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Scientific, Technical and Economic Committee for Fisheries (STECF) - Marketing standards: Review of proposed sustainability criteria/ indicators for aquaculture (STECF-22-13)

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Abstract

Commission Decision of 25 February 2016 setting up a Scientific, Technical and Economic Committee for Fisheries, C(2016) 1084, OJ C 74, 26.2.2016, p. 4–10. The Commission may consult the group on any matter relating to marine and fisheries biology, fishing gear technology, fisheries economics, fisheries governance, ecosystem effects of fisheries, aquaculture or similar disciplines. This report is from the EWG 22-13 on "Marketing standards: review of proposed sustainability criteria / indicators for aquaculture (STECF-22-13)", which met in Brussels from 5 to 9 September 2022.

SCIENTIFIC, TECHNICAL AND ECONOMIC COMMITTEE FOR FISHERIES (STECF) - Marketing standards: review of proposed sustainability criteria / indicators for aquaculture (STECF-22-13)

Request to the STECF

STECF is requested to review the report of the STECF Expert Working Group meeting, evaluate the findings and make any appropriate comments and recommendations.

STECF comments[1]

General observations

EWG 22-13 met in Brussels, from 5-9th of September 2022. The EWG was attended by 13 experts including 1 STECF member along with 2 JRC experts, 2 from DG MARE and 3 observers, who attended the plenary sessions of the EWG. STECF acknowledges that the EWG addressed all of the TORs.

EWG 22-13 was a follow-up of EWG 20-05 "*Criteria and indicators that could contribute to incorporating sustainability aspects in the marketing standards under the CMO*", which took place in 2020. That previous EWG proposed transparent methods of measuring and communicating along the supply chain, selected sustainability aspects of fisheries and aquaculture products, based on scientifically sound, simple and verifiable criteria and indicators.

EWG 22-13 focused only on aquaculture (while EWG 22-12 that was held in parallel focused on fisheries). EWG 22-13 was tasked with (1) developing a globally usable categorization of production system types according to the EU-MAP and FAO classification systems, (2) defining animal welfare criteria and indicators, (3) defining good practices in terms of governance and regulatory requirements to mitigate risks for each production type and criteria and (4) integrating the elements defined in Tasks 1 to 3 into a scoring system based on information on species, production system type and country of origin. These tasks were identified by DGMARE as key steps to define a potential first stage of the revision of the marketing standards for sustainable aquaculture products and follow from the findings of EWG 20-05.

STECF notes that the EWG 22-13 was tasked by DGMARE with addressing only environmental aspects for aquaculture products, to use only Scoring System 1 and focus on identification and description of best practices. System 1 only include publicly available data containing information on the species produced, the technique used and the country of origin.

STECF notes that criteria for environmental sustainability in aquaculture are the first step in determining broader sustainability indicators within aquaculture, wild capture fisheries, and the broader agri-food system, in order to permit appropriate comparisons to be made between them.

Developing a globally usable categorization of production system types and defining the indicators

STEF notes that EWG 22-13 was able to build on preparatory work carried out under an ad hoc contract preceding the launch of the EWG. This preparatory work consisted of a report mapping "*Classification of production systems in aquaculture*". This was a valuable source of information for the EWG.

[1] Ernesto Jardim did not participate in the discussions on this TOR due to a potential conflict of interest with his current employment. The details are contained in his Declaration of Interest Form.

STECF notes that a classification system based on the EU-MAP and FAO (FAO, CWP-IS/2019/3) covers most of the global production methods. However, in some cases the farming techniques need to be unambiguously defined before a classification system can be applied. This is for example the case of ponds where there can be huge difference in how intensively they are utilised, which has an effect in most of the indicators listed in Table 5.4.1 below. Furthermore, environmental impacts of some production systems need to be collected to inform indicator scoring as the current data resolution (e.g., in seafood LCA studies) is insufficient to assess risks/probabilities of environmental impacts (e.g., impact of nutrients uptake on the carrying capacity for mariculture).

The EWG considered the indicators of environmental sustainability that were suggested by EWG 20-05 (presented in Table 5.5.1). A classification of production techniques that is based on current EU-MAP and FAO classification systems was presented. The production techniques cover global production methods and all indicators that had been suggested. STECF notes though that a small number of combinations of species (e.g., mussels, seabream, sea bass and oysters) and production techniques (e.g., on-bottom, off-bottom rafts and cages) dominate both production and consumption in EU.

TABLE 5.5.1 (from EWG 20-05): The selected criteria for aquaculture products and their priorities and feasibility

Table 5.5.1 – EWG 20-05 Indicators	**Priority (A=high)**	**Feasibility Producer**	**Feasibility Data**	**Feasibility Verification**
Effluent management: emissions (in water)	A	B	B	B
Protection of wild populations: escapees	A	D	D	D
Protection of humans: therapeutic treatments	A	A	A	A
Feed: source of marine raw materials	A	B	B	B
Feed: source of agricultural ingredients	A	B	B	B
Solid waste management	B	B	B	C
Interaction with critical habitats and species	A	D	D	D
Non-therapeutic chemical inputs	B	A	B	B
Environmental assessment	A	D	D	C
Area-based management	A	D	D	C
Energy use (on farm, all types)	C	A	A	A
Carbon footprint (farmgate)	A	A	C	C

STECF notes that there is limited knowledge available for assessing animal welfare and that the current mandatory data is not sufficient for assessing animal welfare in a meaningful way. It considers that there is no need for species-specific indicators. However, metrics, data and classification (i.e., scoring of indicators) are required to be species-specific, or potentially in relevant categorization. Animal welfare indicators for aquaculture species should be based on the Five Freedoms (freedom from hunger and thirst; discomfort; pain, injury, and disease; fear and distress; freedom to express normal and natural behavior) (Keeling et al., 2019; WOAH, 2022).

Defining good practices in terms of governance and regulatory requirements

STECF notes that a list of important components of a regulatory system for aquaculture was prepared, based on guidelines for sustainable aquaculture management, with indications of what best practices are, and what the potential effects of their implementation for the different indicators and production techniques.

STECF notes that best practice guidelines and guidelines for good governance are built on preliminary work from FAO (Draft Guidelines for Sustainable Aquaculture (GSA) - Preliminary copy. 30/09/2022). STECF notes that even though this was only a preliminary report at the time the EWG met, potential subsequent revisions of this FAO study before final publishing would not change the conclusions drawn within the EWG report.

STECF notes that it was difficult to standardise this assessment. Defining what a best practice is can differ between countries and the list should be seen primarily as a source for asking relevant questions about aquaculture regulations. STECF further recognises that focusing solely on the legal and regulatory context to assess good practices constrains the sustainability assessment, risks undervaluing practical implementation challenges and excludes market governance mechanisms that can be equally important in ensuring environmental, social and economic sustainability.

STECF notes that an assessment of the regulatory/legal framework requirements in a country must be combined with an assessment of the actual biological/technological performance of a production system to avoid over-/underestimating the importance of country specific regulatory requirements. Furthermore, regulation and best practice should be seen within a country context (e.g., is food security more important than nutrient emissions and is the nutrient emissions important for the local environment).

STECF agrees that the EWG has indicated that these elements of best practice and governance need to be further investigated, potentially in a future EWG, before they can add value to an overall sustainability indicator.

STECF observes that the social aspect is one of the core pillars of governance, which should have a future consideration regarding the sustainability of aquaculture products. Furthermore, economic aspects are also part of the three-pillar approach and should be equally considered when talking about sustainability.

Understanding the proposed scoring system

STECF notes that the general principle of the system of indicators proposed by EWG 22-13 is based on a relative scoring system, where aquaculture products are assessed across a set of criteria to be relatively more/less sustainable than another aquaculture product (and not other food products).

STECF notes that scoring should be seen as a likelihood that a given combination of species, production technique and production country may pose a higher or lower risk for a given environmental impact, and not as a precise measure of performance. The scoring relies on System 1 only (available data from EUMAP and FAO on species, production technique and country of origin), (i.e., limited and roughly categorized average data). Therefore, it will likely result in underestimating scores for some individual producers and overestimating scores for others within a category. For distinguishing better-practice producers within a category, a System 2 scoring with fine-scale data is needed in which producers can differentiate their products and improve the scoring (i.e., achieve a higher score if the product is more sustainable).

STECF recognises that, the EWG managed to demonstrate how such a scoring could be undertaken using two of the indicators previously identified, and the main production systems. The indicators were nutrient emissions (*i.e.,* release of nitrogen and phosphorous into waterbodies) and greenhouse gas (GHG) emissions, which were selected because they represent impacts of high environmental relevance and public interest.

STECF observes that the two indicators present contrasting pictures of aquaculture sustainability. Sufficient knowledge is available from aquaculture Life Cycle Assessment (LCA) literature to be able to score the most common aquaculture products on the EU market. STECF further notes that these two indicators are subsequently referred to throughout the report, but this does not imply that other indicators should be excluded from future development of a sustainability indicator for aquaculture or are less important than the two explicitly tested.

The scoring was undertaken along decision trees where each "case" (combination of species and technique) started on the top score and the score was then subsequently reduced a step (or level) for each emission driver that was present. The full scale from A+ to E was used meaning that, the scoring only contains a relative score in between aquaculture products.

Below is Figure 5-2 of the report (see Tables 5-2 and 5-3 for scoring examples on GHG and nutrient emissions, respectively).

A+	Highest score beyond current sustainability standards (Best-performing systems)
A	High score according to current sustainability standards (High-performing systems)
B	Medium-high score according to current sustainability standards (Good-performing systems)
C	Medium score according to current sustainability standards (Medium-performing systems)
D	Medium-low score according to current sustainability standards (Low-performing systems)
E	Low score according to current sustainability standards (Worst-performing systems)

STECF observes that an important point regarding the two selected indicators is that the impact of GHG emissions is global and the local emissions are relatively inconsequential. However, the nutrient emission will have different local impact depending on where and under what conditions and regulations these emissions occur, which is why adding governance, after first assessing the biophysical performance of the species and technology used, is important.

STECF notes that the EWG explored the opportunity to add more information to the scoring in System 1, based on guidelines for best practice of sustainable aquaculture governance and animal welfare. Animal welfare indicators were developed, one in System 1, and several indicators for System 2.

STECF notes that the EWG did not think that an assessment of animal welfare (task 2) is meaningful in system 1. This is due to the fact that the System 1 indicator only contains information on whether any animal welfare legislation explicitly including aquaculture exists in the country of production.

STECF notes that moving from System 1 to 2 requires clear incentives in terms of scoring higher to make improvements for all producers. Otherwise, producers who perform under average in each combination of species, production technique and production country would benefit from the very broad System 1 scoring and will not be incentivised to make improvements or move to System 2.

STECF notes that scoring of emission intensity for the two selected indicators (nutrients and GHG) provides a complementary picture of the biological-technological resource efficiency of the production system, and that adding the assessment of the regulatory system as a separate step is recommended. This is also in line with the Commission desire to have 'governance complementing the sustainability assessment'.

STECF observes that there is a need to further improve the data availability to be able to move to System 2. This information could be provided by market actors, if a wisely designed System 2 could incentivise actors to make data available in return for receiving a better score.

STECF notes that measures terminate at the farm gate, although there is scope to reducing externalities also after this point. Criteria relating to the full supply chain (processing, losses/byproduct use, distribution, transport) should be considered in the future, as these steps can substantially contribute to the overall supply chain environmental impacts, in particular GHG emissions, and can represent important differences between products produced within and outside the EU.

STECF Conclusions

STECF concludes that the EWG were able to adequately address all the TORs including the tasks to (1) develop a globally usable categorization of production system types according to the EU DCF and EU-MAP classification systems, (2) define animal welfare criteria and indicators, (3) define the good practices in terms of governance and regulatory requirements to mitigate risks for each production type and criteria and (4) integrate the elements defined in Tasks 1 to 3 into a scoring system based on information on species, production system type and country of origin.

STECF concludes that scoring the most important species and production systems in terms of consumption in the EU is possible for at least two of the indicators identified, using available data from EUMAP and FAO and then using a stepwise scoring procedure based on the existence or non-existence of important indicator drivers from the literature.

STECF concludes that even though many concrete steps have been identified towards an applicable approach to scoring aquaculture products, there is still a need to develop the concept further (e.g., unambiguous classification of production systems, country level information on regulation and enforcement, inclusion of more indicators) before it eventually can be operationalised. This work could be facilitated by a further working group as a follow-up to EWG 20-13.

STECF concludes that farmed seafood often depends on capture fisheries (e.g., for feed, wild broodstock or in capture-based ranching/fattening) and that the criteria for both fisheries and aquaculture need to be consistent in their scoring.

STECF concludes that the social aspect is one of the core pillars of governance, which should have a future consideration regarding the sustainability of aquaculture products. Furthermore, economic aspects are also part of the three-pillar approach and should be equally considered when talking about sustainability.

STECF concludes the needs for further improving the data availability to be able to move to System 2. This information could be provided by market actors, if a wisely designed System 2 could incentivise actors to make data available for getting a better score in return.

STECF concludes that measures terminate at the farm gate, although there is scope to reducing externalities also after this point. Criteria relating to the full supply chain (processing, losses/byproduct use, distribution, transport) should be considered in the future, as these steps can substantially contribute to the overall supply chain environmental impacts, in particular GHG emissions, and can represent important differences between products produced within and outside the EU.

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REPORT TO THE STECF

EXPERT WORKING GROUP ON Marketing standards: Review of proposed sustainability criteria / indicators for aquaculture (EWG-22-13)

Physical meeting, 05-09 September 2022

This report does not necessarily reflect the view of the STECF and the European Commission and in no way anticipates the Commission's future policy in this area

1 INTRODUCTION

1.1 Terms of Reference for EWG-22-13

In the context of the Farm to Fork Strategy, the Commission is assessing a potential revision of the existing EU marketing standards for fishery and aquaculture products (FAP). In the context of possible incorporation of a sustainability element in a new standard, the STECF EWG 20-05 was tasked to assess the existing sustainability criteria and indicators for fisheries and aquaculture products in the EU, independently of their origin (domestic and imports).

The work of the STECF resulted in a report STECF-20-05 on Criteria and indicators to incorporate sustainability aspects for seafood products in the marketing standards under the Common Market Organisation that provided an analysis of sustainability aspects that could be addressed through marketing standards and proposed a methodology for measuring and communicating these sustainability aspects along the supply chain. STECF noted that the report provided a sound basis for the further development of policy options to include sustainability criteria in the marketing standards for fishery and aquaculture products, while acknowledging that substantial work is still needed to develop a fully operational system. The STECF suggested to develop a scoring system step by step, starting with a System 1 for products for which more limited data is available based on simple indicators (e.g. in the case of aquaculture, information on species and country of origin plus production technique, which is currently not available), while products benefiting from key additional data (mostly at farm level) may allow for a more reliable assessment of sustainability criteria under a System 2.

The assessment of environmental sustainability criteria can rely in addition on relevant information available on the governance and regulatory requirements for aquaculture activities in the country of origin of the product. There are some references in the STECF report to this, for example in relation to the requirement of an environmental impact assessment, the application of an area-based management approach, or the existence of a waste disposal system in the country of origin. In the EWG 20-05, these were included as a number of indicators.

The consideration of governance and regulatory requirements is important, to allow differentiating already between products according to whether their country of origin has in place requirements for aquaculture activities that mitigate the risk of impacts for a given type of production or not. This information is relevant since it informs about conditions related to sustainability of aquaculture products, without requiring information at farm level, which is more difficult to obtain. Although an assessment of sustainability based on data at farm level would allow for a more accurate score, this involves a major challenge – data verification (most of the input parameters needed for the criteria identified in the STECF report are currently not available in the traceability information, so they rely on self-assessments by operators). This is why at this stage the Commission suggests that the STECF EWG focuses further work on information that can be more easily available, such as the one that can be provided by the country of origin of the product.

Given the relevance of the application of regulations in place that minimize and mitigate such risks in the country of origin, further work should be done on this aspect. This would require defining more in detail the type of governance and regulatory framework that is efficient in minimizing and mitigating risks, taking into consideration the existing FAO recommendations and technical guidelines on management of aquaculture.

Another important aspect of sustainability to consider in relation to aquaculture is the welfare of farmed animals. This is an element that is of increasing concern to citizens and consumers. Therefore, it would be necessary to introduce this sustainability angle to have a more complete assessment of sustainability of aquaculture products. Including animal welfare also imply adressing the social sustainabilty of aquaculture production.

Such work will be relevant not only as part of the work necessary for a future sustainability scoring system, but it will also contribute to the to the implementation of the Strategic Guidelines for a more sustainable and competitive EU aquaculture for the period 2021-20301[2] adopted by the Commission in May 2021. As part of this implementation, the Commission will develop a guidance document on environmental performance in the aquaculture sector that will, among others, include the identification of environmental indicators and voluntary targets for environmental performance and the mapping of good practices relevant for environmental performance. The Commission is planning to adopt this document in 2023. A detailed definition of the different governance and regulatory aspects necessary to manage the risks of aquaculture activities will contribute to the development of this guidance document which, though not legally binding, can become a reference for EU aquaculture and contribute to the objective of increasing its environmental sustainability.

Future work as part of the implementation of the Strategic Guidelines will also include the identification and definition of common environmental indicators for reporting by Member States, which would be encouraged to commit to report such data to national authorities on voluntary basis. The Commission will also, as part of the implementation of the Strategic Guidelines on EU aquaculture, support the development of a code of good practices on the welfare of farmed aquatic animals, as well as fish-welfare indicators throughout the production chain when the fish is alive.

It is also worth noting that the work of the STECF EWG would also be relevant to the work under the future Sustainable Food Systems legislative Framework envisaged in the Farm to Fork Strategy. Such framework should also apply to aquaculture products as part of the food system.

Specific objectives

Objectives of the EWG will be to:

- Continue the development of the environmental sustainability assessment for aquaculture products by: (1) establishing a more detailed and comprehensive classification of the aquaculture production system types (including the intermediate forms of production systems not covered by the report, which represent a combination of aquaculture and fisheries operations), and (2) defining good governance and regulatory practices to mitigate risks for each production type. These good practices should be based on the relevant FAO recommendations and technical guidelines on the sustainable management of aquaculture activities. This will be the basis for consideration of not only the characteristics of each production method, but also the existence in the country of origin of legislative or other measures regarding the management of the potential risks of each production method;
- Introduce animal welfare criteria in the social sustainability assessment: the evaluation of the criteria will take into consideration the existence in the country of origin of legislative measures or other type of measures addressing fish welfare aspects throughout the production chain, including transport and slaughtering. To the extent such indicators exist (e.g. EFSA opinions or other relevant documents defining such indicators), indicators could be species-specific.

Tasks

Task 1: Develop a globally usable categorization of production system types according to the EU DCF and EUMAP classification systems

The STECF-20-05 report gives particular attention to the production system type for the analysis of sustainability of aquaculture products. It suggests that information on the production system type should be considered as mandatory, including for imported aquaculture products. The Commission acknowledges that this information provides an important dimension when assessing the sustainability of aquaculture products, but it is not known if and when this information would become mandatory (along with the species and country of production which are currently mandatory). Nevertheless, with a view of having that as a policy option in the future, given the current discussion about the revision of the marketing standards as well as horizontal legislation on sustainable food systems, the Commission finds the work done so far important and would like to have such categorization developed. Intermediate forms of production systems, which represent

[2] Strategic Guidelines 2021-2030

a combination of aquaculture and fisheries operations, should be included as well, since they were not covered by the previous report.

Task 2: Define animal welfare criteria and indicators to complement environmental criteria and indicators already defined.

Task 3: Define the good practices in terms of governance and regulatory requirements to mitigate risks for each production type and criteria

Defining good practices in terms of governance and regulatory requirements to mitigate the different types of risks of aquaculture activities can complement the assessment of sustainability that is based on species and production system on the basis of easily available information per country of origin. These good practices should be based on the relevant FAO recommendations and technical guidelines on the sustainable management of aquaculture activities.

Task 4: Integrate the elements defined in Tasks 1 to 3 into a scoring system based on information on species, production system type and country of origin.

1.2 Outcomes of the STECF EWG 20-05 (November 2020)

As a first step, the EWG 20-05 analysed what could be done in terms of sustainability scoring with the information only currently available on all fish products placed in the EU markets. In practice, this implies that only data which are mandatory under the consumer information provisions of the CMO regulation will be considered in this first scoring system referred as system 1. The EWG 20-05 pointed out that this information is currently only available for fresh and chilled products. Therefore, no rating system can be put in place for processed products, until the legislation imposes the same consumer information rules, thus making available what appears to be the minimum information required for any assessment of the product sustainability.

Risk-based approaches were used intensively under system 1. Such approaches provide for each category of fishery product a risk-based assessment of sustainability criteria that could be considered on the basis of mandatory information only. Such a rating should be understood as a probability for the product to meet the criteria, this probability being defined on average for all products of the same category regardless of its own specific characteristics.

The EWG 20-05 strongly suggested that production technique is critically needed a piece of mandatory information also for products originating in aquaculture, since it is a key driver and determinant of sustainability performance and the same species can be produced using various technologies. Just as in the case of capture fisheries, aquaculture production is diverse and there is a wide variety of technologies in use, each in many different variants. Therefore, a classification system needs to be developed that splits production techniques into suitable categories based on the drivers of impacts that are to be assessed and demonstrates clear differences in performance.

A long list of indicators identified to be used for sustainability assessment of aquaculture was reduced to 12 indicators, based on a process of grouping them to see if any were redundant. The remaining ones were suggested to be taken further in system 1. Concerns were raised and discussed that producers with a higher performance than the average, risk-based rating would be penalized by a rough scoring based on mandatory information. Lower-than-average-performers on the other hand would benefit from an average score for everyone using a certain technology to farm a certain species in a certain country. To tackle at least the former risk, a system 2 would be needed, in which producers can provide data to show they perform better than the average. However, this is both methodologically challenging and requires systems for data storage and verification, which was no considered possible at this stage by the Commission. It was suggested that the scoring would save the highest rates (A and A+) for system 2 to incentivize data transparency, meaning that in system 1 only scores B to E could be reached.

The major advantage of such a system is that it could be applied to all products from fisheries and aquaculture, including those for which no direct and specific information is available. System 1 therefore could be the basis used at least for fishery products for which no voluntary and verifiable information is provided by stakeholders along the supply chain. This also justifies identifying and detailing what can be done, even if little, under system 1.

2 TASK 1: DEVELOP A GLOBALLY USABLE CATEGORIZATION OF PRODUCTION SYSTEM TYPES ACCORDING TO THE EU DCF AND EUMAP CLASSIFICATION SYSTEMS

2.1 Goal of the categorization

Seafood systems are highly diverse in their production methods and practices compared with land-based food production. Aquaculture systems are typically categorized according to their taxonomical positioning, i.e. grouping of species according to their genetic similarities. While this categorization is often sufficient for determining the nutritional value of a product, it fails to provide enough information to assess sustainability indicators. For that, information is also required on how a species is produced—and a single species can be produced in multiple ways.

The consideration of GHG emissions and nutrient emissions by the EWG highlights the importance of production method when assessing the relative risk of environmental impact associated with aquaculture products. Considering salmon production, open marine cage farms (the most common salmon production method) require relatively little energy to operate, while land-based require energy inputs to provide temperature regulation, oxygen, waste removal, water circulation, and other services that would otherwise be provided by the natural environment. The risk of GHG emissions for production of salmon is thus much higher for land-based systems than for marine systems, recognizing that the greenhouse gas impact of electricity varies substantially between regional grids. These two systems considered against nutrient emissions present a different picture: nutrients released into the local environment by marine systems are more likely to have a local ecological impact, while land-based systems affords for potential capture and management of the produced nutrients. The relative risk related to nutrient emissions from these two systems therefore follows an opposite patterns but is equally dependent on information availability describing the type of production system used for a given species and region.

The understanding of differences between production methods is therefore critical when assessing the relative environmental performance of aquaculture products. Consequently, any scoring of aquaculture products must adopt a consistent and impact-relevant ranking of production methods in order to capture these differences. The classification of techniques should be based on the main drivers of the impacts that need to be assessed, i.e., the selected indicators, so that the categories can be clearly defined and distinguished representing significant difference in indicator relevance between categories (Ziegler et al. 2022). The goal of such a classification is to maximise the differences between categories and minimise variability within categories.

Importantly, categorization of aquaculture systems according to species, production method, and country can still only allow for a rough determination of potential risk for any given environmental impact. Numerous decisions made at the farm level and throughout the supply chain can influence many of the environmental impact categories proposed by the EWG 20-05. This is likely to be the case across most environmental impact categories, including the examples of GHG emissions and nutrient emissions. A System 1 approach to determine potential GHG performance of a country's aquaculture production, taking into consideration both species mix and typical production systems, would identify that fed species are expected to have a higher GHG impact than unfed species, but would fail to capture the large differences in feed compositions used by different farms as well as the source of feed ingredients. For example, a farm using low-GHG feed ingredients and avoiding soy products from regions at risk of deforestation may have a much lower GHG impact than others in the same category. These differences are important to capture and a System 1 approach may fail to encourage the farm-level decision-making that is needed to shift production towards more sustainable practices.

2.2 Review of existing systems for the purpose of sustainability assessment

In order to provide a proposal for a classification system of aquaculture production types that could serve as a baseline for the assessment of sustainability aquaculture products, a literature review of the classification of aquaculture and current classification systems was conducted and summarized in the report and excel database of the *ad hoc* contract (Annex 1). Most classifications of aquaculture production systems focus on growout and are based on one or more primary variables, such as production intensity, water exchange, culture environment, production stage and integration, often combined with production method; yet there is a lack of unified framework which can be applied in practice. These systems contrast with institutional systems in use for statistical data collection in aquaculture (e.g., by FAO, EU, USDA) or under development (i.e. FAO's CWP-IS-2022/9, CWP-IS/2019/3), which often have categories designed to report against and are tailored to monitor aquaculture development over time. However, in order for these to serve the purpose of assessing the socio-environmental sustainability of products or production systems, the categories need to be defined with a view to reflect differences on the drivers of impacts of interest.

In order to avoid using as basis only the EU system, the development of the proposal for a classification system in the *ad hoc* contract was grounded on EU MAP (EC 2016/1251) with the integration of other systems as needed for fulfilling the requirements for the sustainability assessment. To enable this, the analysis mapped the variables that underpin each of the initial 12 indicators suggested by EWG 20-05 and that would have to be considered and integrated in a classification of production systems. Besides the classification requiring country and species-group information, this analysis following EWG 20-05 identified the need for the system to discern production systems through their production method, production stage, integration, siting (land or water based), degree of water exchange (closed, semi-closed or open), water pollution source (point or diffuse source) and production intensity (extensive, semi-intensive or intensive).

A further noteworthy conclusion, further recognised by EWG 22-13, was that the operational implementation of reliable assessment under System 1 was not only dependent on sufficiently describing these three variables (technology, country, systems) within the classification system, but also on significant expert follow-up work on several indicators to collate baseline data for classification (e.g., species origin, chemical use, review of Life Cycle Assessment data).

2.3 Necessary changes identified

An initial disaggregation of the EU MAP classification (EC 2016/1251) according to species groups (finfish, molluscs, crustaceans and 'others') was conducted in the *ad hoc* contract to assess the coverage in terms of production method, production stage and integration. This identified the need to refine and disaggregate EU MAP to sufficiently discern production siting types, degree of water exchange, water pollution source and production intensity in cases where production methods could not be clearly correlated with these (i.e., if a production system under EU MAP included multiple production systems that could potentially score differently regarding sustainability aspects). The re-definition of some of the categories under EU MAP, notably the recirculating systems, could also be considered as an option to disaggregation. In practice, the changes would include splitting ponds, enclosures and pens according to intensity (into extensive, semi-intensive and intensive), and splitting (or re-defining) recirculation systems and cages according to degree of water exchange (into open, semi-closed or closed).

It was further identified the need to further discern between the types of aquaculture integration (beyond monoculture, polyculture), into intermediate aquaculture-fishery systems, production stages and the consideration of under-represented systems (e.g., for algae), thus moving from the EU-production focus to a more global-applicable approach. For this, it was proposed to complement EU MAP with the FAO's CWP-IS-2022/9 current work, as detailed in the next section, though this might require further dynamic alignment.

The full list of proposed changes to comply with the ToRs of the *ad hoc* contract are summarised below on Table 3-1, and described in the Tables 3.7 and 3.8 of this report Annex 1, with the recommendation that these changes should be reviewed (i.e., categories excluded/added, aggregated/disaggregated or re-defined) following the selection of the sustainability indicators within the scoring system developed by EWG 22-13. The EWG 22-13 recognises that preference should be given to make as few changes as possible to the EU MAP system to which countries are used to report, with these changes depending on the final selection of indicators to take forward (out of the 12 initially proposed) and the adopted approach to scoring.

Table 3-1 Production techniques suggested and used for categorization of farmed seafood on the EU market (Franco 2022, Annex 1)

Production system	Origin	Suggested changes
Ponds	EU-MAP	Splitting based on intensity
Tanks and raceways	EU-MAP	
Enclosures and pens	EU-MAP	Splitting based on intensity
Recirculating systems	EU-MAP	Splitting based on the degree of water exchange/addition or closed/semi-closed
Cages	EU-MAP	Splitting based on the degree of water exchange/addition or closed/semi-closed
Off-bottom Rafts	EU-MAP	
Off-bottom Longlines	EU-MAP	
On-bottom	EU-MAP	
Barrages and irrigation systems	FAO-CWP	
Lakes, coastal lagoons and other natural water bodies	FAO-CWP	
Integrated culture: Rice-Fish culture and integration with other aquatic crop plantation	FAO-CWP	
Integrated culture: Aquaponics	FAO-CWP	
Integrated culture: IMTA	FAO-CWP	
Integrated culture: Other polyculture	FAO-CWP	
Plastic bags, photobioreactor tubes or panels	FAO-CWP	
Off-bottom Baskets, Net bags, Net trays, Poles	FAO-CWP	
Off-bottom lanterns, boxes	FAO-CWP	

2.4 Complementing EU with FAO system

In order to move to a globally applicable system, whilst limiting the divergence from international systems, the *ad hoc* work proposed to derive further required categories from recent work by FAO's CWP-IS-2022/9. In practice, this entailed a disaggregation of EU MAP categories such as 'Other fish farming' and 'Other shellfish farming' into 'Barrages and irrigation systems', 'Lakes, coastal lagoons and other natural water bodies', 'Off-bottom Baskets, Net bags, Net trays, Poles', 'Off-bottom lanterns and boxes', and with the addition of 'Plastic bags and photobioreactors tubes and panels' added to account for microalgae production, which could potentially be split into two if considered substantially different from a sustainability standpoint. A point was raised during the EWG whether microalgae culture should be included in the scope of the assessment, a question that remains to be answered. If excluded, it would reduce the number of needed categories, just as a reduction in the number of indicators. For now, it is included, and in other EU initiatives it is generally included in the category "algae". The catch-all category of 'Polyculture' was renamed 'Integrated Aquaculture' and split into 'Rice-Fish culture and integration with other aquatic crop plantation', 'Aquaponics', Integrated Multi-Trophic Aquaculture 'IMTA' and 'Other polyculture', though the latter two categories remain complex and require further resolution. However, as this did not consider a down-selection of systems to those representing only EU-imports, the EWG 22-13 recognises that the subdivision of some of these categories might not be necessary.

For intermediate systems and production phases to be considered, it was proposed to focus on fisheries-to-aquaculture inputs that would weigh on the sustainability of aquaculture products, notably feed inputs from fish-for-feed, and seed and health species inputs from capture-based-aquaculture. However, since the EWG 20-05 concluded that a separate system would have to be developed for feed sustainability, the *ad hoc* work proposed to limit this to seed (*sensu latu*) from aquaculture or fisheries and its phase of entering the aquaculture production chain (hatchery, nursery or broodstock), keeping reporting under the same species and applicable in practice under System 1. Such an approach would entail splitting 'Hatchery and Nursery' into production phases according to the seed source ('aquaculture' or 'capture-based').

The limitations of the proposed system, from the remaining of persistent complex categories to the representation of integrated agriculture-aquaculture systems, farm-gate implications or difficulties of practical implementation of such data collection, beyond and within Member States, are discussed in the Annex 1 of the report.

2.5 Remaining work on classification

The categories of production system types were defined in order to reflect significant differences in performance with regard to the selected indicators. If only a subset of indicators are considered, as was done during the EWG, as a starting point/example, not all categories will be needed. The principle should be to use as few categories as possible to reflect the differences in efficiency in the indicators of relevance. This indicator-first perspective would allow for communication of relative environmental performance that, across the selected indicators, maximizes the differences between systems and minimizes the difference within systems, recognizing that a System 1 approach fails to capture the full variation expected within systems.

Intermediate systems, i.e., systems that fall between fisheries and aquaculture (wild caught broodstock, seed, hatcheries) generally do not have a large impact on farm gate eutrophication potential and GHG emissions of the farmed seafood. The low contribution combined with the low data availability on resource efficiency (e.g., of Life Cycle Assessment (LCA) type) for these intermediate systems lead to recommending not to add specific categories for these systems in the first step. The lack of data is a problem also for many of the farming techniques that were added from the FAO categorization.

Before any classification system can be applied, a very clear and unambiguous definition of each category is needed so that producers can easily know to what category their production belongs to. Several categories, while being defined, may need to be further split up, e.g., recirculating systems may need to be split up into several categories based on the degree of recirculation or the adding of water, as described above.

Any classification will eventually be outdated as new production systems are developed and therefore, to keep it relevant and applicable, an overhaul would be needed when necessary.

To reduce the need for updating, it was suggested to rate systems on a gradient of "naturality" e.g., defined by energy or feed use or water exchange.

It was also discussed to what extent the data already collected under the DCF could be used to classify aquaculture segments into the suggested system of categorisation, e.g., energy costs or feed use or expenditure per tonne produced or as a proportion of the total production. This type of data could be used to assess the feed intensity and energy dependency of production systems. The data at present is of variable quality, and enforcing improved reporting at the relevant levels could be easier than introducing additional data to be collected. A concern was expressed that if DCF data were to be used for the purpose of sustainability assessment, it might change the way it is reported. Also, this data, even if available at high quality, would only be available for the EU production.

3 TASK 2: DEFINE ANIMAL WELFARE CRITERIA AND INDICATORS

3.1 Background on animal welfare

Animal health and welfare is foundational to the sustainability of aquaculture systems (Tlusty, 2020). FAO considered animal welfare to be part of the social aspect (as opposed to the environmental or economic aspects), where a fundamental importance of social sustainability is when food system activities contribute to the advancement of animal welfare (FAO, 2018). Current sustainability assessments of animal production tend to focus more on the environmental perspective (Shields and Orme-Evans, 2015), and where social is included, only addresses working conditions for humans (Tlusty et al. 2016). However, low animal welfare is often also reflected in low production efficiency resulting in poor environmental performance, so fish welfare is certainly linked to and may even be a foundation for environmental sustainability (Philis et al. 2021, Winther et al. 2020, Tlusty 2020). The paucity of animal welfare related studies for aquaculture species (Franks et al. 2021) leads the EWG to conclude that it is of high importance to continue the effort of creating guidance for the development of animal welfare for assessments and labelling as part of the process to ensure social sustainability including safeguarding of the welfare also for aquaculture species. There is also an increased interest and concern regarding animal welfare among European citizens (European Commission, 2016) and animal welfare is an important factor in the international market (Algers, 2011; Sørensen and Schrader, 2019). Despite the increased interest and concern, people are relatively disconnected from animal production (Evans and Miele, 2012) and are generally unaware of the actual conditions in animal production (Algers, 2011). Animal welfare impact, as incorporated in sustainability assessments, is important and would be beneficial to understand the impacts of our choices and to identify actions required to achieve sustainability (Hellweg and Canals, 2014; Fan et al., 2015; Shields and Orme-Evans, 2015).

3.2 Delimitations of the work during EWG STECF 22-13

The total European production of fish by aquaculture is estimated to be 2,570,650 tonnes in 2020, indicating a small increase of 2.8% in total production when compared to 2019. Marine cold-water species (non-Mediterranean) represent 70% of total production, freshwater species 14% and marine Mediterranean 16%. Norway remains the dominant producer in Europe with 58% of the total supply, mainly salmon but also large trout (>1.2 kg) production. The other countries that produce more than 100,000 tonnes annually are Turkey, the United Kingdom and Greece. The main fish species produced are salmon, trout, seabream, seabass and carp, which represent 95% of the total European production in 2020 (FEAP, 2021). EU aquaculture production (top 90%) in 2018 is shown in Fig. 5-4.

Welfare of all animals is of concern for advancing the sustainability of aquaculture. This EWG considered general welfare indicators that could be applied across any aquaculture species. However, exact criteria (e.g., water quality parameters, stunning method, etc.) will be needed to be developed for each species or species group.

The EWG has considered animal welfare aspects throughout the fish production chain, from fry to slaughter, including transport and stunning and killing. Welfare of aquaculture animals in their egg to fry stages and the welfare of crustaceans or molluscs is not less important, but considering the lack of knowledge regarding what a status of good welfare might be for these animals and ditto lack of knowledge on how to assess the status, the EWG concluded that these groups should not be included in the scope of this report.

Broodstock has not been specifically addressed in this report, but the attention regarding welfare shall be the same for all individuals in the growout phase irrespective of their destiny thereafter. The EWG would however emphasise that we do consider it of importance to continue the work regarding indicators, also considering other farmed aquatic species.

3.3 Animal welfare assessments

Animal welfare is, in a scientific context, the state of an animal and the quality of life related to animal health, feelings and behaviour (Keeling et al., 2019). Animal welfare is a widely used term and the definition could depend on epistemic considerations. Research on the topic is ongoing and development might lead to an improved definition of animal welfare (Keeling et al., 2019), which indicates that the indicators suggested in this report must be reconsidered alongside with new scientific evidence and knowledge regarding animal welfare. The EWG is aware of the difficulties in assessing animal welfare since the assessment is based on simplified estimations of complex systems. In addition, the development of the perception in the society on what good animal welfare means, might lead to reconsiderations on how welfare shall be assessed in animal food production including aquaculture. The World Organisation for Animal Health (WOAH) defines animal welfare as "the physical and mental state of an animal in relation to the conditions in which it lives and dies" (WOAH, 2022). The WOAH further states that the definition points at the Five Freedoms, which is one of the most commonly known definitions regarding animal welfare (Keeling et al., 2019; WOAH, 2022):

- Freedom from hunger and thirst,
- Freedom from discomfort,
- Freedom from pain, injury and disease,
- Freedom to express natural behaviour,
- Freedom from fear and distress.

EFSA AHAW Panel (EFSA, 2009) concluded that "the concept of welfare is the same for all the animals", i.e., mammals, birds and fish, used for human food and given protection under the Treaty of Amsterdam. However, the welfare of animals used in aquaculture has not been studied to the same extent as mammals and birds (Franks et al, 2021). Whilst similar measures of welfare developed for other animals are often relevant to fish, clearly defined protocols and evaluation methods for animals raised in aquaculture systems are lacking.

EFSA (2009 on fish sentience) concluded that "different species of fish have evolved highly sophisticated sensory organs to survive in changing and varied environmental conditions. Some of these sensory organs are absent in mammals, for example electroreceptors and the lateral line system." They additionally concluded that "there is scientific evidence to support the assumption that some fish species have brain structures potentially capable of experiencing pain and fear." and "research and developments in cognition and brain imaging techniques should be carried out in fish to further our knowledge and understanding of pain perception. "When assessing animal welfare, it is therefore important to consider several aspects and related indicators rather than limited number e.g., animal health, which would be the case if only using indicators showing health status or occurrence of diseases. The suggested indicators might also have different impact on the welfare, for example would poor water quality have a potentially larger impact on animal welfare compared to changes from natural lightning. Since good welfare is the matter of how "the physical and mental state of an animal is" it is nevertheless difficult to assess the correlation factor between any indicator and to what degree the fluctuations of the indicator really influence the mental stage of the fish.

As such, the EWG group focused on potential indicators that can be applied to reflect the status of the aquaculture fish in relation to the ideal situation expressed by the Five Freedoms.

The EWG has concluded that the indicators used to address animal welfare should be more than one, and distributed within the width of animal welfare addressing each of the Five Freedoms. Due to the complex relationships among the various needs/requirements of farmed fish and their behavioural and physiological consequences, as for all animals it is impossible to find one single measurement or welfare indicator that will cover all possible husbandry systems, farmed species and situations.

EFSA (2009) concluded that a range of welfare indicators should be considered when welfare is being evaluated. Indicators of fish welfare should be species-specific, validated, reliable, feasible and auditable, and preferably diversified (WOAH among the five following areas:

- Water quality
- Animal handling
- Feeding
- Transport
- Species-specific methods for stunning and killing

Another conclusion by the EWG is primarily to have a risk-based approach, which is a commonly used way to assessing animal welfare (EFSA, 2012). A number of different methodologies to quantitatively measure animal welfare were found in the literature, ranging from simple to detailed collection of data and assessments, which consider factors that may lead to stress, ill-health, and ultimately a decrease of individual welfare rather than directly measuring welfare itself. An overall concern with the risk-based approach is that it could result in losing the significance of animal welfare, since animal welfare is more than just the lack of risks of poor health, environment, etc., but also the expression of positive emotional states (EFSA, 2012). To decide what animal welfare issues and related inventory indicators to include in the assessment, selection must be done cautiously and only include those which are likely to reveal animal welfare.

It might be considered as more appropriate to assess the potential loss of animal welfare rather than the animal welfare itself. The same reasoning could be applied on the decision to use animal welfare or animal welfare loss as a unit, i.e., it seems more appropriate to use animal welfare loss instead of animal welfare since the assessment indicates a risk of decreased animal welfare rather than the actual animal welfare.

When it comes to the many different species farmed in aquaculture, with different welfare requirements, EWG considers it as major work and difficult to apply in practice. The challenge is reflected in the EFSA report (2009): "Due to the complex relationships among the various needs/requirements of farmed fish and their behavioural and physiological consequences, as for all animals it is impossible to find one single measurement or welfare indicator that will cover all possible husbandry systems, farmed species and situations."

A suggestion in the Terms of Reference is to design species-specific indicators to the extent it is possible. However, there are a large number of aquaculture species consumed within the EU and a great diversity concerning behaviours, morphology, etc. among them. This might result in a risk of major work to define species-specific animal welfare indicators, and potentially difficulties in applying them in practice. The EWG therefore suggests that, to our best knowledge, there is no need for species-specific indicators. The EWG considers that the suggested indicators are suitable for all species. However, metrics, data and classification are required to be species-specific, or potentially in relevant categorisation to be decided upon in future development.

Additionally, in case of this division, there might be a need to divide the categories "Other freshwater fish" and "Other marine fish" into subcategories. However, if there is only a minor fraction of the total fish production belonging to these subcategories, this should not be considered as highly important.

3.4 Welfare indicators

The EWG has concluded that the current available data (i.e., production system, species and country) is not sufficient for assessing animal welfare. Additionally, the data available regarding animal welfare in fish production is not sufficient. Already in 2009, EFSA AHAW and BIOHAZ panels concluded that "scientific information available on on-farm practices affecting welfare, and that could compromise fish safety, is very limited. Present data do not enable a quantitative assessment of the food safety risks associated with on-farm welfare factors to be made" (EFSA, 2009).

The EWG has concluded that animal welfare regulations with specific requirement on fish/aquaculture production should be an indicator of animal welfare in the country. This would fall under System 1.

A potential issue with this indicator is that there is a division on the free market where this scheme may favour producers from specific countries (those with increased legislation). However, the additional legislation and the requirements will tend to indicate higher animal welfare standards for the average producer, and thus less risk of animals being treated poorly. Additional indicators would be of key value to diversify potential animal welfare indicators used in System 1. However, based on the current knowledge, the EWG concluded that there are no additional indicators addressing animal welfare in a satisfying way in the context of System 1. This is the reason for only one indicator included in the animal welfare assessment in System 1.

The EWG concluded that requirements for any of the included indicators should be that they enable a diversification of animal welfare impact on different species, production systems or countries. In case diversification is not possible based on data in System 1, it should not be included.

In addition to what has been included in System 1, welfare ultimately is an informal contract between the farmer and their livestock. Given that poor welfare results in lower growth and survival, it does not benefit any farmer to hold animals in poor welfare. Yet, regardless of legislative oversight, there are many examples of where animals are indeed treated poorly (across all animal production systems, not only aquaculture). Therefore, it is the conclusion of the EWG that indicators and data in System 2 are of higher relevance and or accuracy compared to System 1, and thus will be the object of attention. If, in the future, indicators are the same, indicators and data in System 2 are of higher relevance/accuracy compared to System 1, and data from System 1 should be exchanged. Additionally, the following indicators are indicators which the EWG consider to be of high importance for assessing animal welfare, but where the EWG consider that the current knowledge of the impact on animal welfare is unclear. Further research is needed in this respect.

The EWG concluded that six indicators are suitable to include in an animal welfare assessment in aquaculture fish production, in accordance with the ToRs (Table 3-2).

Table 3-2 Suggested indicators in animal welfare assessment of aquaculture fish production.

Indicator	Motivation	Example of criteria
Water quality	Water quality is of crucial importance for a well-functioning environment for fish.	Dissolved oxygen, pH, temperature, turbidity and potentially ammonia, nitrite and nitrate.
Morphological appearance	Recording of divergence may reveal potential signs of pain, injury and diseases.	Scoring system (species related) and % animal showing abnormalities.
Behaviours	Observations of behavior may reveal discomfort, distress, malnutrition and diseases.	Normal *vs* not normal. Number of days during a period or production cycle.
Handling	Excessive handling may create fear, distress and discomfort as well as negative physical effects.	Amount, duration, or frequency of handling, consequences of handling. Also methodology and technique.
Survival rate	Can be considered as an overall indicator of the living condition of the fish-groups	Species relevant survival level during grow out. Scoring system based on % survival rate.
Slaughter	Efficient and ethical stunning and killing is important to avoid serious maltreatment.	Stunning (yes or no), Stunning and killing method.

The EWG identified some additional indicators (e.g., malnutrition/feeding and health plan) as potential indicators, but not of as high priority as the previously mentioned six indicators.

As an additional dimension in the future, the EWG considers that it would be of value to add indicators showing animal welfare based on indicators of positive expressions. It is important to highlight that animal welfare is more than lack of potential hazards and risks. It is therefore desirable to include aspects such as positive expressions. There are however difficulties also in this kind of assessment and collection of data. Further research could however investigate whether these kinds of indicators could be included.

4 TASK 3: DEFINE THE GOOD PRACTICES IN TERMS OF GOVERNANCE AND REGULATORY REQUIREMENTS TO MITIGATE RISKS FOR EACH PRODUCTION TYPE AND CRITERIA

4.1 Governance: codified knowledge as a model based on tacit knowledge and best practices

Although governance is one of the pillars of sustainable development, it represents in general a successful guide if tailored to the challenges and needs of the country in which it should push towards lasting sustainability. This is to underline that governance is a barycentric attribute in assessing the degree of sustainability of a country, and in particular of the strategy it adopts to ensure the growth of sustainable aquaculture. As governance is the result of a bottom-up interaction process between stakeholders and key informants about policy, production, management, and market aspects of aquaculture, EWG discussed about the opportunity and value of reporting examples of the best governance practices adopted in Europe and in the countries with the greatest aquaculture production. While the best practices generate benefits to the aquaculture sector and the environment in which it operates, they are also incentives for other countries to test the same governance models and to shape them on the challenges of their national aquaculture sectors. Governance, understood as the participatory co-construction of a sustainable aquaculture and market vision, has not always benefited from legislation and the overlapping of regulations. Through governance, the aquaculture sector will be able to have a long-term vision in which profit is not penalized by environmental constraints. Governance should, in its essence, absorb the tacit knowledge of the production sector and transform it into codified knowledge as a driver for sustainability.

Globally, aquaculture production is growing and is providing an increasing amount of fish and aquatic food products for human consumption, which is a trend that is predicted to continue. Aquaculture can meet the growing demand for aquatic foods and furthermore, contribute to food security and poverty alleviation in many developing countries. However, it is increasingly recognized that the increasing production also has potentially negative consequences for the environment. Thus, public regulation is viewed as a potential/needed instrument to minimizing negative impacts of production for increasing societal and consumer benefits and confidence in aquaculture production and products. Regulations can also be supported by certification schemes and other tools addressing aquaculture products.

To understand why public/private intervention is needed to promote sustainability, a short description of environmental externalities and regulation of these are presented as an introduction to this task.

All forms of food production, including aquaculture, are associated with the production of potentially harmful impacts (negative externalities) that affect the environmental quality and/or human wellbeing (emission of nutrients, chemicals, greenhouse gas (GHG), etc.). If the private producers do not consider these effects (costs) in their business models, public regulation may be needed to ensure a sustainable level of production and to avoid that damaging the environment put at risk future production and health of the environment. The rationale behind this is that the cost of environmental pollution for the individual producer is often less than seen from the society's point of view. Therefore, the individual producer tends to pollute more than is optimal for society (Pigou 1920, Coase 1960). Externalities may not always be negative in their impact. As an example, shellfish and seaweed indirectly or directly subtract nutrients from the water and thereby helps reducing the level of nutrients, which is considered to be a positive externality in areas with excess nutrient levels.

Choosing or designing the right instrument to regulate an externality is important. If the instrument is not designed to handle the externality properly, it can induce human welfare losses. It is therefore important to identify what regulatory measures/instruments can be used to provide an optimal regulation in support of sustainable growth.

A properly designed regulation will ensure that:

- It is environmentally effective. The environmental effectiveness of a system depends on its success in achieving the regulator’s objective. An example could be the aim of reducing nitrogen pollution to a certain level. The effectiveness of a system is often case- or context-specific. The choice of regulation may also depend on the level of risks associated with an increase in pollution, or if the main objective is to control the costs of pollution.
- An effective and systematic control and enforcement systems are in place (otherwise rules and regulations often do not have the desired effects).
- It is flexible and adaptable. The flexibility (adjustment to prices, new technology, climate change and other changes) of a system depends on its ability to adapt to changes in markets and technology and in social, political and environmental conditions.

The customary approach to handling externality problems that affect the environment is through command-and-control based regulations (Hanley et al. 2007). Command and control regulations primarily focus on preventing environmental pollution by stating how a firm should manage pollution directly or indirectly during the production process. With incentive-based regulations, producers can freely choose the measures to reach their target, encouraging the most economically efficient method to be used. Both command-and-control type regulations and incentive-based regulations can ensure a minimum “sustainability framework” when properly enforced, distinguishing products for which the country of origin does not provide for minimum mandatory sustainability thresholds). Nevertheless, incentive-based measure also encourage producers to go beyond the minimum required target, promoting innovation. Command and control regulations are often characterized by limited flexibility (Hanley et al. 2007), which can hinder technical innovation and does not give producers an incentive to move beyond the target set by authorities.

As an alternative, incentive-based regulatory instruments use means, directly or indirectly, to motivate polluters to reduce environmental pollution or the risks imposed by their production process (Hahn and Stavins 1991). An incentive is a factor that motivates people or firms towards a particular course of action, or counts as a reason for preferring one choice to a set of alternatives. These instruments typically provide financial rewards for reducing pollution, and impose costs on various types of pollution. Incentive-based instruments, such as pollution charges and tradable permits, are more cost-effective than traditional forms of command and control regulation (Hanley et al. 2007). Furthermore, incentive-based regulation can encourage innovation and technological change in the management of pollution (Jaffe and Starvin, 1995).

Private certification schemes that are linked to environmental challenges can be another way of improving sustainability in a sector. Standards, with the goal of enhancing sustainability beyond public requirements/regulation, can give private producers an incentive to improve sustainability of their production to gain a market advantage compared to other less-sustainable producers. The market advantage can be accessed via sale through organized distribution chains. Private certification is able to generate an effect on prices of the most qualified product regarding its sustainability, directing its distribution towards consumers who are increasingly erudite about the intangible value of sustainability in food products.

Governance and regulation can minimize the impacts of industrial activities, but it does not make inefficient practices more efficient. In order to reach environmental goals and commitments, it is important not to only rely on high regulatory standards achieving low impacts. Without parallel clear strategies of moving production and consumption towards the most efficient species and production systems, too much focus on high regulatory standards may not only stop development and innovation, but also give the impression of favouring more environmentally sustainable forms of aquaculture than is actually the case.

Governance focused on sharing and measuring horizontally applicable and monitorable standards can effectively and directly contribute to SDG2 and SDG14 of the 2030 UN Agenda Improving the resilience of aquaculture around a re-design of its production model will enable quantitative indicators to support efforts towards the mitigation of the environmental risks of aquaculture. The evaluation of the cost, for example, generated by new production models, can provide information to the decision maker regarding the uncertainties of the system's behaviour. There is a need to establish mechanisms to bring consumers closer to the origin of the product and the farms, and enhance their knowledge and understanding of the sector (MedAID H2020[3]).

Governance at the Country level will have to support and stimulate the re-design of aquaculture business models, to make it inclusive and flexible. Much effort and energy will have to be invested to facilitate the digital transition of micro-enterprises, to systematically feed with their data the necessary forecast models for assessing environmental effects and impacts. The economic incentives are the main drivers of this process. The challenge is the lack of positive response from consumers when they purchase their food, and especially with the current rise of prices and growing inflation.

The selection of the sites and the zones assigned to aquaculture (AZA) are broadly guiding the choices and shared decisions on the role of aquaculture in the countries. It is stressed that governance will have to imply a co-participation approach of the local community, which will have to be informed during the planning process. The FAO approach is adopted to encourage a flow of information to support a homogeneous level of descriptors for marketing standards for aquaculture products. In accordance with draft FAO guidelines on sustainable aquaculture development (Draft Guidelines for Sustainable Aquaculture (GSA) - Preliminary copy. 30/09/2022)[4], the success and flexibility of governance regulations are strongly driven by multi-level, co-participatory approaches.

Annex 2 lists governance areas and practices with sub-categories and indicates which indicators among those identified as important by the 2020 EWG (20-05) are affected. Below are further explanation regarding these areas and sub-categories. Annexes 3 and 4 further detail the two indicators that were selected to be scored, they show how the practices influence the emission drivers and how important each measure is for each production technique for nutrient emissions (Annex 3) and GHG emissions (Annex 4).

4.2 Good practices for sustainability indicators

4.2.1 Standards to prevent escapees

The escape of fish from sea-cage aquaculture is perceived as a threat to natural biodiversity in European marine waters and it may cause undesirable genetic effects in native populations through interbreeding, and ecological effects through predation, competition and the transfer of diseases to wild fish.

The EU project "PREVENT ESCAPE- Assessing the causes and developing measures to prevent the escape of fish from sea-cage aquaculture" conducted and integrated biological and technological research on a pan-European scale to improve recommendations and guidelines for aquaculture technologies and operational strategies that reduce escape events. That project pointed out that

[3] MedAID (Mediterranean Aquaculture Integrated Development) is a four-year RIA (Research and Innovation Action) project, funded by the European Union in the framework of Horizon 2020 (grant agreement number 727315), which together with PerformFISH was approved under the call SFS-23-2016 "Improving the technical performance of Mediterranean aquaculture".

[4] EWG 22-13 notes that these are a draft version not yet endorsed by FAO countries. However, it is a set of guidelines with global coverage suggested by a group of experts considering that the EWG ToR specifically state that the work should be based on relevant FAO technical guidelines and recommendations.

technical and operational failures of fish farming technology cause escapes due to cages break down in storms and wear and tear of the netting causes holes, thus recommending that policymakers introduce a technical standard for sea-cage aquaculture equipment coupled with an independent mechanism to enforce the Norwegian technical standard (NS 9415). This standard was aiming to define the design, dimensioning and operation of for sea-cage farms and was implemented in 2006. As a result, the total number of escaped Atlantic salmon declined from greater than 600 000 (2001 to 2006) to less than 300 000 fish yr^{-1} (2007 to 2011), despite the total number of salmon held in sea-cages increasing by greater than 50% during that period.

Marine Scotland (that is part of the Scottish Government) also developed a standard to minimize fish escape by determining technical requirements for fish farm equipment to be applied to the farming of all species of finfish in Scotland. Moreover, it should be used alongside operational procedures, codes of practice, operators' manuals, and staff training to ensure that equipment is used and maintained appropriately and that procedures are followed correctly.

Such type of standards are well-developed in some European countries, but inexistent in others. In Norway, the control of escapees is based on farmers mandatory reporting to the authorities and the data is published online. Each reported case is followed up by the authority to identify causes for the escapes. Therefore, and as good practice to prevent escapees, Member States should present specific technical standards aiming at protecting wild populations from escapees and to be implemented by fish farmers.

4.2.2 Feed: Source of agricultural ingredients

The change in feed formulations from a traditionally marine-derived to a terrestrial agriculture-derived raw material base has been important for increasing the aquaculture sustainability in relation with the overfishing reduction of the stocks that are used for fishmeal and fish oil production. This trend has been driven both by the perception that crop- or animal by-product-based feed inputs are more sustainable, at least regarding reduction of overfishing, than using fish and the need to decouple aquaculture from limited marine resources if the sector is to continue to grow. When sustainably caught fish is replaced by risk crops like soy farmed in countries with an expanding agricultural land use, or by high impact animal by-products (Parker 2018), such shifting is connected to trade-offs that need to be taken into careful consideration as the GHGs of crop-based feed raw materials in some cases are significantly larger than of fish meal/fish oil. Other novel feed ingredients e.g., based on insects or single cell proteins, could be more sustainable replacements for marine feeds, as long as they fulfil the nutritional needs of the farmed species, and they have the advantage of being scalable with demand. The feed used for farmed products is the most important input in this regard, as it links marine fish to the biodiversity impacts of global agricultural systems. Farmed marine fish is also potentially highly impacting terrestrial biodiversity through its input of feed raw materials from agricultural systems and as long as it prevails.

The Commission has also in the Farm to Fork Strategy document referred to the sector (blue economy) that can contribute by improving the use of aquatic and marine resources and, for example, by promoting the production and use of new sources of protein that can relieve pressure on agricultural land.

A group of leading organizations and stakeholders from different Members States – Marine Fish PEFCR – are working towards the Environmental Footprint Profile of Marine Fish Products, including aquaculture products. That methodology aims to develop a consistent and harmonized set of rules to calculate the Environmental Footprint Profile of Marine Fish Products while engaging with actors and stakeholders in the value chain of food production and consumption, at EU level.

A draft PEFCR had been through a public consultation and thorough review by independent Life Cycle Assessment (LCA) experts appointed by the European Commission. This PEFCR includes a model to calculate the emissions of N, P and C to water from the feeding of fish for one single stage, which can be considered to be a good practice to evaluate the sustainability regarding feed where ingredients are sourced from agriculture.

4.2.3 Governance for Feed (marine raw materials)

While accounting for the highest share in aquaculture production costs, feed also significantly affects the sector environmental sustainability. Fed aquaculture of carnivorous species like shrimp or salmonids largely depend on commercial feeds in part made from fishmeal and -oil, often derived from wild-caught species (e.g., sardines, anchovies etc.). Today, 25-35% of fish meal and fish oil are produced from by-products of fisheries and aquaculture, and the balance (the remainder) comes from targeted reduction fisheries (fisheries entirely destined for non-food purposes) (FAO 2020). These ingredients are finite quantities on an annual basis and one concern relates to the increasing demand that may incentivize overharvesting of the species targeted in reduction fisheries (fisheries entirely destined for non-food purposes), thereby increasing pressure on stressed ecosystems that additionally affects other dependent piscivorous animal species, including other fish species, birds and mammals. Other marine resources are currently being explored and tested in fish feeds, including pelagic zooplankton such as krill (*Euphasia superba*) and calanus (*Calanus finmarchicus*) and various species of so called mesopelagic fish of which very large biomasses are available in the open sea (Irigoien et al. 2014). If such sensitive resources (slow growth and reproduction) could be harvested at safe levels for the stocks and ecosystem, they could provide valuable fish nutrition and avoid excessive use of feed additives. Increased sustainable utilization of marine resources to replace land-based protein production is mentioned in the Farm to Fork strategy (EC 2019). The exploitation of low trophic levels, such as the medium-size zooplankton, could (directly for human consumption or indirectly as feed) offer sustainable opportunities since biomass levels are much higher than of higher trophic levels (it is commonly accepted that only about 10% of the energy is transferred from one trophic level to the next). The standing stock of *Calanus finmarchicus* in the Norwegian Sea is estimated at 30 million tons, and the production during the season from spring to autumn is 270 million tons. Norwegian authorities have set a quota for 2022 to 245 000 tons. However, due to the early stage of the development of proper gear, the total catch will only be approx. 10.000 tons.

The rationale for reducing dependency on marine resources is because fish resources are limited and, if aquaculture is to keep growing, it cannot depend on limited resources. Another argument is that eating food from lower trophic levels is more sustainable and it is therefore less sustainable to use wild fish to feed farmed fish, especially if a larger amount of fish is used than produced. However, it is difficult to scientifically justify that the use of e.g., crops or even animal by-products is more sustainable than marine inputs, as long as these are sourced from sustainably fished stocks.

Another concern is the depletion of so-called "trash" fisheries for feed production. These low-value fisheries are often not managed effectively, thereby also increasing the risk for overexploitation (Bone et al. 2018). Currently, the main buying criteria for fishmeal used in aquafeeds are price and quality. With the decrease of fishmeal and -oil availability and the rise of costs, the aquaculture industry will rely on innovation of new protein sources that are appropriate for fish feed in the future, which should be supported by governments in order to accelerate their development.

In parallel, however, the effective fisheries management of forage species needs to be ensured (Bone et al. 2018). Where wild aquatic organisms are harvested for use as feed, responsible fisheries management frameworks should be put in place and implemented (FAO 2011). Authorities, as well as all value chain actors (buyers of shrimp and fish for market, farmers reliant on feed, feed companies reliant on fishmeal, and fishers reliant on stocks) should actively support sustainable management of these fisheries. This can further be supported by providing sound biological, ecological and environmental data, as well as supply and value chain information.

Additionally, the feed industry should be regulated regarding improved traceability of all feed inputs, and be able to provide, as a minimum, data on used species and country of origin.

Another sustainability issue, related to feed in aquaculture are the farm emissions of nutrients resulting from excess feeding. This issue could be regulated by putting emission caps on farm effluents as a precondition for receiving a license.

4.2.4 Interaction with critical habitats and species (e.g., mangroves)

Aquaculture farms interact with their environment. This is of course more significant for open production facilities such as cages and ponds than for closed systems such as recirculation systems.

This interaction becomes more critical when the farms are operating in, or in close vicinity to marine protected areas (MPAs).

A distinction could however be made for mussel farms, which contribute to water quality and do not conflict with the requirements of the MPAs. In this case, their presence can, under the right conditions, i.e. when be compared to an additional environmental service for MPAs.

The production systems that operate in mangrove areas in production countries outside Europe face the dilemma of impacting these habitats. Moreover, through the grandfathering principle[5] in which a farm was established way before the protected area was established, it is difficult to provide a universal ranking of this aspect.

Yet the interaction of the farm with protected and/or sensitive areas and/or threatened species has to be assessed to establish its sustainability and the geographical location of the farm is needed to be able to make such an evaluation. It requires indicators such as whether a farm is situated in a protected area or of high value for sensitive habitats or in the habitat of endangered or critically endangered species.

In the Technical Guidelines on Aquaculture Certification (FAO 2011), FAO recommends minimum substantive criteria for addressing environmental integrity in aquaculture certification schemes, which can be seen as good practices regarding the "interaction with critical habitats and species" governance approach. That recommendation pointed out other practices, beyond the environmental impact assessments that must be conducted according to national legislation and prior to the approval of the establishment of aquaculture operations, such as the following examples:

· Regular monitoring of on-farm and off-farm environmental quality should be carried out, combined with good record-keeping and use of appropriate methodologies.

· An evaluation and mitigation of the adverse impacts on surrounding natural ecosystems, including fauna, flora and habitats should be carried out.

· Measures should be adopted to promote efficient water management and use, as well as proper management of effluents to reduce impacts on surrounding land and water resources should be adopted.

· Where possible, hatchery-produced seed should be used for culture. When wild seeds are used, they should be collected using responsible practices.

· Exotic species are to be used only when they pose an acceptable level of risk to the natural environment, biodiversity and ecosystem health.

Another example of good practices regarding governance on critical habitat and species is led by Fisheries and Oceans Canada (DFO), the lead federal agency responsible for regulating, licensing and monitoring aquaculture in British Columbia. DFO has a key role to play with respect to reviewing new applications for marine finfish aquaculture. A set of guidelines were developed to locate aquaculture facilities in areas that are best suited to minimize the risks to fish health and the aquatic ecosystem, consistent with regulatory requirements and a precautionary approach to management while promoting an economically prosperous and socially sustainable industry. Applied in concert with the range of other management tools (e.g., conditions of licence, management plans, environmental monitoring), siting guidelines contribute to the strong regulatory and management framework for aquaculture in British Columbia.

[5] This concept was already introduced in the report "Criteria and indicators to incorporate sustainability aspects for seafood products in the marketing standards under the Common Market Organisation (STECF-20-05)".

4.2.5 Monitoring plan to detect alien species

Alien species are those that have been introduced, either intentionally or unintentionally, outside of their natural range having a potentially negative impact on aquaculture. Therefore, it is important to monitor their spread.

As a good practice, Member States should have marine monitoring programmes to detect non-native invasive species on shores.

In accordance with article 5 of Regulation (EC) 708/2007, in Italy, the competent authority is the Ministry of Agricultural, Food and Forestry Policies (MiPAAF), Department of European and International Policies, which with the D.M. 339/2008 of 12.12.2008 and subsequent amendments has appointed an Advisory Committee of experts and has entrusted the Technical Secretariat to support the activities of the Advisory Committee to the Higher Institute for Environmental Protection and Research (ISPRA) and the creation of a register[6] of exotic and locally absent species pursuant to the regulation (CE) n. 708/2007 and of Regulation (EC) no. 535/2008.

Annexes 2-4 list governance practices with sub-categories and descriptions of good practices. Annexes 3 and 4 show, for each of the indicators that were scored in the EWG, the connections between governance practices, impact drivers and the importance of these governance practices for each production technique.

4.2.6 Regulation of emissions

In Denmark, the amount of nutrient emissions allowed for the individual farm is part of the production license. Farmers can choose between to different ways of being regulated, through either feed quotas inputs) or their actual emissions (outputs). Regulating outputs rather than inputs creates incentives to improve because if you can produce more while keeping within the allowed limits, the production results being more efficient per tonne produced. Larger farms are mostly regulated measuring their actual emissions in the water discharged from the farms, because this gives farmers a possibility to increase production if they can stay within the limits of emissions dictated by the license. With this type of system, standards for how emissions shall be measured are needed, otherwise the measurement can be biased or even manipulated. Measuring the content of nutrients in the water discharge from the farms is quite costly and smaller farmers therefore most often choose the feed quota regulation- and are hence not incentivized to improve. In Norway, open sea cage farms are regulated with a maximum allowable biomass (a maximum stocking density that limits the maximum biomass of live salmon in the cages at any point in time during the year) for each production site/license. This is another output-based way of controlling emissions from the farms.

All the three mentioned regulations can be used to reach emission levels below a target threshold of nutrients. However, from an efficiency point of view, only reducing the actual emissions or impacts per tonne of fish is a best practice.

4.3 Cross-cutting best practices

4.3.1 Protection of Humans - Therapeutic treatments

In most EU countries, medicine or treatment of fish is prescribed by veterinarians and the use of medicine is then reported to a central register. In Norway, data on medicine use and treatment is published online at high resolution (per farm) at barentswatch.no. Based on the global human and animal health risks connected to the spreading of antimicrobial resistant genes, with aquaculture playing a non-negligible role in this problem (Santos & Ramos 2018, Reverter et al. 2020), regular

[6] http://www.registro-asa.it/it/registro (verified Oct. 2022)

monitoring for the occurrence of antimicrobial resistant genes should also be encouraged as a best practice (Schar et al. 2021).

4.3.2 Organic Aquaculture

Organic fish farmers must follow a special set of rules to obtain this certification. This includes that the feed provided is organic, the medicine treatment is kept at a minimum, fingerlings used in grow out farms must be organic produced, and there are rules for minimum water flows and maximum fish density. However, these rules do not include any limitation of energy use, nutrient or GHG emission per kilo of produced fish. Overall, there is at present no evidence that this type of production is more environmentally sustainable in relation to the indicators.

As one example, the Italian Ministry of Agricultural, Food and Forestry Policies established with the Ministerial Decree of 04 February 2020 n. 7630 - Recognition of the "Sustainable Aquaculture" Production Regulations. This public national quality system has been defined for sustainable aquaculture and establishes unique rules for the various aquaculture production systems present in Italy, detailing all the processes to be monitored to obtain the certification of the fish product from sustainable aquaculture[7]. Organizations can convey this certification to the consumer and those that have obtained recognition are registered on an official national register.

4.3.3 Environmental Impact Assessment

The key tool for regulation of the aquaculture sector is through the Aquaculture Licence, which often requires an environmental impact assessment (EIA) (Directive 2014/52/EU). EIAs evaluate the effects of aquaculture on the environment. Environmental and production information is gathered and assessed for the environmental impacts of a development (both positive and negative). Under this regulation, national authorities decide if an aquaculture development requires an EIA. This decision is achieved through a ‘screening procedure’ using thresholds of aquaculture activity and potential impacts – thresholds vary between countries and type of aquaculture. This means that in some countries the EIA process is more refined and important in terms of aquaculture development than others.
Despite the commonality of EU Directives, the mechanisms for EIA and monitoring of environmental impact as a statutory regulatory requirement are inconsistent and EIA implementation often depending on bureaucratic processes within individual countries.

4.3.4 Animal welfare

This could be achieved by defining good governance and regulatory practices to mitigate risks in fish production. It could act as a complement to the assessment of sustainability based on species, production system and country of origin. The most important factor for developing a code of good practices and to mitigate risks concerning a poor animal welfare in fish production is to improve the regulations concerning animal welfare. The Council Directive 98/58/EC, requires that ”Members States shall ensure that the conditions under which animals (other than fish, reptiles or amphibians) are bred or kept, having regard to their species and to their degree of development, adaptation and domestication, and to their physiological and ethological needs in accordance with established experience and scientific knowledge, comply with the provisions set out in the Annex.” A suggestion is to expand on this to also consider fish, as well as to expand with requirements specifically concerning animal welfare in fish production.

Additionally, requirements concerning animal welfare in fish production should cover all aspects related to the indicator suggested in Task 2. The suggested indicators address animal welfare

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[7] https://www.politicheagricole.it/flex/cm/pages/ServeAttachment.php/L/IT/D/5%252F6%252Fc%252FD.4a869a96f437e8522e36/P/BLOB%3AID%3D10952/E/pdf?mode=download

issues, and could act as guidance for additional requirements to achieve acceptable animal welfare in fish production.

5 TASK 4: INTEGRATE THE ELEMENTS DEFINED IN TASKS 1 TO 3 INTO A SCORING SYSTEM BASED ON INFORMATION ON SPECIES, PRODUCTION SYSTEM TYPE AND COUNTRY OF ORIGIN

5.1 Selection of indicators

Out of the twelve indicators suggested by the EWG 20-05, two were selected (eutrophication potential and farmgate GHG emissions), based on that they describe central, and partly contrasting, sustainability characteristics of aquaculture production systems, and the possibility to score them based on quantitative as well as qualitative findings of Life Cycle Assessment (LCA) studies. In the developing PEF-CR (EC 2022) these two impact categories or types of environmental impact are listed among the most important ones contributing to 80% of the total environmental impact of farmed seafood products, all in all six impact categories are mentioned. Trade-offs between eutrophication and GHG emissions have been described (Philis et al. 2019) and the two indicators can therefore be seen as complementary. The indicator selection does not signal higher importance or exclusion of other indicators in this stage, only that these were selected as a first start to move closer towards an actual scoring of sustainability indicators for seafood from aquaculture.

5.2 Approach taken to scoring and alignment with the fisheries group (EWG 22-12)

In EWG 20-05, the highest performance scores (on a six-grade-scale from A+ to E were reserved for assessment in System 2, i.e., the highest score a product could get in System 1 was B, on a five-step-scale from A to E. The idea was that data availability should be "rewarded" and that the lower scoring in system 1 should result in an incentive to improve -and collect and submit data showing a better performance. During the EWG, the aquaculture group initiated a meeting with the fisheries group to discuss approaches taken and challenges encountered. It was first concluded that the Terms of Reference differed between the two groups and that the scoring therefore at this stage cannot be expected to be aligned across product groups. For example, the fisheries group was looking both at system 1 and 2, but did not assess governance aspects or best practices, instead their focus remained on identifying indicators and ways to score them. The fisheries group pursued the approach of lower scoring when data were unavailable or of low quality. A special category was also suggested when data is limited, to distinguish that situation from the low performance level. Such a category could be useful also in the aquaculture scoring effort to indicate the lack of data. It is noted however, that the missing data information is difficult to interpret for consumers. It was also discussed whether five or six scoring steps (or levels) was optimal. Five steps have the advantage that one is in the middle, representing an "average". If only B-E are scored in system 1, however, there is no "average" for this system.

In the present report, the full scale with six scores was used, despite only being in System 1 (see Figure 5-1). The use of the A+ score even when data are very limited was motivated by the existence of farmed species that extract directly or indirectly nutrients, i.e., which have a negative nutrient emission level, as described earlier. The best-performing case for an indicator was therefore given an A+, and the worst-performing case for an indicator was given an E, irrespective of how much it differed from the best case. This means that the scale only shows a relative performance for each indicator among aquaculture products only. Given the differences in the scale, in the used indicators, and in the scoring approach, the scoring of aquaculture products would have to be rescaled before being compared with any other food type scores. The scoring done here shall be understood as a relative risk or probability of a certain score, rather than a quantitative matching, i.e., that if a species is produced in a certain type of production system (and a certain country), it has a given probability or risk of having a certain impact and therefore receives a score. In each production system, there should be a score distribution around a mean level with producers performing both above and below that average. The better-performing producers would be incentivized to distinguish themselves from the mean (e.g., in a System 2) and be slightly penalized by the rough resolution of the score, while lower-performers would benefit from the simplified scoring.

A+	Highest score beyond current sustainability standards (Best-performing systems)
A	High score according to current sustainability standards (High-performing systems)
B	Medium-high score according to current sustainability standards (Good-performing systems)
C	Medium score according to current sustainability standards (Medium-performing systems)
D	Medium-low score according to current sustainability standards (Low-performing systems)
E	Low score according to current sustainability standards (Worst-performing systems)

Figure 5-1 The scoring scale used for the aquaculture products.

A fully quantitative way of defining the scores and borders between them (i.e., "score B meaning between x and y kg CO_2e/kg product") was not considered feasible because of methodological differences between the underlying LCA studies and scarce data for some systems.

Instead, a stepwise approach to scoring each of the two selected indicators was developed, based on important drivers for each indicator. The drivers are extracted from the LCA seafood literature and scoring starts on top level, i.e., with A+. For each impact driver that is in place in the system related to feed and used technology (nutrient emissions), and feed and energy (GHG emissions), the score is reduced of one step/level, see Figures 5-2 and 5-3. A step could be a full category (A => B) or parts of it, if drivers are considered of different importance for the indicator. However, if partial steps were to be applied, some system of rounding would be needed to decide the final score as a product can end up in between two scores.

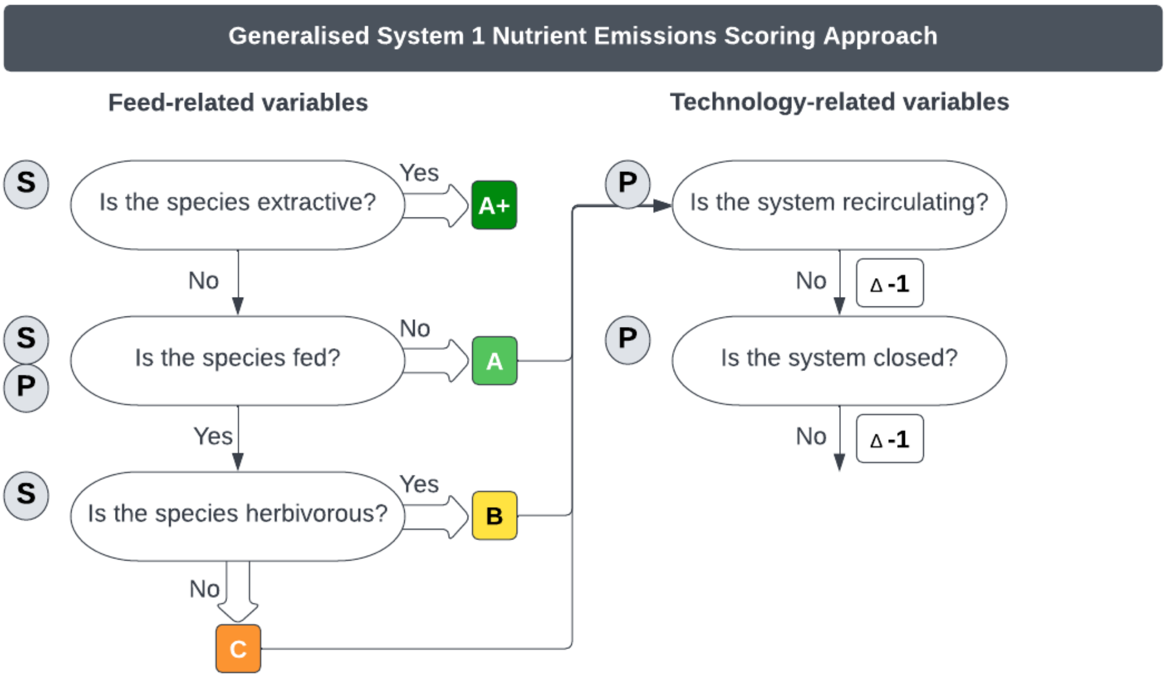

Figure 5-2 Stepwise procedure to score eutrophication potential if only System 1 information is known (species, production method, and country of production). Feed-related variables determine an initial scoring between A+ and C, and technology-related variables then apply a change to the score if applicable, indicated by a Δ. S and P labels indicate if the variable is related to either the species or production method, respectively. Extractive species of nutrients (e.g., algae, molluscs) are always A+ and do not need the technology-related assessment, all other species first go through the feed-related assessment, followed by the technology-related assessment. The reduction steps could be weighted according to their importance. This scoring system is intended as a preliminary approach that was applied in the scoring undertaken by the EWG for this report, and should be further refined based on available studies.

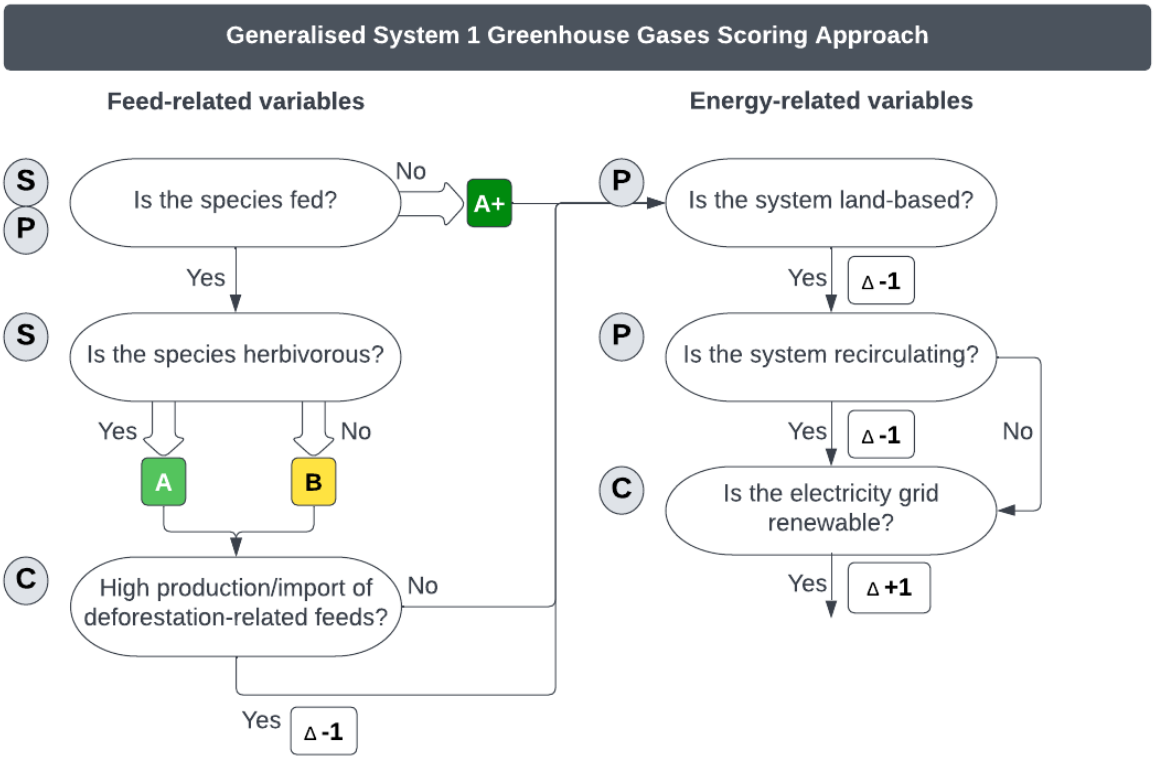

Figure 5-3 Stepwise procedure to score the expected risk of GHG emissions if only System 1 information is known (species, production method, and country). Feed-related variables determine an initial scoring between A+ and C, and energy-related variables then apply a change to the score if applicable, indicated by a Δ. S, P, and C labels indicate if the variable is related to either species, production method, or country, respectively. The reduction steps could be weighted according to their importance. This scoring system is intended as a preliminary approach that was applied in the scoring undertaken by the EWG for this report, and should be further refined based on available studies. In particular, an additional risk category of biogenic (methane and nitrous oxide) emissions could be added to account for risk of GHG emissions, particularly from pond systems, as these are the production systems with the highest risk for biogenic emissions.

A fully implemented system should have a full coverage i.e., score all existing cases (by species and production techniques) that are available on the market, either from the EU production or imports, even though few cases will largely dominate both the production (Figure 5-4) and extra-EU imports (Table 5-1). It was decided to focus on the most important systems dominating either EU production or imports when starting the scoring exercise, which is why the data for Figure 5-4 and Table 5-1 were extracted.

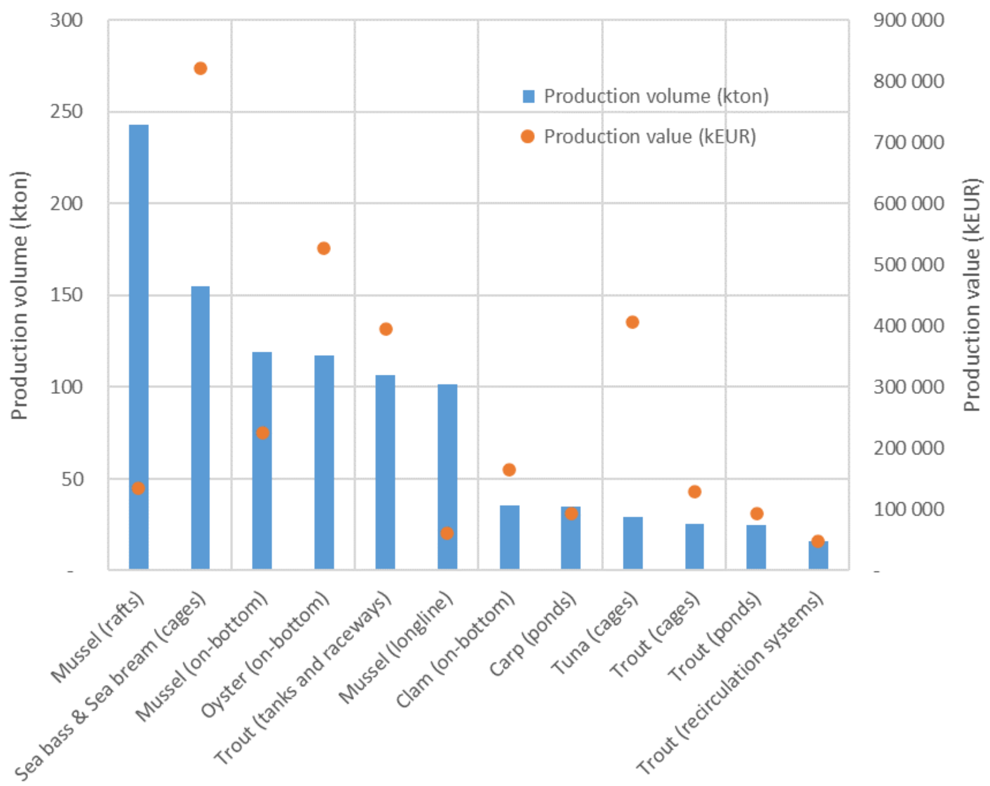

Figure 5-4 Top 90% of produced volume and value in EU aquaculture in 2018 (data from EUMOFA).

Table 5-1 Six species with their dominant country of origin. Six combinations of species, country together constitute 70% of total extra-EU import volume in 2019 (data from EUMOFA).

	Salmon	**Shrimp, warm water**	**Freshwater catfish**	**Mussels**	**Seabream, gilthead**	**Clam**
Dominating country of origin	Norway	Ecuador	Vietnam	Chile	Turkey	Vietnam
Dominating production technique in country	Cages	Pond, semi-intensive/ Pond, extensive	Pond, intensive	Off-bottom Longlines	Cages	On-bottom

The cases that are not (yet) important in production or consumption but that potentially are promising future candidates may also be important to score. We applied the following criteria for prioritisation of cases in the scoring exercise:

1. Importance in production (part of top 90% of production in volume or value),
2. Importance in consumption (part of top 70% of extra EU-imports in volume),
3. Species/species group being listed in the EU strategy documents,
4. Literature indicating or presenting evidence that the case performs well with regard to indicator,
5. Alternative production system for a species important in production or imports (e.g., recirculating system).

5.3 Scoring production systems for the selected indicators

To obtain a list of all possible cases relevant to score important seafood products on the EU market, a list of species and production countries would have been a good starting point that could be expanded to relevant production techniques for each species. Unfortunately, these data are not available, and neither are the traceability data to be used to describe and categorise (and score) the product later on. Traceability data only exist business-to-business between stakeholders of seafood supply chains and is not aggregated or made available for this purpose. Instead, we used EUMOFA seafood trade data, but these data do not distinguish between fished and farmed seafood, and fished species therefore had to be manually removed when extracting the data on production and imports (Fig 5-4, Table 5-1). Potentially, research models and databases built by Reg Watson and/or Jessica Gephart in which trade flows of seafood have been modelled could be useful for this.

So the list of original production systems suggested by the *ad hoc* study (Franco 2022) was extended with the most important species identified in EU production (covering 90% in volume) and 70% of extra-EU import according to EUMOFA. Each species was categorised along with the dominating production technology (e.g., marine net pens for salmon culture). This production method categorisation relies on a combination of expertise, industry data, and literature and may be difficult for some species groups due to the unavailability of global data, namely on what production technologies are used in aquaculture across different countries and even less data availability in the export flows to certain regions.

Each combination of species and production method was scored following the systematic approach outlined in Figs. 5-2 and 5-3 in plenary sessions while discussing the relative rating and ranking of each case among the whole set (see Annex 5). Tables 5-2 and 5-3 show examples of the stepwise scoring of three systems with contrasting performance for GHG emissions (Table 5-2) and nutrient emissions (Table 5-3).

As already mentioned, extractive species of nutrients received top scores in both categories due to both the absence of manufactured feeds (important particularly for greenhouse gases) and the negative nutrient emissions. The extensive, i.e., unfed, shrimp aquaculture also gets A+ for GHG emissions although, in this case, methane or nitrous oxide emissions from ponds could exist and together with a historical risk of mangrove deforestation in source countries. These aspects would need to be considered for a more complete understanding. For the nutrient emissions, the extensive shrimp ponds get an A because these systems are yet unfed despite not including extractive species. Freshwater catfish gets a C for GHG emissions based on being a fed, but herbivorous species farmed in ponds and an E score for nutrient emissions, just like all open cage and pond systems. It is possible that herbivory is given too much importance here, especially since it is well-known that many herbivorous species are given animal-based feeds (e.g., fish or poultry meals). It was done here in part to let the biological requirements of the species influence the assessment, and in part to recognise that protein sources, particularly protein alternatives to replace fish meal and fish oil in carnivorous aquafeeds, can be derived from high greenhouse gas sources such as soy products from deforested regions in South America or livestock by-products from ruminants or other emissions-intensive livestock. The dependency on crops connected to deforestation is assessed on a country basis, either by high production or imports of such crops, this is data that would need to be compiled for all production countries. Semi-intensive and intensive shrimp ponds were assessed with C for GHGs and E for nutrient emissions. Pond-farmed carp received a better GHG rating (B score) than pond-farmed shrimp because they are herbivorous. All recirculating systems get a lower score for GHG emissions and it is possible that a distinction should be made between recirculating ponds and constructed tank systems with recirculating ponds scoring one step higher than constructed tank systems). On the other hand there are currently unknown biogenic emissions from pond systems that could motivate a lower score. All intensive open cages, ponds and tanks and raceways for salmonids have a C in GHGs and an E in nutrient emissions, thus the worst-performing systems with regard to nutrient emissions. The recirculating systems get a better score for nutrients, but the lowest possible score (E) for GHGs, unless the production country has a high proportion of low-GHG energy production, when the score instead is D (this could be assessed as country-based proportion of low-GHG energy produced going into the national electricity grid mix). Of course, a producer could choose to source low-GHG electricity or run the farm on own solar panels, but this is impossible to know under System 1 and would need to be part of a System 2.

Table 5-2 Example scoring of cases resulting in high, medium and low scores, respectively, for GHG emissions.

Questions related to GHG emission drivers:	**Atlantic salmon, cages, Norway**		**Mussels, rafts, Spain**		**Whiteleg shrimp, recirculating system, China**	
	Answer	**Score**	**Answer**	**Score**	**Answer**	**Score**
Is the species fed?	Yes	A	No	A+	Yes	A
Is the species herbivorous?	No	B	n/a		No	B
Production country with high import or production of feed inputs connected to deforestation?	Yes	C	n/a		Yes	C
Is the system land-based?	No	C	n/a		Yes	D
Is the system recirculating?	No	C	n/a		Yes	E
Is the electricity grid in the country of production low-GHG?	Yes	C	n/a		No	E
Final score GHG emissions:	**C**		**A+**		**E**	

Table 5-3 Example scoring of cases resulting in high, medium and low scores, respectively, for nutrient emissions.

Questions related to nutrient emission drivers:	**Atlantic salmon, cages, Norway**		**Mussels, rafts, Spain**		**Whiteleg shrimp, recirculating system, China**	
	Answer	**Score**	**Answer**	**Score**	**Answer**	**Score**
Is the species extractive?	No	A	Yes	A+	No	A
Is the species fed?	Yes	B	n/a		Yes	B
Is the species herbivorous?	No	C	n/a		No	C
Is the system recirculating?	No	D	n/a		Yes	C
Is the system closed?	No	E	n/a		Yes	C
Final score nutrient emissions:	**E**		**A+**		**C**	

The assessment of the two emission indicators resulted in more similar scores than a priori expected, even though the drivers of impact for the two indicators differ in nature and number. The higher number of drivers, the lower the importance of each driver. This should not be taken as an indication that similar agreement could be expected across the full range of indicators, and trade-offs can already be seen between nutrient and GHG emissions- and should be expected if the approach is broadened, given the high heterogeneity of aquaculture production systems.

Despite the broad diversity in the group spanning environmental and social scientists, industry representatives and certification, the scoring was done without much disagreement, which likely indicates robustness. However, the number of score levels and the degree of score reduction in each step needs to be fine-tuned and tested/quality-assured before application, also considering numerous uncertainties for some systems, mentioned in the notes of Annex 5. As mentioned earlier, this scoring is only intended to rank products from aquaculture relative to each other.

For imported seafood, less is known about important drivers and absolute emission levels than for species produced in the EU, making the scoring more difficult and uncertain. Some cases that are important in production, e.g., capture-based tuna ranching, could not be rated as no LCA data is available for such a production system, i.e. no published or unpublished LCA studies are available for runa ranching and it differs in various aspects from the other production systems.

5.4 Scoring animal welfare indicators

The animal welfare sub-group considered that C was the highest score possible to get under System 1, without providing specific information, therefore, the scores A and B are not used below. Possible criteria for classification for welfare indicator in System 1 could be as follows;

D: EU legislation or standards accordingly to requirements in EU legislation, concerning requirements on the protection of fish;

C: legislation with additional requirements compared to EU legislation concerning the protection of fish;

E: requirements or standards lower than EU legislation concerning requirements on the protection of fish.

5.5 Adding the "country layer" to the scoring

After the scoring based on technique and species, EWG explored whether information available about regulations on the national level could be useful to be able to distinguish how aquaculture is managed, i.e., a certain nutrient emission level can lead to very different environmental impacts depending on which recipient they are emitted and how emissions are regulated. This is extensively discussed in section 4. The country also gives (in lack of specific information) the information on average techniques that are used to produce a certain species (information available for some species, e.g., in Bianchi et al. 2022). The EWG noted though that this would be very imprecise and potentially even misleading as the products exported to the EU often considerably differ from the "average product" produced in a country.

Scoring governance could be done with the questions in the provided checklist as a basis, keeping in mind the limitations and concerns presented in chapter 4 and that regulation should be on an optimal level, i.e, where it efficiently minimizes environmental impacts while still allowing aquaculture growth (Hanley et al. 2007; Anderson et al. 2019; Nielsen 2012). Governance practices of different countries have been ranked in the literature (Smith 2010, Davies et al. 2019) and a very simplified way to score governance per country would be to simply apply ratings from these or other publications.

Quantifying, rating or scoring legislation from the perspective of sustainability is complex. In particular, rating regulations to differentiate between the same systems in different countries that incorporates different scales, applications, boundaries issues and representation, is beyond the technical competencies of the EWG 22-13, and is liable to become quickly obsolete. A scoring system based on a checklist is therefore the preferred method for developing a scoring system.

EWG 22-13 focused on identifying environmental sustainability indicators (what needs to be regulated to achieve good governance and sustainability) in aquaculture production systems.

Country can tell: Regulations, production techniques and electricity grid mix.

Species can tell: Feed requirements, suitable environments for open systems.

Production technique can tell: Risk for high nutrient emissions, energy input requirements, potential risk of biogenic emissions, risk of farm site deforestation, other environmental externalities (e.g., escapes).

6 CONCLUSIONS

- A production system classification is mandatory for scoring under system 1.
- The classification should follow the drivers of impacts of interest and aim to maximise differences between categories and minimize differences within categories.
- Categories need unambiguous definitions to be applicable, and these should be coordinated with CWG aquaculture of FAO and other ongoing efforts to classify aquaculture technologies.
- A System 1 classification of production will inevitably overgeneralise products and disadvantage the producers that undertake practices improving the environmental performance.
- A System 1 scoring will create incentives for improvement if a system 2 exists (unless a producer changes production technique, which is unlikely).
- Meaningful animal welfare indicators can only be defined in system 2.
- Data availability limits the current possibility for scoring to very few of the previously identified indicators.
- The indicators used to address animal welfare should be more than one, addressing the welfare status in terms of all the Five Freedoms as described by the world organization for animal health regarding land animals.
- There is no need for species-specific welfare indicators since the suggested indicators are suitable for all species; as guidelines ensuring welfare in aquaculture at farm level will be drafted in the future, more species-specific metrics and data and classification will be required.
- Nutrient and greenhouse gas emissions provide a complementary perspective on the environmental impacts of aquaculture systems and can be scored in a simplistic way in system 1 based on species and production technique.
- The perspective of the regulatory environment needs to be added to the scoring to determine the actual (not only the potential) impact of a certain activity.
- Governance/regulations/best practices differ between locations and are difficult to evaluate in a strictly quantitative way.
- Governance best practices should only be considered within the context of country-specific efforts to address identified risks of impact, and not as determinants of environmental performance. Countries applying high levels of environmental regulation may still undertake high impact production while countries with fewer regulations may undertake lower impact production.
- Producers who wish to enter the EU market could be asked to answer questions in a survey-like form to classify the production system, and then questions related to the scoring of emissions and regulations.
- Environmental aspects, especially limited to nutrient and greenhouse gas emissions, are a limited subset of indicators that provide a partial picture of the sustainability of aquaculture.

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[1] - Information on EWG participant's affiliations is displayed for information only. In any case, Members of the STECF, invited experts, and JRC experts shall act independently. In the context of the STECF work, the committee members and other experts do not represent the institutions/bodies they are affiliated to in their daily jobs. STECF members and experts also declare at each meeting of the STECF and of its Expert Working Groups any specific interest which might be considered prejudicial to their independence in relation to specific items on the agenda. These declarations are displayed on the public meeting's website if experts explicitly authorized the JRC to do so in accordance with EU legislation on the protection of personnel data. For more information: http://stecf.jrc.ec.europa.eu/adm-declarations

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9 List of Annexes

Electronic annexes are published on the meeting's web site on:
https://stecf.jrc.ec.europa.eu/web/stecf/ewg2213

List of electronic annexes documents:

EWG-22-13 – Annex 1 - (Franco 2022) Classification of production systems in aquaculture.
EWG-22-13 – Annex 1bis - (Franco 2022, Excel table) Classification of production systems in aquaculture.
EWG-22-13 – Annex 2 - Checklist for good governance practices.
EWG-22-13 – Annex 3 – Eutrophication - Governance practices affecting eutrophication potential, effect on eutrophication drivers and effect per production technique.
EWG-22-13 – Annex 4 – Energy and GHG - Governance practices which may affect energy use and greenhouse gas (GHG) emissions of aquaculture production.
EWG-22-13 – Annex 5 – Scoring of systems - The scoring of important seafood production systems in EU production and/or consumption for nutrient emissions and greenhouse gas emissions.

10 List of Background Documents

Background documents are published on the meeting's web site on:
https://stecf.jrc.ec.europa.eu/web/stecf/ewg2213

List of background documents:

EWG-22-13 – Doc 1 - Declarations of invited and JRC experts (see also section 8 of this report – List of participants)

STECF

The Scientific, Technical and Economic Committee for Fisheries (STECF) has been established by the European Commission. The STECF is being consulted at regular intervals on matters pertaining to the conservation and management of living aquatic resources, including biological, economic, environmental, social and technical considerations.

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