Product Environmental Footprint Category Rules (PEFCR) for unprocessed Marine Fish Products

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Acronyms

AF	Allocation Factor
AR	Allocation Ratio
B2B	Business to Business
B2C	Business to Consumer
BFCR	Biological Feed Conversion Ratio
BoC	Bill of Components
BoM	Bill of Materials
CF	Characterization Factor
CFF	Circular Footprint Formula
CFF-M	Circular Footprint Formula – Modular form
COD	Chemical Oxygen Demand
CPA	Classification of Products by Activity
DC	Distribution Centre
DMI	Dry Matter Intake
DNM	Data Needs Matrix
DQA	Data Quality Assessment
DQR	Data Quality Rating
DQS	Data Quality Score
DW	Dry weight
EA	Economic Allocation
EC	European Commission
EF	Environmental Footprint
EF2.0 and EF3.0	Environmental Footprint database version 2 or 3
EFCR	Economic Feed Conversion Ratio
EI	Environmental Impact
ELCD	European reference Life Cycle Database
EoL	End-of-Life
FEFAC	European Feed Manufacturers' Federation
FU	Functional Unit
GE	Gross Energy intake
GHG	Greenhouse Gas
GR	Geographical Representativeness
GWP	Global Warming Potential
GWP100	Global Warming Potentials with a time horizon of 100 years
Ha	Hectare
HH	Human Health (used in ionizing radiation HH)
ILCD	International Reference Life Cycle Data System
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organisation for Standardisation
JRC	Joint Research Centre
kWh	kilowatt hour
LCA	Life Cycle Assessment
LCDN	Life Cycle Data Network

LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
LT	Lifetime
LUC	Land Use Change
Lw	Live weight
Lwe	Live weight equivalents
NACE	Statistical classification of economic activities in the European Community
NDA	Non-Disclosure Agreement
NGO	Non-Governmental Organisation
NMVOC	Non-methane volatile compounds
NPK	Nitrogen (N), Phosphorus (P) and Potassium (K)
OEF	Organisation Environmental Footprint
OW	One Way
P	Precision
PCR	Product Category Rules
PDO	Protected Designation of Origin
PEF	Product Environmental Footprint
PEFCR	Product Environmental Footprint Category Rules
PEF-RP	Product Environmental Footprint study of the Representative Products
RAS	Recirculating Aquaculture System
ReCiPe	Impact assessment method
RER	Region Europe
RF	Reference Flow
RP	Representative Product
RUaEP	Resource Use and Emissions Profile
SC	Steering Committee
Scope 1	Referring to the GHG Protocol nomenclature, direct emissions from owned or controlled sources.
Scope 2	Referring to the GHG Protocol nomenclature, indirect emissions from the generation of purchased energy.
Scope 3	Referring to the GHG Protocol nomenclature, all indirect emissions (not included in scope 2) that occur in the value chain of the reporting company, including both upstream and downstream emissions.
SMRS	Sustainability Measurement & Reporting System
TAB	Technical Advisory Board
TeR	Technological Representativeness
TiR	Time Representativeness
Tonne	1000 kg
TS	Technical Secretariat
UNEP	United Nations Environment Programme
UUID	Universally Unique Identifier
WW	Wet weight

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Definitions

The PEF Method [1] provides a complete list of definitions, and the most relevant ones for this PEFCR are also presented here.

Activity data - This term refers to information which is associated with processes while modelling Life Cycle Inventories (LCI). The aggregated LCI results of the process chains that represent the activities of a process are each multiplied by the corresponding activity data[1] and then combined to derive the environmental footprint associated with that process. Examples of activity data include quantity of kilowatt-hours of electricity used, quantity of fuel used, output of a process (e.g. waste), number of hours equipment is operated, distance travelled, floor area of a building, etc. Synonym of "non-elementary flow".

Additional environmental information – Environmental information outside the EF impact categories that is calculated and communicated alongside PEF results.

Additional technical information – Non-environmental information that is calculated and communicated alongside PEF results.

Allocation – An approach to solving multi-functionality problems. It refers to "partitioning the input or output flows of a process or a product system between the product system under study and one or more other product systems" (ISO 14040:2006).

Attributional – Refers to process-based modelling intended to provide a static representation of average conditions, excluding market-mediated effects

Average Data – Refers to a production-weighted average of specific data.

Benchmark – A standard or point of reference against which any comparison may be made. In the context of PEF, the term 'benchmark' refers to the average environmental performance of the representative product sold in the EU market.

Bill of materials – A bill of materials or product structure (sometimes bill of material, BOM or associated list) is a list of the raw materials, sub-assemblies, intermediate assemblies, sub-components, parts and the quantities of each needed to manufacture the product in scope of the PEF study. In some sectors it is equivalent to the bill of components.

Bycatch - The catch of organisms that are not targeted. This includes organisms that are outside legal-size limits, over-quotas, threatened, endangered and protected species, and discarded for whatever other reasons, as well as nontargeted organisms that are retained and then sold or consumed[2].

[1] Based on GHG protocol scope 3 definition from the Corporate Accounting and Reporting Standard (World resources institute, 2011).
[2] http://www.fao.org/documents/card/en/c/CA2905EN/

Company-specific data – It refers to directly measured or collected data from one or multiple facilities (site-specific data) that are representative for the activities of the company. It is synonymous to “primary data”. To determine the level of representativeness a sampling procedure may be applied.

Comparative Assertion – An environmental claim regarding the superiority or equivalence of one product versus a competing product that performs the same function (including the benchmark of the product category) (adapted from ISO 14044:2006).

Comparison – A comparison, not including a comparative assertion, (graphic or otherwise) of two or more products based on the results of a PEF study and supporting PEFCRs.

Co-product – Any of two or more products resulting from the same unit process or product system (ISO 14040:2006).

Cradle to Gate – A partial product supply chain, from the extraction of raw materials (cradle) up to the manufacturer’s “gate”. The distribution, storage, use stage and end of life stages of the supply chain are omitted.

Cradle to Grave – A product’s life cycle that includes raw material extraction, processing, distribution, storage, use, and disposal or recycling stages. All relevant inputs and outputs are considered for all of the stages of the life cycle.

Data Quality – Characteristics of data that relate to their ability to satisfy stated requirements (ISO 14040:2006). Data quality covers various aspects, such as technological, geographical and time-related representativeness, as well as completeness and precision of the inventory data.

Data Quality Rating (DQR) - Semi-quantitative assessment of the quality criteria of a dataset based on Technological representativeness, Geographical representativeness, Time-related representativeness, and Precision. The data quality shall be considered as the quality of the dataset as documented.

Direct elementary flows (also named elementary flows) – All output emissions and input resource use that arise directly in the context of a process. Examples are emissions from a chemical process, or fugitive emissions from a boiler directly onsite.

Direct land use change (dLUC) – The transformation from one land use type into another, which takes place in a unique land area and does not lead to a change in another system.

Discards - Discards, or discarded catch is that portion of the total organic material of animal origin in the catch, which is thrown away, or dumped at sea for whatever reason. It does not include plant materials and post-harvest waste such as offal. The

discards may be dead, or alive.[3] (In some fisheries it can also be referred to as "slipping".)

Elementary flows – In the life cycle inventory, elementary flows include "material or energy entering the system being studied that has been drawn from the environment without previous human transformation, or material or energy leaving the system being studied that is released into the environment without subsequent human transformation" (ISO 14040, 3.12). Elementary flows include, for example, resources taken from nature or emissions into air, water, soil that are directly linked to the characterisation factors of the EF impact categories.

Environmental aspect – Element of an organisation's activities or products or services that interacts or can interact with the environment (ISO 14001:2015).

Environmental Footprint (EF) compliant dataset – Dataset developed in compliance with the EF requirements provided at http://eplca.jrc.ec.europa.eu/LCDN/developer.xhtml.

Environmental Footprint (EF) Impact Assessment – Phase of the PEF analysis aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product (based on ISO 14044:2006). The impact assessment methods provide impact characterisation factors for elementary flows in order to aggregate the impact to obtain a limited number of midpoint indicators.

Environmental Footprint (EF) Impact Assessment method – Protocol for quantitative translation of life cycle inventory data into contributions to an environmental impact of concern.

Environmental Footprint (EF) Impact Category – Class of resource use or environmental impact to which the life cycle inventory data are related.

Foreground elementary flows - Direct elementary flows (emissions and resources) for which access to primary data (or company-specific information) is available.

Foreground Processes – Refer to those processes in the product life cycle for which direct access to information is available. For example, the producer's site and other processes operated by the producer or its contractors (e.g. goods transport, head-office services, etc.) belong to the foreground processes.

Functional unit – The functional unit defines the qualitative and quantitative aspects of the function(s) and/or service(s) provided by the product being evaluated. The functional unit definition answers the questions "what?", "how much?", "how well?", and "for how long?".

[3] http://www.fao.org/documents/card/en/c/CA2905EN/

Gate to Gate – A partial product supply chain that includes only the processes carried out on a product within a specific organisation or site.

Gate to Grave – A partial product supply chain that includes only the distribution, storage, use, and disposal or recycling stages.

Indirect land use change (iLUC) – It occurs when a demand for a certain land use leads to changes, outside the system boundary, i.e. in other land use types. These indirect effects may be mainly assessed by means of economic modelling of the demand for land or by modelling the relocation of activities on a global scale.

Input flows – Product, material or energy flow that enters a unit process. Products and materials include raw materials, intermediate products and co-products (ISO 14040:2006).

Life cycle Assessment (LCA) – Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle (ISO 14040:2006).

Life cycle impact assessment (LCIA) – Phase of life cycle assessment that aims at understanding and evaluating the magnitude and significance of the potential environmental impacts for a system throughout the life cycle (ISO 14040:2006). The LCIA methods used provide impact characterisation factors for elementary flows to in order to aggregate the impact to obtain a limited number of midpoint and/or damage indicators.

Live weight (Lw) and live weight equivalents (Lwe) - Used to specify the weight of fish before it is killed. For farmed fish this also indicates the weight before starving and bleeding.

PEFCR supporting study – PEF study based on a draft PEFCR. It is used to confirm the decisions taken in the draft PEFCR before the final PEFCR is released.

PEF report – Document that summarises the results of the PEF study.

PEF study of the representative product (PEF-RP) – PEF study carried out on the representative product(s) and intended to identify the most relevant life cycle stages, processes, elementary flows, impact categories and any other major requirements needed for the definition of the benchmark for the product category/ sub-categories in scope of the PEFCR.

PEF study – Term used to identify the totality of actions needed to calculate the PEF results. It includes the modelling, the data collection, and the analysis of the results. It excludes the PEF report and the verification of the PEF study and report.

Prepared fishery products - Unprocessed fishery products that have undergone an operation affecting their anatomical wholeness, such as gutting, heading, slicing, filleting, and chopping.

Primary data[4] - This term refers to data from specific processes within the supply chain of the user of the PEF Method or user of the PEFCR. Such data may take the form of activity data, or foreground elementary flows (life cycle inventory). Primary data are site-specific, company-specific (if multiple sites for the same product) or supply chain specific. Primary data may be obtained through meter readings, purchase records, utility bills, engineering models, direct monitoring, material/product balances, stoichiometry, or other methods for obtaining data from specific processes in the value chain of the user of the PEF Method or user of the PEFCR. In this method, primary data is synonym of "company-specific data" or "supply-chain specific data".

Processed fishery products – Products that have undergone a process that substantially alters the initial product, including heating, smoking, curing, maturing, drying, marinating, extraction, extrusion or a combination of those processes.

Product Category Rules (PCRs) – Set of specific rules, requirements and guidelines for developing Type III environmental declarations for one or more product categories (ISO 14025:2006).

Product Environmental Footprint Category Rules (PEFCRs) – Product category specific, life cycle-based rules that complement general methodological guidance for PEF studies by providing further specification at the level of a specific product category. PEFCRs help to shift the focus of the PEF study towards those aspects and parameters that matter the most, and hence contribute to increased relevance, reproducibility, and consistency of the results by reducing costs versus a study based on the comprehensive requirements of the PEF method. Only the PEFCRs listed on the European Commission website (http://ec.europa.eu/environment/eussd/smgp/PEFCR_OEFSR_en.htm) are recognised as in line with this method.

Product flow – Products entering from or leaving to another product system (ISO 14040:2006).

Reference flow – Measure of the outputs from processes in a given product system required to fulfil the function expressed by the functional unit (based on ISO 14040:2006).

Representative product (model) - The RP may be a real or a virtual (non-existing) product. The virtual product should be calculated based on average European market sales- weighted characteristics of all existing technologies/materials covered by the product category or sub-category. Other weighting sets may be used, if justified, for example weighted average based on mass (ton of material) or weighted average based on product units (pieces).

[4] Based on GHG protocol scope 3 definition from the Corporate Accounting and Reporting Standard (World resources institute, 20011).

Round fish - For wild fish this is identical to “live fish”, but for certain aquaculture systems the term “round weight” refers to the biomass after starving and bleeding.

Secondary data[5] - It refers to data not from a specific process within the supply-chain of the company performing a PEF study. This refers to data that is not directly collected, measured, or estimated by the company, but sourced from a third party LCI database or other sources. Secondary data includes industry average data (e.g., from published production data, government statistics, and industry associations), literature studies, engineering studies and patents, and may also be based on financial data, and contain proxy data, and other generic data. Primary data that go through a horizontal aggregation step are considered as secondary data.

Specific Data – Refers to directly measured or collected data representative of activities at a specific facility or set of facilities. Synonymous with “primary data.”

System boundary – Definition of aspects included or excluded from the study. For example, for a “cradle-to-grave” EF analysis, the system boundary includes all activities from the extraction of raw materials through the processing, distribution, storage, use, and disposal or recycling stages.

Unit process – Smallest element considered in the LCI for which input and output data are quantified (based on ISO 14040:2006).

Unprocessed fishery products - Products that have not undergone processing, and includes products that have been divided, parted, severed, sliced, boned, minced, skinned, ground, cut, cleaned, trimmed, husked, milled, chilled, frozen, deep-frozen or thawed.

User of the PEFCR – a stakeholder producing a PEF study based on a PEFCR.

Waste – Substances or objects which the holder intends or is required to dispose of (ISO 14040:2006).

[5] ídem

1 INTRODUCTION

This document is a Product Environmental Footprint Category Rule (PEFCR) that specifies how the Product Environmental Footprint (PEF) Method [1] shall be applied to a specific product category. This PEFCR provides these rules for marine fish for human consumption in the EU market (wild caught and farmed).

This PEFCR has been developed according to the PEFCR guidance document [1] that defines the process of developing a PEFCR and it specifically follows Annex A of that document, "Suggestions for updating the Product Environmental Footprint (PEF) method" by the Joint Research Centre (JRC) [1]. Where the requirements in this PEFCR are more specific to those in the PEF Method, this more specific guidance shall be followed. For any requirements that are not specified in this PEFCR, the user shall refer to the documents that this PEFCR is in conformance with.

The PEF Method [1], which provides detailed guidance on how to conduct a PEF study, is a Life Cycle Assessment (LCA)-based method used to quantify the relevant environmental impacts of products (goods or services). It builds on existing approaches and international standards. PEF studies are carried out for a range of reasons, including internal benchmarking and assessments of continual improvement, as well as to meet voluntary or mandatory reporting requirements.

2 DOCUMENT OUTLINE

The following provides an overview of the content of this document and guidance on how to use it.

- Chapter 3 provides information about how this PEFCR was developed and its main principles. Here details can be found on:
  - The scope of this PEFCR (i.e. the products and life cycle stages covered by the PEFCR).
  - The studies that were performed as part of the development of the PEFCR.
  - Parties that participated in the development of the PEFCR and how it was reviewed through public consultations and by independent experts.
- Chapter 4 presents the most important environmental hotspots in the life cycle of marine fish products (i.e. aspects that are especially relevant when conducting your PEF study). This is based on the results of the analysis performed during the development of the PEFCR (i.e. the PEF study of the Representative Products (PEF-RP)).
  - ✓ For the time being, these results are only presented in the PEF-RP report, but will be included in the final PEFCR document.
- Chapter 5 presents the functional unit and reference flow, among other methodological requirements.
- Chapter 6 presents the data sources that can be used and suggests a procedure to choose what data to use.
- Chapter 7 presents detailed instructions regarding the data that needs to be collected in order to conduct a Marine Fish PEF.
- Chapter 8 presents how a Marine Fish PEF shall be documented.

- Chapter 9 provides the verification procedures.
- Chapter 10 presents the benchmark values for the representative products.
  - ✓ For the time being, this is only presented in the PEF-RP report, but will be included in the final PEFCR document.

In this draft PEFCR and the PEF-RP, green boxes like this will provide information about the current version of this document (e.g. elements that are not currently in place, but that are under development, as well as other information relevant to the current version).

3 GENERAL INFORMATION ABOUT THE MARINE FISH PEFCR

The following sections present central aspects of how this PEFCR was developed and how it shall be used.

3.1 PEFCR Product scope

The product scope of this PEFCR is unprocessed wild and unprocessed farmed marine fish for direct human consumption in the EU market. This scope excludes crustaceans, molluscs and freshwater fish, both wild and farmed (see section 3.1.1 for more detail).

The product scope takes into account the definition of prepared fishery products as outlined in Regulation (EC) No 853/2004 [6], which provides specific hygiene rules for food of animal origin. Per this regulation, "*Prepared fishery products"* refers to unprocessed fishery products that have undergone an operation affecting their anatomical wholeness, such as gutting, heading, slicing, filleting, and chopping. This means that *processing* of marine fish is out of the scope.

Regulation (EC) no 852/2004[7] defines "*processing"* as any action that substantially alters the initial product, including heating, smoking, curing, maturing, drying, marinating, extraction, extrusion or a combination of those processes. This is different from "*unprocessed products",* which refers to foodstuffs that have not undergone processing, and includes products that have been divided, parted, severed, sliced, boned, minced, skinned, ground, cut, cleaned, trimmed, husked, milled, chilled, frozen, deep-frozen or thawed.

For fish that undergo processing, the Marine Fish PEFCR shall work as a module for the life cycle from cradle to processing gate.

3.1.1 Product scope classification

The Classification of Products by Activity (CPA) codes for the products included in this PEFCR are:

[6] Regulation (EC) No 853/2004 of the European Parliament and of the Council of 29 April 2004 (OJ L 226, 25.6.2004, p. 22)

[7] Regulation (EC) no 852/2004 of the European Parliament and of the Council of 29 April 2004 on the hygiene of foodstuffs (OJ L 139, 30.4.2004, p. 1)

- 03.0 Fish and other fishing products
  - 03.00 Fish and other fishing products
    - 03.00.1 Fish, live
    - 03.00.12 Live fish, marine, not farmed
    - 03.00.14 Live fish, marine, farmed
    - 03.00.2 Fish, fresh or chilled
    - 03.00.21 Fresh or chilled fish, marine, not farmed
    - 03.00.23 Fresh or chilled fish, marine, farmed

In addition to these stages, the following classes under C Manufactured products 10.20 Processed and preserved fish, crustaceans and molluscs will also be covered:

- 10.20.1 Fish, fresh, chilled or frozen
- 10.20.11 Fish fillets and other fish meat (whether or not minced), fresh or chilled
- 10.20.12 Fish livers and roes, fresh or chilled
- 10.20.13 Fish, frozen
- 10.20.14 Fish fillets, frozen
- 10.20.15 Fish meat, (whether or not minced), frozen
- 10.20.16 Fish livers and roes, frozen

Products that are **not** included in the scope:

- 03.00.13 Live fish, freshwater, not farmed
- 03.00.15 Live fish, freshwater, farmed
- 03.00.22 Fresh or chilled fish, freshwater, not farmed
- 03.00.24 Fresh or chilled fish, freshwater, farmed
- 03.00.31 Crustaceans, not frozen, not farmed
- 03.00.32 Crustaceans, not frozen, farmed
- 03.00.4 Molluscs and other aquatic invertebrates, live, fresh or chilled
- 03.00.5 Pearls, unworked
- 03.00.6 Other aquatic plants, animals and their products
- 03.00.7 Support services to fishing and aquaculture
- 03.00.11 Live ornamental fish
- 10.20.2 Fish, otherwise prepared or preserved
- 10.20.21 Fish fillets, dried, salted or in brine, but not smoked
- 10.20.22 Fish livers and roes dried, smoked, salted or in brine
- 10.20.23 Fish, dried, whether or not salted, or in brine
- 10.20.24 Fish, including fillets, smoked
- 10.20.25 Fish, otherwise prepared or preserved, except prepared fish dishes
- 10.20.26 Caviar and caviar substitutes
  - 10.8 Other food products
    - 10.85.1 Prepared meals and dishes
    - 10.85.12 Prepared meals and dishes based on fish, crustaceans and molluscs

3.2 PEFCR system scope

The scope of this PEFCR covers the life cycle stages of wild and farmed marine fish products as illustrated in Figure 3-1 for wild products and Figure 3-2 for farmed products. The life cycle of marine fish products is divided into the following stages:

- Fishing (raw material acquisition): growing of feed raw materials, fishing and production of other feed raw materials and compound feed production (see paragraph 3.2.1 regarding use of PEFCR Feed for food-producing animals).
- Production (manufacturing): Aquaculture juvenile production and grow out.
- Distribution: Transport of fish from landing to preparation to retailer (including transshipment at sea). This stage also includes storing of the fish and transport packaging. Transport of fish to shore is part of the raw material acquisition (fishing) or production (farming) stages.
- Preparation (manufacturing): Harvest, gutting, filleting and refrigeration and/or freezing. This stage also includes transport of the fish from landing to preparation.
- Packaging: This includes production of the packaging materials and waste handling of the materials after use.
- Retailer and Consumption (use): This stage includes the retail of the product, transport of the consumer, consumption and end-of-life treatment of the product and packaging.

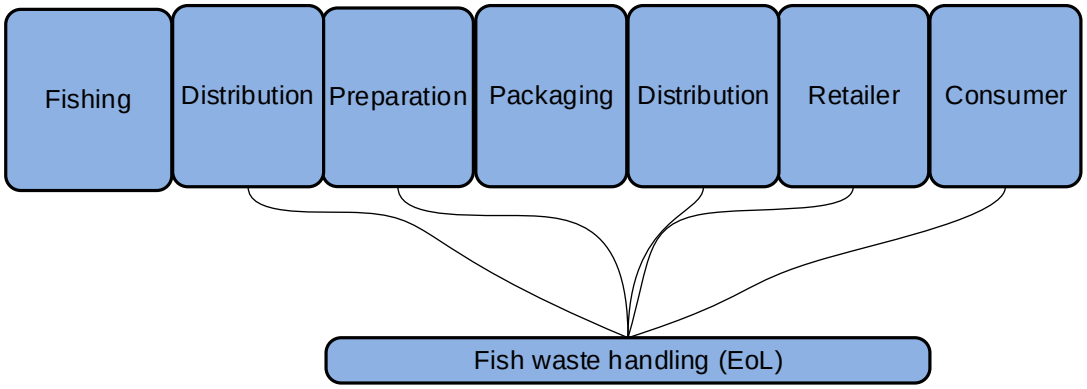

Figure 3-1 System scope wild marine fish

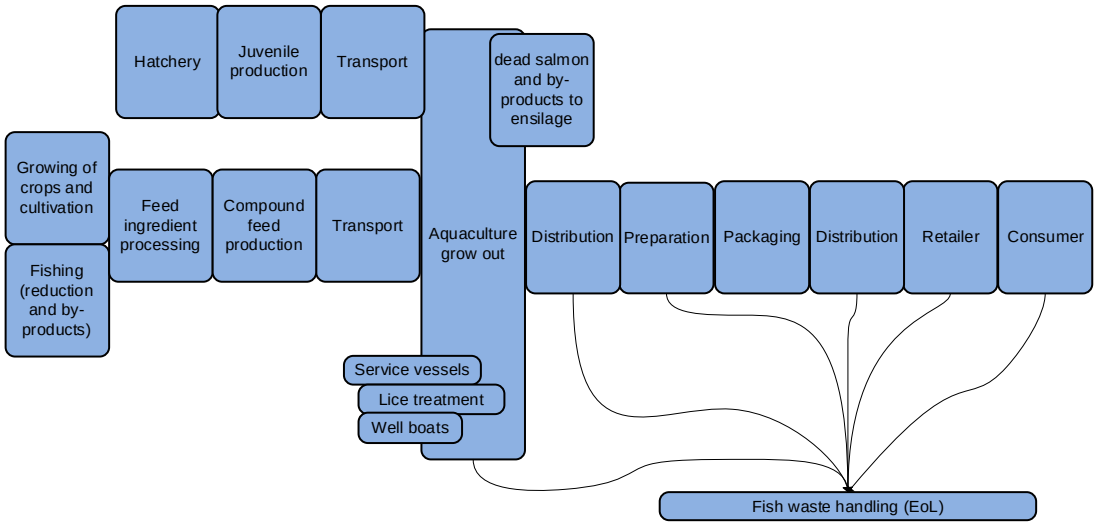

Figure 3-2 System scope farmed marine fish products

3.2.1 Feed for fish farming and system boundaries

Feed for fish farming is within the system boundaries for this PEFCR, meaning that the feed production shall be included in the PEF profile of farmed marine fish products, but the instructions on how the PEF profile of the feed (as it enters the fish farm) shall be calculated are found in the PEFCR Feed for food-producing animals [3]. Thus, the Marine Fish PEFCR does not provide the instruction on how the PEF profile of feed inputs shall be calculated, as that instruction is provided by the PEFCR Feed for food-producing animals [3].

3.3 Targeted audience

This PEFCR is mainly aimed at the actors operating fishing and fish farming and that have access to the key data that determines the environmental footprint of their products (primary data). For actors with only limited information about the products (e.g. mongers that source fish from many producers, but that do not have access to product specific data), generic data are also suggested.

3.4 Conformance to other documents (guiding documents for this PEFCR)

This PEFCR has been prepared in conformance with the following documents (in prevailing order):

- The PEF Method as defined in the report, “Suggestions for updating the Product Environmental Footprint (PEF) method” by the Joint Research Centre (JRC), the European Commission’s science and knowledge service [1] . **This PEFCR provides specifications for how the PEF Method shall be applied for Marine fish consumed in the EU market.**
- Annex A - REQUIREMENTS TO DEVELOP PEFCRS AND PERFORM PEF STUDIES IN COMPLIANCE WITH AN EXISTING PEFCR in the report “Suggestions for updating the Product Environmental Footprint (PEF) method” by the Joint Research Centre (JRC).

3.5 Terminology: shall, should and may

This PEFCR uses precise terminology to indicate the requirements, the recommendations and options that could be chosen when a PEF study is conducted.

- The term "shall" is used to indicate what is required in order for a PEF study to be in conformance with this PEFCR.
- The term "should" is used to indicate a recommendation rather than a requirement. Any deviation from a "should" requirement has to be justified and made transparent when developing a PEF study.
- The term "may" is used to indicate an option that is permissible. Whenever options are available, the PEF study shall include adequate argumentation to justify the chosen option.

The section on Definitions provides more useful definitions of selected terms.

3.6 Technical Secretariat

This PEFCR is the product of the work of a Technical Secretariat (TS). *Table* 3-1 presents the TS members. The development of this PEFCR is possible thanks to the financial contributions of the TS members and a generous grant from the Norwegian Seafood Research Fund (FHF)[8].

Table 3-1 TS members

Organization	Type of Organization	Contact
EU Fish Processors and Traders' Association (AIPCE-CEP)	Representative organization	ksipic@kellencompany.com
Asplan Viak AS	Research institute	erik.hognes@asplanviak.no
AZTI (Observer)	Research institute	sramos@azti.es
The Bellona Foundation	NGO	stefane@bellona.no
Cermaq Group AS	Company (aquaculture)	daniel.pescatores@cermaq.com
Federation of European Aquaculture Producers (FEAP)	Representative organization	catherine@feap.info
European Feed Manufacturers' Federation (FEFAC)	Representative organization	avandenbrink@fefac.eu
Force Technology (Observer)	Research institute	mimi@force.dk
Lerøy Seafood Group ASA	Company (fishing and aquaculture)	ahm@leroy.no
Norwegian Fishermen's Association	Representative organization	jan.henrik.sandberg@fiskarlaget.no
Norwegian Seafood Federation (TS Chair)	Representative organization	henrik.stenwig@sjomatnorge.no
Pelagia AS	Company (fishing and feed production)	andri.thorleifsson@pelagia.com

[8] https://www.fhf.no/fhf/about-fhf-english/

Royal Greenland AS	Company (fishing and retail)	lisc@royalgreenland.com

3.7 Consultations and stakeholders

The development of this PEFCR included public consultations and stakeholder involvement. This included the following activities:

- Public consultation of the PEF-RP studies
- Public consultation of PEFCR drafts
- Establishment of a website for outreach to interested parties
- Contact and engagement with NGOs and other stakeholders that were considered relevant.

3.8 Review of the PEFCR development

Table 3-2 presents the members of the independent panel that provided external reviews throughout the development of this PEFCR. Their reviews were performed according to section A.2.9 in Annex A of the PEF Method [1].

Table 3-2 Members of the PEFCR review panel

Category	Name	Affiliation
Industry expert	Alex Olsen (Chair)	Espersen (Retired)
LCA expert	Angel Avadí	CIRAD
LCA expert	Ian Vázquez-Rowe	PUCP

Annex 12.1 presents the biographical sketches of the Review Panel members.

3.8.1 Review statement

General statement (referring to the PEFCR, the RP and the supporting studies) to be added once the review has been done.

3.9 Geographic validity

This PEFCR is valid for fisheries and aquaculture providing the EU market with marine fish.

3.10 Language

The PEFCR is written in English. The original in English supersedes translated versions in case of conflicts.

3.11 Representative products and studies

The development of this PEFCR included the establishment of representative products that reflects the products this PEFCR covers as they are consumed in the EU. A PEF study performed on these representative products is referred to as the PEF-RP, which provided knowledge to define the rules of this PEFCR. The RPs and the PEF-RP study were also used to calculate the benchmark presented in chapter 10.

Two representative products are modelled:

- A fished marine fish product (wild caught)
- A marine fish product from marine and land-based aquaculture (farmed)

Both are a “virtual (non-existing) product”, since they are made up of different technologies/materials and calculated based on average sales-weighted characteristics of all technologies/materials covered by the scope of the PEFCR.

Table 3-3 The representative products

Product group	Product category	Representative product (one for each category)
Marine Fish for human consumption	Wild caught marine fish	Virtual product based on data on EU consumption of marine fish and global fisheries.
	Farmed marine fish from marine and land-based aquaculture	Virtual product based on data on EU consumption of marine fish and global aquaculture production.

Notice to reader: For the time being (07/26) the complete presentation of the representative products is only available in the PEF-RP report (Marine Fish PEF-RP analysis draft report). In the final PEFCR, the representative products will be presented in full detail.

3.12 Default values and data

This PEFCR includes suggestions of default values and references to secondary data to be used when certain data-gaps are unavoidable. In general, the default values in this PEFCR can be considered as conservative or less favourable for assessing the PEF profile of the given product than the, on average, expected values based on primary data. The intention is to encourage use of primary data and to reduce the risk of a "green-washing" effect when using default values.

3.13 Comparability

The PEF profile that is produced according to this PEFCR can be compared across the product sub-categories (farmed and wild) and within each sub-category if the following requirements are met:

- The DQRtotal score shall be lower than 3 when comparison is not intended.
- The DQRtotal score shall be lower than 2 when comparison and/or comparative assertion is intended.

3.14 Contact information

For questions about this PEFCR please contact:

- Henrik Stenwig: henrik.stenwig@sjomatnorge.no
- Erik Skontorp Hognes: erik.hognes@asplanviak.no

4 MOST RELEVANT IMPACT CATEGORIES, STAGES, PROCESSES AND ELEMENTARY FLOWS

This chapter presents conclusions based on PEF studies of the Representative Products presented in section 3.11. The results of these studies are used to determine the most important impact categories, stages, processes and flows.

As of July 2021, the PEF Representative Product study is not finished, therefore this chapter will be completed according to the results of that study and the supporting studies.

The current identification of the most important impact categories, stages, processes, and flows is presented in the draft Marine Fish PEF-RP Report. In the final PEFCR these findings will be presented in full detail.

5 REQUIREMENTS: SCOPE

5.1 Functional unit and reference flow

The functional units shall be 1 kg of edible products as presented in *Table* 5-1.

The reference flow is the amount of product needed to fulfil the defined function and shall be measured in kg. All quantitative input and output data collected in the study shall be calculated in relation to this reference flow.

See section *3.1* for a description of the types of products for which this PEFCR is valid.

Table 5-1 Definition of functional unit

What	Marine fish products for human consumption and the packaging needed to deliver it.
How much	1 kg consumed edible fish.
How well	The product should be appropriate for human consumption.
How long	For products where durability or shelf-life is established.

5.2 System boundary

Note that the production of feed is to be included according to the PEFCR Feed for food-producing animals [3]. Table 5-2 presents a short description of the activities in each life cycle stage. Section 3.2 PEFCR system scope also provides instructions on the system/stages/processes that this PEFCR covers and thus shall be addressed in a Marine Fish PEF.

Table 5-2 Description of life cycle stages that shall be included

Life cycle stage	Farmed	Wild
Raw material acquisition	Growing, fishing and other production of feed raw materials. Processing of feed ingredients and compound feed production.	Fishing (including production of bait and onboard preparation).
Production (Manufacturing)	Hatchery, juvenile production and grow out of fish.	N/A
Preparation (Manufacturing)	Harvest (slaughter), gutting, filleting, refrigeration and/or freezing.	Gutting, filleting, refrigeration and/or freezing.
Distribution	Packaging materials and transport, including cooling, from preparation to retailer.	
Consumption (Use)	Retail of the product and consumption.	
End of life	Handling of fish mass that is not sold as a commercial product, or not consumed.	

5.3 Impact Assessment

The impact assessment shall be performed according to the current EF impact categories and models[9]. The current method is EF 3.0.

5.4 Additional technical information

The following additional technical information shall be reported:

Farmed products:

- The system descriptions shall include the types of technologies that are used and where the different stages and activities are taking place. Examples of relevant aspects to describe:
  - Kind of containment: Open net pen, closed or land based.
  - Density of fish in cage.
  - Fallowing period.

Wild products:

- Classify the fishing gear that is used according to Annex 3 in the Regulation (EU) No 1379/2013[10] of the European Parliament on the common organisation of the markets in fishery and aquaculture products.
- Specify fishing area according to FAO codes for Major Marine Fishing Areas[11].
- Other relevant information:

[9] The current EF impact assessment method can be found here: https://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml

[10] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32013R1379

[11] http://www.fao.org/cwp-on-fishery-statistics/handbook/general-concepts/fishing-areas-for-statistical-purposes/en/

- Specify the main targeted species.
- Specify the clearly separated seasons.
- Specify by-catch and/or discards during the fishery.
- Specify if the vessel(s) use different fishing gears throughout the season.
- With reference to the targeted fish species, specify if the vessels visit different fishing grounds throughout the season.
- Specify, if relevant, the on-board preparation or processing done as part of the fisheries.

5.5 Additional environmental information

Marine fishing and marine aquaculture are highly relevant for a number of environmental impacts not captured by the current PEF impact assessment method (EF3.0, section 5.3). Among these other impacts, biodiversity impacts (biotic impacts) are the most important. Marine fish production has direct impact on marine ecosystems and indirect impacts through the different inputs. 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.

The additional environmental information required by this PEFCR is limited by the requirements in the PEF Method (section A.3.2.7.1) [1], which states that "Additional environmental information may be included only if the PEFCR specifies the method that shall be used for its calculation.", thus only impacts that can be quantified are suggested as additional environmental information.
The Scientific, Technical and Economic Committee for fisheries (STECF) has suggested *Criteria and indicators to incorporate sustainability aspects for seafood products in the marketing standards under the Common Market Organisation* (STECF-20-05) [12]. The report points at fishing pressure, unwanted landings and discards as well as impacts on the seabed as feasible criteria to assess impact on biodiversity of fishing. All of these are covered by the additional technical and environmental information listed above and below.

The list of additional environmental information is a preliminary list of candidates for relevant quantitative indicators for the biotic impacts of marine fish products. It is not intended to be a list of **all** known impacts, but rather a list of indicators for the **most important** impacts.

[12] https://stecf.jrc.ec.europa.eu/nb_NO/reports/strategic-issues/-/asset_publisher/5fZb/document/id/2872432?inheritRedirect=false&redirect=https%3A%2F%2Fstecf.jrc.ec.europa.eu%2Fnb_NO%2Freports%2Fstrategic-issues%3Fp_p_id%3D101_INSTANCE_5fZb%26p_p_lifecycle%3D0%26p_p_state%3Dnormal%26p_p_mode%3Dview%26p_p_col_id%3Dcolumn-2%26p_p_col_pos%3D1%26p_p_col_count%3D2

The following additional environmental information shall be reported:

Wild products

- Ghost fishing
  - Amount of fishing gear lost per unit of catch.
  - Information about systems to retrieve lost fishing gear in the fishing areas that are used.
  - The properties of the fishing gears are expected to be reported under "additional technical information".
- Quantify the biotic impacts of fisheries according to Annex 2: Suggestion for addressing biotic impacts of fisheries[13].
- Area trawled. Distance trawled per unit of landed catch.
- Number of mammals killed per unit of catch landed.
- Number of birds killed per unit of catch landed.
- Amount of plastics lost into the sea.

Farmed products

- Escapees: number of fish escaped per unit of fish produced.
- Number of mammals killed per tonne of production (specify species as well as accidental versus deliberate animal removals).
- Number of birds killed per unit of production.
- Amount of plastics lost into the sea.

5.6 Limitations

The complete list of limitations will be finished when the PEF-RP study and the supporting studies are finished.

5.6.1 Capital goods – infrastructure and equipment

Infrastructure and equipment shall be included but default data can be used when specific data are not available.

5.6.2 Comparisons and comparative assertions

Comparability is addressed in section 3.13.

5.6.3 Data gaps and proxies

Solutions for frequently encountered data gaps for company-specific data are presented in chapter 6.

List of processes excluded from this PEFCR due to missing datasets that shall not be filled-in by the user of the PEFCR.

[13] Annex 1 of "Marine Fish PEFCR: Screening and recommendations" (2016). Available at: https://www.marinefishpefcr.eu/resources-1

List of processes for which the user of the PEFCR shall apply ILCD entry level (ILCD-EL) compliant proxies: These are presented in Chapter 6.

6 REQUIREMENTS: LIFE CYCLE INVENTORY

This section introduces the rules regarding the data that the PEF study shall include and the data quality requirements.

The PEF will be calculated by many different actors in the marine fish life cycle and this PEFCR tries to provide solutions for different cases, but the basic principle is that the analysis is performed with the availability of the most important data for the PEF of marine fish products (section 6.2). In other words, the intended user of this PEFCR is the fishing vessel operator or the fish farmer, but solutions for other actors are presented in section 6.5.

6.1 Data sampling

If case sampling is needed, it shall be conducted as specified in section A.4.2. of the PEF Method [1]. However, sampling is not mandatory and any user of this PEFCR may decide to collect the data from all the plants or farms, without performing any sampling.

6.2 List of mandatory company-specific data

This section presents the minimum list of mandatory processes that shall always be modelled with primary/company-specific data. Without these primary/company-specific data this PEFCR cannot be applied.

Chapter 7 presents more detail on these processes and the data that shall be collected for them.

Farmed products - Mandatory company-specific data:

- Feed efficiency in grow out (ratio of feed to round fish produced).
- Energy use at the fish farm and by vessels supporting fish grow out and transport of fish from grow out to preparation.
- The PEF profile of the feed according to the PEFCR for Feed for Food-Producing Animals [3].
- Direct emissions from the fish farm. This includes nutrients from uneaten feed, faeces and chemicals (e.g. from antifouling agents used on the farm equipment).
- Fish mass balance over the farming stage. A complete mass balance for all that enters the fish farm. This includes a quantification of all flows and clear definition of their fate. This includes escapees, losses, commercial products and all other fish biomass.
- Relative value/price of the fish co-products from the fish farm.
- Use of fresh water for fish grow out and juvenile production.
- Mass of waste generated and type of handling it is sent to.
- Management of wastewater and sludge from land-based systems.

Wild products - Mandatory company-specific data:

- Energy (fuel) use efficiency in fishery (ratio of energy invested/consumed to fish landed).
- Emission of refrigerants from fishing vessel.
- Fish mass balance of fishery. Complete mass balance for all fish that are retrieved from the sea (fished). This includes the targeted species, by-catch and discards. Each mass flow shall be specified in terms of species and fate after it is fished, and quantified.
- Yield in preparation onboard the fishing vessel. Species-specific yield.
- Energy use for onshore preparation.
- Relative value/price of the fish co-products from fishing, which includes co-products in terms of targeted catch and by-catch, and from onboard preparation if that occurs.
- Bait, amount of bait used, and type (i.e., species).

All products (farmed and wild)

- Energy use in preparation stage.
- Fish mass balance for the preparation stage. Complete mass balance for the fish that enters preparation and how it leaves. This includes specification of the fate of each mass flow, unambiguous definition of state (e.g. fillet or head off gutted) and the fate of all mass flows.
- Relative value/price of the fish co-products from preparation.
- Type of refrigerants used in preparation plant.
- Packaging, Bill of Materials and mass of packaging per unit fish. This include both transport and consumer packaging.

6.3 List of processes expected to be run by the company (should be company-specific data)

Farmed products:

- Production of fertilized eggs.
- Production of juveniles.

All products (wild and farmed):

- Packaging materials (Bill of Materials). This includes packaging used during production, distribution, and consumer packaging.
- Transport from landing/preparation to retailer/client.
- Fishing gear, production and end of life (EoL).

6.4 Data quality requirements

The data quality of each dataset and the total PEF study shall be calculated and reported according to section B.5.3 of the PEF Method [1]. The following presents a short description of the procedure. The Excel file “Marine Fish PEFCR Inventory

Data and DQR" includes two sheets with a prepared setup for the DQR of company specific ("17) Company-specific data DQR") and generic data ("18) Secondary dataset DQR").

The calculation of the DQR shall be based on the following formula with four criteria:

$$DQR = \frac{TeR + GeR + TiR + P}{4}$$

where TeR is technological representativeness, GeR is geographical representativeness, TiR is time representativeness, and P is precision. The representativeness (technological, geographical and time-related) characterises to what degree the processes and products selected are depicting the system analysed, while the precision indicates the way the data is derived and the related level of uncertainty.

For company-specific data, the DQR shall be calculated both for the activity and elementary flow data. For generic data, only the time, technology and geography criteria are considered.

Based on the DQR of the most important data sets (company-specific and generic), the overall DQR of the study is calculated.

A DQR calculator is provided for both company-specific and secondary datasets in the Excel file "Marine Fish PEFCR Inventory Data and DQR".

6.5 Data needs matrix (DNM)

All processes required to model the product and outside the list of mandatory company-specific data (listed in section 6.2) shall be evaluated using the Data Needs Matrix (DNM) as described in section B.5.4 of the PEFCR guidance document [1]).

Each PEF study done in accordance with this PEFCR shall provide a diagram indicating the activities falling in situation 1, 2 or 3 of the DNM.

6.5.1 Data needs matrix for selected cases

This section presents examples of how this PEFCR and its data shall be applied for cases where product-specific data is only partially available:

1) Supplier of fish from several vessels without primary data from the fishing process:
    - Use data presented in the Excel file "Marine Fish PEFCR Inventory Data and DQR" to include the fishery (e.g. sheet 4) Fishing). The precision will be improved if there is knowledge about which fisheries supplied the products.

2) Supplier of fish from fish farming without primary data from the fish farming process:
    - Use data presented in the Excel file “Marine Fish PEFCR Inventory Data and DQR” to include the fish farming and the feed production (e.g. sheet 1) Farming net pen grow out). The precision will be improved if the feed efficiency is representative of the systems farming the fish.

Both of the above cases fall under “Situation 3” of the Data Needs Matrix:
- Situation 3: where the process is not run by the company applying the PEFCR and this company does not have access to company-specific information.
- Option 1 or Option 2: use an EF-compliant secondary data set in aggregated form (DQR≤3.0 if a most relevant process and DQR≤4.0 if not a most relevant process).

As noted, there are two possible options associated with Situation 3:

- Option 1: If it is on the list of the most relevant processes, following the procedure described in section 6.3, the company performing the PEF study shall make the DQR criteria context-specific by re-evaluating TeR, TiR and GeR. The parameter P shall keep the original value. To simplify the re-evaluation of the DQR values, the calculators included in the Excel file “Marine Fish PEFCR Inventory Data and DQR” can be used.
- Option 2: If it is not on the list of the most relevant processes, following the procedure described in section 6.3, the company performing the PEF study shall take the DQR values from the original dataset.

3) Supplier of fish from fish farming without primary data from the fish farming process but with access to data about how much (but not what kind of) electricity the fish farm uses.

    - Use data presented in the Excel file “Marine Fish PEFCR Inventory Data and DQR”.

If regarding a most relevant process, this case falls under “Situation 2 and Option 2” of the Data Needs Matrix:
- Situation 2: where the process is not run by the company applying the PEFCR and this company does have access to company-specific information.
- Option 2: use company-specific activity data for transport (distance), and substitute the sub-processes used for electricity mix and transport with supply-chain specific EF compliant datasets (DQR≤3.0). Re-evaluate the DQR criteria within the product specific context. To simplify the re-evaluation of the DQR values, the calculators included in the Excel file “Marine Fish PEFCR Inventory Data and DQR” can be used.

If not regarding a most relevant process, this case falls under “Situation 2 and Option 3” of the Data Needs Matrix:

- Situation 2: where the process is not run by the company applying the PEFCR and this company does have access to company-specific information.
- Option 3: use company-specific activity data for transport (distance), and substitute the sub-processes used for electricity mix and transport with supply-chain specific EF compliant datasets (DQR≤4.0). Use the default DQR values.

6.6 Which datasets to use?

This PEFCR lists the secondary datasets to be applied by the user.

According to section A.4.4.2 of the PEF Method [1], whenever a dataset needed to calculate the PEF profile is not among those listed in this PEFCR, then the user shall choose data from among the following options (in hierarchical order):

- Use an EF compliant[14] dataset available on one of the nodes of the Life Cycle Data Network http://eplca.jrc.ec.europa.eu/LCDN/
- Use an EF compliant dataset available in a free or commercial source.
- Use another EF compliant dataset considered to be a good proxy. In such case this information shall be included in the "limitations" section of the PEF report.
- Use an ILCD entry level (EL) compliant dataset. These datasets shall be included in the "limitations" section of the PEF report. A maximum of 10% of the total environmental impact may be derived from ILCD-EL compliant datasets (calculated cumulatively from lowest to largest contribution to the total EF profile).
- If no EF compliant or ILCD-EL compliant proxy is available, it shall be excluded from the PEF study. This shall be clearly stated in the PEF report as a data gap and validated by the PEF study and PEF report verifiers.

6.7 Allocation rules

Allocation refers to, "partitioning the input or output flows of a process or a product system between the product system under study and one or more other product systems" (ISO 14040:2006). The rules for allocation are set according to section 4.5 in the PEF Method [1]. **The first allocation rule** is that wherever possible, allocation should be avoided by dividing the unit process to be allocated into sub-processes and collecting the input and output data related to these sub-processes; system expansion with substitution should be avoided because it can lead to arbitrary choices. **When allocation cannot be avoided** the allocations shall as a general principle be economic allocation. Table 6-1 presents different stages/processes where allocation is necessary and the allocation rules to use.

Fish flows that have no positive economic value for the operator (e.g. discards), shall not be attributed any of the environmental burdens (the environmental

[14] Compliant with quality requirements and coherence in terms of Methodology, Documentation, and Nomenclature, for the two compliance systems allowed (ILCD entry level and PEF/OEF). https://eplca.jrc.ec.europa.eu/permalink/Guide_EF_DATA.pdf .

footprint) up to the point of allocation. This means that fish that is, for example, lost or just a waste flow and that has no economic value for the producer shall not be attributed any of the system (i.e. none of the environmental footprint up to the point of allocation).

Section 6.8 on how fish waste flows shall be handled also includes instructions on when allocation can be used and when the CFF formula shall be used.

Table 6-1 Allocation rules

Process/stage	Allocation rule
Fishing, allocation of fishing effort between products landed.	Economic allocation
Aquaculture fish farm, allocation of products for human consumption and other products.	
Feed production.	
Preparation, allocation between main products and by-products.	
Transport	Allocation according to section 4.4.3.1 of the PEF Method [1].

According to the PEF Method) [1], if the applicant multi-functional processes are **not** listed in *Table* 6-1, allocation shall be done according to the hierarchy of the PEF Method (section 4.5) [1]:

1) wherever possible, allocation should be avoided by dividing the unit process to be allocated into two or more sub-processes and collecting the input and output data related to these sub-processes; system expansion should be avoided because it can lead to arbitrary choices.
2) where allocation cannot be avoided and subdivision cannot be applied, the inputs and outputs of the system shall be partitioned between its different products in a way that reflects relevant underlying physical relationships between them.
3) Allocation based on some other relationship may be possible. For example, economic allocation refers to allocating inputs and outputs associated with multi-functional processes to the co-product outputs in proportion to their relative market values.

6.7.1 Economic allocation rules

The allocation factor for each co-product shall be calculated based on the value ratio between the different co-products at the stage where the allocation is done. It shall be documented that this is achieved. The basic principle is that the allocation factor shall reflect the value of the co-product flow for the producer and thus these values are mandatory company-specific data.

The data that is used to set the economic allocation factor shall be representative for the last 3-year average.

One common way of determining the economic allocation factor is to use the market price of the co-product. Since it is the value ratio between the co-products that are relevant it does not matter which currency this ratio is defined in, but the values that are used for each co-product shall be representative for the same market/situation.

Equation (1) presents how the economic allocation factor (AF) to "product a" shall be calculated using the market price (V_a and V_b) and mass yield of "co-products a and b" (M_a and M_b).

Both the unit value (V_a and V_b) and the mass yield (M_a and M_b in equation) shall be documented.

$$Allocation\ factor\ (AF)\ for\ product\ a: A_a = \frac{M_a * V_a}{(M_a * V_a + M_b * V_b)} \quad (1)$$

The following figure and equation present a generic example of how economic allocation is done at stage/process X among "co-products a and b". The example uses the carbon footprint as an example, but the principle is the same for a complete PEF:

$$CF_a\left(\frac{kgCO2e}{kg\ product\ a}\right) = \frac{CF_{TOT} * \frac{M_{a*V_a}}{V_{TOT}}}{M_a} = \frac{CF_{TOT} * \frac{M_a * V_a}{(M_a * V_a + M_b * V_b)}}{M_a}$$

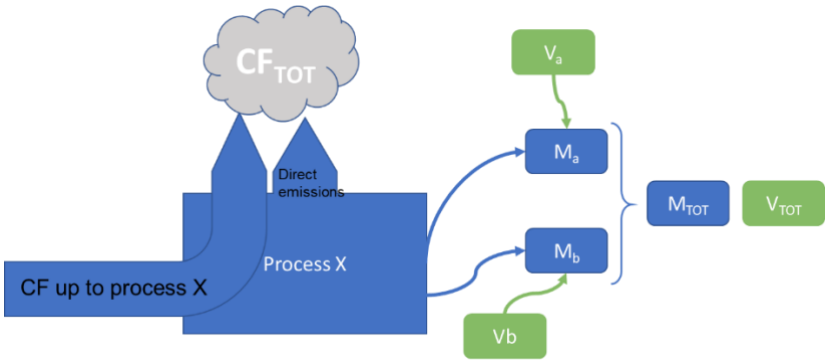

Figure 6-1 Example of economic allocation

6.7.2 Allocation - farmed products

The PEF up to the stage where fish leaves the fish farm shall be allocated among **all products with a documented commercial value**. The value that is used for each product shall reflect the value for the fish farmer.

Aquaculture can include the output of products other than fish (e.g. utilization of sludge to grow vegetable in aquaponics). If these products present a net income to the producer, they can be attributed a share of the environmental footprint by applying economic allocation.

Table 6-2 presents the default allocation factors to be used if product-specific data is not available. These factors are set by expert judgement by the Marine Fish PEFCR TS and according to section 3.12.

Table 6-2 Default allocation factors for fish output at fish farmer gate

Product	Allocation factor (A_a in equation 1) ONLY TO BE USED IF COMPANY SPECIFIC DATA IS NOT AVAILABLE
Products going to direct human consumption	0,9
Products not going to direct human consumption	0,1

The default values presented at the current state are set by expert judgement but will ultimately be based on considerations by the TS and data collection from market and industry.

6.7.3 Allocation - wild products

The fishery can include the process of catching the fish and onboard preparation of the fish. Preparation ranges from the simple process of bleeding the fish to a complete fillet factory with freezing and meal/oil production (from by-products).

The following rules apply for allocation of the fishery:

a) If possible, allocation should be avoided (e.g. only products that are prepared onboard carry the impacts from preparation). The following rules are valid for the case where such measurements/data are not available:
b) The complete activity of the fishing vessel shall be allocated among the products that are landed and have a commercial value. Outputs with no value shall not be assigned any of the fishing activity.
c) The value assigned to each product shall reflect the value of the product as is at landing.

The allocation factor that is used should be company specific as it will determine the final PEF profile (result) of the product.

Table 6-3 presents the default allocation factors to be used if product-specific data is not available. These factors are set by expert judgement by the Marine Fish PEFCR TS and according to section 3.12.

Table 6-3 Default allocation factor for fishery activity

Product	Allocation factor (AF) (A_a in equation 1) – ONLY TO BE USED IF COMPANY SPECIFIC DATA IS NOT AVAILABLE.
Targeted species fillets and gutted fish	0,99

Targeted species by-products from onboard preparation	0,005
Non-targeted species – all products	0,005

The default values currently presented are set by expert judgement but will ultimately be based on considerations by the TS and data collection from market and industry.

6.7.4 Allocation - onshore preparation

This applies for both fished and farmed products. This describes the rules for allocation at the stage where the co-products leave onshore preparation. Allocation of the fishing and fish grow out shall be performed before the onshore preparation stage.

The following rules apply:

a) When possible, the different processes of the preparation stage should be assigned to the specific product that causes them. If such data are not available, the following rule applies:
b) The preparation activity shall be shared among only the products with a commercial value.

Section 7.2.5 presents the default allocation factors for the preparation step.

6.8 End-of-life, waste handling and recycling

"End of life" includes the process from when the mass is discarded and ends when the product is returned to nature as a waste product or enters another product's life cycle (i.e. as a recycled input). The Excel file "Marine Fish PEFCR Inventory Data and DQR" present default data for the application of the CFF formula on fish and other relevant waste flows for marine fish systems.

The CFF formula (section 6.8.2) shall be applied for all waste flows. The waste handling of products used during the manufacturing, distribution, retail, use, or after use stage shall be included. These processes/flows shall be modelled and reported at the life cycle stage where the waste occurs.

To separate between products and waste flows the following distinction shall be used:

- "Products" are mass flows that represent a net income to the producer: value > 0. Products are handled according to the allocation rules (section 6.7).
- "Waste" are mass flows that represent a zero income or net expenses to the producer: value ≤ 0.
  Waste flows will include fish and other materials. These flows shall be modelled and included at the life cycle stage where they occur following the instructions for the use of the end-of-life formula.

Figure 6-2 illustrates how fish/biomass from a marine farmed fish system shall be handled.

The following processes shall be taken into consideration (non-exhaustive list):

- Collection and transport to end of life treatment facilities;
- Sorting and other types of processing;
- Storing, including emissions from degradation during storing;
- Wastewater of products used/dissolved in or with water;
- Composting or other organic-waste-treatment methods;
- Incineration and disposal of bottom ash;
- Landfilling and landfill operation and maintenance.

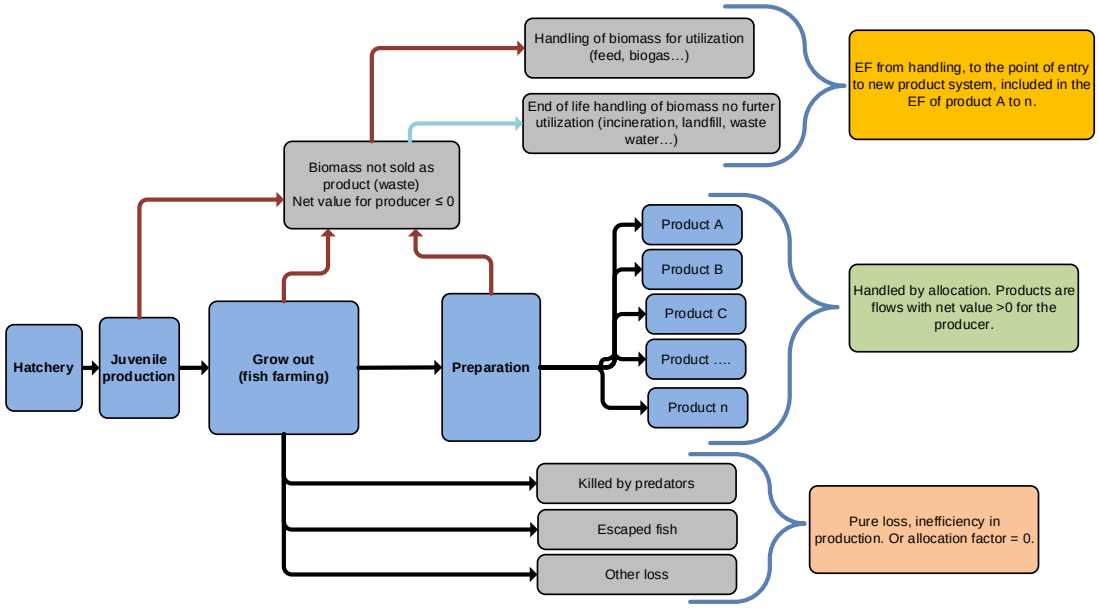

Figure 6-2 Illustration of handling of products and waste from marine aquaculture

6.8.1 Fish biomass and sludge carbon and energy content

Waste handling of fish biomass and sludge from fish farming shall be included based on the actual carbon content of these flows. The sheet "16b) Fish and sludge CFF data" in the Excel file Marine Fish PEFCR Inventory Data and DQR presents data to be used if specific data are not available.

6.8.2 End of life formula

The end-of-life stage shall be modelled using the Circular Footprint Formula (CFF) from section 4.4.8 of the PEF Method [1]. The sheet "16a) CFF data" presents the parameters that shall be used **if primary data is not available**. For waste flows that are not listed here, section 4.4.8 of the PEF Method [1] shall be used.

$$CFF = material + energy + disposal$$

$$Material: (1-R_1)E_v + R_1\left(AE_{rec} + (1-A)E_V\frac{Q_{Sin}}{Q_p}\right) + (1-A)R_2\left(E_{recEoL} - E^*_V\frac{Q_{Sout}}{Q_p}\right)$$

$$Energy: (1-B)R_3 * \left(E_{ER} - LHV * X_{ER,heat} * E_{SE,heat} - LHV * X_{ER,elec} * E_{SE,elec}\right)$$

$$Disposal: (1-R_2-R_3)E_D$$

$$\boldsymbol{CFF\ with\ cut\ off\ approach: (1-R_1)E_v + R_1E_{rec} + R_3E_{ER} + (1-R_2-R_3)E_D}$$

Parameters of the CFF

A: allocation factor of burdens and credits between supplier and user of recycled materials.

B: allocation factor of energy recovery processes. It applies both to burdens and credits.

Q_{sin}: quality of the ingoing secondary material, i.e. the quality of the recycled material at the point of substitution.

Q_{sout}: quality of the outgoing secondary material, i.e. the quality of the recyclable material at the point of substitution.

Q_p: quality of the primary material, i.e. quality of the virgin material.

R_1: it is the proportion of material in the input to the production that has been recycled from a previous system.

R_2: it is the proportion of the material in the product that will be recycled (or reused) in a subsequent system. R2 shall therefore take into account the inefficiencies in the collection and recycling (or reuse) processes. R2 shall be measured at the output of the recycling plant.

R_3: it is the proportion of the material in the product that is used for energy recovery at EoL.

$E_{recycled}$ (E_{rec}): specific emissions and resources consumed (per functional unit) arising from the recycling process of the recycled (reused) material, including collection, sorting and transportation process.

$E_{recyclingEoL}$ (E_{recEoL}): specific emissions and resources consumed (per functional unit) arising from the recycling process at EoL, including collection, sorting and transportation process.

E_v: specific emissions and resources consumed (per functional unit) arising from the acquisition and pre-processing of virgin material.

E^*_v: specific emissions and resources consumed (per functional unit) arising from the acquisition and pre-processing of virgin material assumed to be substituted by recyclable materials.

E_{ER}: specific emissions and resources consumed (per functional unit) arising from the energy recovery process (e.g. incineration with energy recovery, landfill with energy recovery, etc.).

$E_{SE,heat}$ and $E_{SE,elec}$: specific emissions and resources consumed (per functional unit) that would have arisen from the specific substituted energy source, heat and electricity respectively.

E_D: specific emissions and resources consumed (per functional unit) arising from disposal of waste material at the EoL of the analysed product, without energy recovery.
$X_{ER,heat}$ and $X_{ER,elec}$: the efficiency of the energy recovery process for both heat and electricity.
LHV: lower heating value of the material in the product that is used for energy recovery.

6.9 Period of data collection

Primary data shall be collected for a period of the last three years using a floating average. This includes the data used for allocation.

6.10 Electricity modelling

The use of electricity shall be included following the requirements of section B.5.8 of the PEF Method [1].

6.11 Climate change modelling

The impact category climate change shall be modelled according to section B.5.9 of the PEF Method [1].

6.12 Biogenic carbon

A simplified approach can be used, and only biogenic methane shall be modelled.

Biogenic methane emissions shall be considered for at least:

Farmed products:

- Biogenic methane from anaerobic degradation of sludge. This includes both sludge that is built up under the open net pen fish farms and sludge that is collected and stored (e.g. from land-based farms).
- Fish waste.

Wild products:

- Biogenic methane from anaerobic degradation of fish waste. Section 6.8.1 presents default values for the calculation of potential biogenic carbon emission from fish biomass and sludge.

7 LIFE CYCLE STAGES

This chapter presents the different processes that shall be included for each life cycle stage.

Figure 7-1 presents the different stages, processes and flows that shall be taken into consideration when performing a PEF of a wild marine fish product.

Error! Reference source not found. presents the different stages, processes and flows that shall be taken into consideration when performing a PEF of a farmed marine fish product.

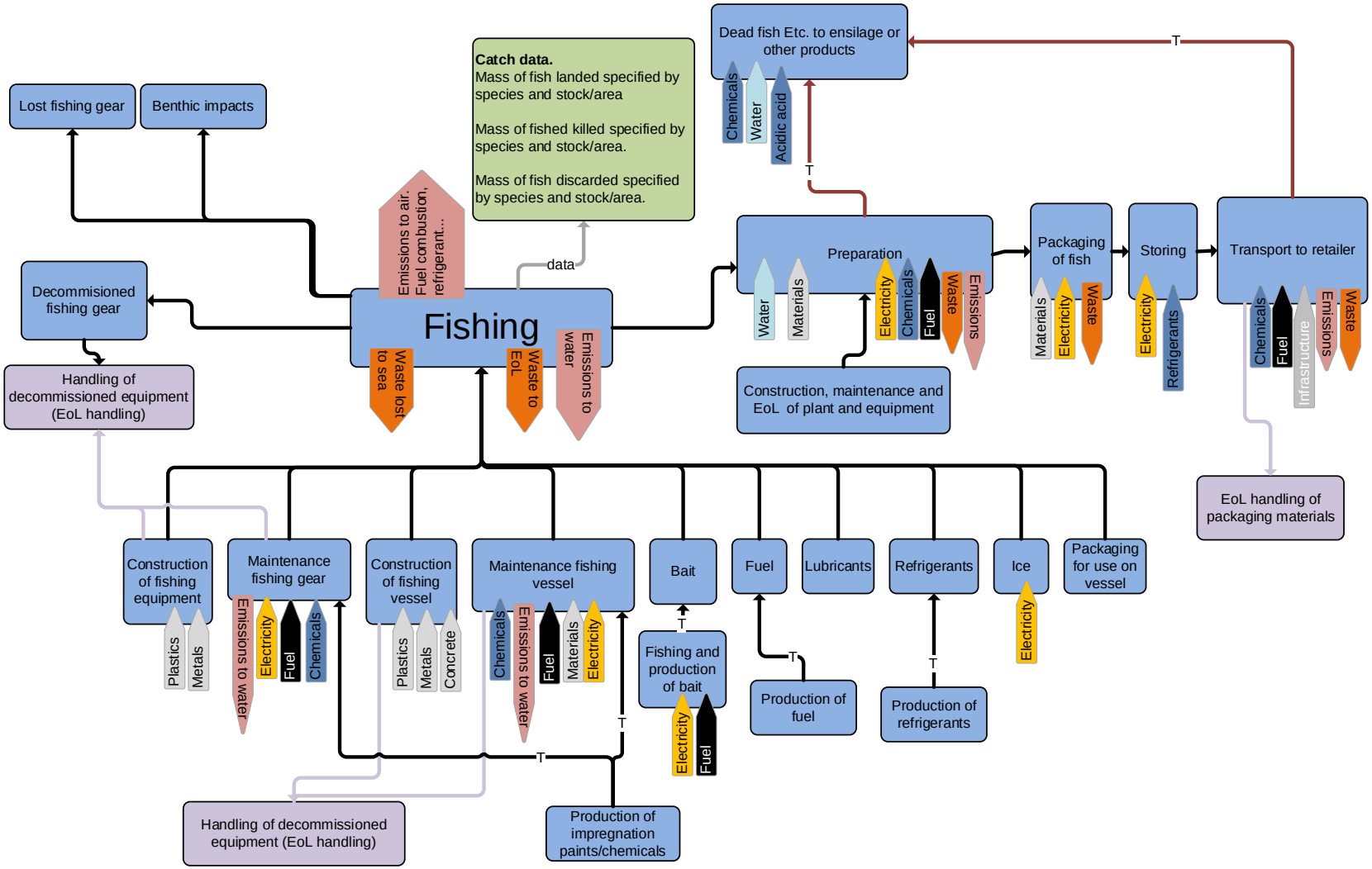

Figure 7-1 Fishing product flow chart. A "T" simply indicate that transport of that flow is included.

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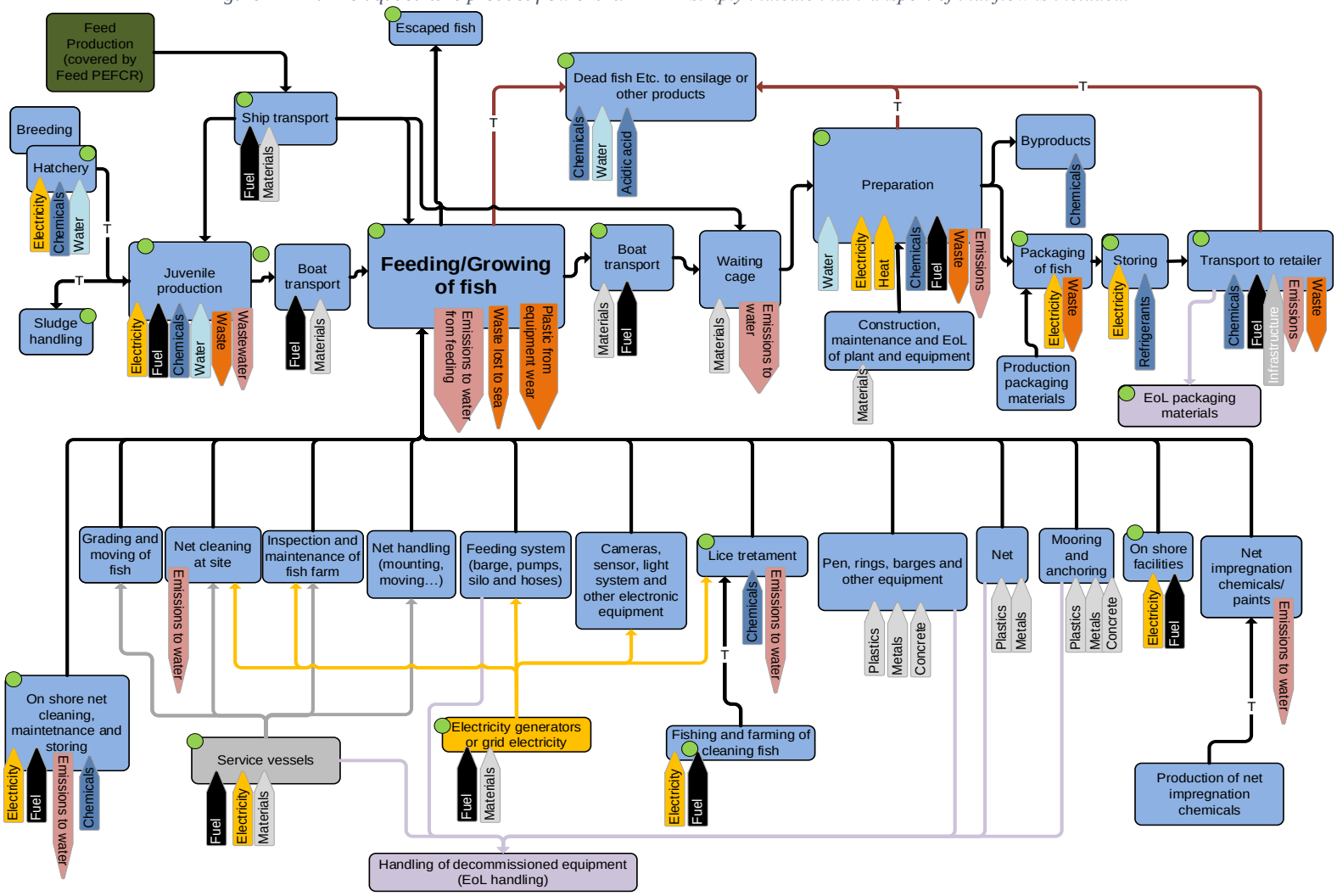
Figure 7-2 Marine aquaculture product flow chart. A "T" simply indicate that transport of that flow is included.



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7.1 Raw material acquisition and pre-processing

7.1.1 Fishing

Fishing includes all activities that the fishing vessel goes through to be able to deliver fish to shore. *Table* 7-1 presents an example of activities that are part of the fishing activity.

Sheet "4) Fishing" of the Excel file "Marine Fish PEFCR Inventory Data and DQR" lists the activities and direct elementary flows that shall be quantified and the default datasets for the sub-processes linked to the activity data within this process.

Table 7-1 Activities that are part of fishing.

Transport of fishing vessel and catch to and from fishing ground
Maintenance operations and transport of fishing vessel to maintenance
Catching of fish
Onboard preparation of fish
Onboard refrigeration and ice production
Harbour activities and onshore ice production

7.2 Manufacturing

7.2.1 Transport of inputs

Transport from raw material acquisition (fishing) to the preparation and transport of inputs to farming shall be included according to section 4.4.3 of the PEF Method [1].

The sheet "14) Transport inputs" presents the transports that shall be included and the default data to be used if primary data are not available.

7.2.2 Aquaculture: Production of juveniles

Juvenile production can be the production of small juveniles that is only a small percentage of the harvest weight (e.g. salmon juveniles of 100 gr that are grown out to 4-5 kg at harvest), to fish that are brought up to a considerable percentage of their final harvest weight. When the juvenile production represents a large percentage (more than 10%) of the harvest weight, this stage shall be included according to section *7.2.4*. For other circumstances a dataset will be developed.

7.2.3 Aquaculture: Marine net pen grow-out

The growing of fish in marine net pen grow-out includes the system from when juvenile fish are released into the fish farm and until they are ready for harvest. Growing of fish here includes all activities that are necessary to keep the fish farm operating and to handle the fish. For example, this includes the different vessels that are used, as well as those operated by sub-contractors, see *Table* 7-2.

In the Excel file "Marine Fish PEFCR Inventory Data and DQR", the sheet "1) Farming net pen grow out" lists the activities and direct elementary flows that shall be quantified and the default datasets for the sub-processes linked to the activity data within this process.

The data for the grow out shall be collected for at least a period covering the complete production cycle of the product (from juvenile production to ready for harvest).

Table 7-2 Activities that are considered to be part of the grow out of fish in marine net pen.

Feeding and all handling of feed
Maintenance operations of fish cages, mooring systems and all other equipment
Transport of fish
Handling of fish such as grading and veterinary treatment
Transport of personnel and materials between land and fish farm
Energy used by equipment on the fish farm (e.g. generators, pumps, communication and monitoring systems, lighting and monitoring, oxygen production, cleaning systems and facilities for the operators).

7.2.3.1 Direct emissions from net pen fish farm

During the feeding of fish, nutrients are emitted through feed spills and faeces. Emissions to water of nitrogen, phosphorus, dissolved organic carbon and carbon from the salmon cage shall be included. The Excel file "Marine Fish PEFCR Feed emission mass balance model" presents a model of a feeding mass balance that shall be used to calculate these emissions based on the content of the feed, feeding efficiency and retention in the fish.

7.2.4 Aquaculture: Recirculating Aquaculture System (RAS) grow-out

This stage includes both juvenile production and full grow out of fish. The stage includes all activities and inputs that are necessary to operate the plant. Recirculating aquaculture systems also often include a continuous input of water, and this flow shall be included in the PEF. The output and handling of sludge shall be included until this stage. If the sludge presents an income to the RAS plant, it can be included in the allocation.

In the Excel file "Marine Fish PEFCR Inventory Data and DQR", the sheet "2) Farming RAS production" lists the activities and direct elementary flows that shall be quantified and the default datasets for the sub-processes linked to the activity data within this process.

7.2.5 Preparation

Preparation includes transformation of the fish such as gutting, filleting, freezing, etc., and this process shall be included using company-specific data. See section 3.1 for more information on the difference between preparation and processing. For fished products, preparation can happen both on the fishing vessel and on shore.

For preparation on the fishing vessel, this process shall be included in the data for the fishery as stated in section 7.1.1.

In the Excel file "Marine Fish PEFCR Inventory Data and DQR", the sheet "6) Preparation" lists the activities and direct elementary flows that shall be quantified and the default datasets for the sub-processes linked to the activity data within this process.

7.2.6 Waste from manufacturing

Waste generated during manufacturing, that is both fish and other materials, shall be included in the modelling.

If primary data needed to use the Circular Footprint Formula (section 6.8) is not available, sheets "16a) CFF data" and "16b) Fish and sludge CFF data" in the Excel file "Marine Fish PEFCR Inventory Data and DQR" present the default data that can be used.

7.3 Distribution stages

The distribution stage includes the transport activity, packaging and product loss and waste handling.

7.3.1 Transports

Fish is distributed in many ways from the point where it is landed to final consumption. The following transport processes shall be included:

- Transport from landing to preparation
- Transport from preparation to retailer
- Storage and redistribution
- Transport to consumer

Systems may include numerous iterations of sequences of preparation and storage and all transport of fish shall be included.

Transport of the fish before it is landed shall be included in the fishing or farming stages.

In general, these distribution processes shall be included according to section 4.4.3.5 of the PEF Method [1]. The sheet "14) Transport inputs" in the Excel file "Marine Fish PEFCR Inventory Data and DQR" presents the transports that shall be included and the default data to be used if primary data are not available.

7.3.2 Transport packaging production and waste handling.

Transport packaging shall be included with production of materials, transport and end-of-life handling (waste handling).

The sheet "13) Packaging" in the Excel file "Marine Fish PEFCR Inventory Data and DQR" presents the data that shall be included and default data that can be used if primary data are not available.

7.3.3 Product waste from distribution

The waste of products during distribution and retail shall be included in the modelling. (Waste refers to all fish biomass that leaves the value chain without a value for the producer.) The sheet "8) Waste rates" presents the default rates that shall be used if company-specific data are not available. The waste handling shall be included according to section 6.8.

7.4 Retailer and consumer

The retailer and the consumer stage shall be included. The sheet "9) Retailer" in the Excel file "Marine Fish PEFCR Inventory Data and DQR" presents the data that shall be included and default data that can be used if primary data are not available.

The data for the retailer stage are based on data from the Retail OEFSR[15] and the consumer stage.

Waste at retailer and consumer stage shall be included. If specific data is not available default loss rates are presented in the sheet "8) Waste rates" in the Excel file "Marine Fish PEFCR Inventory".

7.5 End-of-life fish consumer product

Waste handling of the fish products that are not consumed and their packaging materials shall be included according to section 6.8.

The end-of-life stage for the fish begins when the product and its packaging is discarded by the user and ends when the product is returned to nature as a waste product or enters another product's life cycle (i.e. as a recycled input). In general, it includes the waste of the product in scope, such as the food waste, and primary packaging.

Here the end-of-life stage is defined as the waste handling of fish that is not eaten by the consumer. Not eaten includes fish that is thrown out before it is prepared and fish that is prepared, but not eaten. If specific data are not available, default loss rates are presented in sheet "8) Waste rates" of the Excel file "Marine Fish PEFCR Inventory Data and DQR".

If primary data needed to use the Circular Footprint Formula (section 6.8) is not available, the sheets "16a) CFF data" and 16b) Fish and sludge CFF data in the Excel file "Marine Fish PEFCR Inventory Data and DQR" present default data.

[15] Retail OEFSR: Microsoft Word - OEFSR-Retail_DraftOEFSR_15052018 woln.docx (europa.eu) https://ec.europa.eu/environment/eussd/smgp/pdf/OEFSR-Retail_15052018.pdf

8 PEF RESULTS

8.1 PEF profile

The user of the PEFCR shall calculate the PEF profile of its product in compliance with all requirements included in this PEFCR. **The impact assessment method that shall be used is presented in section 5.3.** The following information shall be included in the PEF report:

- full life cycle inventory;
- characterised results in absolute values for all impact categories (as a table);
- normalised results in absolute values for all impact categories (as a table);
- weighted result in absolute values for all impact categories (as a table);
- the aggregated single overall score in absolute values.

Together with the PEF report, the user of the PEFCR shall develop an aggregated EF compliant dataset of its product in scope. This dataset shall be made available to the European Commission. The disaggregated version may remain confidential.

9 VERIFICATION

A PEF study carried out in compliance with this PEFCR shall be verified according to section B.8. of the PEF Method [1].

10 BENCHMARK VALUES

The benchmarks were calculated by the PEF-RP study conducted during the development of this PEFCR. See more on that study in section 3.11 and Annex 12.3.

The PEF-RP report presents the preliminary benchmark results for the two product groups wild and farmed marine fish. The results will be included in this PEFCR once they are final.

11 REFERENCES

[1] L. Zampori and R. Pant, “Suggestions for updating the Product Environmental Footprint (PEF) method,” 2019.

[2] S. Fazio, L. Zampori, A. de Schryver, O. Kusche, L. Thellier, and E. Diaconu, *Guide for EF compliant data sets (Version 2.0)*. 2020.

[3] EC, “PEFCR Feed for food producing animals version 4.1 April 2018,” no. April. 2018.

12 ANNEXES

12.1 Annex 1: Review Panel

Industry expert, **Alex Olsen** graduated with a degree in Environmental Management from the Technical University of Denmark in 2009 and received his MSc in Food Science from the Royal Veterinary and Agricultural University (Denmark) in 1986. Mr. Olsen is current self-employed after working as Head of Sustainability for A. Espersen A/S for the past 14 years (2007-2021). Prior to this, he was Manager of McDonald's Europe's Agricultural Assurance program from 2002-2007 and Supply Chain Manger for McDonald's Denmark (1995-2002) after starting his career as Project Leader for Food Manufacturing and Microbiology for the Danish Meat Institute (1987-1995), Food Inspector in Holbaek, Denmark (1986-1987), and Food Policy Officer, Danish Consumer Association (1986). During his career at Espersen, Mr. Olsen managed numerous projects focused on seafood sustainability, including: coordinating an international working group that aims to secure a healthy marine eco-system for the future in the northern-most part of the Northeast Atlantic around the island of Svalbard; developing Disruptive Seafood Harvest design concepts; developing the Espersen Sustainability Program "Our Seas, Our Fish, Our Food"; coordinating MSC certification of the Danish East Baltic cod fishery and providing assistance to Lithuanian and Latvian authorities to support their move towards MSC certification; developing the Issuing Supplier Agreement (a set of rules to avoid buying fish from unregistered catches); presenting the company's revised calculation on illegal, unreported and unregulated fishing (IUU) in Baltic cod fisheries based on industry data to The International Council for the Exploration of the Sea (ICES); actively engaging in the development of the European Fish Processors and Traders Association (AIPCE-CEP); and developing guidelines for the responsible sourcing of fish.

LCA expert, **Dr. Angel Avadí** graduated in Computer Systems Engineering in 2002, from the Catholic University of Guayaquil (Ecuador). He obtained in 2006 a MSc in e-Business (International University of Japan), in 2008 a MSc. in International Cooperation Policy (Ritsumeikan Asia Pacific University - Japan), and in 2010 a MEng. in International Material Flow Management (University of Applied Science Trier - Germany). Between 2011 and 2014, he worked on his PhD thesis (University of Montpellier - France) focused on the sustainability of value chains associated with Peruvian fisheries, including aquaculture. Since 2015, he is a researcher at the French Agricultural Research Centre for International Development (CIRAD). He has contributed to various projects focused on seafood systems, including a project funded by Sustainable Recycling Industries (SRI) in the course of which he provided dozens of LCI datasets to ecoinvent (2018); and two European Value Chain Analysis for Development (VCA4D) projects focused on Zambian aquaculture (2018) and Gambian fisheries and aquaculture (2020). Angel has contributed dozens of life cycle inventory datasets to the French AGRIBALYSE agricultural LCA database. Angel has also reviewed projects and methodological guidelines focused on seafood systems, such as VCA4D projects on Cambodian aquaculture (2017) and Malian

inland fisheries (2020), as well as several project proposals submitted to the German Research Foundation (2017) and the Research Council of Norway (2020). He has published 35 scientific papers to date, with nine additional pieces currently under review.

LCA expert, **Dr. Ian Vázquez-Rowe** graduated in Biology in 2006 at the University of Texas at Arlington. He then continued his graduate studies in Environmental Engineering at the University of Santiago de Compostela – USC (2006-2008), with a short Erasmus period at the University La Sapienza in Rome where he developed his master thesis. In October 2008 he initiated his research career at USC, where he obtained his PhD in Chemical Engineering in July 2012. Currently, Dr. Vázquez-Rowe is an Associate Professor at the Department of Engineering at the Pontificia Universidad Católica del Perú. He has participated in numerous research projects at a European, Spanish, Galician, Luxembourgish and Peruvian level, as well as recent projects with UN Environment. Dr. Vázquez-Rowe has published over 110 articles in international journals. Currently, he is also the editor for Ocean Resources and Marine Conservation at the International Journal of Life Cycle Assessment and for Journal of Environmental Management. One of his main research lines has been linked to analyse the environmental sustainability of seafood products, mainly from wild fisheries. He has contributed to various projects focused on seafood systems, including a project funded by Sustainable Recycling Industries (SRI) in the course of which he provided dozens of LCI datasets to ecoinvent (2018), together with Ángel Avadí. More recently, he has started working on the environmental impacts related to the dissipative release of plastic fragments to the ocean and the associated effects on human health and (ocean) ecosystem quality. Since 2019 he co-chairs the Marine impacts in Life Cycle Assessment (MarILCA) projects, which aims at establishing novel characterization factors and impact categories to compute environmental impacts and damages associated to marine plastics in Life Cycle Impact Assessment.

12.2 Annex 2: Suggestion for addressing biotic impacts of fisheries

Suggested approach to integrate assessment of biotic impacts in seafood from capture fisheries PEF pilots

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Summary of suggestions:
Including ecological impacts of seafood production is vital for a comprehensive assessment in the sense of covering all relevant environmental issues. However, the development and use of these methods in LCA is a work in progress, with constraints related to both available methods and data. Based on findings so far and which ecological aspects that are important to consider, different approaches are suggested for on impact on target species, by-catches, habitats and ecological communities.

1. ***For target species, overfishing through fishing mortality (OF) and overfishedness of biomass (OB) is suggested.***
2. ***For by-catch, a hierarchical approach consisting of excluding catches with biological reference points and assessing the remaining part of the catch as impact on threatened species according to the IUCN Red List (VEC) and the rest as amount of data-limited catch (D-L) is suggested.***
3. ***For habitats, a model for quantifying seafloor area swept (m^2) is recommended as a rough metric, not yet assessing actual impacts on habitats.***
4. ***For ecological communities, quantifying the primary production required (PPR) of catches (landings and discards) is suggested. This is an approach of high relevance to seafood from aquaculture.***

In appendix I, examples on how to perform the impact assessment are given. Appendix II comprise of response to the comments given by the EU commission on the methods provided.

Life cycle assessment of seafood: coverage of methods for ecological assessment

For many types of industrial food production, ecological impacts are important (Foley *et al.* 2011); this is especially true for food production which interferes with biodiversity while depending on productive and functioning ecosystems, and in particular seafood from capture fisheries, representing the only large-scale food production based on a wild resource. As for seafood LCAs, the need to assess the potential impacts from removal of marine ecosystem components has repeatedly been pointed out (Pelletier *et al.* 2007, Vázquez-Rowe *et al.* 2012a, Avadí & Fréon 2013).

The PEF requirements mandate that (article 4.4):

> *"The selection of EF impact categories should therefore be comprehensive in the sense that they cover all relevant environmental issues related to the product supply chain of interest."*

As the most renowned environmental impact and resource use of fisheries are those of depletion of natural fish production and ecological effects in the marine ecosystem, reflected in for example the focus by environmental NGOs, consumer awareness and public debate, the inclusion of ecological assessment of the seafood from capture fisheries should be imperative.

However, one of many methodological challenges with ecological assessment methods in LCA is that the impact assessment methods in LCAs normally are independent of time and space; yet ecological impacts of fisheries could be characterized as being a proximate ecological concern. This area is in general not adequately covered in traditional LCAs (Reap *et al.* 2008), but similar discussions are had in e.g. impact assessment of land use (i Canals *et al.* 2007). The ISO standard also mandates that impact categories, category indicators and characterization models should for example be internationally accepted, scientifically and technically valid and environmentally relevant (4.4.2.2.3 ISO 14044:2006). Therefore, in the case of seafood from capture fisheries, new impact assessment approaches, choice of

indicators and characterization methods with a higher level of resolution in terms of time and space.

Seafood from capture fisheries

One approach to make sure that important elements of ecosystem interference are covered is to make use of the framework ecological risk assessment (ERA) of fisheries, which scope has been to cover fishing pressure on ecological components of an ecosystem in such was that all elements of an ecosystem are covered (Hobday *et al.* 2011). These have been split into the following categories:

1) Target species
2) By-product and by-catch species
3) Threatened, endangered and protected species (TEP)
4) Habitats
5) Ecological communities

This categorization of impacts will hence be used as a basis for presenting and categorising currently available LCA impact assessment methods and proposing which methods to use in seafood PEFs for ecological assessment of capture fisheries. On note, categories two and three are merged as one by-catch category.

1. Target species

The most evident ecological impact of fishing is removal of biomass from a natural ecosystem, which may have various effects on ecosystem structure and function depending on catch amount, frequency of disturbance, species impacted and more (see e.g. Jennings & Kaiser 1998).

LCA methods available

Emanuelsson *et al.* (2014) developed a quantitative methodology (three midpoint impact categories) to include overfishing in seafood LCAs based on the Maximum Sustainable Yield (MSY) framework. MSY represents the theoretical maximum annual landing (or yield) that can be harvested from a wild fish stock over time and has been a concept in fisheries science since it was initially developed in the 1930s (Punt & Smith 2001). The use of MSY in seafood LCA to account for single-stock overfishing is in Emanuelsson *et al.* (2014) done in three midpoint impact categories: lost potential yield (LPY),a future projection of fishing under more optimal conditions, overfishing through fishing mortality (OF) and overfishedness of biomass (OB). The two latter categories relate current fishing mortality and spawning stock biomass to the target levels for those parameters, respectively. OF and OB are complementary categories which may be used either to interpret LPY results, or separately when all input parameters are not available.

Langlois *et al.* (2014a,b) also suggested a framework for assessing biotic resource depletion in LCAs of fisheries at endpoint level, using the MSY framework and the primary production needed with impact pathways to two Areas of Protection (AoP), natural resources and ecosystem quality. However, the theory behind this approach is questionable in terms of being scientifically valid; to mention some points of critique,

a) the unit referred to for both AoPs is time for regeneration of biomass (which could not be quantified as part of this framework as it depends on more factors than suggested (see e.g. Hutchings & Reynolds 2004) and b) referring to impact on ecosystem quality while studying separate fish species trophic level is an inadequate as it depends on the total amount of biomass that is taken out of an ecosystem; a low catch of higher trophic level species from an ecosystem may be less severe that a high catch of lower trophic level species in terms of ecosystem quality depending on how the ecosystem production is controlled (Hunt & McKinnel 2006) or the strength of the connectivity of the species in the food chain (Smith *et al.* 2011). Similar critique, i.e. the scientific robustness of estimating time perspectives for resource depletion and replenishment, applies to the LPY-framework proposed by Emanuelsson *et al.* (2014), as well as data availability for estimating LPY. These frameworks are therefore seen as not applicable for seafood in their current format.

Proposed method for assessing overfishing of target stock:

The OF and OB midpoint impact categories suggested by Emanuelsson *et al.* (2014). The information needed is catch in mass of a certain stock and year to be inserted in Simapro where characterization factors are available based on:

$$OF = F/F_{MSY} - 1;$$

$$OB = B_{MSY}/B - 1$$

OF, referring to fishing pressure, describes how close to the target fishing mortality the fishery is at present (with the OF value to be understood as how many kilos that are currently fished too much for every kilo that is landed), while OB, referring to fish biomass, describes how close the stock is to its target biomass (the resulting OB value to be understood as how much too low the spawning stock biomass is in kilos per kilo landed). Note that when $F=F_{MSY}$ and $B=B_{MSY}$ both OF and OB are 0, indicating no ongoing overfishing or overfishedness. The characterization model is therefore expressed for OF so that the optimum case ($F=F_{MSY}$) to result in no impact per FU, and for OB to correspond to zero impact when $B = B_{MSY}$ and is also inverted in order to make larger value equal to higher impact).

SimaPro applicability

For all stocks that have defined MSY-values, these could be inserted into SimaPro in a format that would only require the practitioner to inventory catch in mass per species/stock and year.

Data availability and plan for update

The RAM Legacy Stock Assessment Database (Ricard *et al.* 2012) has MSY values for 138 stocks that are fished globally. Additional MSY values may be found in the publicly available database administered by ICES (ices.dk). In 2012, F_{MSY} values were found for 31 major European stocks (Emanuelsson *et al.* 2014), and more values will become available as all European stocks shall be managed with an MSY objective in the reformed Common Fisheries Policy (CFP; EU 2013).

The values for MSY would have to be updated at least once per year, based on new stock assessment and scientific advice.

2. By-product and by-catch species including threatened, endangered and protected species (TEP)

By-catch, i.e. the unintentional catch of non- targeted species or sizes which are either discarded at sea or landed, can be vast is some fisheries and is as a waste of resources and unsustainable pressure on vulnerable species (Kelleher 2005). Fishing activities undeniably also affect vulnerable species whether these are targeted or not and contribute to loss and/or depletion of species (e.g. Dulvy *et al.* 2014; Hoffman *et al.* 2010); to which extent depends on e.g. gear type and target species.

LCA methods available

Different approaches have been suggested and evaluated to include by-catch of fish species in seafood LCAs. Predominantly, by-catch and discard have at best been assessed in terms of live weight (in kilo discard per landing, possible separated by species composition); in recent years, new approaches has been suggested and evaluated such as discard rate in a fishery relative to a global discard rate (GDI), primary production required (PPR) of discards, mass or count of fish classified as threatened by the IUCN Red List of Threatened species (VEC) or quantified in mass as data-limited (D-L) by-catch per unit of landing (Hornborg *et al.* 2012,Vázquez-Rowe *et al.* 2012a,b, Ziegler *et al.* in press).

Discard mass in weight:

The first method proposed to assess by-catch was that of simply inventory the mass discarded per functional unit, possibly also stating the dominant species or a qualitative discussion on the potential impact (e.g. Ziegler *et al.* 2003, Ziegler & Valentinsson 2008). Even if this could be seen as being only an inventory result, this indicator shall be included in any seafood LCA based on capture fisheries, given the discard rate contribution to sustainable use of resources and marine ecosystem impacts (Kelleher 2005; Coll *et al.* 2008).

Primary Production Required (PPR):

Primary Production Required (PPR) is metric intending to reflect the disturbance of ecosystem flows as it takes into account the trophic level of the species affected by estimating how much carbon that has to be assimilated through photosynthesis to produce a certain species (Hornborg *et al.* 2013a). Global fisheries catches have been identified to be constrained by the available primary production (Chassot *et al.* 2010, Watson *et al.* 2014), and depending on discard amount may jeopardize sustainable use of fish resources (Coll *et al.* 2008). Estimating the primary production required is therefore an important advancement; however, as the discarded part represent a resource that is thrown back to the ecosystem it might be argued that this impact assessment is more related to ecological communities. Following this reasoning, PPR may be used to assess marine ecosystem appropriation when fish is used as feed for aquaculture (see section on seafood from aquaculture).

Hierarchical framework including Data-Limited (D-L) stocks:

This approach offers a hierarchical framework for assessing by-catch impacts, proposed and tested in Ziegler (in press). The method basically inventory which information is available for the assessment; if biological reference points such as those related to MSY are available for the species, the target stock method proposed by Emanuelsson et al. (2014) is used. If those are not available, the rest of the catch is screened for presence of threatened species according to the IUCN Red List is used, following the framework of Hornborg et al. (2013b). The rest of the catch is then reported as being Data-Limited, i.e. the amount of the catch (in weight) that have neither biological reference points, nor been assessed by the IUCN Red List. It has e. g. been estimated that 80 % of global landings lack proper stock assessment (Costello *et al.* 2012) and about one-quarter (4,337 of some 17,000 species of marine fish) were on the IUCN Red List in 2013 (Colette *et al*. 2013). Of the marine fish species assessed by the IUCN, 416 species are considered as threatened (i.e. Critically Endangered, Endangered or Vulnerable) and 1,180 species are Data Deficient. All in all, by this approach, the whole fish catch in a fishery would be categorised in any of the three compartments (target, VEC or data-limited).

Constraints of the method comprise of the limited coverage of the IUCN Red List assessment and its geographical resolution and time for assessment (risk of being outdated), and the fact that the Data-Limited part does not convey any information on the situation of these fish.

Global Discard Rate (GDI):

The Global Discard Rate (GDI) index was proposed by Vázquez-Rowe *et al.* (2012b) as a dynamic midpoint indicator. The discard rate in the assessed fishery is related to a global discard rate according the Kelleher (2005). Two options are presented: either by computing PPR of the discard (GDI_{BRU}) and relate this to a global average of PPR of discards, which is assumed to be 3.1 based on the estimate of mean trophic level (MTL) of landings from Pauly et al. (1998), or merely use the mass reference without computing PPR (GDI_{mass}).

Based on the difficulty of interpreting the MTL metric (Hornborg et al. 2013a) and in the next step, the rough assumption that has to be made for computing global average of PPR of discards for computing GDI_{BRU}, this approach is not seen as coherent with the ISO requirements as discussed earlier (4.4.2.2.3 ISO 14044:2006). As for the mass approach (GDI_{mass}), this is not much of an advancement compared to merely presenting discard in mass and then discuss results in relation to what is a high and low discard rate in a fishery based on literature (such as Kelleher 2005). Thus, none of these methods of high relevance to include in SimaPro.

Vulnerable, Endangered or Critically endangered (VEC) fish species

It was initially proposed by Lindeijer *et al.* (2002) to make use of the International Union for Conservation of Nature (IUCN) Red List Categories and Criteria to assess risks of extinction in impact assessment methods for biotic resource extraction. The

IUCN Red List was initiated with the aim to "identify and document those species most in need of conservation attention if global extinction rates are to be reduced", and has over time expanded its remit to also monitor trends in global levels of biodiversity loss (IUCN 2012). Inclusion of the IUCN framework in seafood LCA has been initiated in terms of assessment of catch of threatened fish by Hornborg *et al.* (2013b) and applied in case studies (Hornborg *et al.* 2012; Ziegler *et al.* accepted). In Hornborg *et al.* (2013b), it is proposed that the amount of threatened fish (i.e. VEC; stands for Vulnerable, Endangered or Critically Endangered, the three threat categories) is quantified as volume of VEC discarded per kilo landed, in mass (kilo) and individuals (number). Hornborg *et al.* (2013b) also opened up for assessing landed by-catch as VEC in case no biological reference points were available, an approach that was further tested in Ziegler *et al.* (in press). Another metric, the Red List Index, was also tested in Hornborg *et al.* (2013b) but dismissed.

When evaluated in case studies (Hornborg *et al.* 2012; 2013a), this method showed coherence with other estimates on vulnerability and what is known of the studied fisheries impacts on sensitive fish species, further supported by a prior study (Dulvy *et al.* 2005). It was thus concluded that the study of the amount of VEC fish discarded per landed kilo of seafood is a new and promising quantitative approach for assessing differences in un-wanted catches of sensitive species on a product level. However, constraints comprise of species resolution (the IUCN assess species while there may be major differences between separate stocks), choosing geographical resolution (species may have different level of threat locally compared to globally), and update frequency of assessment (insufficient globally, every five years in regional initiatives) why the target species approach is preferable.

The method only covers fish species, at it is proposed now, but may be used to assess by-catch of other threatened species such as marine mammals and birds (Online Resource 3 in Hornborg *et al.* 2013b). There have also been doubts on whether the assessment by the IUCN is appropriate for actively regulated stocks, where it could falsely lead to false alarms as well as missing signals that indicate risk (ICES 2009a,b), partly due to the low update frequency (Rondinini *et al.* 2014).

Proposed method for assessing landed by-catch and discard:

The hierarchical framework including Data-Limited (D-L) stocks developed by Ziegler *et al.* (in press).

1. **Exclude fish landings that have OF and/or OB values in SimaPro (these belong to target)**
2. **Quantify quantities of the remaining part of the catch (landed by-catch and, if available discarded, as separate entities) comprising of species listed as VEC or is at all assessed by the IUCN Red List**
3. **Quantify the rest of the fish catch as being Data-Limited catches (by-catch and discard respectively, in mass)**

LCA software applicability

Catch (landings and discards in mass and species composition) is an important part of inventory and should thus be collected by the LCA practitioner and inserted into in e.g. SimaPro as input from nature.

To calculate the VEC indicator, threatened species will be available as inputs from nature and the LCA practitioner would have to multiply by mass. Species listed as VEC will count as 1, those that are not as 0.

Data availability and plan for update

Data on landings are found in national statistics, or could be collected by the practitioner from the industry if absent or higher resolution that the total landing by a country is needed for a specific study.

Data on discard mass in weight may be collected and available for use from management authorities, or if absent possibly be inventoried by the LCA practitioner from the industry or as the last option, found in literature on the specific fishery (such as Kelleher 2005) and merely be discussed qualitatively.

Increased coverage of species by the IUCN Red List is essential. Species groups known to be extra sensitive to fishing pressure have been given priority in terms of assessment, and the global IUCN Red List currently covers e.g. all cartilaginous fishes (Hoffman *et al.* 2010). The assessment of marine species by the IUCN Red List is highly prioritized, with currently one-quarter of marine fish assessed, and recent initiatives intend to complete assessments within five years (Collette *et al.* 2013). These efforts will be most useful for future product comparisons. All European fish species have now been assessed by the IUCN Red List Categories and Criteria; the complete list will be released beginning of June 2015.

3. Habitats

Fishing gears in contact with the seafloor, predominantly demersal trawls, alter the physiological structure, species composition and ecosystem function of the benthic habitat (Puig *et al.* 2012; Watling 2005) even if potential effects are far from fully understood (Sheppard 2006).

LCA methods available

Nilsson & Ziegler (2007) developed a function for estimating seafloor area swept by various demersal trawls and related that to the spatial distribution of fishing activities, frequency of disturbance and what was known of habitat distribution. Since then, the function for estimating area swept has been applied in several case studies (e.g. Hornborg *et al.* 2012, Ziegler *et al.* in press). Recent development includes a theoretical best-practise framework to stepwise guide an LCA practitioner in how to assess seafloor impacts (Emanuelsson & Ziegler unpublished).

Given that the area metric is sufficient as a basic habitat impact, there are new models that can be used for assessing seafloor area swept. Outcomes of the BENTHIS-project

(Eigaard *et al.* in press) offer a characterization model for assessing doorspread D (width of trawl):

D=a(kW)b

Were *a* and *b* are fishing-type specific parameters and kW is the kW of the boat. Seafloor area swept can then be estimated from:

Seafloor area= D*speed of the boat*hours trawled

Proposed method for assessing impact on habitats:

The general BENTHIS-model:

Door spread (m)=(a*kWb)

with *a* and *b* fishing-type specific parameters (found in Eigaard *et al.* in press) indicating the width between otter boards in seafloor contact during trawling, in meters. To calculate seafloor area swept per kilo landing, this estimate needs to be multiplied with the speed of the trawl (in meters/hour) adjusted for the landing per hour trawled (CPUE, in kg/hour).

Data availability and plan for update

The LCA practitioner will have to inventory the kW of the boats involved in the fishery, trawling speed and hours trawled in order to perform the seafloor assessment. These data should be available by the national fisheries authority.

4. Ecological communities

Ecological communities are affected by fishing activities and may alter the ecosystem in terms of trophic structure, size composition, diversity, primary production and more (Fulton *et al.* 2005, Rochet & Trenkel 2003).

LCA methods available

This is an area of method development that has been the least advanced in LCA of seafood, in part due to the complexity. The impact on ecological communities is the sum of all fishing activities and more, making the impact contribution from a certain fishing activity hard to decouple from the total impact. Of note, Avadi *et al.* (2014) coupled LCA with ecosystem modelling in the form of Ecopath with Ecosim (EwE; Christensen & Walters 2004). This is a promising area, but given the novelty, Simapro and LCA practitioner applicability is yet to resolve. The sea use approach suggested by Langlois *et al.* (2014b) could also be seen as an attempt to take a wider approach to ecosystem effects but was earlier dismissed as not being scientifically valid.

In one sense, the PPR metric (or biotic resource use, BRU) offers a measure of this aspect and may be used until more complete approaches are defined (Hornborg *et al. 2013a*). This metric has been widely applied for assessing feed composition in

aquaculture (e.g. Pelletier *et al.* 2009). PPR is calculated according to an equation from Pauly and Christensen (1995).

<u>Proposed method for assessing impact on ecological communities:</u>

Quantifying PPR for both landings and discard. This is done based on a conservative 9:1 conversion ratio of wet weight to carbon:

$$\mathbf{PPR} = \sum_i (Y_i/9) \times \left(\frac{1}{TE}\right)^{(TL_i - 1)}$$

where Y_i is landing yield for species i with trophic level TL_i, and transfer efficiency TE (global average 10%).

Based on the fact that different regions have different TE (Coll *et al.* 2008), regional values may be used (Hornborg *et al.* 2013a).

SimaPro applicability

The LCA practitioner would have to inventory catch volume per species. Regionalized characterization factors for estimating PPR would be available in Simapro.

Data availability and plan for update

Trophic level estimates are found on FishBase (fishbase.org). Regionalized TE values are found in e.g. Coll *et al.* (2008).

Directions on how to calculate biotic impacts

Examples are here provided on how biotic impact assessment may be done for a seafood product (cod, haddock and shrimp) from capture fisheries, here landings from a Norwegian freeze-trawler during 2013 in the Barents- and Norwegian Sea (Ziegler *et al.* 2015). Mass allocation is used.

1. Target species

The OF and OB midpoint impact categories are as suggested by Emanuelsson et al. (2014):

$$OF = F/F_{MSY} - 1;$$
$$OB = B_{MSY}/B - 1$$

OF, referring to fishing pressure, describes how close to the target fishing mortality the fishery is at present (with the OF value to be understood as how many kilos that are currently fished too much for every kilo that is landed), while OB, referring to fish biomass, describes how close the stock is to its target biomass (the resulting OB value to be understood as how much too low the spawning stock biomass is in kilos per kilo landed). Note that when $F=F_{MSY}$ and $B=B_{MSY}$ both OF and OB are 0, indicating no ongoing overfishing or overfishedness. The characterization model is therefore expressed for OF so that the optimum case ($F=F_{MSY}$) to result in no impact per FU, and for OB to correspond to zero impact when $B = B_{MSY}$ and is also inverted in order to make larger value equal to higher impact).

Alternatively, if there are no reference points relating to MSY while it is sustainably fished according to scientific advice, the OF is set to 0.

To calculate overfishing through fishing mortality (OF), the fishing mortality *F* for the assessed species during the year it was caught is compared with the target fishing mortality for maximum sustainable yield F_{MSY} for the stock during the same year, as defined by the International Council for the Exploration of the Seas (ICES). For the example below, landings from a fishery that took place during 2013, the reference points for *F* (i.e. the fishing mortality during 2013) and F_{MSY} (i.e. the target value for 2013) is taken from the ICES advice released in 2014. Values for *F* and F_{MSY} for the specific stock, is found under stock advices at the ICES webpage (ICES 2015).

Four species/stocks had biological reference points allowing them to be evaluated in terms of impact on target species; OF was 0 kg/kg for cod and hake, whereas 0.6 kg/kg for haddock in 2013 (Table 1). Shrimp did not have explicit reference points related to *MSY* identified, but was categorised as green in the advice (harvested sustainably).

Table 12-1 Calculation of overfishing through fishing mortality (OF) in 2013 for a Norwegian seafood product (cod or haddock) delivered to port.

Fishery	Stock	Scientific name	F	F_{MSY}	Landings (kg)	OF x kg	OF (kg/kg)
Cod-haddock	Northeast Arctic cod	*Gadus morhua*	0.23	0.4	4 557 259	0	0
Cod-haddock	Northeast Arctic haddock	*Melanogrammus aeglefinus*	0.56	0.35	489 078	293 447	0.06
Cod-haddock	Hake (northern stock)	*Merluccius merluccius*	0.24	0.24	144	0	0
Shrimp	Northern shrimp[16]	*Pandalus borealis*	-	-	185 768	0	0

As the fishing boat had different target species during different trips during the year, the trips for cod and haddock were separated from those targeting shrimp. For the cod-haddock fishery, there was a total landing of all species of 5 225 305 kg during 2013 (trips 5, 6, 9-11, 13, 16-23). The only species caught with an impact value for OF was haddock; this implies a total OF for the fishery at 293 447/5 225 305 = 0.056 kg/kg landing in the cod/haddock fishery (see By-catch assessment). Pure shrimp fishing was only done in one trip (trip 7), with no by-catch of fish, resulting in an OF of 0 kg/kg shrimp.

Overfishedness of biomass (OB) was not possible to calculate due to lack of reference points in the advice.

2. By-catches

The hierarchical framework developed by Ziegler et al. (2015) is as follows:

4. ***Exclude fish landings that have OF and/or OB values (these belong to target)***
5. ***Quantify the composition of the remaining landings comprising of species listed as VEC or is assessed by the IUCN Red List***
6. ***Quantify the rest of the landings as being Data-Limited catches***
7. ***If there is data on discards, repeat the procedure for the discarded part of the catch; if discard data is lacking, provide for alternative references for estimates of discard rate (e.g. Kelleher 2005)***

[16] The stock are given no quantitative reference points in the advice, merely "green"= harvested sustainably.

From the same data set as for the target species impact assessment, landings belonging to the OF category was excluded and landings were screened for presence of species listed as threatened, i.e. belonging to either the Vulnerable (VU), Endangered (EN) or Critically endangered (EN) category, on the latest Norwegian Red list of Threatened Species (Kålås *et al.* 2010). Two species were assessed to have a threat status, both red fishes: *Sebastes marinus* and *Sebastes mentella*. Landings of these two species combined comprised of 33 720 kg in the cod/haddock fishery during 2013, none in the shrimp fishery, resulting in a VEC-value of:

33 720/5 225 305 = **0.006 kg VEC/kg landing in the cod and haddock fishery**; and 0/185 768 = **0 kg VEC/kg landing in the shrimp fishery**

Of note, Norway and Sweden provide unique examples of having national IUCN Red Lists updated every five years. There is however a recent European initiative that has categorised all European marine fish according to the IUCN framework. When available, national lists are preferred, as is the case with Norway. If the European IUCN Red List would have been used, the two red fish species would have been categorised as VEC, plus a few additional species, namely halibut *Hippoglossus hippoglossus* (VU), roundnose grenadier *Coryphaenoides rupestris* (EN) and possibly wolffish (but it was not identified to a species level and only one is considered to be threatened). There is also a global IUCN Red list.

The rest of the catch, i.e. the total catch minus OF- and VEC-species, was categorised as Data-Limited catches (D-L), estimated as follows for the cod-haddock fishery:

5 225 305 – 4 557 259 – 144 – 489 078 – 33 720 = 144 960 D-L landings

Per landing, this is equivalent to **0.03 kg D-L/kg cod/haddock.**

The shrimp fishery had no reported by-catch of fish, thus **0 kg D-L/kg shrimp.**

Discard data was not available. According to a Norwegian report from 2004 (Kommisjonen for tiltak mot utkast av fisk 2004), the discard ratios are relatively small in these two fisheries. The shrimp fishery uses a species-selective grid, but may discard juvenile fish, mainly gadoids (approximately 0.05- 0.1 kg/kg landed shrimp; table 3). In the cod-haddock fishery, discards are also in the range of 0.05-0.1 kg/kg landing.

3. Habitats

The general BENTHIS-model is as follows:

$$\textit{Door spread (m)} = (a * kW^{b})$$

Where a and b are fishing-type specific parameters indicating the width between otter boards in seafloor contact during trawling, in meters. To calculate seafloor area swept per kilo landing, this estimate needs to be multiplied with the speed of the trawl (in meters/hour) adjusted for the landing per hour trawled (CPUE, in kg/hour).

For crustacean trawling (OT_CRU, table 4 in Eigaard et al. 2015), this equals to:

Seafloor area per landing m^2/kg=((5.1*$kW^{0.47}$)*speed)/CPUE; and
for demersal fish trawling (OT_DMF):

Seafloor area per landing m^2/kg=((9.6*$kW^{0.43}$)*speed)/CPUE

According to the online resource 1 in Ziegler et al. (2015), the Norwegian freeze-trawler reported different speed depending on target species, higher for fish than for shrimp. A typical shrimp haul has a speed up to 2.5 knots, whereas a typical cod and haddock haul has a speed up to 3.8 knots; 1 knot equals to 1 852 m/h. The engine effect of the boat was approximately 3840 kW.

As there was no information on trawl hours for 2013, this assessment was based on the background data on catch per unit effort (CPUE, in kg/h) from 2011. The seafloor impact for the shrimp fishery, with an average CPUE of 680 kg/h and speed of 2.5 knots thus equals to:

((5.1*3840*0.47)*(2.5*1 852))/680= **1 680 m^2/kg shrimp**

For cod and haddock, trawling with a speed of 3.8 knots and a CPUE of 6200 kg/h, this equals to:

((9.6*3840*0.43)*(3.8*1 852))/6200= **380 m^2/kg cod/haddock**

5. Ecological communities

The quantifying of primary production required (PPR) for catches is done based on a conservative 9:1 conversion ratio of wet weight to carbon:

$$PPR = \sum_i (Y_i/9) \times \left(\frac{1}{TE}\right)^{(TL_i - 1)}$$

where Y_i is landing yield for species i with trophic level TL_i, and transfer efficiency TE (global average 10%).
Based on the fact that different regions have different TE (Coll et al. 2008), regional values may be used (Hornborg et al. 2013a).

To estimate PPR, trophic levels are found at Froese and Pauly (2015). If ecosystem-specific transfer efficiencies *TE* are not found, the global average 10% may be used. Ecosystem-specific values can be found at webpages (Pauly and Zeller 2015; NOAA 2015) http://www.seaaroundus.org/or scientific publications such as Coll et al. (2008).

Using the 10% global average for *TE* and the data from 2013, PPR for the cod and haddock fishery was 139 gC/kg cod and haddock (table 2) whereas shrimp had the equivalent of 56 gC/kg (table 3).

Table 2 PPR estimates for cod and haddock fishing.

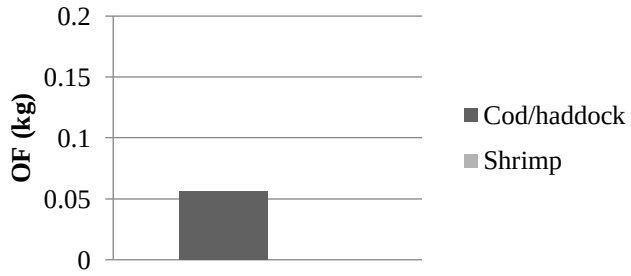
Species	TL	Landing (kg)	PPR (g C)	PPR/kg
Cod	4.1	4 557 259	637 472 129	
Haddock	4.0	489 078	54 342 000	
Others	3.6-4.4	178 968	32 997 155	
Total		5 225 305	724 811 284	**139**

Table 3 PPR estimates for shrimp fishing.

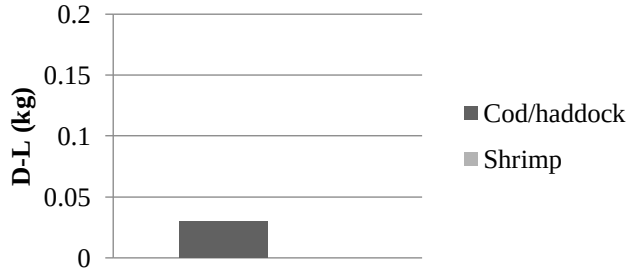
Species	TL	Landing (kg)	PPR	PPR/kg
Shrimp	3.7	185 768	10 344 950	
Total				**56**

Discard data was not available.

Overall results

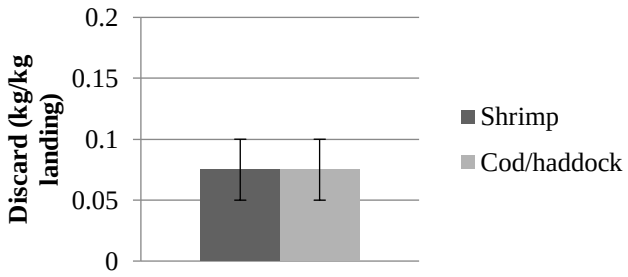


Overfishing is low in the cod and haddock fishery and there is no overfishing in the shrimp fishery.

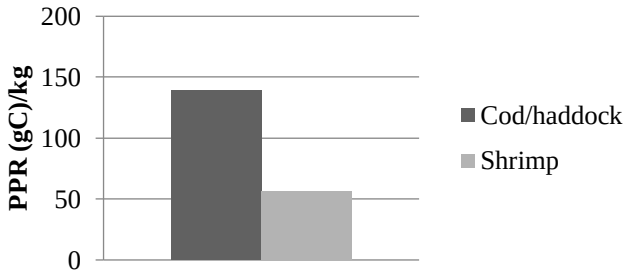


Landing of Data-Limited species is low in the cod and haddock fishery and none in the shrimp fishery.

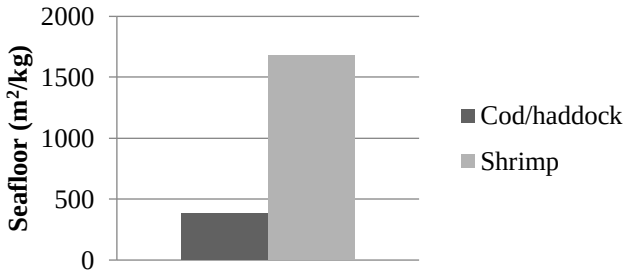
Landing of threatened species is low in the cod and haddock fishery and none in the shrimp fishery.



No inventory data was available on discards; figures are based on a report describing discards in the two different fisheries. The shrimp fishery is estimated to have lower discards per kilo landing, or they could the same.



The primary production required is more than double for the cod and haddock fishery compared to the shrimp fishery.



The seafloor area swept per kilo is more than three times as high for the shrimp fishery compared to the cod and haddock fishery.

Some considerations on the methods proposed by SP Food and Bioscience and presented in Annex I

As regards overfishedness of biomass (OB) the application of the method is complex, also given the quality of data, and that part might be questioned due to that. However, biomass is an indicator evaluated by ICES, the scientific body delivering data to the EC and also internationally (e.g. US/Canada) so data is available.

As regards by-catch, some might consider that the IUCN list should not be the reference. However, since the IUCN categories and criteria, is a globally applied assessment method which is e.g. supporting one of the indicators to the Convention of Biological Diversity. The recent initiative on assessing the status of all marine fish further strengthens its applicability in European waters and this is not to say that it cannot be used outside of EU waters.

With regard to the last two impacts, namely on habitats and ecological communities, one might consider as first option is what is already available in EU regulations. In particular, Appendix XIII of Commission Decision of 18 December 2009 (2010/93/EU) adopting a multiannual Community programme for the collection, management and use of data in the fisheries sector for the period 2011-2013 defines a series of environmental indicators to measure the effects of fisheries on the marine

ecosystem, that are linked to the Marine Strategy Framework Directive. The Commission will soon start working on the preparation of a new proposal replacing decision 93/2010, the Multiannual Programme for data collection, but for the moment this may constitute a reference for the definition of environmental indicators.

Similarly, Annex III of Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive) provides an indicative lists of impacts on the environment caused by human activity. This is a piece of ENV legislation. Below is the link to one of the last reports released by ICES on descriptors and indicators related with the MSFD: http://www.ices.dk/sites/pub/Publication%20Reports/Advice/2015/Special_Requests/EU_Revisions_to_MSFD_manuals_for_Descriptors_346.pdf

Another option, envisaged under point 4.5 of the recommendations on the use of methods for PEF (2013/179/EU) PEF, might be that the impacts on habitats and ecological communities should be explained by means of qualitative descriptions as provided in the abovementioned legal acts.

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12.3 Annex 3: Description of how the representative product was developed

(To be added in the next draft.)

12.4 Annex 4: Default datasets

See Excel file “Marine Fish PEFCR - Inventory Data and DQR”.

12.5 Annex 5: Public Review Report

See Excel file “Marine Fish PEFCR - Review Panel Report - 19 07 2021”.