These ideas will be the basis of the AQUA-LIT Toolbox (to be released December 2020), with the aim to address the three core aspects of marine littering: **prevention & reduction, monitoring & quantification, and removal & recycling.**

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

The core of this report is structured in the following sections (Figure 1):

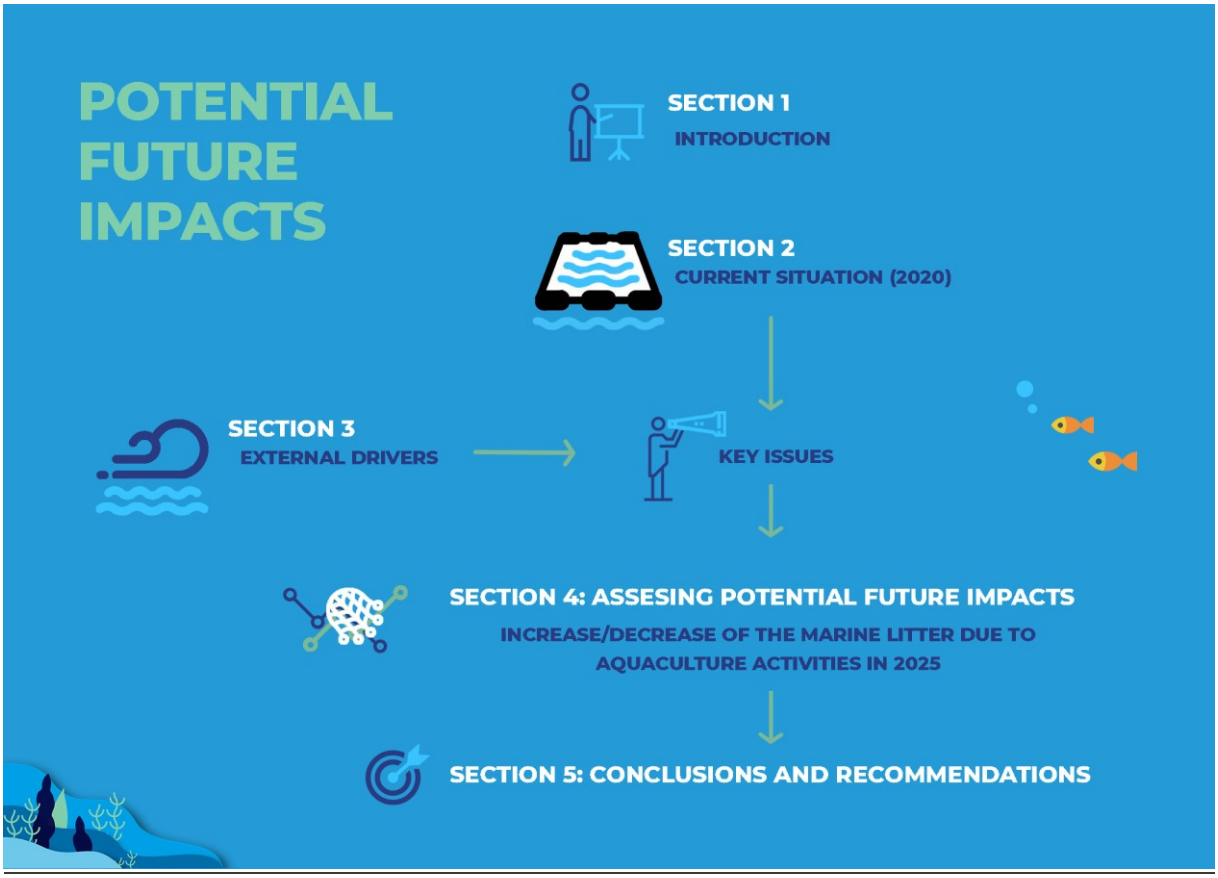

Figure 1: Scheme of the deliverable

- SECTION 1: Introduction and objectives of the deliverable.
- SECTION 2: Current situation of the management of the potential litter that comes from the aquaculture. The aim of this section is to provide an overview of the main barriers and also good practices that are being applied by the stakeholders by 2020. Four main sources of information have been used:
    - Data on the current aquaculture facilities and production at European level wil be provided from Deliverable 2.2 AQUA-LIT: Knowledge Wave on Marine Litter from Aquaculture Sources. This deliverable includes the Marine Litter Inventory, which includes data from the available literature and databases (e.g. OSPAR, HELCOM, Marine Litter Watch).
    - Information regarding current policies in place at a European level: Deliverable 2.3 AQUA-LIT: Available Tools and Measures.

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

- Assessment on the barriers faced by the aquaculture stakeholder and the good practices that they are applying regarding marine litter: Deliverables 3.2, 3.3 and 3.4 AQUA-LIT Learning Lab reports.
- Bibliographical research (see References section), to complement the information provided by the AQUA-LIT deliverables.

- **SECTION 3:** Identification of the external drivers. They are defined as external forcing factors or drivers (e.g. climate change, policies, etc) which affect the interactions within the aquaculture facilities and their environment (FAO, 2010). They have been identified based on the information gathered in the AQUA-LIT Learning Lab reports and also in bibliographical research.

- **SECTION 4:** Assessing the potential future impacts by 2025. This section contains the identification of the issues related to the aquaculture litter management and the derived and expected potential increase or decrase of marine litter; as well as an evaluation on the effects caused by external drivers. A summary of the effects caused by external drivers and of the potential increase and decrease of marine litter related to the aquaculture isssues is also included in the Table 1 and 2 (Annex a).
  - A general overview of the potential increase or decrase of the marine litter by aquaculture type and sea basin is also provided.
  - The evaluation provided in this section is based on the information gathered from the more than 120 stakeholders who participated in the AQUA-LIT Learning Labs and interviews, additional to an extensive literature research.

- **SECTION 5:** this section includes the main conclusions of the report and the recommendations to be considered in future in-depth analysis of the impacts regarding marine litter that comes from aquaculture.

1.1. Potential Future Impacts deliverable objectives

The main objective is to **forecast the potential future impacts of aquaculture activities** in terms of **marine litter increase or decrease**, considering the following aspects:

- The **current situation** of the aquaculture facilities and techniques.
- The identified **external drivers** related to the three core aspects of the marine litter management: prevention & reduction, monitoring & quantification, and removal & recycling.
- **The dimensions and expansion of aquaculture in the future** as a part of the European Blue Growth agenda for economic growth in the frame of the Sustainable Development Goals 12 and 14 of the United Nations Agenda 2030.

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

The Potential Future Impacts report is a preliminary approach for the analysis of the impacts of the aquaculture sector regarding the non-organic marine litter. It is based on literature research and on the collected information from the aquaculture stakeholders during the AQUA-LIT Learning Lab reports.

Its applicability and potentiality relies on settling the path for future and more detailed studies with a scientific approach, which will include new data collection and an in-depth analysis. Therefore, it provides a framework for the development of further investigations and forthcoming projects, also in view of changing, improved materials, treatment facilities and legislation.

© Mariana Mata-Lara

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

2. Current situation of the management of the potential litter that comes from aquaculture (2020)

Considering the information collected during the AQUA-LIT Learning Labs, a brief description of the current situation of the main types of aquaculture (finfish, shellfish, seaweed and Integrated Multi-Trophic Aquaculture) is included in this section. The aim is to provide a general overview of the main challenges, focusing on the barriers that farmers are facing regarding the waste management and to consider some of the good practices that are currently being applied regarding the mentioned barriers.

Some of the common barriers in all types of aquaculture are:

- Support:
  - Lack of financial and technical support needed for the development and implementation of innovative and sustainable gear.
  - Weak support from decision-makers for producers to invest in easy to recycle and more durable materials and to implement national EPR schemes according to the Single-Use-Plastic Directive (SUPD).
  - Limited initiatives to support training enhance communication and raise awareness.
  - Lack of clear roles and responsibility assignation among all the aquaculture stakeholders regarding the management of the potential litter.
- Legislation:
  - Lack of specific licensing criteria.
  - Regulatory obstacles in national laws.
  - Weak implementation of provisions of the Common Fisheries Policy to label aquaculture gear.
- Knowledge gaps:
  - Lack of specific information related to material losses from aquaculture.
  - Lack of scientific and technical knowledge related to response of equipment offshore conditions, sustainable gear alternatives, innovative recycling procedures, design of facilities, etc
  - Limited knowledge exchange through interdisciplinary collaborations.

Moreover, specific challenges and currently applied good practices can be specifically linked to each of the main types of aquaculture:

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

Finfish

Barriers

In general, the design of the gear is not optimized to the harsh marine conditions where some of the aquaculture activities take place and, therefore, gear can be easily broken and lost during extreme storms. Moreover, there is a lack of proactive approaches to improve the design of the gear products to make them more resistant or to prevent the use of specific plastics

Finally, related to aquaculture gear, the biofouling on the equipment (like aquaculture nets) needs to be considered. Biofouling increases the gear fragility since fish are attracted by this organic material and can ingest fibres forming the net (see Good Practice, G.P.1).

From the knowledge perspective, there is not enough technical training for staff of aquaculture farms related to the life cycle and durability of aquaculture equipment (e.g. knowledge on effective material replacement before gear degradates and gets easily broken and creates microplactic contamination) (G.P.2). From the support point of view, there is not enough official support for environmental enhancement initiatives like beach clean-ups (which are frequently organized by NGOs and/or based in volunteering initiatives) (G.P. 3)

Regarding the specific issue of ALDG, there are no direct incentives for aquaculture farmers to return accidently collected ghost gear for collection and treatment. Confusion remains for them operating in EU waters about possible additional costs they have to bear. In consequence, ghost gear is left in the sea. A homogenous solution is needed to motivate farmers bringing ashore such kind of fishing gear (G.P.4).

Finally, the waste management systems are facing some problems like the lack of efficient systems and facilities for collecting, storing and processing of used gear and equipment and, on the other side, there is a lack of appropriate waste management infrastructures to handle worn out aquaculture and fishing equipment (G.P. 5).

In this context, circular schemes based on recycling end-of-life nets to produce recycled nets does not seem to have, currently, economic viability since recycled nets are much more expensive than regular nets. This is due to marine litter recycling is very difficult and complicated because of the degradation level. Besides, aquaculture gear sometimes has mixed different types of material, which makes recycling even more difficult and expensive (G.P.6).

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

Good practices

Similary to identified barriers, some of the good practices exposed by the different stakeholders involved in the AQUA-LIT learning Labs include:

G.P.1: Enlarge the life-cycle of the nets by following a regular maintenance scheme including washing, disinfection, repairing and applying anti-fouling treatments, among others.

There are many international companies that produce aquaculture gear which also provide maintenance services, mainly aquaculture nets, in multiple areas of the world.

G.P.2: Methodology for removing and preventing the abandonment of fishing gears at sea, including aquaculture nets.

The Baltic Blue Biotech Alliance The "BBA Baltic Blue Biotechnology Alliance" (Interreg 2016 - 2019) has developed a joint concept by experts from the marine biotechnology / blue biotechnology of the Baltic Sea Region (BSR) to improve innovative product, including sustainable, easy to recycle aquaculture gear, to foster a more sustainable blue sector. The international consortium is derived of BioCon Valley partners from Denmark, Poland, Lithuania, Sweden, Finland, Latvia and Estonia.

G.P.3: Organisation of clean-up activities for companies

Mowi has organised a Global Clean-up Day every year since May 2018. Mowi staff and their families, joined resources and mobilised a communal effort to clean local beaches of plastics and other marine litter.

G.P.4: Incentive fund for aquaculture farmers paid by producers

In the Baltic Sea, an institutionalised fund is under development to support farmers with bringing ashore containers of old fishing gear, as well as to support the costs of their treatment (recycling) or discarding. The costs are paid by producers of fishing gear, according to Art. 8 of the European Single Use Plastic (SUP) Directive. It is predicted that developing such an insurance fund for fishing gear will reduce cost shares to increase the incentive for farmers to bring back ghost gear and bring a sense of liability for both the farmers (and fishermen) as well as EU Member States concerned with ghost gear.

G.P.5: Improved dismantling procedure of worn out materials

During 2019, MOWI has established a national agreement in Norway with a waste handler to ensure a safe and standardized handling of the waste and easier access to the waste data.

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

G.P.6: Removal, recycling and upcycling initatives related to the marine litter.

Although most of the current initiatives are not strictly linked to aquaculture, they can be considered a first step for the sensibilization of the fishery and aquaculture sectors. For example, the BlueNET project involves 3 fishing ports of the Basque Country, accounting for 24 fishing vessels. Recovered nets, nets that have reached the end of life and aquaculture ropes are being recycled and upcycled to produce aquaculture ropes for mussel production.

Shellfish

Barriers

In the case of the North Sea, the design of the shellfish equipment is not always adapted to offshore environments or stormy weather (G.P.1). Moreover, under these harsh conditions, tracking devices are still too expensive for elaborate use, missing out on opportunities to prevent the loss of larger gear.

On the other side, some Mediterranean countries face a lack of specific environmental legislation concerning mussel culture and its waste management (e.g. Greece) (G.P.2) and a lack of disposal points that sometimes lead to inappropriate management practices like burning the nets and pile barrels close to the ports. In some Baltic Sea States (as well as in the UK), guidelines for Best Available Techniques are developed by practicioners to support the responsible administration on national, regional or municipal level. This seems to be a useful approach to combat debris in a collaborative, transparent way (G.P.3).

In the general European context, there is not enough knowledge on the existence of sustainable alternatives for aquaculture shellfish material (G.P.4). Shellfish aquaculture stakeholders believe that there are no real alternatives to the SUP elements currently used, especially if comparing their price and resistance. Finally, the Directive (EU) 2019/883 on port reception facilities for the delivery of waste from ships refers only to nets as the passively fished waste. In this context, to design a complete removal and recycling process of the aquaculture (and fishery) gear, it would be necessary to include other equipment and material like the small items and/or SUP elements frequently used for shellfish culture (G.P. 5). Also, the transfer of knowledge from science to business in an open and trustful way would be crucial to foster the development of better recyclable and more sustainable aquaculture material (G.P.6).

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

Good practices

G.P.1: Replace buoys and floats by steel poles in mussel larvae collector installations

In the Dutch Wadden Sea and Oosterscheldt, the MZI's hardly ever lose a float or buoy anymore since the use of big steel poles were introduced. These metal poles are positioned a few meters under the seabed for the attachment of the horizontal lines. Over the years, the installations have been developed in such a way that they have become increasingly robust.

G.P. 2: Enforcement of the governance related to non-organic marine litter: establisment of POAY, consortia that manage operations of mussel farms in the North of Greece.

Recenlty, two mussel farming consortia (POAY, "Areas of Organized Development of Aquaculture"), were established in the norther part of Greece, which will be governed by a Board of Councils, compose of members which are representatives of the involved municipalities, farmes and other authorities. Stakeholders in charge of the POAYs expect that the full function of the consortia will change the situation radically, with better management and legislations, including waste monitoring and management.

G.P.3: Use Best Available Technologies as guideline for all stakeholders

In many Baltic Sea countries like in Poland or Sweden, the utilization of updated documentation of Best Available Technologies (BAT) is considered the most efficient tool when communicating with the respective authority. Often, a municipal or communal authority has only very limited experience in dealing with aquaculture. In Germany, these documents are less frequently updated and are developed by aquaculture experts from state authorities, typically state-driven research institutions, in close connection with producers and other experienced stakeholders. Therefore, these BAT documents have the highest effectiveness and impact – also on the reduction of debris - when they are formulated by practitioners and other experts (including scientists), when they are publicly available and visually appealing and are also regularly referenced in other contexts (e.g. as an industry standard in a marketing context) as well as being living documents, i.e. under regular review.

G.P.4: Alternative materials for mussel larvae collector lines made of natural and degradable fibres.

Machinefabriek Bakker from Yerseke, the Netherlands, has been awarded the sustainability award of the shellfish conference foundation for the development of a biodegradable sock for mussel suspension cultures and mussel larvae collector installations. This alternative material serves as a replacement for cotton socks that are harmful to the environment if lost or damaged during aquaculture practices.

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

G.P.5: Cooperation in collecting waste between local associations.

In some regions in France, after a storm, local associations in coordination with the regional shellfish committees organise collecting activities to assist the producers in locating and collecting their lost materials. For instance: CAP 2000 in Brittany, Windsurf in Normandy, and Surfrider in Southern Brittany.

G.P.6: Transfer of knowledge between science and business

The InnoAquaTech project was developing innovative and sustainable aquaculture technologies in the South Baltic area (Interreg South Baltic). The aim of the project (2016 - 2019) was to further transfer knowledge in the area and involved partners from science and business in Denmark, Germany, Lithuania and Poland.

Seaweed

Barriers

In the case of seaweed farms in the Nort Sea, the design of equipment is not always adapted to offshore environments or stormy weather (G.P.1).

Main limitations are also related to the lack of guidelines and specifications for different types of materials and equipment (e.g. specify differences between consumables and durables). Finally, it has to be considered that producers are not responsible for cleaning-up measures or recycling related to fishing/aquaculture gear and this gap will not be closed by the new EU Single-use-plastic Directive until 2021. Therefore, capacity building and knowledge transfer seems to be a key for more sustainability (G.P.2).

Good practices

G.P. 1: Technical studies to determine storm proof character of installation

In the Netherlands, a technical study is mandatory to receive a permit for the installation of offshore seaweed farms. This requested technical study determines whether the installation is storm proof. Although there is never 100% certainty, this likely reduces the risk of damage to the installation.

GP2: Capacity building on new environmental friendly approaches, including the reduction of debris

GRASS project aims to raise awareness and build capacity on macroalgae cultivation, harvesting and reduced use of SUP elements among public authorities and other relevant stakeholders across the region. Public authorities, ministries, planning regions and counties play a crucial role in promoting macroalgae as they are the main legislative bodies that also control much of national and regional funding.

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

Emerging types of aquaculture facilities and techniques

Integrated Multi-Trophic Aquaculture

In the last decade, IMTA systems have become more important in aquaculture facilities given that they provide an opportunity to reduce environmental impacts through direct uptake of dissolved nutrients. These systems rely on the incorporation of multiple species from different trophic levels, while at the same time increasing cost-efficiencies due to a higher number of marketable products. Given the integration of different species in one same scheme and the different type of materials needed for these, impacts derived from the structures could be diverse. Even though of their success, there is not enough available data highlighting the importance to consider these types of systems in analysing potential future impacts of aquaculture and derived marine litter.

However, in the Baltic Sea, the IMTA seem to promise the only acceptable method of open cage fish farming. In Denmark, a concept of the IMTA has been introduced in fish farming. A few of the Danish mussel farms represent the "Danish model" of fish farms that compensate nutrient outlet from their fish farm by growing and harvesting mussels (IMTA). Invertebrates filter and absorb the nutrients from the fish operations. Then, not only can the cultured fish be sold, but also the mussels. This method reduces the environmental impact of aquaculture and simultaneously increases profitability. According to studies, adding variations of IMTA to existing near-shore open net cage systems can significantly reduce their environmental impact through the direct uptake of particulate nutrients by filter feeders (e.g. mussels), and through harvesting, remove the nutrients from the location. The materials involved in these systems are still quite mixed but efforts exist to reduce too many different materials.

Moreover, aquaculture can acquire a multi-use concept, by being combined with other offshore uses, such as wind farms or tourism. In this respect, a few pilot studies are running to investigate various aspects of offshore multi-uses. Examples of this are the EDULIS project in Belgium, investigating the feasibility of mussel culture in offshore wind farms and the SOMOS project in the Netherlands, aiming to develop a meaningful safety assessment and safety control to stimulate the production of energy (wind farms) and food (seaweed) at sea (Sandra et al., 2019)

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

3. External drivers

The litter management from the aquaculture sector depends not only on mechanisms specifically related to the waste management and production in the aquaculture frame, but also on **external forcing factors or drivers which affect the interactions within the aquaculture facilities and their environment, adding uncertainty** (FAO, 2010). **These underlying causes are a combination of complex interactions from the social, economic, political, cultural, industrial and technological which can happen far from any aquaculture facility**.

Identifying those external drivers is essential to obtain an overall picture of all the elements that have a role on the litter impact. In order to asses the potential future impacts of aquaculture activities, a set of external drivers have been identified which are detailed in this section. These external forces have been established using the AQUA-LIT Deliverables 3.2, 3.3 and 3.4 Learning Lab reports as the main references, and complementary bibliography.

3.1. Ensuring sustainable consumption and production pattern of aquaculture products in the European context.

A sustainable expansion of aquaculture in Europe is expected to happen within the next 5 years due to multiple factors (APROMAR, 2019):

- The European coasts offer suitable conditions for the facility location from environmental, physical and oceanographic points of view.
- The European aquaculture industry is working towards achieving the environmental and social sustainability while being economically profitable.
- Member States are leaders in technology, research, and training in the marine sciences.
- In this context, the European Commission's Scientific Advisory Mechanism (SAM) recommends considering aquaculture a priority of the EU policies, taking into account the international framework of the need to increase the food production.

In this context, the EU is fully committed to the implementation of the SDGs in the frame of the Agenda 2030 (European Commission, no data), with the aim to end poverty and other deprivations from a sustainable development point of view.

The production increase will be accompanied by many multiperspective challenges which need to be taken into account by the stakeholders to ensure the sustainability of the sector expansion. Some of these challenges that have a link with the potential production of marine litter are (European Parliament, 2014):

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

In general:

- Improvement of competitiveness, support to the innovation, diversification and economic activity.
- Simplification of licesing procedures and authorizations.
- Sharing information and good practices.

- Finfish specific challenges:

- Create new partnerships for integrated culture practices (e.g. Integrated Multi-trophic Aquaculture).
- Improving the management of offshore production.
- Effective marine and coastal spatial planning.
- Overcoming extreme weather events.
- Ensure that innovation and good management practices are applied.

-Shellfish specific challenges:

- Ensuring production in deeper waters.
- Increasing competitiveness.
- Introducing compensation schemes to combat eutrophication.

External driver 1- An expansion of aquaculture in Europe is expected to happen within the next 5 years due to multiple factors. This growth is going to happen under the frame of the UN Agenda 2030, taken into account the environmental and social sustainability of the activity while being economically profitable.

3.2. Climate change

There is evidence, considering observations gathered since 1950, that there is a change in some climate extremes, and that the increase of the atmospheric concentrations of greenhouse gases could be one of the main reasons behind this process (IPCC, 2012). This could lead to changes in the frequency, intensity, spatial extent, duration, and timing of extreme weather events (IPCC, 2012).

For aquaculture, there is a general concern regarding the impact of climate change on the sector, which could be intense and diverse depending on the region (Stavrakidis-Zachou et. al., 2018). Some of the expected changes with potential effects on the aquaculture sector include (ClimeFish, 2020):

1. Temperature changes in water and air.
2. Changes in oceanographic conditions, including currents, wind speed and waves.
3. More intense and frequent weather events, e.g. storms.

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

In this scenario, finfish and shellfish could be more susceptibles to stress and to suffer from physiological effects (e.g. affections to growth and development) (ClimeFish 2020).

In spite of the forecasts, the uncertainty regarding the future implications of the climate change implies the necessity to identify frameworks, tools and solutions to be applied for better management decisions which ensures the sustainability and the maximisation of the production (Stavrakidis-Zachou et. al., 2018).

External driver 2-Extreme weather events linked to climate change are likely to happen more frequently in a short-term future. In this context, the uncertainty of the implications of climate change creates the need to identify frameworks, tools and solutions to ensure the sustainability of the sector and the maximisation of the production.

3.3. Gear manufacturers

Plastic is widely used in the aquaculture systems including buoys, ropes, nets and meshes, feeding systems and floating collars (Huntington, 2019). This material is resistant to abrasion and rust, it is light weighted and, therefore, costs associated to handling are less compared to other materials (Huntington, 2019).

Other materials used to producer aquaculture gear include natural textiles (mainly in ropes), rubber (e.g. gloves and boots) and metal (e.g. thimbles or metal drums for flotation) (Sandra et al., 2019).

The role of the gear manufacturers regading the management of the marine litter is essential and it is becoming absolutely indispensable in the European context. The European Directive 2019/904 highlights that Member States have to create **specific Extended Producer Responsibility (EPR) schemes for fishing gear** (which includes any item or piece of equipment that is used in fishing or aquaculture) **and components of fishing gear containing plastic**. **Producers of fishing gear working with plastic will cover the costs** related to the separate collection of waste fishing gear (containing plastic) that has been delivered to adequate port reception facilities (or equivalent collection systems), its subsequent transport and treatment. Moreover, gear producers will cover the costs of the awareness measures regarding fishing gear containing plastic. Member States shall bring into force the laws, regulations and administrative provisions necessary to comply with this 2021.

Therefore, gear manufacturers engagement is a key factor in the next few years regarding the marine litter that comes from aquaculture.

In this context**, facilitation of the knowledge exchange among all the involved aquaculture stakeholders**, especially governmenthal institutions, plastic gear and plastic manufacturers,

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

waste managers and aquaculture farmers are needed. The aim of the communication improvement is to clearly identify the needs of each step of the process regarding the EPR systems and, moreover, to define the roles and responsibilities of all the stakeholders (Altvater et al., 2020; De Raedemaecker et al., 2020; Vidal et al., 2020).

Besides, to be able to put EPR schemes in place, **they will need support** from multiple perspectives, e.g. (Altvater et al., 2020; De Raedemaecker et al., 2020; Vidal et al., 2020):

- **Legislative support**: the transposition of the European SUP Directive to the national regulations will happen by 2021. The development of the EPR systems depends on the consequent national regulations. It has to be clarified whether producers are also responsible for clean-up measures for fishing gear, which is not part of the SUPD provisions (Art. 8) yet. Here additional national regulations are possible, ideally developed at round tables with relevant stakeholders from different governance levels and sectors (waste etc.).
- **Tackle uncertainty** among aquaculture farmers (and fishermen) how to deal with ALDG and install insurance funds.
- **Knowledge** support: technical support and training to ensure the feasibility of the EPR scheme. This support could be provided by EPR experts, gear manufacturer clusters and/or policy makers involving, in addition, plastic manufacturers, fishermen and aquaculture farmers.
- Potential **economic aid from governmenthal authorities**, at least during the first stages of the process of putting the EPR system in place.

External driver 3- The role of the gear manufacturers regading the management of the aquaculture marine litter is becoming absolutely indispensable in the European context. The costs related to the EPR schemes for fishing gear will be covered by producers of fishing gear working with plastic (European Directive 2019/904).
In this scenario, identifying the needs and defining the roles and responsibilities of all the engaged stakeholders are essential to ensure the success of the EPR system.
Besides, providing the legislative frame and the knowledge and economic support will be a key factor to ensure the feasibility of the EPR systems.

3.4. Plastic producers

Plastic industry is in continued expansion: the world production of plastic materials increased from 348 million tonnes in 2017 to 359 million tonnes in 2018 (PlasticsEurope, 2019). The European plastic industry was third at a worldwide level (after Asia and the North American Free Trade Agreement Region), representing 17% of the word production in 2018, and it was ranked the 7th EU industry regarding the industrial value added(PlasticsEurope, 2019).

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

Plastic industry holds a prominent role from the economic, social and environmental point of view, all over the world and in many sectors, like aquaculture, as most of the gear, equipment and facility pieces are made of plastic.

Nevertheless, **there is a growing concern in the sector about the necessity to include a sustainable approach to the plastic production, although this is at its first development steps**. In the European context, clusters of plastic manufacturers like PlasticsEurope include circular economy and resource efficiency in the production criteria. There are also initiatives like European Plastic Pack which aim is to provide support to the reuse and recycling of SUP products and packaging involving with an interdisciplinary approach. The Circular Plastics Alliance (which includes over 175 organizations representing industry, academia and public authorities) aims to boost the EU market for recycled plastics to 10 million tonnes by 2025.

The sector is also expanding to innovative solutions including **biodegradable plastics**, which have been developed from the biodegradability point of view, and **bioplastics** (or biobased plastics), in which biomass is used as the raw material (Rujnić-Sokele and Pilipović, 2017). In the first case, the biodegradability of the plastic depends on (Rujnić-Sokele and Pilipović, 2017):

- The raw material.
- The thicknes of the product itself.
- The chemichal composition.
- The environment in which the plastic is going to biodegrade.

The use of biodegradable plastics as an alternative to traditional plastics faces some challenges. To start with, biodegradable plastics are **more expensive** and they hold **lower mechanical properties** (e.g. resistance to hars conditions) compared with traditionall plastic materials (Rujnić-Sokele and Pilipović, 2017; Altvater et al., 2020; De Raedemaecker et al., 2020; Vidal et al., 2020).

And from the sustainability point of view, it has to be considered that they **strongly depend on the agricultural land availability** and that the **biodegradation process is affected by the temperature and the presence of microorganisms**. In this context, the most aggressive environment to enhance the process is compost, followed by soil, fresh water, marine water and landfill: **only a few biodegradable plastics can degrade in marine environments** (Rujnić-Sokele and Pilipović, 2017). Taking into account all these factors, biodegradable plastics are not currently considered a proper alternative to traditional plastic for the production of aquaculture gear.

External driver 4- Plastic industry is in continued expansion, and it is likely to continue due to its prominent role in many sectors at a worldwide level. Nevertheless, there is a growing interest in the sector about sustainable approaches applied to plastic production, by including concepts like circular economy and resource efficiency in the production process. Moreover, potential innovative solutions include the bioplastics and biodegradable plastics.

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

Biodegradability is limited in the marine environment. Moreover, this type of material holds, currently, lower mechanical properties compared with traditional plastics and it is more expensive.

3.5. Certification bodies

There are multiple organizations at a worldwide level which currently provide a **certification for good practices applied in the aquaculture sector from the sustainability and environmental point of view**. The objective of this certification practices is to influence the consumer's choices and, therefore, to increase demand and market access for certified seafood (ASC, 2020b) while minimising the negative effects and preserving the marine environment (Friend of the Sea, n.d.).

Nowadays, concerns about the marine litter impact have arised, and criteria related to waste and pollution action plans are taken into account by the certification bodies. For example, in the case of GLOBALG.A.P., provisions for waste recycling and waste disposal or presence of waste/litter in the vicinity of the production site are included as criteria. Moreover, some organizations are going further by considering the inclusion of **specific indicators for specific marine litter issues** like the impact of plastic and the ghost gear (ASC, 2020a).

These new criteria are likely to have a **positive effect on the improvement of the waste management by aquaculture farmers**, as they will be forced to meet these indicators in order to get the certification.

External driver 5-Certification bodies are essential to promote good practices that can minimise negative impacts in the marine environment and ensure a sustainable production. Recently, specific criteria related to waste management have been included in order to get some aquaculture certification. This is likely to cause a reinforcement of the waste management improvement.

3.6. European policies and legislation

European policies and regulations that will be considered in the impact analysis include:

1. **Regional Action Plans of the European Sea Conventions**: For three of the four European marine regions, the Baltic Sea, the North-East Atlantic including the North Sea and the Mediterranean, there is now a regional action plan against marine litter (still pending for the Black Sea). The OSPAR Action Plan for the North-East Atlantic was adopted in 2014 and is valid for the period from 2014 to 2021. The countries bordering on the Baltic Sea Region have adopted the Regional Action Plan against marine litter 2015 as part of the Helsinki Convention (HELCOM). Recently, the Atlantic

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

Action Plan 2.0 (SWD 2020/140) as a new approach to the Atlantic maritime strategy (2011) has been adopted with its goal 7 to fight marine pollution to preserve marine ecosystems while at the same time unlocking the potential of blue economy in a sustainable way.[1]

2. The Marine Strategy Framework Directive (2008/56/EG) provides for the good environmental status of marine waters to be achieved or maintained by 2020. A good environmental status with regard to marine litter exists when the properties and quantities of marine litter do not have any harmful effects on the coastal and marine environment. The implementation of the MSFD includes the establishment of national programs of measures to achieve good environmental status. The MSFD can be linked to the MSPD (see No. 6). Although Marine litter, D10, lacks MSP-relevant attributes, it can be distinguished between drivers potentially subject to spatial planning and the descriptors they are likely to influence, and drivers beyond the remit of MSP but with pressuresthat might need explicit consideration (like shipping, aquaculture farms etc.) when developing plans.

3. One of the European Commission's 10 priorities 2019-2024 is to boost the efficient use of resources by moving to a clean, circular economy and cut pollution (Roadmap with actions of the European Green Deal).

4. The European Strategy for Plastics in a Circular Economy (COM 2018/28 final) recognises that marine litter remains an issue and that plastic is a significant source of pollution. It sets out, in its action plan, that additional action on fishing gear, including EPR will be examined.

5. The revision of the Port Reception Facilities Directive (2000/59/EG) includes measures to ensure that waste generated on ships or gathered at sea has to be returned to land and adequately managed.

6. The Common Fisheries Policy Control Regulation[2] contains measures on retrieval and reporting on lost fishing gear as well as the requirement to mark and identify of all fishing gear. It was reviewed (in parallel to the PRFD) to improve the Fisheries Control System with rules on reporting of lost fishing gear, e.g. through the introduction of e-reporting, and on its retrieval, which has also an effect on the aquaculture sector.

7. According to the Single Use Plastic Directive (2019/904) and the new Circular Economy Action Plan (2020/98) as one of the main blocks of the European Green

[1] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020DC0329&from=EN

[2] Council Regulation (EC) No 1224/2009 of 20 November 2009 establishing a Community control system for ensuring compliance with the rules of the common fisheries policy

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

Deal[3], Member States shall bring into force the laws, regulations and administrative provisions necessary to comply with it until 2021. It foresees an EPR for producers of fishing and aquaculture gear to pay in a balanced and transparent manner for collection, transport and treatment, with a focus on recycling. Also awareness-raising measures have to be supported. One of the reasons for including fishing and aquaculture gear into this legal framework is the lack of market incentives for the effective participation in separate collection. For example, despite the removal of financial penalties for fishermen to bring gear ashore under the proposed revision of the Port Reception Facilities Directive, the effects of paying even indirect fees may not be sufficient as an incentive to completely exclude disposing of damaged gear at sea if storage space on board is at a premium.

8. Standardisation is seen as powerful instrument for self-regulation and deregulation as it is a stable and reviewable, generally accepted and coherent process. It is a request from the European Commission to the European Standardisation Organisation (ESO) to draw up and adopt European standards in support of European policies and legislation. The Single Use Plastic Directive (2019/904) is the base for the Commission to request the ESO and the related expert Group CEN to develop harmonized standards for the circular design of fishing gear to encourage preparing for re-use and faciltiate recyclability at end of life by the end of 2020. The process might take at least two years.[4]

9. The white paper from the Aquaculture Stewardship Council (ASC)has determined that extreme weather is currently one of the major causes of plastic 'ghost gear' from fish farms entering oceans and rivers, and warns that increasingly unpredictable weather caused by climate change could exacerbate the problem.

10. Maritime Spatial Planning (MSP): The EU MSP-Directive (MSPD 2014/89/EU) the European Parliament and the Council have adopted legislaton to create a common framework for maritime spatial planning with the aim to ensure marine activities take place in an efficient, safe and sustainable way (European Commission, 2020c). It allows all involved parties, including aquaculture and fisheries, to contribute equally in the development of marine spatial plans (FAO 2016). Planners can adapt MSFD data to more MSP-specific needs and in line with the efforts to combat sea-based litter sources.

External driver 6 - European policies and regulations provide a general frame to be developed by the Member States in order to improve the marine litter management, including the elements that come from aquaculture.

[3] https://ec.europa.eu/knowledge4policy/publication/communication-com202098-new-circular-economy-action-plan-cleaner-more-competitive-europe_en#:~:text=Communication%20COM%2F2020%2F98%3A%20A%20new%20Circular%20Economy%20Action%20Plan,%20Geographic%20coverage%20%20%20European%20Union%20

[4] https://webgate.ec.europa.eu/maritimeforum/en/system/files/collatedcirculardesign_mrag.pdf

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

3.7. Research

Sustainable aquaculture is one of the key priorities areas for the EU. As reference and example, approximately 20% of funding from the European Maritime and Fisheries Fund (EMFF) for the 2014-2020 period was planned to be invested in the development of the aquaculture sector from a sustainable point of view.

In this context, EU is providing support to projects focused on, for example, reducing the impact of ghost fishing gear (marGnet), recycling and upcycling discarded or abandoned gear (from fishing activites and/or aquaculture) (OCEANETS), developing new technologies to track fishing gears (mostly nets) in case gears got lost (NetTag or MARELITT Baltic), **promotinginnovative** materials (e.g. biobased ropes for aquaculture, Novamont) and the use of waste products as alternatives to plastic in the aquaculture context (LIFE BAQUA), developing new technologies, tools and strategies for a sustainable European Aquaculture (NewTechAqua), or identifying innovative solutions to tackle the plastic crisis in oceans and seas (CORDIS Results Pack), among others. Besides, the EU is developing ambitious research and innovation framework programmes to deliver solutions to ensure healthy oceans, seas, coastal and inland waters (Mission Areas).

All these projects can involve multiple types of stakeholders, including environmental consultancies, research centers (public and private), gear manufacturers, farmers (and fishermen) and waste managers. Therefore, they provide a suitable context for knowledge exchange and for setting up further collaborations.

The increasing awareness about the marine litter issues has also lead **international institutions to focus their research on this topic**. With the aim to generate specific knowledge on the marine litter that comes from sea-based sources (including aquaculture), the Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) established the Working Group on Sea-Based Sources of Marine Litter (WG-43) in April 2019 (GESAMP, 2020). Another example is the Food and Agriculture Organization of the United Nations (FAO). FAO publishes the biennial The State of World Fisheries and Aquaculture (SOFIA) reports, which have been lately focused on sustainability. FAO has also has published more specific reports discussing, for example, the role of microplastics from aquaculture and fisheries.

Finally, Each **Member State of the EU promotes, from their own governance structures and organizations, their own research projects and specific programmes** related to the management of litter that comes from marine activities and ends up in sea, e.g. the Projecte Xarxes of the Agència Catalana de Residus in Spain, or the Spanish Pleamar programme. In the Baltic Sea the Association for Marine Aquaculture (GMA) was founded and a professorship for marine aquaculture (and its debris) was installed at the Kiel University in Germany. Another network, the Competence Network Aquaculture currently combines the expertise of approx. 1.000 individuals from all across the Baltic Sea. These network members are affiliated with

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

457 different institutions, specifically 279 companies (mostly SMEs), 75 research organizations and universities and 103 other, e.g. NGOs.

In this scenario, research is a key factor for a better understanding of the aquaculture marine litter issue. There are many knowledge gaps that need to be filled in like (Altvater et al., 2020; De Raedemaecker et al., 2020; Vidal et al., 2020):

- Quantification of the impact of aquaculture litter in the environment.
- The reasons behind the aquaculture gear losses and breaks.
- And the innovative solutions that need to be developed to provide solutions to the farmers for the waste management, among other topics.

External driver 6-Research on the aquaculture marine litter is expanding in the European context, to ensure the sustainability of the production and for a better understanding of the aquaculture marine litter issue.

International, national and regional initiatives are trying to fill in the knowledge gaps related to the impact of aquaculture litter in the marine environment. The success of all these initiatives relies on the collaboration between public and private research centers, farmers, gear producers, waste managers and environmental consultancies.

3.8. Consumers

The expansion of aquaculture, if not well planned, can cause environmental impacts and social and human health issues. It has been reported **that consumers from Western countries show concerns regarding these impacts, animal welfare and health**; those perceptions can affect sales and prices of the farmed products (Bacher, 2015).

In fact, and according to some reports, there is an increasing awareness related to food transparency. For example, a major part of the US consumers consider the information provided regarding a particular product before purchasing. Moreover, more than 37% of the US consumers would switch brands if their previously chosen brands do not provide them with the information they look for (Label Insight, 2016). Therefore, brands have a market opportunity by increasing and improving the information provided to the potential consumers (Label Insight, 2016).

From the policy perspective, EU is commited to increase transparency of the risk assessment in the food chain and to reinforce the reliability, objectivity and independence of the information used by the European Food Safety Authority (EFSA). In order to achieve this goal, a new Regulation on the transparency and sustainability of the EU risk assessment in the food chain was adopted on June 2019. This regulation amends the General Food Law Regulation adopted in 2002.

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

Moreover, the European Comission has developed the Farm to Fork Strategy, with the aim to achieve a fair, healthy and environmentally-friendly food system. This strategy is a new comprenhensive approach to how Europeans value food sustainability, and it is an opportunity to improve lifestyles, health and the environment.

In this context, **consumers play a key role in providing support to the aquaculture certification iniciatives or to the more sustainable companies**, because they have the chance to decide to purchase certified products to be sure of the sustainability of the product or to the more transparent brands. By doing this, consumers are incentivating the adoption of those good practices by the farmers and, thus, they are having an indirect positive effect regarding the marine litter management.

Moreover, **they are essential in attracting attention to the aquaculture marine litter issue by participating in volunteering clean–up and monitoring activities**. At the same time, these initiatives are essential to increase the knowledge of the impact of the aquaculture sector regarding the marine litter.

External driver 8-_Consumers' concerns regarding the impacts from aquaculture have lately risen. In this context, they play a key role in attracting attention to the marine litter issue by participating in monitoring and clean-up initiatives. Besides, they are essential to enforce the adoption of good practices by the farmers, by providing support to certified aquaculture products.

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

4. Assessing the potential future impacts: increase or decrease of the marine litter from aquaculture by 2025

4.1. Guidelines for assessing potential future impacts

To forecast an impact analysis focused on marine litter as a consequence of the aquaculture ativities in a short term (by 2025) two main bibliographical references are used.

To start with, FAO published the Aquaculture Development 4. Ecosystem approach to Aquaculture in 2010. These guidelines are developed to support Articles *9 – Aquaculture development* and *10 – Integration of fisheries into coastal area management* of the FAO Code of Conduct for Responsible Fisheries (CCRF). The aim FAO report is *"(...) to assist countries, institutions and policy-makers in the development and implementation of a strategy to ensure the sustainability of the aquaculture sector, integration of aquaculture with other sectors and its contribution to social and economic development*".

The core of the FAO guidelines is the Ecosystem Approach to Aquaculture (EAA), which is defined as a strategy for the integration of the aquaculture activity within the wider ecosystem in a sustainable way.

As a part of these FAO guidelines, when describing the steps to prepare and initiate the practice of the EAA, an overview of the issue identification analysis is included. The aquaculture issues are defined as "*effects on the ecosystem and effects of other ecosystem components and external drivers on aquaculture*".

For the purpose of the identification of those issues in the FAO guidelines, a schematic tree is developed (figure 2). The schematic tree contains the main factors to be considered for the issue identification, and they are categorised under the perspective of the aquaculture production process, that is to say, inputs, resource uses and outputs.

For example, under the input production step, main factors to be considered for the identification of the aquaculture issues are seeds, feeds, energy, infrastructure and labour.

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

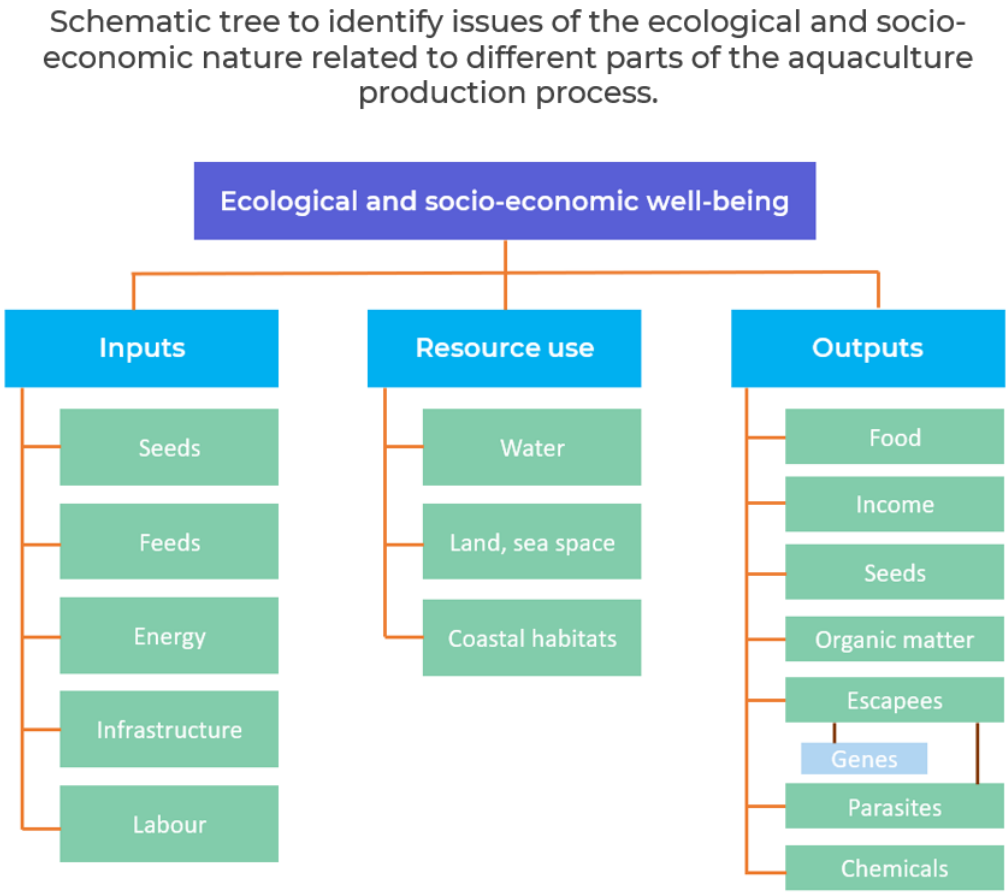

Figure 2: Schematic tree included in the FAO Aquaculture Development 4. Ecosystem approach to Aquaculture (2010) for the issue identification purposes

For each of these factors, an identification of the potential linked ecological and socio-economic issues and their consequences (or impacts) is performed. For example, regarding to "feeds", in some regions trash fish and/or small pelagic species are used to feed marine carnivorous cultivated species, and this can imply a negative impact on the small pelagic stocks and also on the local pelagic predators (figura 3a). On the other side, the local small-scale fishermen who live on these fisheries can be benefited from the price paid for this feed (figura 3b), which is a positive impact.

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

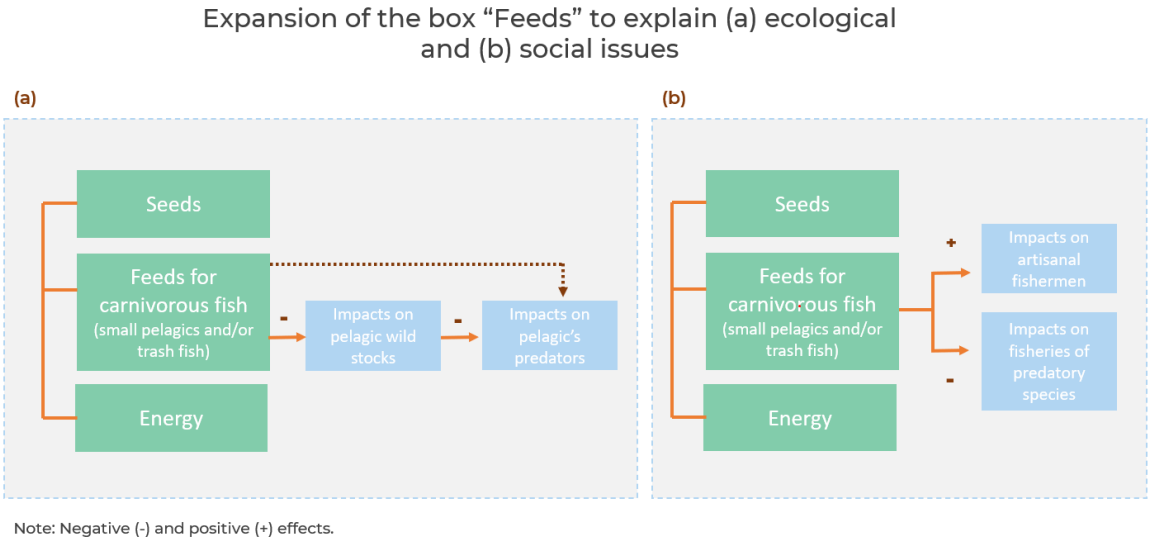

Figure 3: Example of Identification of issues and impacts (from Aquaculture Development 4. Ecosystem approach to Aquaculture, 2010)

In order to have a more complete perspective of the issues, the external drivers are also taken into account. The external drivers, like climate change previously mentioned, can affect the interactions between the aquaculture activities and the ecosystems in which they take place and, therefore, they can increase the uncertainty.

Four years later, in 2014, the European Parliament published the study 'The long-term economic and ecological impact of larger sustainable aquaculture' (performed by the Directorate-General for Internal Policies/Policy Department B: Structural and Cohesion Policies/Fisheries). The objective of this European report is to provide *"(…) an assessment of the impact of increased growth of the European aquaculture sector, by identifying the challenges to growth and how these may be overcome*." In this context, various methodologies to identify environmental impact indicators and to perform the analysis of the environmental assessment are gathered and developed by the authors.

For the purposes of this European Parliament study, the main sources of impact or ecological interaction within aquaculture production systems are identified. Those sources of impact are schematized using the same tree that was previously developed by FAO in (2010), although focusing more on the ecological interactions.

In the mentioned study, for each of the factors included in the schematic tree aquaculture issues from the ecological perspective are defined and characterised, considering the potential impacts in the environment. For example, the factor "water" includes the following information: "*The major concern is freshwater consumption where this supply for alternative*

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

uses is limiting. Care is needed in defining and measuring this as consumption by aquaculture itself is minimal, but in some systems (e.g. ponds) there can be losses due to seepage and evaporation. A more significant issue can be the degradation of water quality, linked with the nutrient outputs discussed below".

In the context of the AQUA-LIT Potential Future Impacts deliverable, the schematic tree and the description of the aquaculture issues and potential linked impacts (increase or decrease of marine litter) by 2025 has been adapted to the marine litter management frame.

Therefore, a schematic tree (figure 4) has been created for the purpose of the present report. The factors to be considered are categorized under inputs, resource uses and outputs, depending on the following criteria:

- Input factors: are related to all the external (brought into the facility by the farmer) elements and their characteristics that can be linked to aquaculture marine litter issues. These issues can generate a positive or negative impact regarding marine litter, that is to say, a reduction or an increase of the marine litter.
- Resource use factors: they are related to internal decisions made in the facility by the farmer or the personnel, which are strongly influenced and linked to the level of awareness of the personnel and the good practices that are already being applied by them. Again, these factors are connected to aquaculture marine litter issues, which can generate a reduction or an increase of the marine litter.
- Output factors: include the external results or consequences of the decisions made by the personnel on the inputs brought into the facility. Depending on those decisions, some aquaculture marine litter issues can be identified and, therefore, their related positive or negative impact regarding marine litter.

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

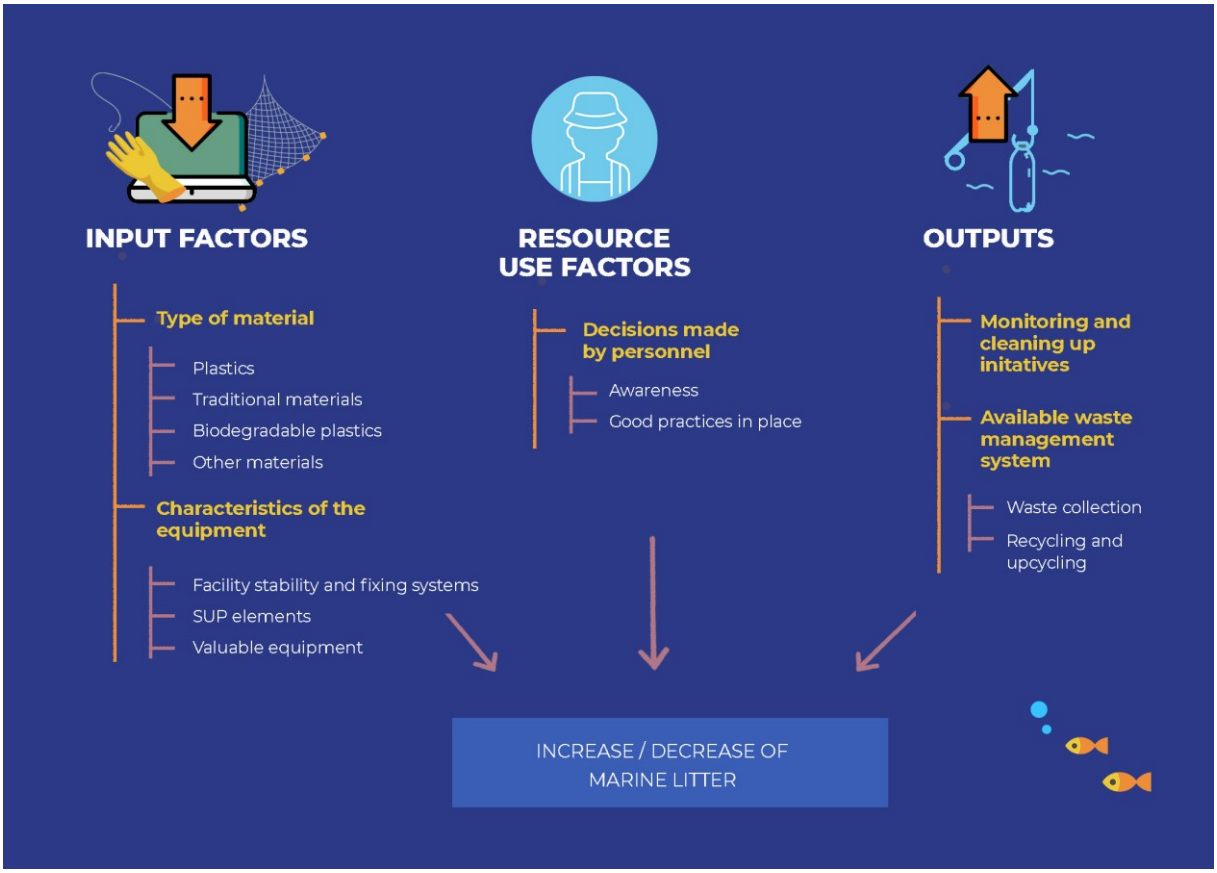

Figure 4: Schematic tree for the aquaculture marine litter issues identification purpose.

Thefore, each of the factors is characterised depending on (1) the related marine litter issues, and (2) the potential future impacts, that is to say, the consequent marine litter increase or decrease by 2025.

Lastly, a preliminary framework for the analysis of the potential future increase or decrease of marine litter by 2025 is forecasted by aquaculture type and by sea basin.

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

4.2. Potential future impacts related to aquaculture litter management by 2025

This section includes the identification of the potential impacts of the aquaculture activities regarding the increase or decrease of the marine litter by 2025.

The examination of the impact on the increase or decrease of marine litter is firstly approached by each of the factors that have been previously identified in the schematic tree. This examination includes the interaction on one hand, of each of those factors with the main external drivers, and on the other, the related marine litter issues and their impacts (that is to say, increase or decrase of the marine litter) (section 4.2.1).

Furthermore, this analysis has been summarized in 'Annex a' in the form of the tables 1 and 2. Table 1 includes the interaction between the external drivers and each of the factors. Table 2 summarizes the issues and the forecasted increase or decrease of marine litter per each of the factors.

Lastly, a preliminary framework for the development of a future impact analysis by sea basin (Mediterranean, North Sea and Baltic) regarding the potential increase or decrease of marine litter per each type of aquaculture is presented (section 4.2.2).

4.2.1 Examination of the potential future impacts (increase or decrease of marine litter)

Input factors

TYPE OF MATERIALS

Plastic in aquaculture

Plastic materials are widely used in the aquaculture sector due to their resistance and low cost. Taking into account that it is generally considered that there is no real alternative to this material (e.g. biodegradable plastics are more expensive and less resistant) (Altvater et al., 2020; De Raedemaecker et al., 2020; Vidal et al., 2020), **the use of plastic is expected to continue increasing (in parallel with the expansion of the plastic industry) by 2025 in the aquaculture sector. And this issue can generate an increase of the marine litter, due to losses and breaks of equipment pieces or gear. The negative impact worsens if it is considered that plastic gear and equipment are not biodegradable and that they can lead to an increase of the microplastics in the marine environment.**

The issues related to plastics are worsened by the fact that, sometimes, gear is made of mixed plastics. Mixed plastic is hindering an easy recycling process and a closed plastic life cycle due

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

to the difficulty to separate different plastic elements. In consequence, old material is incinerated and more and more new materials are produced without using recycled gear due to high costs and very small amounts.

Innovative approaches of the private and research sector are currently testing new, less mixed materials as well as using recycled gear for new products. However, as long as these efforts are not sufficiently funded and supported, they will not be competitive on the market; circular economy approaches related to gear will not be successful on a large scale with **no apparent reduction of plastic litter.**

Neverheless, there are some external drivers that have to be considered in this analysis for a better forecast of the situation by 2025. On one hand, climate change can increase the negative impact, as more losses and breaks are likely to happen under extreme weather conditions. On the other hand, European policies regarding the environmental plastic impact like the future request for standardisation circularity design for fishing gear can have a positive effect in the marine litter management. In this context, the European Strategy for Plastics in a Circular Economy provides a general framework for the plastics management in a medium-term, by 2030. Some of the specific objectives are:

- By 2030, more than half of plastic waste generated in Europe should be recycled.
- Thanks to improved separate collection and investment in innovation, skills and capacity upscaling, export of poorly sorted plastic waste would be phased out. Recycled plastic would become an increasingly valuable feedstock for industries, both at home and abroad.
- The plastic value chain would be far more integrated, and the chemical industry would work closely with plastics recyclers to help them find wider and higher value applications for their output.

Moreover, the recent Directive (EU) 2019/904 on the reduction of the impact of certain plastic products on the environment considers the **fishing gear containing plastic and** products made from **oxo-degradable plastic,** together with SUP elements**, a critical issue** in the context of marine litter, as they can suppose a severe risk to marine ecosystems, to biodiversity and to human health, in addition to causing damage to multiple activities such as tourism, fisheries and shipping.

This EU Directive specifies that each Member State has to establish Extended Produder Responsibility (EPR) systems for fishing gear containing plastic, covering all costs related to waste management, clean-up of litter and awareness measures.

Therefore, there is a clear involvement of the European institutions on the prevention and reduction of plastic marine litter from aquaculture. In this context, it is necessary to highlight that these European policies are the frame in which the expansion of the sustainable aquaculture sector of the region is expected to happen. Thus, although an increase of the

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

plastic marine litter could be expected due to the European production growth, the application of European policies in place can imply a progressive reduction of the increase rate.

Moreover, the European policies have to be transpositioned by all the Member States. Therefore, **national policies will also play a role on the progressive reduction of the marine litter production rate.**

Two more external drivers that can influence this factor are the roles of the consumers and the certification bodies. Both of them can positively influence to reduce the plastic marine litter from aquaculture by 2025. **Due to the increasing awareness of the consumers regarding marine litter, preferences for plastic-free aquaculture production could raise**, and this could lead to an increase of the interest by the farmers **to get a certification** that could prove the good practices applied and, therefore, to a progressive reduction of the plastic marine litter. In this context, it has to be taken into account that waste management criteria are starting to be included by some aquaculture certification bodies.

Finally, **plastic gear manufacturers play a key role in this context**. On one hand, they will be responsible for setting up the EPR schemes (Directive (EU) 2019/904). On the other, they will have to adapt their production process to the new policy frame and to the raising concern on plastic marine litter, by developing alternatives to the use of this material. In this context, the role of the research focused on plastic alternatives is essential to achieve the reduction of the marine litter.

Plastic marine debris and marine litter will increase as a consequence of the aquaculture and plastic industry expansion by 2025, due to it is generally considered that there are no currently real alternatives to this material for most of the aquaculture gear and equipment. This scenario can be worsened by the fact that extreme weather events are likely to increase the rate of gear and equipment losses and breaks.

Nevertheless, this growth will happen in parallel with the development of specific European and national policies, increase of the consumers' awareness and potential growing of the public interest on certified good practices. Therefore, in spite of the expected marine litter expansion, a progressive reduction of the increase rate can be forecasted, that will probably become more significant in a long-term perspective (2030).

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

Traditional materials in aquaculture

Testing traditional materials as an alternative to plastic material is not a priority under the European policy frame neither in the research field.

Some suggestions which can illustrate this issue, cited by aquaculture stakeholders, were included in Vidal et al. (2020). For example, the plastic stoppers used in the Galician (Spain) mussel farms were traditionally made of *Acacia* wood. Nowadays, *Acacia* cannot be planted in the country since it is an invasive species. Therefore, research could focus on finding an alternative native wood suitable to produce plastic stoppers, which are currently considered one of the main sources of marine litter in that area. But this is not currently happening.

Another example is related to the expanded polyethylene (EPS) boxes that are currently being used for transportation of the cultivated fish. Before the plastic expansion, fishes were usually transported in wooden boxes, which are currently considered not hygienic enough. In this context, and considering the circular economy approach and the sustainable design concepts, it would be interesting to make a research effort focused on finding the most suitable system to reduce the hygienic limitations associated with the wooden boxes. Nevertheless, efforts are not being done in this direction.

Moreover, the issue is likely to worsen because **traditional materials still used in small farming facilities (e.g. eucalyptus wood as the basis of the "batea", the traditional structure used in Spain for mussel cultivation) may be progressively substituted by non-traditional materials like polyethylene**. Nowadays, polyethylene is more durable, and it needs less daily maintenance, but it is still more expensive. Once prices normalise, an increase of plastic "bateas" could be expected.

In this scenario, the progressive substitution of traditional materials can lead to an increase of the non-sustainable marine litter (e.g. plastic made equipment and gear) by 2025.

An increase of plastic marine litter between 2020 and 2025 is likely to happen, as a consequence of the potential and progressive substitution of traditional materials, which use is not being promoted, neither supported.

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

Biodegradable plastic and bio plastics in aquaculture

Biodegradable plastics are defined by the European Commission as *"(…) entirely degraded by biological activity (compostable) without leaving behind any residue. They can be manufactured from renewable materials and fossil fuels, as well as mixtures of those*". (European Commission, 2020b).

Multiple Mediterranean aquaculture stakeholders agree (Vidal et al., 2020) that biodegradable plastics have not proved to be, at the current moment, a suitable alternative to conventional plastics for aquaculture gear and equipment, because **they are not resistant enough to harsh environmental conditions. Moreover, they are more expensive than traditional plastic. All these issues suggest that, in some cases, aquaculture farmers are reluctant to use plastic alternatives, and that they maybe will switch from traditional plastics to biodegradable plastics only if if their resistance is improved and their price is reduced**.

It also needs to be taken into account that **biodegradability levels are reduced in marine environments** (Rujnić-Sokele and Pilipović, 2017).

Therefore, in this context the **role of the plastic and gear manufacturers is essential**, to:

- Expand the research and development efforts to improve the characteristics of biodegradable plastics in the marine environment.
- Increase their level of production once they have been improved and launch specific marketing campaigns. The more these materials are applied to produce aquaculture gear and equipment, the more their prices will reduce.

In this scenario, European policies and supported research programmes focused on biodegradable plastics are also fundamental. **The European Commission supports the development of innovations that ensure the biodegradability of these materials and will assess the analysis of the conditions in which biodegradable plastics would be beneficial.**

In fact, the European Union has promoted the research on the biodegradable plastics in the last years, e.g. through the Horizon 2020 Framework Programme (STAR-ProBio, RoadToBio, RefuCoat, BioCanndo) and the EMFF Programme (BIOGEARS). Therefore, it is expected that, in parallel to the expansion of the biodegradable plastics performed by the manufacturers and gear producers, the European Union will keep interest in the research focused on improving their characteristics, pushing the industry to move forward with a focus on sustainable designing.

Moreover, efforts are also made on developing new biocomposite materials for offshore use. For example SeaBioComp is an Interreg funded collaborative project (covering the coastal regions along the Southern North Sea and Channel area including 4 EU member states: England, France, The Netherlands and Belgium) with the aim to develop and produce novel bio-based thermoplastic composite materials and the analytical protocols to evaluate long-term durability and reduced ecological impact on the marine environment.

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

While these improvements are being developed, the European Strategy for Plastics in a Circular Economy considers that biodegradable plastics could worsen the plastic leakage and create problems for mechanical recycling, if there is no clear labelling or marking for consumers and if the lack of an adequate waste collection and treatment system continues. And this can lead to similar consequences than if they were conventional plastics, that is to say, an increase of the marine litter by 2025.

A light increase of the use of biodegradable plastics can happen by 2025.

However, it will take time to increase their resistance to harsh conditions and compete with conventional plastics given their higher costs. Only if their lack of resistance and their biodegradability characteristics are improved, prices are reduced and aquaculture farmers' reluctance is overcomed, their use can be related to a reduction of the marine litter in the next 5 years.

Other materials used in aquaculture

This section includes references to natural textiles (mainly in ropes), wood (e.g. wooden pallets or fish boxes), rubber (e.g. gloves and boots) and metal (e.g. thimbles or metal drums for flotation) (Sandra et al., 2019).

Just like plastic gear and equipment mentioned previously, all those materials can end up in the sea due to loss, breakdown or abandonment. In the frame of the potential expansion of the sustainable European aquaculture, extreme weather events will be the main driving forces of increase of the marine litter related to them.

In spite of the general growth of the marine litter due to these elements and events, the environmental impact is expected to be lower in the case of the items made of biodegradable materials like wood and natural textiles than in the case of non-biodegradable materials.

However, even non-plastic materials can cause environmental negative effects. In the case of the **natural rubber, the biodegradation process is very slow. Moreover, this material can be mixed with other compounds and even additives which are required for vulcanization or to influence the material properties** (Rose and Steinbüchel, 2005), which can have a negative impact on the environment.

Metals, on the other side, can be affected by corrosion. Seawater is a complex medium in which chemichal, mineral and biological elements interact to create, on metal surfaces, a complex corrosive medium (Memet, 2007). To avoid this issue, application of chemichal anti-corrosion is a frequent practice. Nevertheless, it has been proved that some corrosion protection products can produce a negative impact in the marine environment. For example, epoxy or polyurethane resins can be a source of bisphenol A, which have caused concern in

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

terms of its negative impact on human helath and possible environmental toxicity (Vermeirssen et al., 2017).

Finally, it has to be considered that none of these types of materials is not a priority *per se* in the current European frame, not at the policy level neither at research level. In this scenario, the growing general concern related to the increase of marine litter and the inclusion of specific criteria related to waste management in all the aquaculture good practices certification procedures could lead to an increase in the interest in evaluating their impacts. And, moreover, this could maybe set the basis for a progressive reduction of the aquaculture related marine litter in a medium-term future.

In conclusion, marine litter associated to non-plastic materials used in aquaculture (including natural textiles, wood, rubber and metal, among others) is expected to increase in 2025 due to the more frequent extreme weather events, in parallel with the expansion of the aquaculture. Including specific criterias in the certification processes and an increase of the concern regarding these materials could lead to a potential decrease of the related marine litter in a medium-term future (e.g. 2030).

EQUIPMENT

Facility stability

The elements related to the farm's robustness include fixing systems, anchoring systems, and the structural stability themselves need to be taken into account in this analysis. Chosing and maintaining the most appropriate fixing and anchoring systems is essential to reduce the chances of breaks and losses and, therefore, to reduce the marine litter (Altvater et al., 2020; De Raedemaecker et al., 2020; Vidal et al., 2020).

The importance of the facility stability characteristics will increase in parallel with the raise of extreme weather events and to the expansion of the aquaculture in the European context. In fact, the European Parliament (2014) forecasted that by 2030 warmwater marine and shellfish aquaculture will expand to offshore/deeper water areas in the European context. This means that there will be a need to increase the robustness and stability of the farms, to be able to resist to harsh conditions, in addition to adapt the fixing and anchoring systems of the most traditional-near coast shellfish cultivation structures to the new farming conditions. In this context, aquaculture stakeholders highlight the need of more design efforts on creating stable and solid infrastructures to minimize damages (Altvater et al., 2020; De Raedemaecker et al., 2020; Vidal et al., 2020). It is also important to raise efforts to find and promote more sustainable, resistant and durable alternatives to SUP fixing elements like cable ties (Altvater et al., 2020; De Raedemaecker et al., 2020; Vidal et al., 2020).

From the design perspective, some initiatives have been recently developed by engineering and farm construction companies, in order to improve the facility's robustness. Although

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

technical developments with focus on stable and solid infrastructures still need time to be fully developed, many facilities are already in a testing phase (e.g. ground lock systems in Scotland, New Zeeland system).

Nevertheless, to ensure the effectiveness of the improvements on the fixing systems, there is a need to provide **specific trainings to aquaculture personnel** on the new fixing and anchoring systems. Organizing trainings for the aquaculture staff in collaboration with gear production companies can help to increase the stability of the facilities (Altvater et al., 2020; De Raedemaecker et al., 2020; Vidal et al., 2020).

It is expected that all current efforts focused on increasing the facilities' robustness and to improve the fixing systems (e.g. development of more solid infrastructures, finding alternatives to SUP fixing systems, proving specific trainings to the aquaculture personnel) will be further developed in the coming years, and presumably initiate a decrease of marine debris by 2025.

Single Use Plastic (SUP) elements

SUP gear is very frequent in the aquaculture facilities, e.g. mussel meshes and cable ties. **These elements are not frequently recyclable neither reusable. Usually, when they have reached the end of life, they are brought to the common dumpsters or simply abandoned during daily tasks** (Altvater et al., 2020; De Raedemaecker et al., 2020; Vidal et al., 2020).

SUP elements (from all sources) are among the items most commonly found on beaches, and represent an estimated 50% of marine litter (Directive (EU) 2019/904). Thus, **SUP gear elements can be considered one of the major marine litter issues related to aquaculture. Their negative impact is especially severe in some areas of the Mediterranean Sea, as a consequence of the shellfish cultivation activities** (Altvater et al., 2020; De Raedemaecker et al., 2020; Vidal et al., 2020). **And this issue is likely to continue and increase by 2025, in parallel with the expansion of the aquaculture.**

However, there are some internal factors and external drivers that can imply a progressive reduction of the increase rate of the SUP marine litter.

In fact, one of the current environmental priorities in the EU is reducing the SUP use, **and, thus, Member States will have to address this issue in a short-term future in their national policies**.

The importance of the SUP has been stated in the European Strategy for Plastics in a Circular Economy (2018) and also, as it has been previously mentioned, in the Directive (EU) 2019/904. This EU Directive considers the **SUP**, as well as fishing gear containing plastic and

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

products made from oxo-degradable plastic, a particularly **serious problem** in the context of marine litter. The European Union has high concerns regarding the SUP due to there are still not suitable and/or more sustainable alternatives readily available, and the consumption of most such single-use plastic products is expected to increase.

To reverse the trend and to promote efforts towards more sustainable solutions, Member States are requiered to introduce the Extended Producer Responsibility schemes to cover the necessary costs of waste management, clean-up of litter and awareness measures to prevent and reduce it.

The Directive (EU) 2019/904 goes further by adding that in case of existence of more suitable and more sustainable SUP alternatives which are affordable and available, Member States are required to forbid placing SUP elements in the market.

This current EU Directive does not include the SUP aquaculture gear elements in the list of the SUP items covered. Nevertheless, these items are considered "waste fishing gear" and, therefore, they are affected by the plastic fishing gear normative included in the same Directive (see *Plastic in aquaculture* section).

In this scenario, **external drivers like increase of extreme weather events, expansion of the sustainable aquaculture in the European context, consumers' awareness and good practices certification hold an equivalent role for SUP than for general plastic fishing gear. Moreover, gear producers are also responsible to include these elements in the EPR schemes**.

However, the **fact that the SUP items are rarely collected after using them is a critical limitation to be taken into account before setting up the EPR scheme**. This issue is due to many factors which include (Altvater et al., 2020; De Raedemaecker et al., 2020; Vidal et al., 2020):

- There is not enough awareness in the sector regarding their impact in the marine environment.
- They do not have economic value and, thus, aquaculture technicians do not care if loosing or abandonning them after using them.

Therefore, before ccreating the EPR systems, there is a need to (Altvater et al., 2020; De Raedemaecker et al., 2020; Vidal et al., 2020):

1. Increase the awareness of all the aquaculture stakeholders in relation to the environmental impact of these SUP elements.
2. Make an effort on research focused on alternatives to aquaculture SUP elements (e.g. improving their design to make them more resistant to harsh conditions, using alternatives to plastic, among other potential solutions).
3. Support the creation of deposit schemes for passive aquaculture gear including SUP elements, to raise the return rate of those products. There are two options:

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

a) Grant a discount on following purchases: the farmer brings back the used items to the seller/manufacturer and gets a discount on the price of the following purchase depending on the weight/volume/quantity returned.
b) Return a deposit: to purchase an order, the farmer pays not only for the bought items but he also leaves a deposit, which will be returned by the seller/manufacturer once the farmer returns the used items.

It is likely that marine litter from SUP gear will continue increasing by 2025. Nonetheless, a light progressive reduction of the increase rate can be expected once new and improved European policies are in force and they have been transpositioned by the Member States in the national policies.

The impact is expected to progressively reduce in parallel with specific solutions for SUP elements like increasing the awareness of the sector about the consequences of their use, supporting reseach focused on alternatives to current SUP and creating deposit schemes in the frame of the EPR systems.

Valuable items

Valuable items like nets, buoys and other large structural pieces are not usually abandonned at sea, but lost or broken due to major weather events or lack of maintenance. In this context, the potential role of the increasing extreme weather events is crucial, as losses and breakdowns are likely to happen more frequently in the next years.

As these are expensive items, farmers are very interested in recovering them before they end up as debris in the marine environment (Altvater et al., 2020; De Raedemaecker et al., 2020; Vidal et al., 2020)

In fact, tracking valuable items is an initiative currently developed in the area of the North Sea (De Raedemaecker et al., 2020). For example, the Lost Gear Finder is a solution that has been recently launched, with the aim to retrieve lost gear from fishermen and aquaculture farmers. A transponder is attached to the gear and a transducer is installed on board, as well as a processor connected to a monitor. In case of gear loss, the user can search for lost gear's position underwater. The effective range for the transducer is as much as 5,000 meters, which makes the search very efficient. When the onboard unit receives response from the transponder, the position is calculated quickly and lost gear is easily found. Moreover, at a more general level, the NetTag project provides new technologies to track fishing gear in case of losses; these innovations include acoustic tags and acoustic transceivers for uniquely localization of lost items and an automated-short-range robotic recovery system.

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

Nevertheless, this **kind of initiatives faces some issues** that need to be addressed in the short-term future, including (De Raedemaecker et al., 2020):

- High associated costs: tracking a buoy costs more than 1,000 Euros. Farmers do not currently receive support from governments.
- Electronic monitoring can be difficult in marine conditions.
- GPS signals do not cover installations located further than 12 nautical miles from the coast.

Apart from the technical innovations, **international organizations are also playing a key role to aware about the importance of reducing losses of big gear items** like nets. For example, World Animal Protection has called on the member states of the United Nations Food and Agriculture Organisation (FAO) to ensure all fishing nets are ID tagged by 2025 to reduce the numbers of marine animals being killed by lost fishing nets. Moreover, organizations like Global Ghost Gear Initiative and initiatives like Fishing for litter are raising the general awareness and the aquaculture and fishery stakeholders' concerns regarding the impacts of these items in the marine enviroment.

More efforts are currently being done to provide **suitable maintenance services for aquaculture nets**, with the aim to enlarge their life cycle and to reduce the chances of loss or break. These services are usually provided by gear producer companies, and they include washing and disinfection, repair and anti-fouling treatment. Improving the resistance to biofouling is another topic in which technical research has been focused on.

In conclusion, some efforts are being currently done from innovative perspectives regarding the tracking of the valuable items from aquaculture. Although most of the technical initiatives are still facing some challenges, new improvements are expected to happen in a medium-term future. Therefore, no reduction or increase of the marine litter is forecasted by 2025, due to innovative solutions are expected to be still under development.

On the other hand, many gear producers offer maintenance services for valuable items like nets. The scheduled maintenance services can help to reduce the marine litter by 2025 by reducing losses and breakdowns.

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

Resources key-issues

PERSONNEL

Awareness

Although most aquaculture stakeholders are slightly aware of the potential impacts of litter on the marine environment, and show genuine interest in mitigating it, there is still a clear need for more attention regarding this issue (Altvater et al., 2020; De Raedemaecker et al., 2020; Vidal et al., 2020).

In fact, raising their level of awareness and providing specific trainings to the aquaculture personnel were two of the most frequently suggested solutions in the frame of the AQUA-LIT Learning Labs. **A significant reduction of the marine litter could be expected if their concern about the impact of marine litter was expanded and trainings to improve the management of the potential litter were implemented.**

On one side, these **trainings** could be focused on many topics like, for example, **the importance of the anchoring systems, sustainable selection criteria for purchasing gear, improvements in potential alternatives to traditional plastics, alternatives to SUP elements**, etc. These specific trainings could be lead by aquaculture farmers but also by gear producers, plastic manufacturers or members of certification bodies, among others.

On the other side, **multiple types of efforts could be done with the aim to raising the awareness of the aquaculture farmers**. In this context, all the initiatives that are currently being made in the fishery sector (e.g. Fishing for Litter schemes) can settle the path for specific and adapted aquaculture activities or for placing collaborations between fishery and aquaculture stakeholders. These collaborations can facilitate the knowledge exchange and the understanding about the marine litter issue from a sea-based source perspective.

Secondly, all the research projects, clean up and monitoring initiatives performed by NGOs, international organizations, research institutions etc, which involve aquaculture farmers like AQUA-LIT, can help to increase their level of awareness. All these initiatives provide the opportunity to support the communication between all the involved stakeholders in the aquaculture chain, share the current knowledge and identify new approaches.

Moreover, **certification bodies are starting to consider the management of the marine litter as a certifiable criteria**. The inclusion of this topic in the good practices certification will specifically increase the interest and consciousness of the aquaculture farmers in this issue.

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

Currently, some efforts are made to increase the awareness regarding marine litter from sea-based sources. Although most of them are related to the fishery sector, there is a growing interest in involving the aquaculture farmers as well.In this context, collaboration between farmers and gear producers and aquaculture farmers can help to frame partnership training schemes addressed to aquaculture personnel.

If these efforts are maintained over time, they can lead to a progressive reduction of the marine litter by 2025.

Good Practices in place performed by the farmers

Good practices applied by the farmers and currently in place are numerous, and they help to reduce the marine litter. However, most of them have not been standardised or not even evaluated from the environmental or economic point of view (as they have not been included by the certification organizations).

Non standardised good practices depend on their own responsibility and include, among others, purchasing very resistant gear, performing scheduled maintenance plans surveilling the farm's infrastructure (e.g. nets), reusing bags to sell the product to the consumers (e.g. mussels) and establishing collaborations with other sectors like decorators and architects (e.g. reusing the wood from older bateas for decorative purposes) (Vidal et al, 2020).

All those good practices are currently being performed under volunteer basis. Moreover, due to the lack of communication among all the sectors involved in the aquaculture marine litter management, it is very difficult that those non-standardised good practices reach any other aquaculture company or certification body. In this context, there is no reinforcement or positive feedback to those applying them.

Although these good practices can be very beneficial at individual or company level, it is not very probable that they will be applied by other companies without any incentives. And to be able to receive incentives for applying them, it is necessary to support the communication between all aquaculture stakeholders especially, in this case, among farmers and certification bodies.

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

Thus, those current good practices would mean an effective reduction of the marine debris by 2025 if they could be linked to a motivating certification and/or economical benefit. This trend can be expected considering that certification institutions like ASC and GLOBALGAP start considering potential marine debris as a certification criteria.

Output key-issues

WASTE MANAGEMENT SYSTEM

Currently, there are knowledge gaps on how to manage non-organic marine litter from aquaculture facilities in many European countries.

Some of the crucial issues to be considered are (De Raedemaecker et al., 2020; Altvater et al., 2020; De Raedemaecker et al., 2020; Vidal et al., 2020):

1. Lack of information regarding roles and responsibilities;
2. Lack of appropriate waste management infrastructures and structural support for environmental enhancement initiatives like beach clean-ups and recycling projects;
3. There is additional national legislation needed to put in place European policies referred to specific EPR schemes;
4. Currently, producers are not responsible for clean-up measures or recycling related to fishing/aquaculture gear. This gap will not be closed by the new EU Single-use-plastic Directive until 2021;
5. There is a resistance to change attitudes or habits and a lack of awareness of the necessity to do so;
6. Lack of a complete circular economy perspective (e.g. regarding plastic production).

Nevertheless, there are specific issues for each step of the waste management system. For the analysis purpose of this report, focus will be on collection issues and recycling/upcycling issues.

Collecting

The situation in 2020 clearly shows the need to improve the current waste management systems and, specifically, the collection step in order to be able to keep up with the expansion of the aquaculture industry (Sandra et al., 2019) and the potential increase of marine litter due to other factors like the increasing extreme weather events.

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

Recently identified barriers include, among others (De Raedemaecker et al., 2020; Altvater et al., 2020; De Raedemaecker et al., 2020; Vidal et al., 2020):

1. There is a **lack of efficient system**s and facilities for collecting, storing, and processing of used gear and equipment. There is a resistance to collecting all types of materials in ports. For example, dirty materials are not taken by all recyclers.
2. **In some Mediterranean countries, as there are no proper disposal points**, farmers often burn the nets and pile barrels close to the ports;
3. **Waste management points (or recycling centers) are not usually near the collection points for aquaculture litter** and the transportation costs are very expensive (payment of taxes or management/transport of waste to waste management facility). Even more, some ports do not have facilities for collecting nets or other type of waste;
4. There are **no containers for small size material** (e.g. small SUP items).
5. Waste collection points sometimes compete with touristic places which generates **spatial conflicts**.
6. **Directive (EU) 2019/883 on port reception facilities for the delivery of waste from ships refers only to nets as the passively fished waste**;
7. Fishermen may be asked **to recover the nets but it only happens on a voluntary basis** (they do this when they are rewarded and they collect ghost gear and equipment that is valuable).

Overcome all these limitations and put in place disposal points in the frame of feasible EPR systems can be challenging for many European countries, specially considering the multiple steps to take into account, which include (Altvater et al., 2020; De Raedemaecker et al., 2020; Vidal et al., 2020):

- Transposition of the European policy frame to a national level of the Member States (e.g. European SUP Directivehas to be trasnpositioned by Member States by 2021),
- The analysis of the economic feasibility of the EPR scheme.
- The identification of all the involved actors, mainly aquaculture farmers, gear producers and waste managers,a part from the policy makers and the certification bodies.
- The identification of roles and responsibility of all the involved actors.
- Creating the potential support frame to be provided by public institutons or private companies in order to put the EPR in place.
- And to raise the level of awareness among the aquaculture stakeholders.

Therefore, the creation and development of feasible collection systems in the frame of the EPR schemes depends on time, human and economic resources. Probaly, for some countries or regions in the Europewill be challening to set them up in a short period of 5 years time, **although first steps will have been taken and their development will be in progress.**

In the meantime, and taking into account the priorities of the European policies, the inclusion of waste management criteria by certification bodies and the general growing concerns on

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

marine litter, **an increase of specific gear (e.g. nets) disposal points**, not necessarily linked to a full-working EPR systems Is expected to happen.

This can have **a positive impact regarding marine litter**, that is to say, a potential reduction of the litter can be expected by 2025. Nevertheless, it is likely that the needs of an aquaculture expansion sector will not be completely covered due to the aquaculture expansion rate can overcome the capabilities of some European Member States or regions.

The increase or decrase of marine litter related to the collection system strongly depends on the current status of each national and/or regional waste management system. As a consequence, and although the number of the disposal points and the sector's awareness is expected to grow by 2025, it is likely that the accompanied needs of an aquaculture expansion will not be completely covered in some European contries or regions.

Recycling and upcycling

Most of the recycling and upcycling initiatives in place in Europe are related to nets, although this is something that is in the first steps of development (e.g. OCEANETS project and BlueNET project). The main **challenges** that recycling and upcycling processes are facing in 2020 are (De Raedemaecker et al., 2020; Altvater et al., 2020; De Raedemaecker et al., 2020; Vidal et al., 2020):

1. Currently, circular schemes **to recycle end-of-life nets don't seem to be economicaly viable**. Recycled nets are much more expensive than regular nets;
2. **Marine litter recycling is very difficult and expensive because of the degradation level and the mixture of materials**;
3. **Market is not using all types of recyclable material**;
4. **There are no plants adapted to recycle all types of material**;
5. There is a **shortage of protocols for cleaning and recovering materials** prior to recycling.
6. **Designers and manufacturers of aquaculture equipment are not sufficiently encouraged to be innovative** and seek other alternatives, such as, collecting and recycling services, in order to reduce the impact of their products on the natural environment.
7. **Recycling companies are located too far from the farm to collect**, sort & recycle worn out gear and other waste. This barrier leads to dumping of waste without sorting it.

In this context, **the collaboration within research institutions, waste managers, gear producers and plastic manufacturers is essential** to be able to provide solutions to those multiple challenges. This collaborative frame needs to be settled down in the frame of the

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

specific EPR system and, therefore, under a national policy framework that has to be developed by each Member State of the EU.

Therefore, in the same way that has been stated for the collection phase, the development of economicaly feasible recycling and upcycling methodologies will need resources and time. Some of these initiatives are already in place, but the majority are in the testing phase. Therefore, although the impact of the recycling and upcycling initiatives is expected to be positive by 2025, it will not probably cover the full needs of an aquaculture sector in expansion.

> Some of the recycling and upclycing initiatives linked to aquaculture gear and equipment are already in place, but the majority of the currently ones are in the testing phase. Therefore, although the impact of the recycling and upcycling initiatives is expected to be positive in the medium-term future, it will not probably cover the full needs of an aquaculture sector in expansion by 2025.

.

Clean up activities/monitoring programmes

Apart from the official marine waste monitoring programs, marine litter is frequently collected and/or quantified during clean-up and/or monitoring initiatives.

Monitoring is essential to have a general overview of the marine litter issue related to aquaculture. It makes it possible to estimate the marine litter impact in the environment and provides information on the most frequent found objects and the location where these objects are found. Therefore, monitoring programmes can help to understand the reasons behind the fact that those items are so frequently found as litter on one side; and, on the other, they can help to establish, for instance, the role of the ocean currents in the marine debris and litter dissemination

However, there is a **lack of data from many countries regarding aquaculture litter found on beaches, the sea surface and the seafloor** (Sandra et al., 2019,). Besides, there is a **lack of harmonization of the monitoring programmes and the quantification protocols** between regions and countries and, as a consequence, it is difficult to compare data from different areas (Sandra et al., 2019; Altvater et al., 2020; De Raedemaecker et al., 2020; Vidal et al., 2020).

Some efforts have been done recently from the research perspective to address this issue. For example, under the AQUA-LIT project, Sandra et al. (2019) performed an analysis on the occurrence of aquaculture marine litter in three main European sea basins (Baltic Sea, North

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

Sea and Mediterranean). The objective was to estimate the average number of observed aquaculture-related litter items per 100 m.

Besides, there has been a **development of the European frame regarding marine data from the aquaculture sector**. For example, the Establishment for the Collection, Management and Use of Data in the Fisheries Sector and Support for Scientific Advice Regarding the Common Fisheries Policy Council Regulation (EC) No 199/2008 was implemented in the decision D (EU) 2016/1251 of 12 July 2016 (which adopted a multiannual Union programme for the collection, management and use of data in the fisheries and aquaculture sectors for the period 2017-2019), and in the decision D (EU) 2016/1701 of 19 August 2016 (laying down rules on the format for the submission of work plans for data collection in the fisheries and aquaculture sectors). Consequently, Member States created their own data base, which helps tracking the evolution of both industries. Although no specific indicators related to marine litter were included, one can consider this a first step in creating public databases at a European level using a standardised protocol.

National initiatives are also taking place. Recenlty, two mussel farming consortia (POAY, "Areas of Organized Development of Aquaculture"), were established in the norther part of Greece. The POAY will be governed by a Board of Councils, composed of members who are representatives of the involved municipalities, farmes and other authorities. Stakeholders in charge of the POAYs expect that the full function of the consortia will imply a better management and legislations including, among other factors, waste monitoring and management (Altvater et al., 2020; De Raedemaecker et al., 2020; Vidal et al., 2020).

Besides, as a result of the increased citizen awareness, **many volunteering clean-up and monitoring initiatives are being performed around Europe**, in which the volunteers also collect data on the found marine litter. In some cases, the collected information is filtered and shared with public authorities to feed the official monitoring programme databases.

Therefore, **while the public concern increases and the collaboration among multiple stakeholders expands, an improvement in the aquaculture marine litter collection data can be expected by 2025**. This will have a positive impact on the specific European policies and national policies (by feeding the databases), research institutions (as it will provide useful information for a better understanding of this global concern) and farmers (as general awareness is expected to increase when data will highlight the impact of the marine litter). All these positive effects can lead to a reduction of the marine litter by 2025.

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

Monitoring and cleaning up initiatives can help to better understand the marine litter issue from aquaculture and can help to raise the awareness at a general level. This will have a positive impact on the specific European policies and national policies (by feeding the databases), research institutions (as it will provide useful information for a better understanding of this global concern) and farmers (as general awareness is expected to increase when data will highlight the impact of the marine debris). All these positive effects are likely to lead to a reduction of the marine litter by 2025.

4.2.2. Preliminary framework for the evaluation of the potential future impacts of each aquaculture techniques in each sea basin.

This section includes a **preliminary assessment of the potential increase or decrease of marine litter per each type of aquaculture and per each sea basin included in the AQUA-LIT project**. The aim is to provide a general overview of the probable situation regarding this issue in the European context by 2025, and to settle the path for future extensive impact analysis.

MEDITERRANEAN SEA BASIN

In the Mediterranean context, **shellfish aquaculture is linked to a major use of SUP elements that are frequently lost in the sea**. This issue is due to accidental lost due to environmental conditions, lack of attention while handling the gears, lack of awareness and lack of disposal points. This situation is expected to continue by 2025, which will lead to a **potential increase of the marine litter linked to the use of SUP elements**.

Besides, it has to be taken into account that most of the mussel farmers of the biggest mussel producer in Europe, Spain, still keep the traditional cultivation structures made from eucalyptus wood ("bateas"). Nevertheless, **a progressive substitution of these traditional materials for non-sustainable alternatives like polyethylene is expected to happen by 2025**, as a consequence of the plastic structures price reduction and the improvement of their technical characteristics. And this could lead to an increase of the plastic marine litter by 2025.

Moreover, as aquaculture stakeholders believe that there are no alternatives (e.g. biodegradable materials) to plastic made gear than can match its resistance and low price, **general plastic marine litter from all types of aquaculture is likely to continue increasing by 2025.**

Finally, most of the Mediterranean countries do not have proper disposal points neither recycling facilities prepared for aquaculture (and fishery) gear. Sometimes, aquaculture

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

farmers dump their gear in unspecific collection points or even burn them (e.g. in Greece). And, frequently, there is no specific policy frame in place. In this context, **the transposition of the SUP EU Directive will be a milestone for most of Mediterranean countries**. **While developing the national policies, some improvements in the waste management systems and an increase of testing recycling and upcycling initiatives is expected. Nevertheless, as they will not cover all the necessities derived from the expansion of the aquaculture industry, they will not probably have a significant impact on the reduction of marine litter by 2025**.

Nevertheless, **there are some factors in the Mediterranean Sea basin that can settle the path for a progressive reduction of these increasing rates**. The crucial ones are:

- **Increasing levels of awareness among the aquaculture sector**: current initiatives like AQUA-LIT, or volunteering clean up and monitoring initiatives, schemes similar to fishing for litter, etc can have a positive impact regarding the marine litter in all aquaculture stakeholders, including farmers. As higher is their knowledge about the effects of marine litter in the environment and about their essential role to reduce them, a faster reduction of litter is likely to happen. Collaborations between fishermen, gear producers and aquaculture farmers can be potentially settled under the European SUP Directive frame, which can lead to a progressive increase of the marine litter concerns and, therefore, a progressive decrease of the marine litter by 2025.
- Lots of producers apply their **own good practices to reduce the marine litter**. Nevertheless, their positive impact is, somehow, testimonial as they are carried out individually. Only if efforts are done to facilitate the communication among farmers and between farmers and certification bodies, **the consequent reduction of marine litter could be significant by 2025.**

NORTH SEA BASIN

In the North Sea, facilities for **the aquaculture of finfish** are clustered in favourable areas in the Northern North Sea, Skagerrak and Kattegat. Categories of debris originating from finfish aquaculture activities are poorly represented in the available litter databases, but the AQUA-LIT litter inventory points at the number of items related to this type of aquaculture (Sandra et al., 2019). Besides typical strings and clips (Alvater et al., 2020), feeding tubes used in finfish farms have a high risk to be lost according to the stakeholders (De Raedemaecker et al., 2020).

On the other side, **seaweed aquaculture** predominates in France and Norway (brown seaweeds). Most of the materials today are made of plastic, as there are no good alternatives available (as the biodegradables are not resistant enough to harsh environmental conditions). For seaweed cultivation only longlines are reported as litter item (Sandra et al., 2019). Currently, new innovation projects deal with new offshore materials (e.g. InterReg

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

SeaBioComp project) and robust seaweed & bivalve cultivation equipment (e.g. H2020 UNITED project), what is expected to have a **positive impact by 2025**.

Finally, **mussel cultivation** (pole culture – suspended rope culture – bottom culture) is dominated by France and the Netherlands (Sandra et al., 2019). **Oyster farming** has increased again since 2014, and the sector is dominated by France while UK and the Netherlands have limited production capacity. The sector is characterized by being composed mainly of small, family-owned businesses of limited financial capacity (Sandra et al., 2019). The AQUA-LIT litter inventory revealed that mainly bivalve farming depends on SUP objects that are often lost. Therefore, shellfish aquaculture is likely to **increase the plastic debris by 2025** significantly, especially regarding the use of the SUP elements. Currently, producers are not responsible for cleaning-up measures related to fishing/aquaculture gear. This gap will not be closed by the new EU Single-use-plastic Directive (SUPD) until 2021. The integration of the management of plastic waste in the company's policy on reduction of plastic waste is essential to tackle SUP waste from the aquaculture sector (De Raedemaecker et al., 2020)

On the other side, lots of efforts are currently being done and tested to improve the facility stability, especially for offshore facilities (e.g. H2020 UNITED project) and, therefore, they have to be robust enough for very harsh conditions. This is expected to have **a positive impact by 2025**, as a reduction of the losses and breakdowns from offshore facilities is likely to happen.

Moreover, lots of efforts are also being made to improve the retrieval of valuable items both in the case of shellfish and finfish aquaculture, including the development of innovative solutions like GPS. This is also expected to have a positive impact in future, as recovery of the valuable lost and broken items will be more feasible. However, studies are on-going, so **no direct impact is expected by 2025**.

The level of awareness raising in the aquaculturesector is a key factor to ensure the reduction of marine litter and the use of sustainable alternatives. The main focus of these kind of activities is still the fishing sector, e.g. the Fishing-For-Litter Initiative. Projects such as AQUA-LIT and the national initiatives and marine litter action plans will support the awareness in the aquaculture sector, what will have a **positive impact by 2025.**

Status of the waste management system (including a deposit system) in the North Sea region and countries can ensure a **reduction of the marine litter by 2025**. The integration of the plastic waste management in the company's policy of all aquaculture farmers in the North Sea is necessary. The implementation depends on future national or regional obligations to include specific guigelines and rules in the existing waste management laws.

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

BALTIC SEA BASIN

In the Baltic Sea, fish production from aquaculture facilities has remained constant in terms of production volume with the amount of marketable size fish with the main producers in Finland, Denmark and Sweden. The main reasons for this stagnation have been the concerns about eutrophication increase, high costs for energy and labour, and restrictions in terms of environmental and animal protection. Debris originating from finfish aquaculture have categorized in very few national monitoring programmes like in Denmark and Germany. The numbers of these data are low and no statistical assessments can be derived of. On a regional level, litter data is provided by HELCOM contracting parties in response to the data call for State of the Baltic Sea report. For this report, the data on the same litter categories/items have been used like in other EU sea basins. However, due to different monitoring and coding methods, it was not possible to collect data for all types of finfish aquaculture gear among Baltic Sea countries (Sandra et al., 2019). According to the stakeholders, strings and clips used in finfish farms have a high risk to be lost (Altvater et al., 2020).

In the Baltic Sea, Denmark is the largest aquaculture producer of seaweed. For seaweed cultivation (mainly macroalgae) ropes and longlines are reported as litter item (Altvater et al., 2020).

Mussel cultivation, especially of blue mussel, has a lower production rate in the Baltic proper, due to lower salinity, compared to the outer Western Baltic Sea and Swedish East Coast region, with higher salinity. Mussel cultivation is using mainly suspended rope culture and bottom culture with an increase of SUP elements and ropes. For compensation schemes to reduce eutrophication and open new markets to farmers in low salinity areas, new cultivation techniques have been introduced at more advanced Technological Readiness Level (TRL) with smaller ropes by innovative farmers in 20165. Still, some ropes have been lost unintentionally.

Until now, the integration of the management of plastic waste in the company's policy of all mussel production farmers in the Baltic Sea is seen as necessary, however difficult to implement (Altvater et al., 2020). Stakeholders are expecting guiding support by administration and policy in accordance with the on-going implementation of the SUPD provisions. First round tables, like the German Lower Saxonian government commission is elaborating specific guidelines and integration of rules in existing waste and circular economy laws.

[5] see the Baltic Blue Growth (BBG) Interreg project with its Swedish farm at the St. Anna archipelago, https://www.submariner-network.eu/images/SUBMARINER_Paper_Mussel_farming_in_the_Baltic_Sea_September_2019.pdf

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

Apart of these activities, some efforts are currently being done and tested to improve the facility stability, especially in the case of the finfish and shellfish facilities. Although often located near the coast, a robust design is needed and not always sufficient related to harsh conditions.

All these efforts are expected to have a positive impact by 2025, as a reduction of the losses, especially of SUP items, ropes and nets and breakdowns from facilities is likely to happen.

Moreover, lots of efforts are also being made to improve the retrieval of valuable items both in the case of shellfish and finfish aquaculture, including the development of innovative tracking and labeling systems, funded by Baltic Sea member countries and their agencies. However, so far, no convincing tracking systems could be found to reduce the impact of aquaculture gear by 2025. Studies on this issue are therefore on-going and discussed.

Some awareness raising activities in the aquaculture sector are on their way. The main focus of these activities is still the fishing sector, e.g. by island initiatives or the Fishing-For-Litter Initiative. Therefore, more ambition is necessary to ensure the reduction of marine litter by 2025 and the use of sustainable alternatives. Additional funding can be derived from the EPR schemes under the SUPD. The producers have to pay for awareness raising activities in a reasonable and transparent way, presumably organized via producer responsibility organisations (PRO).

Another approach discussed on national levels in some Baltic Sea Region countries is the introduction of deposit schemes for aquaculture and other fishing gear, mainly for passive fishing gear due to an easier implementation, to ensure a reduction of the marine litter by 2025 (Altvater et al., 2020).

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

5. Conclusions and recommendations

5.1. Conclusions

For the purpose of the present report, the main conclusions are presented considering the aquaculture factors included in the schematic tree.

1. Plastic industry expansion: Marine litter derived of plastic will increase because of the expected aquaculture and plastic industry expansion by 2025. No current real alternatives to this material for most of the plastic aquaculture gear exist.
   Moreover, mixed plastic is hindering an easy recycling process and a closed plastic life cycle due to the difficulty to separate different plastic elements. In consequence, old material is incinerated and more and more new materials are produced without using recycled gear due to high costs and very small amounts.
   Nevertheless, this growth will happen in parallel with the development of European and national policies, increase of the consumers' awareness and potential growing of the public interest on certified good practices. Therefore, in spite of the expected plastic marine litter expansion, a progressive reduction of the increase rate can be forecasted, that will probably become more significant in a long-term perspective (2030).
   The increase of plastic use is an issue which is expected at an European level, with no distinction of sea basin.
   Expectation by 2025: increase of plastic litter

2. Substitution of traditional materials: an increase of marine litter made of plastic materials between 2020 and 2025 is likely to happen, as a consequence of the progressive substitution of traditional materials like, for example, wood which is used in the traditional Spanish bateas. Currently, the use or the development of new applications based on additional materials are not being promoted, neither supported.
   Expectation by 2025: light increase of plastic litter.

3. Biodegradable plastic items: a light increase of the use of biodegradable plastics can happen by 2025. If their biodegradability characteristics are really adjusted for all environmental conditions and their resistance is improved in the next 5 years, the impact of their use could be positive. Nevertheless, part of the aquaculture sector is still reluctant to purchase biodegradable plastic instead of traditional plastic.
   Expectation by 2025: using more biodegradable plastics can lead to a decrease of marine litter made of traditional plastic. But this can happen only if their biodegradability characteristics are adjusted for all environmental conditions, their resistance is improved, their prices are reduced, and farmers' reluctance overcomed.

4. Other materials used in aquaculture: marine litter associated to non-plastic materials is expected to increase in 2025. Although some factors can lead to a potential

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

reduction of this litter (for example including specific criterias in the certification processes and increasing the aquaculture stakeholders' concerns regarding the negative impacts of these materials in the environment), their effects are not expected to compensate the increase of marine litter related to the expansion of the sector and the more frequent extreme weather events.
Expectation by 2025: increase of non-organic litter.

5. Facility stability: efforts are currently performed focused on increasing the facilities' robustness and improving the fixing systems (e.g. development of more solid infrastructures, finding alternatives to SUP fixing systems, proving specific trainings to the aquaculture personnel, among other). If these efforts are kept in time and are further developed in the coming years, the potential consequence will be a reduction of the marine litter by 2025.
   The North Sea and Baltic Sea basins are, in fact, the areas in which the reduction of marine litter related to the improvement of the fixing and anchoring systems is more likely to happen, especially for the finfish facilities which are located offshore for the North Sea and both finfish and shellfish in the Baltic Sea.
   Expectation by 2025: initiating a decrease of marine litter.

6. SUP elements: it is likely that marine litter from SUP will continue increasing by 2025, due to being widely used and not having current alternatives. Nonetheless, a light progressive reduction of the increase rate can be expected once new and improved European and national policies are in force. The linked litter is also expected to progressively reduce in parallel with the development of specific solutions for SUP elements like: increasing the awareness of the sector about their impact, supporting reseach focused on alternatives to current SUP and creating deposit schemes in the frame of the EPR systems.
   SUP elements are one of the biggest concerns of aquaculture from the shellfish production perspective, especially in the Mediterranean Sea and the North Sea, and their impact is expected to continue by increasing the marine litter. On the other side, some efforts are currently being done in the Baltic and North Sea regarding the on-going implementation of the European SUP Directive provisions, which can imply a clear reduction of their losses by 2025 in that area.
   Expectation by 2025: increase of plastic litter.

7. Tracking of valuable items: Efforts are being currently done from innovative perspectives (especially in the North Sea and the Baltic Sea) regarding the tracking of the valuable items from aquaculture. Although most of the technical initiatives are still facing some challenges, new improvements are expected to happen in a medium-term future (e.g. 2030). Therefore, no reduction or increase of the marine litter is forecasted by 2025, due to innovative solutions still under development.
   On the other hand, many gear producers offer maintenance services for valuable items like nets. The maintenance services can help to reduce the marine litter by 2025 by reducing losses and breakdowns.

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

Expectation by 2025: light decrease of marine litter related to the maintenance services for valuable items. On the other side, tracking systems are not likely to have any impact on the reduction of marine litter by 2025.

8. Personnel awareness: some efforts are currently being made to increase general concerns regarding the marine litter issue from sea-based sources, mostly related to the fishery sector. Nevertheless, there is a growing interest in involving, among others, the aquaculture farmers (e.g. AQUA-LIT project). In this context, the collaboration among farmers, gear producers and the fishery sector can help to frame partnership training schemes addressed to the aquaculture issues. If these efforst are maintained over time, they can lead to a progressive reduction of the marine litter by 2025.
   Expectation by 2025: decrease of marine litter if current efforts are more ambitious in the aquaculture sector.

9. Good practices in place performed by the farmers: those current good practices can imply an effective reduction of the marine litter by 2025 if they can be linked to a motivating certification and/or economic benefit. This trend can be expected considering that certification institutions like ASC and GLOBALGAP start considering potential marine litter as a certification criteria.
   Expectation by 2025: light decrease of marine litter if they could be linked to a motivating certification and/or economic benefit

10. Waste management system-collecting phase: Although the number of the disposal points and the sector's awareness is expected to grow by 2025 considering the European policy frame and the future national transpositions, it is likely that the accompanied needs of an aquaculture industry in expansion will not be completely covered in some European regions. As a consequence, an increase of the marine litter can be expected, although increasing rates will progressively disminish in parallel with the increase of disposal points with subsequent transport and treatment in accordance with upcoming EPR systems..
    In the case of the Baltic Sea region, some countries are discussing deposit schemes for aquaculture and other fishing gear to raise the amount of collected gear material for an economically sound recycling system. This can mean that by 2025 those countries could be able to collect mostly all the potential aquaculture litter.
    Expectation by 2025: depends on the status of the current national/regional management systems and the ability of each Member State or European region to put in place feasible disposal points.

11. Waste management system-recycling and upcycling phase: Some of the recycling and upcycling initiatives linked to aquaculture gear and equipment are already in place, but the majority of the current ones are in the testing phase. Therefore, although the impact of the recycling and upcycling initiatives is expected to be positive, it will not probably cover the full needs of an aquaculture sector in expansion by 2025.

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

Expectation by 2025: increase of non-organic litter while developing recycling and upcycling methodologies.

12. Clean up activities/monitoring programmes: monitoring and cleaning up initiatives can help to better understand the marine litter issue and to fill in the current knowledge gaps related to the impact from the aquaculture sector. Besides, they can help to arise the general concerns regarding the marine litter. Moreover, the information collected during these activities can have a positive impact on the specific European and national policies (by feeding the databases) and research institutions (as it will provide useful information for a better understanding of this global concern). However, clean-up measures need to be structured and administratively organised to support aquaculture farmers, facing unclarity about the costs of further treatment of ALDG; this may lead to increased delivery of these kind of gear materials to ports. All these positive effects are likely to lead to a general reduction of the marine litter by 2025.
Expectation by 2025: decrase of non-organic litter

5.2. Recommendations

This report is a first approach to forecast the potential increase or decrease of the marine litter that comes from aquaculture in a short-term period (by 2025). It has been based on literature research and the information collected through the participation of more than 120 stakeholders from 12 categories from the aquaculture industry chain in our four AQUA-LIT Learning Labs and interviews. As such, a considerable part of the information found here is subjective. However, the intention was to enrich the already published literature with information from the ground and direct experiences from the sector across Europe, to shed a light on the direction where more scientific research is needed.

This report thus, aims at pointing out the direction of what a more in-depth study should consider either for future iniciatives and/or research projects. We suggest to further develop and expand the methodology applied, and use the information provided as the basis to perform a most detailed analysis.

In this context, we propose some criteria and parameters that we consider need to be taken into account to be able to develop a more analytical perspective.

1. SDG were adopted by 2015, with a horizon of 15 years. This means that only 5 years have passed since their adoption, which is a short period considering the included ambitious goals. Therefore, in the next years, the SDGs will be continously implemented at a global level and this development will provide a more complete perspective of the achievements and the efforts needed from the sustainable aquaculture consumption and production point of view. Therefore, the impact analysis considering the expansion of the aquaculture under the SDG frame will become clearer in the short term.

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

2. The implications of the climate change in the aquaculture sector are expected to be more evident in the following years. Therefore, this can help to better **forecast the effects of the extreme weather events in the frequency of losses and breakdowns of the aquaculture gear and, thus, in the potential increase of marine litter**.

3. The **role of the gear manufacturers on the reduction of the marine litter** will be more understandable **once the European SUP Directive has been adopted by the Member States**, which will happen in 2021. Currently, the forecast can be approached considering that they will be responsible for the EPR systems, but the success of this depends on the status of the national waste management systems, their own national policies and their resources to stablish feasible EPR systems.

4. **Aquaculture certification bodies** are currently starting to consider the waste management criteria. Therefore, it is not possible to **assess the impact** of this measure. This part of the analysis will need to be developed once criteria have been included by the certification bodies and adopted by the farmers.

5. Ongoing legislation: the **SUP Directive** was adopted in 2019 and it **will be transponded by the Member States by 2021**. Currently, it is not possible to **analyse and quantify the impact of this regulation** regarding the increase or decrease of marine litter, as this can only be done once the Member States have implemented it under their national regulations. Similarly, the impact of the Port Facilities Reception Facilities legislation cannot be currently measured. Nevertheless, both legislations are expected to play a key role in the reduction of the marine litter, and they will have to be taken into account for in-depth impact analysis.

6. **Research on bioplastics, biodegradable plastics, circular economy, quantification of marine litter, microplastics**, among others, is being under development **at national, regional and international levels**. It is expected that the available information regarding all these topics will be further expanded in the next years. This will provide more precise data to fill in current knowledge gaps related to:

    a. Biodegradability of the biodegradable plastics.

    b. Resistance under harsh conditions of the alternatives to plastic (bio based materials and biodegradable plastics).

    c. Recycling and upcycling methodologies adapted to marine litter and/or aquaculture (and fishing) gear that has reached the end of life.

    d. Impact (quantification) of the aquaculture on the marine environment.

    e. Role of the aquaculture plastics regarding the microplastics.

    f. Current innovative solutions for tracking valuable items.

7. **Research and pilot cases on new aquaculture systems like IMTA** are ongoing and may bring new systems to the sea with less harmful impacts. It will be crucial to consider

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

material selection and recycabiltiy of these materials during the production processes and whether producers will apply approaches to reduce mixed plastic materials in collaboration with designers and other stakeholders.

8. Impact of the food transparency growing interest by the consumers and the new European legislation on the transparency of the risk assessment in the food chain, which was adopted in 2019. It will be essential to determinate if this increasing interest and policy concern has an impact on the aquaculture products and forces to the farmers to adapt their production to a more transparent and sustainable methodology.

9. Implications of the inclusion of waste management criteria by the good practices' certification bodies.

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

6. Annexes

Table 1: interaction between the external drivers and each of the factors.

	FACTOR 1	FACTOR 2	FACTOR 3
	Plastic in aquaculture	Traditional materials in aquaculture	Biodegradable plastic in aquaculture
External drivers	**Effects of the external drivers**		
Ensuring sustainable consumption and production pattern of aquaculture products in the European context	Expansion of the aquaculture	Expansion of the aquaculture	
		The European aquaculture industry is working towards achieving the environmental and social sustainability while being economically profitable	
Climate change	More losses and breaks are likely to happen under extreme weather conditions		
Gear manufacturers	Responsible for the Extended Producer Responsibility (EPR) by 2021	Progressive substitution of traditional materials	Developing alternatives to traditional plastic gear
	Developing alternatives to traditional plastic gear		
Plastic producers	Expansion of the plastic industry		
	Developing alternatives to traditional plastic materials		Developing alternatives to traditional plastic materials
Certification bodies	Certification bodies are starting to include waste management criteria regarding the aquaculture activities.	No significant interaction/Unknown	No significant interaction/Unknown
European policies and legislation	Clear involvement of the European institutions on the prevention and reduction of plastic marine litter from aquaculture	Testing traditional materials as an alternative to plastic material is not a priority under the European policy frame	The European Commission supports the development of innovations that ensure the biodegradability of these materials.
Research	Developing alternatives to the use of this material		The European Union has promoted the research on the biodegradable plastics in the last years.
Consumers	Increasing awareness of the consumers regarding marine litter.	No significant interaction/Unknown	Increasing awareness of the consumers regarding marine litter.

	FACTOR 4	FACTOR 5	FACTOR 6
	Other materials used in aquaculture	Facility stability	Single-Use-Plastic elements
External drivers	**Effects of the external drivers**		
Ensuring sustainable consumption and production pattern of aquaculture products in the European context	Expansion of the aquaculture		
	The European aquaculture industry is working towards achieving the environmental and social sustainability while being economically profitable		
Climate change	More losses and breaks are likely to happen under extreme weather conditions		
Gear manufacturers	No significant interaction/Unknown	Some initiatives have been recently developed by engineering and farm construction companies, in order to improve the facility's robustness	Responsible for the Extended Produder Responsibility (EPR) by 2021
Plastic producers	No significant interaction/Unknown	No significant interaction/Unknown	Expansion of the plastic industry
			Expansion of the SUP elements
			Developing alternatives to traditional plastic materials
Certification bodies	Waste management criteria are starting to be included in the good practices certification	No significant interaction/Unknown	Waste management criteria are starting to be included in the good practices certification
European policies and legislation	None of these types of materials is not a priority *per se* in the current European frame,	No significant interaction/Unknown	One of the current environmental priorities in the EU is reducing the SUP use
Research	None of these types of materials is not a priority *per se* at research level	Some initiatives have been recently developed by engineering and farm construction companies, in order to improve the facility's robustness	Developing alternatives to plastic material
Consumers	Increasing awareness of the consumers regarding marine litter.	No significant interaction/Unknown	Increasing awareness of the consumers regarding marine litter

	FACTOR 7	FACTOR 8	FACTOR 9
	Valuable items	Personnel awareness	Good practices in place performed by the farmers
External drivers	Effects of the external drivers		
Ensuring sustainable consumption and production pattern of aquaculture products in the European context	Expansion of the aquaculture	No significant interaction/Unknown	
	The European aquaculture industry is working towards achieving the environmental and social sustainability while being economically profitable		
Climate change	More losses and breaks are likely to happen under extreme weather conditions	No significant interaction/Unknown	
Gear manufacturers	Gear manufacturers are establishing suitable maintenance services for aquaculture nets	Lack of specific trainings provided by gear producers on facility stability, anchoring systems, SUP management, etc	Stablishing collaborations among different sectors, including gear producers, help to support individual good practices
Plastic producers	No significant interaction/Unknown	Lack of specific trainings provided by gear producers on facility stability, anchoring systems, SUP management, etc	No significant interaction/Unknown
Certification bodies	No significant interaction/Unknown	The inclusion of the waste management in the good practices certification can increase the consciousness of the aquaculture farmer	Lack of communication among farmers and certification bodies
European policies and legislation	No significant interaction/Unknown	Awareness activities regarding the plastic gear has to be covered by gear producers under the European SUP Directive	No significant interaction/Unknown
Research	Some initiatives focused on tracking valuable items are being tested	Collaborations in multiple projects and initiatives (e.g. Fishing for litter)	No significant interaction/Unknown
Consumers	No significant interaction/Unknown	Current clean up initiatives can help to increase their awareness level	Stablishing collaborations among different sectors, including consumers, help to support individual good practices

	FACTOR 10	FACTOR 11	FACTOR 12
	Waste management system-collecting	Waste management system: recycling and upcycling	Clean up activities/ monitoring programmes
External drivers	Effects of the external drivers		
Ensuring sustainable consumption and production pattern of aquaculture products in the European context	Expansion of the aquaculture		
	The European aquaculture industry is working towards achieving the environmental and social sustainability while being economically profitable		
Climate change	More losses and breaks are likely to happen under extreme weather conditions		
Gear manufacturers	Responsible for the Extended Producer Responsibility (EPR) by 2021		No significant interaction/Unknown
Plastic producers	Lack of a complete circular economy perspective in the plastic production		No significant interaction/Unknown
Certification bodies	Waste management criteria are starting to be included in the good practices certification		Some certification bodies are supporting volunteering clean up initiatives
European policies and legislation	Clear involvement of the European institutions on the improvement of the waste management		Development of the European frame regarding marine data from the aquaculture sector
Research	Some initiatives focused on recycling and upcycling valuable items like nets and ropes are being tested		Collaborations among research institutions and clean up /monitoring initiatives can help to increase the available data and its quality
Consumers	Increasing awareness of the consumers regarding marine litter		

* Negative interaction: potential increase of the marine litter due to the external driver effect on the factor

* Positive interaction: potential decrease of the marine litter due to the external driver effect on the factor

* No significant interaction/Unknown

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

Table 2: Summary of the aquaculture issues and the forecasted potential increase or decrease of marine litter per each of the factors.

FACTOR	ISSUES		CONCLUSIONS
Plastic in aquaculture	Plastic materials are widely used in the aquaculture sector due to their resistance and low cost		Plastic marine debris and marine litter will increase as a consequence of the aquaculture and plastic industry expansion by 2025. Nevertheless, a progressive reduction of the increase rate can be forecasted, that will probably become more significant in a long-term perspective (2030)
	It is generally considered that there is no real alternative to this material (e.g. biodegradable plastics are more expensive and less resistant)		
	Plastic gear and equipment are not biodegradable		
	Plastics can lead to an increase of the microplastics in the marine environment.		
Traditional materials in aquaculture	Traditional materials still used in small farming facilities are progressively substituted by non-traditional materials like polyethylene		A light increase of plastic marine litter by 2025 is likely to happen due to the substitution of traditional materials for plastic materials
Biodegradable plastics and bio plastics in aquaculture	Some farmers are reluctant to switch fro traditional plastic to plastic alternatives		A light increase of the use of biodegradable plastics can happen by 2025. Only if their lack of resistance and their biodegradability are improved while prices reduced and farmer's reluctance overcome, their use will potentially be related to a reduction of the marine litter by 2025.
	They are not resistant enough to harsh environmental conditions		
	They are more expensive than traditional plastic		
	Biodegradability levels are reduced in marine environments		
Other materials used in aquaculture	Some of these materials are biodegradable (e.g. wood)		Marine litter associated to the non-plastic materials used in aquaculture (including natural textiles, wood, rubber and metal, among others) is expected to increase in 2025 due to the more frequent extreme weather events, in parallel with the expansion of the aquaculture..
	The biodegradation process of the natural rubber is very slow, and can be mixed with other compounds which can have negative impact on the environment		
	Metals can be affected by corrosion		
Facility stability	European Parliament (2014) forecasted that by 2030 warmwater marine and shellfish aquaculture will expand to offshore/deeper water areas in the European context		It is expected that all current efforts from research centers and gear/facilities manufacturers (see external drivers) focused on increasing the facilities' robustness and to improve the fixing systems will be further developed in the coming years, and presumably initiate a decrease of marine debris by 2025
	Currently, lack of specific trainings to aquaculture personnel on the new fixing and anchoring systems.		
SUP elements	SUP gear is very frequent in the aquaculture facilities		It is likely that marine litter from SUP gear will continue increasing by 2025. Nonetheless, a light progressive reduction of the increase rate can be expected
	These elements are not frequently recyclable neither reusable		
	Usually, when they have reached the end of life, they are brought to the common dumpsters or simply abandoned during daily tasks		
	Low awareness in the sector regarding their impact in the marine environment		
	Lack of economical value		
	Lack of specific disposal points		
Valuable items	They are not usually abandonned at sea, but lost or broken due to major weather events or lack of maintenance		No reduction or increase of the marine litter is forecasted by 2025, due to innovative solutions are expected to be still under development. Besides, a light decrease of marine litter related to the maintenance services for valuable items can be expected
	As these are expensive items, farmers are very interested in recovering them before they end up as debris in the marine environment		
	Related innovative initiatives face some issues that need to be addressed in the short-term future, including: high associated costs, difficulties with the electronic monitoring in marine conditions, and GPS signals do not cover installations located further than 12 nautical miles from the coast		
Awareness	Most aquaculture stakeholders are slightly aware of the potential impacts of litter on the marine environment		There is a growing interest in involving the aquaculture farmers in marine litter activities. If general and specific awareness efforts are maintained over time, they can lead to a progressive reduction of the marine litter by 2025.
	There is still a clear need for more attention regarding this issue		
Good practices in place	Good practices applied by the farmers and currently in place are numerous, and they help to reduce the marine litter.		These current good practices would mean an effective reduction of the marine debris by 2025 if they could be linked to a motivating certification and/or economical benefit
	Most of these good practices have not been standardised or not even evaluated from the environmental or economical point of view		
	All those good practices are currently being performed under volunteer basis and there is no reinforcement or positive feedback to those applying them.		
Waste management system-collecting	Lack of efficient systems and facilities for collecting, storing, and processing of used gear and equipment		The impact of the collection system on the increase or decrease of marine litter strongly depends on the current status of each national/regional waste management system. Although the number of the disposal points and the sector's awareness is expected to grow, it is likely that the accompanied needs of an aquaculture expansion will not be completely covered in some countries. As a consequence, marine litter will probably increase by 2025.
	Resistance to collecting all types of materials in ports		
	In some Mediterranean countries, as there are no proper disposal points, farmers often burn the nets and pile barrels close to the ports		
	Waste management points (or recycling centers) are not usually near the collection points for aquaculture litter		
	There are no containers for small size material		
	Spatial conflicts with tourism		
	Directive (EU) 2019/883 on port reception facilities for the delivery of waste from ships refers only to nets as the passively fished waste		
	Fishermen may be asked to recover the nets but it only happens on a voluntary basis		
	The creation and development of feasible collection systems in the frame of the EPR schemes depends on lots of time, human and economical resources		
Waste management system-recycling and upcycling	Most of the recycling and upcycling initiatives in place in Europe are related to nets		Some of the recycling and upclycing initiatives linked to aquaculture gear and equipment are already in place, but the majority of the currently ones are in the testing phase. Therefore, although the impact of the recycling and upcycling initiatives is expected to be positive, it will not probably cover the full needs of an aquaculture sector in expansion by 2025 and there will be an increase of the marine litter.
	Some of these initiatives are already in place, but the majority are in the testing phase		
	Currently, circular schemes **to recycle end-of-life nets don't seem to be economicaly viable**.		
	Marine litter recycling is very difficult and expensive because of the degradation level and the mixture of materials		
	Market is not using all types of recyclable material		
	There are no plants adapted to recycle all types of material		
	There is a **shortage of protocols for cleaning and recovering materials** prior to recycling		
	Designers and manufacturers of aquaculture equipment are not sufficiently encouraged to be innovative		
	Recycling companies are located too far from the farm to collect, sort and recycle worn out gear and other waste		
Clean up activities/ monitoring programmes	Monitoring programmes can help to better understand the marine litter issue related to aquaculture		Monitoring and cleaning up initiatives can help to better understand the marine litter issue and to fill in the current knowledge gaps related to the impact from the aquaculture sector. Besides, they can help to arise the general concerns regarding the marine litter. All these positive effects are likely to lead to a general reduction of the marine litter by 2025
	Lack of data from many countries regarding aquaculture litter found on beaches, the sea surface and the seafloor		
	Lack of harmonization of the monitoring programmes and the quantification protocols between regions and countries		

VERY NEGATIVE IMPACT: POTENTIAL INCREASE

NON SIGNIFICANT IMPACT

VERY POSITIVE IMPACT: POTENTIAL DECREASE

EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

7. References

Altvater, S., De Raedemaecker F., Sandra M., Devriese L., Gin I., Vidal Rigo M., Alomar C., Deudero S., Mata Lara M. (2020). Learning Lab report Baltic Sea. D3.2 Aqua-Lit project. Berlin, Germany. 82 pp.

APROMAR (2019). La acuicultura en España 2019. Retrieved from:

Aquaculture Stewardship Council (ASC) (2020a). ASC's focus on Plastics, Marine Litter and Ghost Gear: https://www.asc-aqua.org/what-we-do/programme-improvements/gear-management/

Aquaculture Stewardship Council (ASC) (2020b). What is our approach: https://www.asc-aqua.org/what-we-do/our-approach/our-approach/

Bacher, K. (2015). Perceptions and Misconceptions of Aquaculture: A Global Overview. GLOBEFISH Research Programme, Vol. 120, Rome, FAO. 35 pp. Retrieved from: http://www.fao.org/3/a-bc015e.pdf

Béné, C., Barange, M., Subasinghe, R., Pinstrup-Andersen, P., Merino, G., Hemre, G.-H.-, Williams, M. (2015). Feeding 9 billion by 2050 – Putting fish back on the menu. Food Security – March 2015. DOI: 10.1007/s12571-015-0427-z.

Cao, L., Diana, J.S., Keoleian, G.A. (2013). Role of life cycle assessment in sustainable aquaculture. Reviews in Aquaculture nº 5, p. 61-71. doi: 10.1111/j.1753-5131.2012.01080.x

ClimeFish (2020). Climate change and impacts on aquaculture: https://climefish.eu/climate-change-and-impacts-on-aquaculture/

De Raedemaecker F., Sandra M., Devriese L., Gin I., Altvater S., Vidal Rigo M., Alomar C., Deudero S., Mata Lara M. (2020). *Learning Lab report North Sea*. D3.4 Aqua-Lit project. Oostende, Belgium. 71 pp.

European Commission (no data). EU approach to sustainable development: https://ec.europa.eu/info/strategy/international-strategies/sustainable-development-goals/eu-approach-sustainable-development-0_en

European Commission (2018). A European Strategy for Plastics in a Circular Economy. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Brussels. 18 p. Retrieved

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

from: https://eur-lex.europa.eu/resource.html?uri=cellar:2df5d1d2-fac7-11e7-b8f5-01aa75ed71a1.0001.02/DOC_1&format=PDF

European Commission (2019). A new dataset on alage production in Europe: https://ec.europa.eu/jrc/en/science-update/new-dataset-algae-production-europe

European Commission (2020a). Algae biomass production for the bioeconomy: https://ec.europa.eu/jrc/en/science-update/algae-biomass-production-bioeconomy

European Commission (2020b). Biodegradable plastics/Compostable plastics: https://ec.europa.eu/knowledge4policy/glossary/biodegradable-plastics-compostable-plastics_en

European Commission (2020c). Maritime Spatial Planning: https://ec.europa.eu/maritimeaffairs/policy/maritime_spatial_planning_en

European Parliament (2014). The Long-Term Economic and Ecologic Impact of Larger Sustainable Aquaculture. Directorate – General for Internal Policies – Policy Department B: Structural and Cohesion Policies – Fisheries. 100 pp. IP/B/PECH/IC/2013_162. PE 529.084. Retrieved from: https://www.europarl.europa.eu/RegData/etudes/STUD/2014/529084/IPOL_STU(2014)529084_EN.pdf

FAO (2008). Building an ecosystem approach to aquaculture. FAO Fisheries and Aquaculture Proceedings. No. 14. Rome. 231 p. Retrieved from: http://www.fao.org/3/a-i0339e.pdf

FAO (2010). Aquaculture development. 4. Ecosystem approach to aquaculture. FAO Technical Guidelines for Responsible Fisheries. No. 5, Suppl. 4. Rome. 53p. Retrieved from: http://www.fao.org/3/i1750e/i1750e.pdf

FAO (2016). Marine spatial planning for enhanced fisheries and aquaculture sustainability. Its application in the Near East. FAO Fisheries and Aquaculture Technical Paper. Nº 604. Rome. 104 p. Retrieved from: http://www.fao.org/3/a-i6043e.pdf

FAO (2018a). Achieving Blue Growth: Building vibrant fisheries and aquaculture communities. 28 p. ISBN 978-92-5-130771-7. Retrieved from: http://www.fao.org/3/CA0268EN/ca0268en.pdf

FAO (2018b). The State of World Fisheries and Aquaculture 2018 - Meeting the sustainable development goals. Rome. Licence: CC BY-NC-SA 3.0 IGO. Retrieved from: http://www.fao.org/3/i9540en/i9540en.pdf

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

FAO (2020). Sustainable Development Goals: conserve and sustainably use the oceans, seas and marine resources: http://www.fao.org/sustainable-development-goals/goals/goal-14/en/

Friend of the Sea (n.d.). Sustainable aquaculture: https://friendofthesea.org/sustainable-standards-and-certifications/sustainable-aquaculture/

GESAMP (2015). "Sources, fate and effects of microplastics in the marine environment: a global assessment"(Kershaw, P. J., ed.). (IMO/FAO/UNESCO IOC/UNIDO/WMO/IAEA/UN/UNEP/UNDP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection). Rep. Stud. GESAMP No. 90, 96 p. Retrieved from: https://ec.europa.eu/environment/marine/good-environmental-status/descriptor-10/pdf/GESAMP_microplastics%20full%20study.pdf

GGN Certified Aquaculture (n.d.). Aquculture in Europe: https://aquaculture.ggn.org/en/aquaculture-in-europe.html

Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) (2020): http://www.gesamp.org/work/groups/wg-43-on-sea-based-sources-of-marine-litter

Huntington, T (2019). Marine Litter and Aquaculture Gear – White Paper. Report produced by Poseidon Aquatic Resources Management Ltd for the Aquaculture Stewardship Council. 20 pp plus appendices. Retrieved from: https://www.asc-aqua.org/wp-content/uploads/2019/11/ASC_Marine-Litter-and-Aquaculture-Gear-November-2019.pdf

IPCC (2012). Summary for Policymakers. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 1-19. Retrieved from: https://www.ipcc.ch/site/assets/uploads/2018/03/SREX_FD_SPM_final-2.pdf

Iribarren, D., Moreira, M.T., Feijoo, G. (2011). Life Cycle Assessment of Mussel Culture. In *Mussels: Anatomy, Habitat and Environmental Impact* (Ed: Lauren E. McGevin), p. 357-377. Nova Science Publishers, Inc. ISBN 978-1-61761-763-8

Khoshnevisan, B., Rafiee S., Tabatabaci, M. (2018). Waste Management Strategies: Life Cycle Assessment (LCA) Approach. In *Biogas, Biofuel and Biorefinery Technologies* (Eds: Tabatabaci M. and Ghanavati H.), p. 305-331. Springer International Publishing AG. https://doi.org/10.1007/978-3-319-77335-3_12

Lusher, A.L.; Hollman, P.C.H.; Mendoza-Hill, J.J. (2017). Microplastics in fisheries and aquaculture: status of knowledge on their occurrence and implications for aquatic organisms

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

and food safety. FAO Fisheries and Aquaculture Technical Paper. No. 615. Rome, Italy. Retrieved from: http://www.fao.org/3/a-i7677e.pdf

Martínez-Porchas, M., Martínez-Córdova L.R. (2012). World aquaculture: environmental impacts and troubleshooting alternatives. The ScientificWorld Journal, volume 2012. DOI:10.1100/2012/389623

Memet, J.B. (2007). The corrosion of metallic artefacts in seawater: descriptive analysis. In Corrosion of Metallic Heritage Artefacts (Eds. Dillmann P., Béranger, G., Piccardo, P. and Matthiesen, H.) p. 152-169. European Federation of Corrosion (EFC) Series. https://doi.org/10.1533/9781845693015.152

PlasticsEurope (2019). Plastics – the Facts 2019: https://www.plasticseurope.org/application/files/9715/7129/9584/FINAL_web_version_Plastics_the_facts2019_14102019.pdf

Rech, S., Salmina, S., Borrell Pichs, Y.J., García – Vázquez, E. (2018). Dispersal of alien invasive specied on anthropogenic litter from European mariculture areas. Marine Pollution Bulletin 131, pp 10-16. https://doi.org/10.1016/j.marpolbul.2018.03.038.

Rose, K. And Steinbüchel, A. (2005). Biodegradation of Natural Rubber ad Related Compounds: Recent Insights into a Hardly Understood Catabolic Capability of Microorganisms. Applied and Environmental Microbiology 71(6), pp 2803-2812. DOI: 10.1128/AEM.71.6.2803-2812.2005

Rujnić-Sokele, M. and Pilipović, A. (2017). Challenges and opportunities of biodegradable plastics: a mini review. Waste Management & Research 35(2), pp 132-140. DOI: 10.1177/0734242X16683272

Sandra M., Devriese L., De Raedemaecker F., Lonneville B., Lukic I., Altvater S., Compa Ferrer M., Deudero S., Torres Hansjosten B., Alomar Mascaró C., Gin I., Vale M., Zorgno M., Mata Lara M. (2019). *Knowledge wave on marine litter from aquaculture sources*. D2.2 Aqua-Lit project. Oostende, Belgium. 85 pp.

Stavrakidis-Zachou, O. Papandroulakis, N., Sturm, A., Anastasiadis, P. Wätzold, F., Lika, K. (2018). Towards a computer-based decision support system for aquaculture stakeholders in Greece in the context of climate change. Int. J. Sustainable Agricultural Management and Informatics, Vol. 4, Nos.3/4, p. 219-234.

The World Bank (2013). Fish to 2030: Prospects for Fisheries and Aquaculture. World Bank Report Number 83177-GLB. Retrieved from: http://www.fao.org/3/i3640e/i3640e.pdf

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.

United Nations, Department of Economic and Social Affairs, Population Division (2015). Population 2030: Demographic challenges and opportunities for sustainable development planning (ST/ESA/SER.A/389). Retrieved from: https://www.un.org/en/development/desa/population/publications/pdf/trends/Population2030.pdf

United Nations, Department of Economic and Social Affairs, Population Division (2019). World Population Prospects 2019: Highlights (ST/ESA/SER.A/423). Retrieved from: https://population.un.org/wpp/Publications/Files/WPP2019_Highlights.pdf

United Nations (2020). Sustainable Development Goals Knowledge Platform: https://sustainabledevelopment.un.org/?menu=1300

Vermeirseen, E.L.M., Dietschweiler, C., Werner, I., Burkhardt, M. (2017). Corrosion Protection Products as a Source of Bisphenol, A and toxicity to the Aquatic Environment. Water Res., pp. 586-593. doi:10.1016/j.watres.2017.07.006

Vidal M., Alomar C., Deudero S., Zorgno M., De Raedemaecker F., Sandra M., Devriese L., Gin I., Altvater S., Mata Lara M. (2020). *Learning Lab report Mediterranean Sea*. D3.3 Aqua-Lit project. Palma, Spain. 88 pp.

Viool V., Oudmaijer S., Walser B., Claessens R., van Hoof L, Strootman W.J. (2018). Study to support impact assessment for options to reduce the level of ALDFG. European Commission. Framework Contract EASME/EMFF/2016/029. Retrieved from: https://webgate.ec.europa.eu/maritimeforum/en/system/files/Final%20Report%20Plastics%20from%20Fishing%20Gear%20Delivered.pdf

Werner, S., Budziak, A., van Franeker, J., Galgani, F., Hanke, G., Maes, T., Matiddi, M., Nilsson, P., Oosterbaan, L., Priestland, E., Thompson, R., Veiga, J. and Vlachogianni, T. (2016) Harm caused by Marine Litter. MSFD GES TG Marine Litter - Thematic Report; JRC Technical report; EUR 28317 EN; doi: 10.2788/690366. Retrieved from: https://publications.jrc.ec.europa.eu/repository/bitstream/JRC104308/lbna28317enn.pdf

This project has received funding from the European Union's EASME-EMFF funding programme under grant agreement EASME/EMFF/2017/1.2.1.12/S2/04/S12.789391.