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WP 3 – Policy and markets

Task 3.1 Review of regulatory and legislative issues for the circular economy in aquaculture

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1. Executive summary

Aquaculture in the EU has experienced a low growth over the last decades. It competes with other economic sectors and it is also necessarily and accordingly regulated to guarantee environmental protection and the social uses of coastal and other aquatic sites.

Sustainable growth is thus the only option to increase the productivity of EU aquaculture, and for this purpose, the eco-intensification of this economic activity has been proposed. Eco-intensification is a concept that includes components of circular economy and involves an increase in productivity, balanced with the necessary environmental protection and in the case of aquaculture, animal welfare.

This white paper is one of the outcomes of the H2020-funded project GAIN (Green Aquaculture Intensification in Europe). GAIN is a collaborative project designed to support the ecological intensification of aquaculture in the EU and the European Economic Area (EEA), with the dual objectives of increasing production and competitiveness of the industry, while ensuring sustainability and compliance with EU regulations on food safety and environment. GAIN, as a whole, aims to contribute to transform EU aquaculture, still a largely lineal economic sector, through the implementation of circular economy principles and concepts.

This document builds on a previous policy and regulation analysis (D3.1)¹ carried out within GAIN to detect gaps and opportunities based on current directives and provide recommendations to adapt the regulatory framework to address the challenges to implementation of the circular economy. The above analysis also reviewed the specific situation of the aquaculture sector regarding the opportunities for its transition to the circular economy, addressed by specific strategies. According to the conclusion of the report, current relevant policies are restricting the implementation of circular processes. Despite this drawback, the opportunities derived from the use of residual side streams or by-products as raw materials reveal scenarios for the sustainable intensification of aquaculture in the EU. The sector interests could benefit from higher flexibility in terms of the total or partial reuse and/or recovery of the unused or under-used animal by-products, sludge, wastewater, and other resources, proposing economic and environmental viable solutions to promote the long-awaited lift towards eco-intensification.

¹ Mohamed Soula, Richard Newton, Carlos Ruiz, Leticia Regueiro, Diego Mendez, Martiña Ferreira, Johan Johansen, David Little. Report on legislation, regulation, and certification of aquaculture within the circular economy. 2019. Deliverable 3.1. GAIN - Green Aquaculture INtensification in Europe. EU Horizon 2020 project grant nº. 773330. 73 pp.

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2. Introduction

Aquaculture products in the EU are farmed accordingly to high standards of food safety and quality, environmental protection and labour conditions. Initiatives aimed to boost the productivity and competitiveness of EU aquaculture must be aligned to these bedrock principles.

The EU is in the position to launch strategies and policies to support the environmentally sustainable intensification, or eco-intensification, of aquaculture production, drawing on its technological and professional capacities and the corpus of available scientific and technical knowledge.

The eco-intensification of EU aquaculture must integrate complementary lines of action:

- Contribution to the development of the proper political and regulatory framework for the implementation of circular economy principles applied to aquaculture production.
- Creation of value from by-products and other side streams within the aquaculture sector, or by transferring to other productive sectors and vice versa.
- Demonstration of the contribution of the developed value chains to the economic and environmental sustainability of aquaculture.
- Provision of guidelines and recommendations to farmers and policy-makers for sustainable ecological and economic intensification.
- Education of consumers to raise awareness on the need to move from current production and consumption models to a more sustainable consumption behaviour.

Eco-intensification of aquaculture may bring a series of benefits for the European society, economy and environment:

- For consumers: more availability of healthy and safe aquaculture products, with affordable prices and guaranteed traceability.
- For business: opportunities for the development of new value chains based on circular economy. More security in the availability of supplies. Less pressure or dependence from/on third-country imports. Lower production costs and less environmental taxes, e.g. waste and wastewater management.
- For the environment: improvement of the environmental status at local and global level; higher welfare of farmed aquatic animals.
- For the society: opportunities for job creation, particularly in rural areas contributing to sustainable communities; better coexistence of the uses of coastal and waterside areas.

The implementation of circular processes in the EU aquaculture can pose a contribution to the EU commitment to the UN Sustainable Development Goals (SDGs), through the enhancement of responsible consumption and production and the sustainable management of natural resources, as well as through the support to the sustainability of rural communities.

A common approach for aquaculture eco-intensification is required at EU level to reach critical mass and demonstrate circular processes at a scale enough to create a significant impact and provide technical, economic and environmental evidence to support the introduction of policies and regulations on this field.

This document aims to provide a view on the position of aquaculture in a context of rising of the circular economy in the EU. With new strategies and policies rolling out, EU aquaculture must exploit the opportunities to adapt policies and regulations, or to take an active role in developing new directives, in order to meet its needs in the transition to circular processes.

3. Vision

The EU has launched the European Green Deal², the roadmap for making EU's economy environmentally sustainable, through actions targeted to move to a circular economy which boosts the efficient use of resources, to restore biodiversity and to cut pollution. As part of this agenda, a new Circular Economy Action Plan³ has been recently published. Building on actions implemented since 2015 when the first Circular Economy Action Plan⁴ was launched, the new action plan aims to involve economic actors, consumers, citizens and civil society organisations in the dynamisation of the regulatory framework, so that opportunities from the transition are maximised, while minimising burdens on people and businesses. The objective is to make sustainable products, services and business the norm, not the exception. For this purpose, a strong and coherent product policy framework must be created.

This action plan opens a new horizon for the implementation of circular economy in aquaculture production. One of the most important changes with regard to the 2015 action plan is that food, water and nutrients are considered one of the key resources and thus will be given priority on policy development. Another critical aspect for the success of this strategy towards circular economy is the creation of a well-functioning internal market for high quality secondary raw materials, which ensures that resources are kept in the EU economy for as long as possible. Both initiatives must be put together in order to lift some of the barriers that currently block the incorporation of aquaculture side streams to circular value chains. Main burdens in this sense are the lack of measures to incentive or enforce their reinjection on

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²COM(2019) 640 final.

³COM(2020) 98 final. ⁴COM(2015) 614 final.

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productive schemes and the poor development of a stakeholder network which fosters the collection of the different types of aquaculture waste, their transformation into secondary raw materials and their reintroduction in the value chain. Whereas other goods such as electronic devices or vehicles are under the scope of directives regulating recyclability, life span, reusability, repairability or the introduction of recycled materials in manufacturing, directions to prompt circularity in aquaculture processes are still missing. In order to confirm the environmental performance of candidate circular processes and derived products, it is essential to develop impact assessment methodologies that encompass the particular features of food production and specifically of aquaculture. Currently available methodologies fail to take into account impact indicators typical of biological systems. Procedures must be harmonised to create an impact assessment "toolbox" that integrates the strengths of consolidated methodologies such as Life Cycle Assessment (LCA) with the incorporation of ad hoc indicators to track the environmental impact of aquaculture products, particular those from processes where circularity approaches are applied.

The acknowledgement of considering food, water and nutrients as key resources is reflected on the tools the Commission aims to develop on this purpose. It is foreseen that an Integrated Nutrient Management Plan3 will stimulate markets for recovered nutrients and ensure more sustainable use. Likewise, the new Water Reuse Regulation3 will facilitate water reuse and efficiency, both in agriculture and in industrial processes. Nevertheless, a comprehensive exploration of all possible ways of maximising the recovery of these resources is required. Current wording of the Circular Economy Action Plan does not point out particular productive sectors, so aquaculture must demonstrate its potential to develop circular economy on its own context or in connection with other productive sectors, and the need to accordingly develop a specific policy and regulatory framework as part of the global strategy on biological resources. This should include the revision and update to current scientific and technical knowledge of relevant in force regulations which may hinder the options to upgrade aquaculture outputs.

4. Current situation and possible perspectives for the ecointensification of aquaculture

Eco-intensification of European aquaculture is a transdisciplinary challenge that requires the integration of scientific and technical innovations, new policies and economic instruments, and the mitigation and, if possible, removal, of social constraints. The design of a strategy towards this goal reveals that the creation of the appropriate social and policy framework is a crucial aspect. Whereas technical and scientific developments attempt to use process inputs more efficiently and to create value from outputs, an actual impact of these advances on the ecological intensification of aquaculture can only be reached if their implementation is

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Social perception is an important issue, not only due to its role as a driver for policy development, but mostly because consumers' decisions may determine the success or the failure of measures to introduce new production processes and new products. Successful communication of the benefits of circular economy innovations, taking into account public perception over food safety and other issues, is key to successful implementation. On the other hand, the implementation of circular processes also relies on the receptivity of aquaculture companies. It is uncertain that industry can be involved in eco-intensification exclusively through the enforcement of regulations dealing with stringent measures e.g. on the disposal of outputs in order to minimise environmental footprint. When different options for managing waste and side streams are available, incentive schemes should exist in order to encourage the choice of those with the highest potential to increase aquaculture productivity, besides guaranteeing environmental protection.

Thus, guidelines to foster the eco-intensification of EU aquaculture must cover the following aspects:

- Identification of those areas with highest potential for eco-intensification, regarding the sustainability and efficiency on the use of resources and the creation of value from process side streams, and whenever possible prioritising the reinjection into aquaculture production chains.
- Analysis of the regulatory aspects affecting the creation and implementation of the potential valorisation routes for each input or output.
- Proposals for the adaptation of policies and regulations to enable the implementation of those valorisation processes as industrial practice.
- Effective communication and dissemination strategies that facilitate adoption.

4.1. Identifying the potential for eco-intensification of EU aquaculture

EU aquaculture produced 1.4 million tonnes of aquatic organisms in 2017, worth 5.1 billion \in . Fish and bivalve molluscs make for almost the whole of this production. Approximately 219,000tonnes correspond to marine fish, 500,000 tonnes to freshwater fish and 623,000 tonnes to bivalves, with respective values in first sale of 1.4, 2.2 and 1.2 billion \in ⁵. Other aquaculture activities such as the rearing of other invertebrates –crustaceans, echinoderms

⁵EUROSTAT, 2020. <u>https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=fish_aq2a&lang=en</u>. Accessed on 23-03-2020.

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or gastropods- and seaweeds contribute a small fraction of EU production.

Specific culture systems for the variety of reared organisms coexist in the EU, with different production capacities and intensiveness degree:

- Intensive fish farming may be land-based (fish are reared in tanks or ponds) or off-shore (fish are reared in cages in the environment). Both systems are used for marine and freshwater fish, though off-shore aquaculture is typically practised in marine sites. Land-based aquaculture facilities may be open-flow, if water is constantly fed (pumped or by gravity) in and discharged after passing through the system, or recirculating aquaculture systems (RAS), where culture water is treated and reused, and only a low percentage, up to 10 %-15 %, is exchanged daily.
- **Extensive fish farming** consists on the rearing of fish in estuaries or ponds at low biomass densities. In this type of farming, farmers provide a limited amount of feed and sometimes fertiliser to encourage primary productivity, so fish largely rely on natural feed sources.
- **Bivalve aquaculture** is by concept extensive or semiextensive, since individuals rely exclusively on natural food, i.e. phytoplankton and microplankton. Nevertheless, culture density may be high in terms of biomass per production unit, such as the case of mussel rafts. Hatcheries where bivalves are reared from larval stages to spat are an exception to this model, since feed is supplied as onsite cultured microalgae, but this is only feasible in the first stages of the production cycle.

Typical inputs in aquaculture systems -excluding reared animals- are: feed (for fish and for bivalves in hatcheries), water, energy (electric power, for lights, pumps, water treatment and heating), miscellaneous consumables (nets, mesh, ropes, buoys) and chemicals and drugs. Aquaculture outputs other than the marketed products are: by-products from fish and shellfish processing -viscera, heads, spines, trimmings, shells-, mortalities and discards, solid waste or sludge as faeces and uneaten feed, wastewater loaded with particulate and dissolved organic and inorganic matter and miscellaneous waste (plastic, etc.). It is obvious that resource consumption strongly differs among intensive and extensive aquaculture systems, and so does the generation of side streams and the feasibility of recovery and reintroduction in productive processes.

Considering the economic and environmental cost of the different aquaculture inputs and outputs, the development of circular processes must focus on fish feed, side streams from product processing, mortalities, bivalve shells, sludge and dissolved and particulate matter.

Although fin-fish aquaculture has low feed conversion ratios (FCRs) compared to terrestrial livestock, they often compete for similar resources. Most aquaculture Life Cycle Assessments have demonstrated that the embodied impacts of feed contribute in excess of 90% of the environmental footprint of production. Therefore, it is important to improve the efficiency of feed conversion and provide more sustainable ingredient supplies. Much of the focus on

sustainable ingredient supply has been concerning marine ingredients; fishmeal and fish oil as important dietary components of aquafeeds. Even though advances in formulation have enabled to drastically reduce the use of fishmeal and fish oil in aquafeeds, aquaculture still consumes around 70 % of the world supply of these ingredients⁶. FAO calculations⁷ forecast a 19 % increase of the global production of fishmeal and fish oil in 2030 compared to 2016, reaching 5.3 and 1.0 million tonnes respectively. Simultaneously, the amount of fishmeal and fish oil obtained from by-products are predicted to increase from 30 % to 34 %⁸ of total production. Europe manufactures almost as much fishmeal and fish oil from by-products as from wild-caught forage fish; nevertheless, aquaculture contributes to a low percentage of the total of by-products which are processed for both ingredients.

Since fish by-products are a low value resource, economies of scale play an important role to make them attractive for valorisation. An increasing proportion of fish is processed before reaching the final consumer thus rendering more by-products available for the production of fishmeal and fish oil, but logistics and manufacturing schemes must be accordingly implemented. On the other side, fishmeal and fish oil of European origin may have advantages at achieving certifications thanks to more accurate traceability and assumed more sustainable production.

Besides processing side streams, aquaculture facilities often generate dead fish during the normal production period. These may be culls at grading, damaged fish or weak fish that succumb to competition within the culture environment. There may also be larger mortality events due to disease or other reasons different than slaughtering for human consumption. Dead fish (morts) are also a by-product, but EU legislation strongly restricts their utilisation as animal feed and limits applications to lower added-value uses such as biogas or fertilisers, which in many occasions discourages their valorisation and prompts their management as waste instead. The upgrading of mortalities and similar residues to high-value applications poses a great challenge from the technical and the regulatory point of view, related to product safety.

Bivalve shells are a locally abundant aquaculture animal by-product (ABP). It was estimated that 35,000 tonnes of mussel shell and 56,000 tonnes of oyster shell were generated in 2017 in Galicia and France respectively. The interest on the valorisation of this residue relies on its calcium content and mineral nature, as feed additive, fertiliser, or soil amendment. Other applications e.g. as construction material are also receiving attention. Nevertheless, the opportunity for adding value is very low and uses in aquaculture seem to be limited to their use in RAS as a substrate for the growth of nitrifying bacteria and to maintain pH and alkalinity,

⁶Jackson, A. 2016. Fishmeal & fish oil. Its role in sustainable aquaculture. Symposium on Perspectives for Fishmeal and Fish Oil. Hirtshals, Denmark, August 29-30, 2016.

⁷FAO. 2018. The State of World Fisheries and Aquaculture 2018 - Meeting the sustainable development goals. Rome. Licence: CC BY-NC-SA 3.0 IGO.

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or as substrate for the attachment and growth of bivalve larvae or seaweeds.

The interest in water reuse in land-based aquaculture facilities relies mostly on economic reasons, related to saving energy for pumping and heating or cooling. Freshwater is a highly valuable and scarce resource in some EU countries which may be affected by shortages in some times of the year; additionally, the use of freshwater for industrial purposes is often affected by taxes aimed to the protection and restoration of aquatic ecosystems, which is another way to stimulate measures to water reuse. When considering aquaculture effluents, discharged organic and inorganic matter cannot be disregarded since they constitute an interesting source of nutrients for aquaculture, agriculture and bioprocesses. Notwithstanding this potential, discharge with previous treatment when needed is the predominant fate for aquaculture effluents in the EU. However, in flow through systems the cost of collecting effluent outweighs its value in any application, although if treatment/reuse allows for higher production, this could be of interest. As more RAS systems are favoured, particularly for smolt production, then the use of aquaculture sludge/effluent is becoming more interesting for value addition.

Sludge of variable solids content may build up to high amounts in land-based aquaculture or on the seabed underneath mussel rafts or marine fish cages. This material is made up of faeces and uneaten feed and therefore rich in organic matter and can accumulate under sites with poor water current flow. Valorisation processes such in situ co-incineration, biogas production or fertilisers manufacturing can be applied to sludge, although circular alternatives would be possible to reintroduce this waste into aquaculture production, mainly related to integrated multi-trophic aquaculture (IMTA) or aquaponics. Although there has been interest in such systems for several decades, it has not become economically viable at large scales in Europe.

4.2. Current policy framework regarding aquaculture eco-intensification

When analysing the regulatory context that applies to the implementation of circular economy in aquaculture, different scenarios can be found:

- In some cases, legal restrictions constraint the full implementation of circular processes. This applies e.g. to the consideration of Category 2 aquaculture animal by-products (ABPs), that are globally considered as high-risk material, which strongly constraints their options for valorisation. Another example could be the use of fish waste to feed filter- or deposit-feeding invertebrates. In these situations, a revision of in-force regulations to promote changes is relevant. Current science knowledge may provide enough support for regulatory modifications, but in some cases, further research or technical advice may be necessary.
- Some particular processes of aquaculture production may be subjected only to lax legal restrictions, or these may not exist at all, due e.g. to the low environmental impact or to the presence of regulatory gaps. In this context, it must be considered whether it is

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appropriate to introduce new legislation forcing circularity in view of environmental protection or if on the contrary, the implementation of circular processes should be encouraged rather than imposed, through incentives such as tax benefits or ecolabelling. Examples of this may be water reuse or the discharge of N and P through effluents.

 In occasions, decisions behind the implementation of circular processes, such as integrated multi-trophic aquaculture (IMTA) or aquaponics, are likely to be of economical nature exclusively. In this scenario, the policy approach must focus on the support to companies for the purchase of technology and process development in order to foster the creation of circular value chains. Tax benefits and environmental certifications may act as incentives as above.

The diversity of situations shows that each case requires a specific and comprehensive analysis. Whereas some areas that are related to circular economy are widely approached by current legislation, in other cases there are clear gaps. Overregulation may unduly restrict the implementation of circular processes; on the other side, the existence of legal gaps may equally create burdens to circular economy, either due to regulatory reasons or to the lack of interest on this type of processes and the preference for non-circular alternatives. Thus, the creation of the appropriate legal framework in view of enabling the implementation of circular processes in aquaculture involves different strategies, from adapting extant regulations to creating new ones from scratch.

5. Strategies to promote eco-intensification of EU aquaculture via revision of the regulatory framework

To unlock the potential for the eco-intensification of EU aquaculture, action has to be taken at multiple fields and involving all relevant players (industry, regulatory bodies, advisory entities, consumers), in order to create critical mass and significant impact in terms of economic profit and environmental sustainability. Whereas regulatory gaps and barriers are a fact, other burdens exist related to technical capacities, economies of scale, business models, logistics and markets, which highlights the need for a holistic approach. This transdisciplinary challenge involves research and technical innovation, mitigation of social constraints and specially, the development of *ad hoc* policies.

Focusing on policies, the different categories of regulatory aspects affecting ecointensification of the EU aquaculture require different approaches to be satisfactorily revised and eventually modified in order to promote circularity in the field, provided that food and feed hygiene and safety are guaranteed, as well as human and animal health standards.

Regarding current situation to address the potential for improvement, it must be considered

that technological development is well-stablished to drive eco-intensification changes. In some cases, there is scope to optimise available technology, along with solid-based scientific knowledge which however may need to increase the verification grade. Notwithstanding that, the greatest challenge lies on the regulatory aspects, which should be rethought to promote eco-intensification (Figure 1).



Figure 1. Percentage of current progress/advance in the three pillars in which to boost the eco-intensification in aquaculture.

5.1. Scientific and technical knowledge as support to lift regulatory barriers

EU legislation provides the highest standards on consumers protection through strict regulations on food and feed safety and hygiene and on human and animal health. Notwithstanding, the question arises whether these rules could be posing excessive burdens to the full capacity of EU aquaculture to valorise resources and develop circular processes. Considering the inarguable principles of health and safety, but also environmental, economic and social needs, an examination of the latest scientific and technical evidence is essential to revise existing regulations and determine whether some restrictions are still realistic in view of current knowledge, or whether they can be partially alleviated. Observing these rules, innovative technical approaches may result in realistic options for the valorisation of a range of aquaculture side streams, provided other constraints, e.g. economics or consumer

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acceptance are solved. However, some cases may require further research to demonstrate that certain restrictions to circular processes can be lifted with no risks to human or animal health.

5.1.1. The case of aquaculture ABPs

ABPs provide a good example of an extensive body of regulations which may be too restrictive and that could be revised and improved in benefit of a more efficient upgrading of a valuable resource.

Classification, use and disposal of ABPs are strictly regulated in the EU^{9,10}. Notwithstanding, EU regulations acknowledge that "progress in science and technology may lead to the development of processes which eliminate or minimise the risks to public and animal health. Amendments to the lists of animal by-products set out in this Regulation should be possible, in order to take account of such progress". Hence, the development and implementation of alternative methods for the use of ABPs is allowable, provided those methods are equivalent to standard processing methods in terms of reduced risk to public and animal health.

Aquaculture ABPs classified as Category 3 according to Regulation (EC) No 1069/2009 are low risk, e.g. by-products from slaughtered fish after filleting or other processing. These ABPs can be used to produce fishmeal and fish oil as ingredients for feed through one of the seven authorised processing methods. Nevertheless, the regulation provides flexibility on the procedures to process Cat. 3 aquaculture ABPs, provided that relevant hazards for animal health in the starting material are identified and reduced to a non-significant risk after treatment, and that the final product complies with a set of microbiological standards. This expands the range of viable methods to process Category 3 ABPs, not only for the production of fishmeal and fish oil but for more valuable products, such as protein hydrolysates and peptides. The design of feasible and cost-effective processing methods, together with a prompt authorisation mechanism, is the way forward to maximise the valorisation of Category 3 ABPs.

Category 2 ABPs includes farm mortalities due to diseases or any other cause, e.g. hypoxia, slaughtered animals for any other reason than human consumption, and contaminated material. Mixtures of Category 3 and Category 2 ABPs are classified as Category 2, regardless of the proportion and the type of Category 2 ABPs; likewise, animals killed for disease control are considered Category 2 even when they may not be clinically ill or infected. Valorisation options for this leads to a poor degree valorisation of Cat. 2 ABPs, which is restricted to low value applications, e.g. to biogas, organic fertilisers, feed for non-farm -except fur- animals, cosmetic, medical and veterinary products, medical devices or composting. Legislation does

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⁹ Regulation (EC) No 1069/2009

¹⁰ Regulation (EU) No. 142/2011

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not take into account the wide variety of Category 2 ABPs and therefore the different degree of hypothetical risk, even the absence of risk, to human and animal health.

Category 2 ABPs may be processed by four out of the seven methods authorised for Cat. 3 ABPs. Nevertheless, current regulation may be creating inconsistencies related to safety criteria for both types of ABPs. Whereas regulation establishes microbiological only for one out of the seven methods authorised for Cat. 3 ABPs, it follows that any other processing method effectively guarantees the same safety standards, and that this is applicable to both Cat. 3 and Cat. 2 ABPs. It follows that Category 2 ABPs which pose no risks other than microbiological -e.g. chemical contamination- could yield a final product as fit as a Category 3 ABP after processing. It must be also highlighted that, whereas Category 3 ABPs, including aquaculture by-products, can be used to produce aquafeed ingredients, fish pathogens are excluded from microbiological standards in current legislation, when this should be an essential criterion to demonstrate the safety of a fish feed ingredient regarding animal health.

5.1.2. The case of regulatory restrictions and gaps on the implementation of IMTA

In an IMTA system, an external feed input is supplied to a high-trophic level species (e.g. fish or shrimp), and two side streams are generated: particulate organic matter and dissolved organic and inorganic nutrients. Thus, two additional trophic levels can be added to the system: a filter-feeder (bivalves, anemones) or a detritivore (sea urchins, sea cucumbers) to feed on particulate matter and seaweeds to uptake dissolved nitrogen and phosphorous.

In the EU, the use of animal waste to feed other animals is banned¹¹, thus posing strong restrictions to the use of filter-feeders or detritivores in IMTA schemes and the implementation of circular economy in EU aquaculture. The precautionary principle behind the ban on the use of animal waste as feed is related to the preservation of animal health and eventually, the potential risk of disease transmission to humans. Nevertheless, it can be questioned whether the restriction is excessive in view of the likelihood of disease transmission between fish and filter- or deposit-feeders. The regulation envisages a crossed infection from fish to invertebrates, but the other way round seems to be more realistic, since invertebrates may act as reservoirs of fish pathogens but the opposite is an unlikely event. In any case, this is an example of the need to increase knowledge and support regulations on science-based evidence. Technical arrangements such the use of separate tanks for each species and the maintenance of a one-way water flow from fish to invertebrate tanks would also contribute to avoid the risk of infection for fish.

Regarding human health, the risk of transmission of diseases typical of aquatic animals is negligible. On the other hand, the safety of the bivalves and by analogy other aquatic invertebrates that are placed on the market is guaranteed by Regulations (EC) No 853/2004 and (EC) 854/2004. In an indirect way, Regulation (EC) No 853/2004 might entail an additional

¹¹ Regulation (EC) No. 767/2009.

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restriction, or a gap, on the rearing of these organisms in IMTA, since it defines bivalve production areas as any sea, estuarine or lagoon area containing either natural beds of bivalves or sites for cultivation. The rearing of bivalves or deposit-feeders in IMTA systems during juvenile stages, far before commercial size, could be a halfway solution to circumvent current regulatory restrictions and introduce IMTA circular processes. This could particularly contribute to the expansion of hatchery bivalve aquaculture, in which feed production is the largest operational cost.

5.2. Regulatory incentives and demonstration of economic performance as drivers for aquaculture eco-intensification

Certain types of aquaculture side streams are not efficiently valorised due to the absence of regulations that promote their use. Aquaculture sludge, composed of particulate matter, was typically dispose of or used for low value application such as the production of biogas. An opportunity for the upgrading of sludge arose with the 2015 Circular Economy Action Plan, which identified the need for new valorisation routes for organic waste materials whose nutrient content made them appropriate to be used as fertilisers. Nevertheless, at that time, differences in rules as well as in quality and environmental standards among MS hampered the circulation of fertilisers based on recycled nutrients in the EU: as a result only conventional non-organic fertilisers could be freely traded¹². As part of the implementation of the 2015 Action Plan, this regulation was revised and recently replaced by Regulation (EU) 2019/1009 which harmonises the requirements for fertilisers produced from organic primary or secondary raw materials. It is expected that this new regulation will increase the interest towards organic-rich side streams such as aquaculture sludges.

The valorisation of sludges will also benefit from the development of the use of novel technologies such as magnetic particle separation and sono-electrocoagulation, complemented by on-site drying. The expected high removal rate of dissolved and particulate matter by these techniques also would result in a better quality of the treated water, which might enable to reduce the exchange rate in RAS or the incoming flow rate in open systems, and consequently water footprint of aquaculture production.

Aquaponics is an example of valorisation process which is not affected by stringent regulations but limited by economic factors. Aquaponics may constitute an option to increase the sustainability and productivity of freshwater aquaculture facilities through the reuse of water and the recycling of nutrients released by fish. However, the consolidation of aquaponics as an economic activity in Europe is still behind initial expectations, and only one third of the companies truly rely on production of fish and vegetables as their source of income. Aquaponics is a case in which the proof of concept of the production system has not been fully

¹² Regulation (EC) 2003/2003.

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validated yet neither technologically nor commercially¹³. Technology has to reach maturity and prove economic viability through the demonstration of large-scale facilities before it can be commercially implemented. The most suitable approach could be the use of aquaponics as a complementary activity of existing aquaculture facilities, or as a method to reduce the nutrient load in discharged water and thus related taxes.

5.3. Opportunities for the development of ad hoc policies and regulations

The launch of the new Circular Economy Action Plan entails new opportunities to boost circular economy in aquaculture thanks to the focus on food, water and nutrients as part of key products value chains. Since those resources had not been tackled in previous initiatives, there is a wide scope for the creation of policies and regulations that best fit the specific interests and needs of the aquaculture sector.

The implementation of efficient measures for the sustainable use of water will be ruled by the Water Reuse Regulation. The reference document for this directive is the proposal COM(2018) 337 final on minimum requirements for water use, which aims to respond to the increasing pressure on water resources through facilitating the reuse of treated waste water as an alternative water supply, particularly for irrigation or industrial purposes provided minimum microbiological quality criteria are fulfilled. By means of this regulation, freshwater aquaculture facilities might be granted permits to act as suppliers of reclaimed water or become reclamation plant operators. The main advantage for aquaculture companies would probably lie on the decreased costs of water treatment before discharge aligned with tax benefits depending on the quality of the discharged effluent, according to the "polluter pays" principle. On the other hand, the irrigation of crops might benefit from the presence of dissolved nutrients in aquaculture effluents.

Related to the reuse of aquaculture effluents, the Circular Economy Action Plan considers the assessment of biological processes such as the cultivation of algae for the treatment of wastewater and sewage sludge, in the context of the revision of relevant directives. There is a wide body of scientific evidence to support the use of microalgae to remove nutrients and pollutants from different types of wastewater, but legal gaps may exist on the regulation of the use of the produced microalgal biomass. Aquaculture feed would be the most interesting application in order to create a circular value chain, provided this microalgal biomass complies with the requirements on feed safety, hygiene and use of Regulations (EC) No 178/2002, (EC) No 183/2005 and (EC) 767/2009 and of Directive 2002/32/EC on undesirable substances on animal feed. Algae *sensu lato* are included in the latest version of the Catalogue of feed

 ¹³Turnsek M., Joly A., Thorarinsdottir R., Junge R. 2020. Challenges of commercial aquaponics in Europe: beyond the hype.
Water 12, 306; doi:10.3390/w12010306

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materials, but microalgae are not explicitly mentioned. At the same time, Regulation 183/2005 does not apply to the direct supply of small quantities of primary production of feed at local level by the producer to local farms for use on those farms; therefore the production of microalgae from wastewater by fish farms and their use on site or in local e.g. fish or bivalve hatcheries could be subjected to simpler rules.

Seaweed culture is another option to uptake and valorise dissolved nutrients in aquaculture wastewater which is out of scope of EU directives, apart from regulations related to the deployment of aquaculture structures on the open sea or on the coast, or to the safety of seaweeds as food. Initiatives to boost circular economy are a clear chance to foster seaweed culture as one of the ways towards the intensification of EU aquaculture. This may include the development of the regulatory framework in terms e.g. of authorised species, facilities requirements or food safety.

5.4. The need for the harmonisation of methodologies for environmental benchmarking to evaluate the performance of aquaculture processes

Since consumers started becoming more aware of the environmental damage linked to products that they purchase, retailers have become interested in benchmarking products for environmental performance. Particularly, electronic appliances have been rated using a "traffic light system" for energy consumption. However, for food production, the systems tend to be a lot more complex and it has proven inherently difficult to benchmark them. A large part of the reasoning for this is that there is significant disagreement between experts on how methodology should be applied.

Since 2010, the EU Joint Research Centre together with the Director General for the Environment has been developing an environmental footprint benchmark for all products called the Product Environmental Footprint (PEF). However, this is fraught with challenges and there are still several question marks over how it would be applied to ecolabelling and communicated to the public with scientific hurdles still unresolved. Difficulties remain over applying a universal methodology to all products and between stakeholders with suggestions that different approaches are adopted e.g. for business to business compared with business to consumer or that approaches harmonise with existing ecolabels, particularly EU Flower, although EU Flower does not cover food production. Concerns not only surface about the methodology of the LCA but the communication vehicle of the PEF to provide value to stakeholders within business and consumer groups.

By far the most common underpinning methodology for measuring the cumulative impact of any production systems is Life Cycle Assessment (LCA) and forms the central methodology for the PEF. LCA is a useful tool for policy makers because it characterises environmental emissions into impact categories, relating emissions to a reference emission equivalent, which makes it easier to compare than the often complex and expansive raw emissions data. As LCA

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measures impacts throughout the entire supply chain it also avoids problem shifting between different parts of the chain and between different impacts. However, there are different accepted methodologies which can lead to very different outcomes and interpretations as has been evidenced from the LCAs published for aquaculture species. The EU have issued regulations concerning the application of LCAs (2013/179/EU¹⁴), following closely ISO guidelines published in 2006, which defines how PEFs should be developed. However, ISO guidelines are not definitive, in that they offer a choice hierarchy which is open to wide interpretation. The PEF development process has been endeavouring to harmonise the different LCA methodologies which may be adopted within this hierarchy.

The lack of consensus on methodology substantially weakens environmental labelling endeavours that has prevented retailers from adopting LCA based sustainability assessments as a method for benchmarking products. It is considered impossible to develop a methodology that encompasses all products, therefore PEF Category Rules (PEFCR) are being developed individually. However, as these are being developed independently by experts in those fields, there is also a problem with harmonisation as it is dependent on the particular views or agendas of the practitioners developing the PEFCR and how they interpret the guidelines within ISO and 2013/179/EU. It is The Aquaculture Advisory Council (AAC) aim to provide a level playing field between producers globally, but while there are inconsistencies in the PEFCR between different inputs into aquaculture value chains, this will not be the case.

Although LCA is a suitable methodology in many cases for the benchmarking of products, it fails to communicate some other critical issues regarding biological systems and particularly relevant for seafood, e.g. marine resource use, ecosystem impacts. There are also issues around how LCA can measure social aspects affectively, although there have been efforts to develop social impact categories with varying levels of success and uptake. Therefore, LCA alone is inadequate for benchmarking seafood products and must be supported with other indicators

There is also a vast scope of issues that certification attempts to address and specific to the type of product, which extend beyond LCA and even environmental issues. However, ecolabels and other certification, usually do not cover the entire life cycle of a product, which is evident in aquaculture certification that often focuses on the farm (e.g. Aquaculture Stewardship Council), although some have developed feed standards such as Best Aquaculture Practice and GlobalGAP. Although certification does step beyond the categories of LCA into socio-economic and sometimes welfare issues, they generally do not provide an index score which to benchmark products again but just a pass or fail based on minimum attainment. Thus, the development of an index that can be applied to aquaculture products taking into account, the key benefits of LCA and other indicators is a requisite for a correct

¹⁴ On the use of common methods to measure and communicate the life cycle environmental performance of products and organisations

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benchmarking of aquaculture products, particularly regarding circular processes.

6. Recommendations and conclusions

Eco-intensification may provide the ultimate chance for EU aquaculture to sustainably develop its full potential in the supply of aquatic products and maintain competitiveness in the global market. In the context of recently launched political agendas dealing with the transition to a greener economy such as the Circular Action Plan and the European Green Deal, new opportunities arise to include aquaculture as a strategic sector within the value chain of food, water and nutrients. This involves the revision of the regulations that may currently restrict the full implementation of circular processes, always complying with the highest standards on human and animal health and welfare, and food and feed safety. Complementary approaches seem to be necessary in this sense, from the relax of strict directives on the use of side streams, to others reinforce reutilisation and recycling, together with the development of economic incentives to encourage the implementation of circular economy concepts. Participation of the industry and other stakeholders will be crucial to develop the regulatory framework that unlocks the potential for eco-intensification of EU aquaculture. The most relevant actions would deal with the creation of ad hoc policies, the revision of current directives and the development of certification schemes to thoroughly assess the environmental performance of aquaculture value chains.

Creation or adaptation of policies to promote circularity in aquaculture:

- Involve all relevant stakeholders (aquaculture producers and suppliers, professional organisations, regulatory bodies, environmental advisory bodies and consumer organisations among others) in policy making to foster the implementation of circular economy in aquaculture. Particularly, in the implementation of the 2020 Circular Economy Action Plan.
- Assess the feasibility of the use of freshwater aquaculture effluents in view of the forthcoming approval of the Water Reuse Regulation.
- Develop sound and harmonised environmental certification schemes based on LCA and other relevant indicators as an incentive for circular economy in aquaculture.
- Develop financial incentive schemes to stimulate the implementation of circular processes in aquaculture companies, related to tax benefits, funding of technology purchase, etc.

Development of environmental certification standards:

• Harmonise all food production PEFCRs to the same methodology.

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- Develop new indicators to support PEFs.
- Apply benchmarking methodologies to assess the environmental performance of aquaculture products and processes.

Revision of currently in-force regulations:

- Promote the revision of authorised uses of Category 2 aquaculture ABPs based on the potential health and safety hazards and the efficiency of authorised processing methods to eliminate those hazards.
- Promote the revision of the definition of Category 2 aquaculture ABPs, since it is too broad and encompasses a wide range of by-products of different origins, characteristics and potential risks. Sub-categories should be created to classify Category 2 aquaculture ABPs and authorised uses should be different for each subcategory, depending on their potential risks and the efficiency of authorised processing methods to eliminate those risks.
- Design and validate safe and cost-effective processing methods for Category 3 aquaculture ABPs in order to extract high-value products such as protein hydrolysates and peptides.
- Generate scientific and technical knowledge to evaluate the potential risks for human and animal health associated to the feeding of filter- and deposit-feeder aquatic invertebrates with fish waste in IMTA facilities, in order to frame a regulatory change on Regulation (EC) No. 767/2009.