Marine Fish PEFCR

Goal and scope description for the PEFCR

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1. About this document

This document presents a draft plan for the development of Product Environmental Footprint Category Rules for marine fish products. The intended readers are the European Commission and those that will be involved in the development of the PEFCR.

The document includes presentation of methodical decisions for the intended PEFCR, this must be understood as a basis for discussion as they in the end will be the product of the complete secretariat producing the PEFCR and based on inputs according to the requirements of an open, inclusive and transparent development process.

2. Background

The development described in this document will be a continuation of a process to develop a Marine Fish PEFCR that started in 2014 as a part of the second wave of PEFCRs pilots[1]. The development continued until May 2016 when it was decided to stop the process as it became clear that it do not exist the necessary data to develop a Marine Fish PEFCR in compliance with the requirements of the PEFCR Guideline and due to time-constraint it was unmanageable to finish within the timeline of the Pilot-phase. At that stage a draft PEFCR had been through public consultation and through review by independent LCA experts appointed by the EU commission. The work was summarised in a report that gave recommendations for a PEFCR for Marine Fish Products[2].

A Product Environmental Footprint Category Rule (PEFCR) can be understood as a set of rules that specify how the Product Environmental Footprint (PEF) method[3] shall be applied for a specific product category. E.g. there are distinct differences between the environmental profile of a seafood product and that of a battery, and thus the rules for how their environmental footprint shall be calculated and documented needs to be specified. The PEF method is a Life Cycle Assessment (LCA) based method to quantify the relevant environmental impacts of products (goods or services). It builds on existing approaches and international standards.

The development of PEFCRs is a part of the EU policy for sustainable production and consumption. The "single market for green products"[4] policy, that intend to make the environmental properties of product a part of its economy. To be able to achieve that, the environmental footprint of the product has to be calculated and documented in terms of a set of known and trusted rules, a PEFCR. A PEFCR is developed according to a PEFCR Guidance document (the current version is 6.3) [5] that defines the requirement to the organisation and the process of developing a PEFCR.

PEFCRs should be developed and written in a format that persons **with technical knowledge (in LCA as well as with regard to the considered product category)** can understand it and use it to conduct a PEF study. The PEFCRs shall implement the materiality principle, meaning that a PEF study shall focus on those aspects and parameters that are the most relevant in determining the environmental performance of a given product.

2.1 Terminology: shall, should and may

This document refers to requirements and suggest requirements. Thus, a clear use and understanding of the following terms are important:

- The term "shall" is used to indicate what is required in order for a PEFCR to be in conformance with the PEFCR Guidance.

[1] Link to more information about the PF pilots: http://ec.europa.eu/environment/eussd/smgp/ef_pilots.htm
[2] Link to project report
[3] Link to the PEF method: http://ec.europa.eu/environment/eussd/pdf/footprint/PEF%20methodology%20final%20draft.pdf
[4] Link to more information about the Single Market for Green Products policy: http://ec.europa.eu/environment/eussd/smgp/index.htm
[5] Link to PEFCR Guidance v6.3 document: http://ec.europa.eu/environment/eussd/smgp/pdf/PEFCR_guidance_v6.3.pdf

- The term “should” is used to indicate a recommendation rather than a requirement. Any deviation from a “should” requirement has to be justified when developing the PEFCR and made transparent.
- The term “may” is used to indicate an option that is permissible. Whenever options are available, the PEFCR shall include adequate argumentation to justify the chosen option.

3. Organization

Since the first attempt of making a Marine Fish PEFCR there has been a continuous work to make the seafood industry and its surrounding governments aware of the “single market for green products” policy and the importance of taking an active role to secure the development of a good PEFCR.

3.1 Requirements: Representativeness

There are strict requirements to representativeness in the development of a PEFCR (PEFCR Guidance v6.3, chapter 6.6.3): A PEFCR is considered to be representative of a specific product category when all the following conditions are met:

1) The Technical Secretariat in charge of a specific product category has invited to contribute to the PEFCR development process all the major competitors, or their representatives (i.e. via industry associations) covering for at least 75% of the EU market (in terms of yearly turnover or production). All companies contributing to more than 10% to the EU market (in terms of yearly turnover or production) have been invited.
2) The industry stakeholders (producers/importers, either as single companies and/or as business associations) participating to the whole process cover at least 51% of the EU market (in terms of yearly turnover or production). The participation of stakeholders will be judged on the basis of their inputs to the process and/or participation to meetings. The 51% target has to be achieved by the end of the drafting phase.
3) The Technical secretariat has invited and involved in the PEFCR development process a wide range of stakeholders, with particular reference to SMEs, consumers' and environmental associations.

3.2 Technical secretariat (TS)

For each PEFCR development there shall be a Technical Secretariat that are responsible for ensuring that the development is done according to the PEFCR Guidance and activities such as drafting the PEFCR proposal and organising consultation meetings and public hearing.

Table 3-1 TS members (example of candidates to be invited)

Type	Examples of potential members	Activity	Comments
Pelagic industry	Pelagia	High sea pelagic fisheries	
Aquaculture industry	Cermaq, Lerøy, Nova Sea, Midt Norsk Havbruk.	Open net pen marine aquaculture	
Groundfish industry	Lerøy,		
SME (requirement			
NGO (requirement)	WWF, Bellona, MSC, ASC,		
Industry organisations	FEFAC; AIPCE – CEP FEAP		European Feed Manufacturers' Federation AIPCE-CEP is the EU Fish Processors and Traders Association Federation of European Aquaculture Producers
Fishing Industry	Europêche EAPO		Association of national organizations of fishing enterprises in the European union The European Association of Fish Producers Organisations
	SUM (requirement)		

Table 3-2 Companies and other relevant initiatives for supporting studies, data and other cooperation

Company or group name	Products, value chain description, geographic area, technologies used.	Comments
Agribalyse	The AGRIBALYSE® program consisted in elaborating a database of Life Cycle Inventories (LCI) of the main French agricultural products at the farm gate[6]	Does also include seafood products

3.3 Stakeholder involvement

The process of developing the PEFCR shall be open and transparent and shall include an open consultative format with relevant stakeholders. The stakeholders should be involved following a supply chain approach. The relevant stakeholders for a PEFCR may include, but are not limited to, material suppliers, manufacturers, trade associations, purchasers, users, consumers, government representatives, non-governmental organizations (NGOs), public agencies and, when relevant, independent parties and certification bodies.

[6] https://www.ademe.fr/en/expertise/alternative-approaches-to-production/agribalyse-program

3.3.1 Marine Fish PEFCR development web page

A simple web page will be established as a part of the Marine Fish PEFCR development. This will secure a simple way of spreading information about the process and the different documents that are needed to secure public involvement.

3.3.2 Kick off workshop

Before the PEFCR development starts a workshop will be arranged in a European city to invite interested parties to become an active party of the development and to provide their suggestions and inputs to the development. In front of the workshop a preliminary plan for the PEFCR development will be made available. This to enable interesting parties a better understanding of what a development of a PEFCR for marine challenges include and what challenges it brings.

4. Methodical considerations for the PEFCR development

The following chapter describes the goal and the scope of the Marine PEFCR together with other methodical and data aspects. The PEFCR development will be done with respect to the PEFCR Guidance (v 6.3)[7].

4.1 PEFCR Scope

The PEFCR shall cover marine fish for human consumption in the EU market. The rationale for this scope is explained in the following text.

This scope is considered as wide as there are a single main function but different applications/technologies/materials.

The function of the product is to provide a meal for human consumption.

The scope is defined with respect to the stated goal by the PEFCR Guidance v6.3 (chapter 1.7): *"Pilot testers are advised to define an as broad as possible scope for the PEFCR, including all products that are capable of fulfilling the same function. A too narrow (small) product category definition would result in a very large number of PEFCRs, diminishing the usefulness of the developed PEFCRs. In its extreme, it could lead to meaningless PEFCRs."*

This goal must however be considered with respect to the requirements to data quality and representativeness. The reason why the scope is limited to a specific list of fisheries is a consideration of the data that is available against the sum of requirements on representativeness and data quality in the PEFCR Guidance. Based on the previous attempt to develop a Marine Fish PEFCR, and more than a decade of experience with LCA of seafood producing systems, we think that the seafood LCA data that is available, even though limited, is sufficient to perform the necessary screening and supporting studies, and to make a robust and responsible PEFCR for marine fish. .

[7] The PEFCR can undergo changes during the PEFCR development and if/when that occur we try to follow the latest available version at all times.

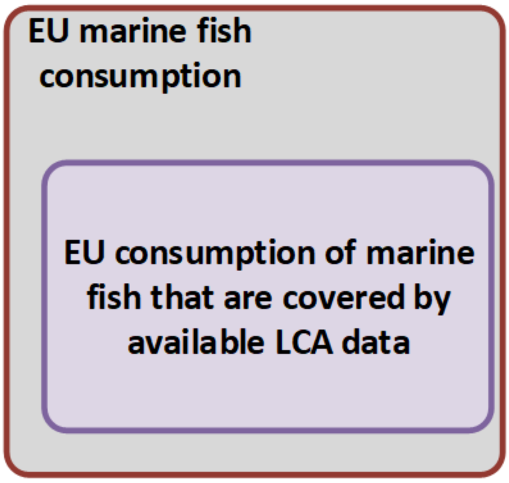

Figure 4-1 Actual marine fish consumption vs PEFCR scope (size of boxes does not reflect actual volumes)

4.2 Scope: Life cycle stages

The PEFCR will cover the life cycle stages of marine fish as indicated in Figure 4-2. For marine fish products the PEFCR will cover the life cycle including fishing and through preparation. For marine fish from aquaculture the environmental footprint of the feed input will be covered by the Feed PEFCR (see chapter 4.10).

The life cycle of marine fish products can be divided into the following stages:

- Production: Fishing, compound feed production (including the upstream stages of raw material production), aquaculture juveniles production and aquaculture grow out
- Preparation: Slaughter, gutting, filleting and refrigeration and or freezing
- Distribution: Packaging materials and transport from preparation to retailer

The scope will be comprised by the definition of prepared fishery products as defined in Regulation (EC) No 853/2004 [8] laying down specific hygiene rules for food of animal origin: "*Prepared fishery products"* means 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. *Processing* as defined in *Regulation (EC) no 852/2004*[9]*: "processing"* means any action that substantially alters the initial product, including heating, smoking, curing, maturing, drying, marinating, extraction, extrusion or a combination of those processes. In difference from *"unprocessed products"* which means 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;

[8] 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)

[9] *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)*

For fish that goes into other types of processing not included in term *preparation* the Marine Fish PEFCR shall work as a module for the life cycle from cradle to processing gate.

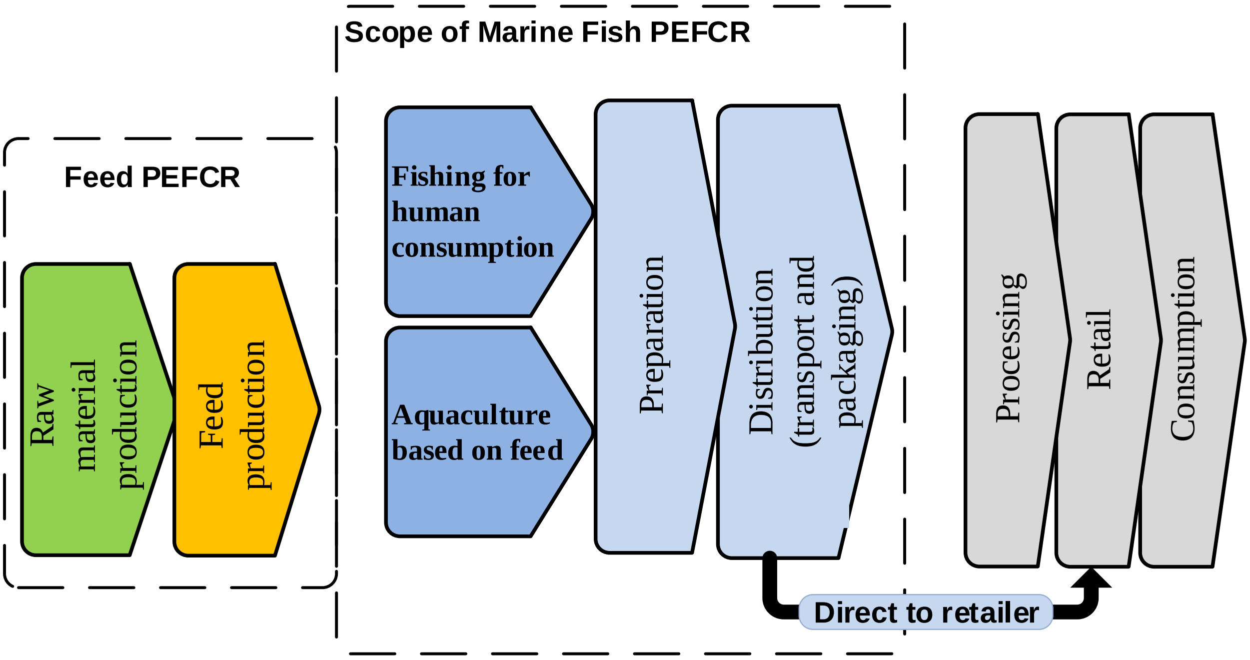

Figure 4-2 Scope (life cycle stages scope) of the Marine Fish PEFCR

4.3 Functional unit

The functional unit (FU) is the quantified performance of a product system, to be used as a reference unit. Meaningful comparisons shall only be made when products can fulfil the same function. Therefore, the FU of a PEFCR should describe qualitatively and quantitatively the function(s) and duration of the product. For the marine fish PEFCR the FU is defined like this:

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

4.4 Scope: Representative Product

Based on the functional unit and the defined scope of the PEFCR a model of the product, as it is sold in the EU market, will be developed. This model is referred to as the “representative product”. It is this “product” that will be assessed in the screening study and thus the RP forms the basis for:

1. Identifying the most relevant impact categories, life cycle stages, processes and direct elementary flows;
2. Facilitating the comparison between products that fall within the same RP

3. Calculate the benchmarks (the EF-profile of a representative product is the benchmark)
4. Define the classes of performance (if The RP is used)

Two representative products are modelled:

- A wild caught marine fish product
- A farmed/aquaculture marine fish product

The RPs are defined as 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 4-1 Explanation of product scope

Product group	Product category	Representative product (one for each category)
Marine Fish for human consumption	Wild caught marine fish	Virtual product composed of fishery categories. Share of each fishery calculated based on data on EU marine fish consumption, import, production and data on the relevant fishing fleets.
	Marine fish from marine open net pen aquaculture	Virtual product is a product from marine open net pen aquaculture.

4.4.1 The wild caught representative product

The representative product for wild caught products will be modelled as a virtual product composed of 16 different groups of fisheries (see Figure 4-3). These groups, present different types of fisheries that on an average have a significantly different environmental footprint (per unit of landed catch) compared to each other. The share of each fishery will be calculated with the following method: Starting with data on the EU seafood consumption, the consumption is traced back to how it was fished. This link can be found through data on where the consumed fish was caught and/or imported from and data on the fishing fleet of each supplier. Important sources for such data will be The European Market Observatory for fisheries and aquaculture (EUMOFA) and Eurostat. The development of the marine fish representative products will be developed in dialogue with these resources. This approach will end up with a representative product that is composed of the 16 different groups of fisheries. Figure 4-3 illustrate the model for the wild caught marine fish representative product.

To explain the rationale for the approach of building the RP as a product of fisheries (rather than specific species) we start with a discussion of what are the most important environmental aspects of wild caught products. It is easy to argue that the most environmental aspect of fisheries is the impact on the targeted stock and its surrounding ecosystems, e.g. other species influenced by the fishery (by-catch) and the benthic environment. Such impacts are most directly connected to the targeted species. However, such impacts are not captured by the existing impacts assessment methods used in PEF and LCA [1][2][3]. The inclusion of any kind of biotic impacts in PEF is a challenge for all sectors, not just marine fish. See chapter 7 “Suggested approach to integrate biotic impacts in marine fisheries PEFs” for further discussion and suggestion for future solution for how biotic impacts of fisheries can be included in a marine fish PEF.

The environmental impacts that is covered by the established impact assessment methods (including ILCD) are for fished products dominated by the energy use (fuel that is) during the fishery [4]–[12]. See chapter 5 for a more extensive explanation of the environmental footprint of caught and farmed marine fish products and the results of the screening analysis that was performed in the previous Marine Fish PEFCR pilot.

With the realization that the PEF of a wild caught marine fish product starts out from and is dominated by the fuel use, fisheries can be grouped according to the following properties:

- High sea or coastal fisheries. Fisheries that operate close to the coast have the potential to use less fuel on transport between fishing ground and harbour.
- Active or passive fishing gears. Active fishing gears such as trawls that are dragged through water have to spend considerably more energy than passive fishing gears such as gillnets and other gears that does not involve a lot of drag forces except the process of getting the fish on board.
- Demersal or pelagic fishing. This includes two different properties. Where in the water column the fish is situated influences how much energy that is spent to get the fishing gear there. E.g. a demersal trawl uses more energy getting to the depths it operates in and can have drag forces against the bottom. The other difference is that pelagic species often operate in more dense populations, so they are possible to capture more efficiently.

These three different properties can divide fisheries into 8 different groups: High sea demersal active, high sea demersal passive, high sea pelagic active, high sea pelagic passive, coastal demersal active, coastal demersal passive, coastal pelagic active and coastal pelagic passive.

It is important to note that in terms of fuel efficiency it is not possible to state a general rule that coastal fisheries are more efficient than high sea or passive gears more fuel efficient than active. There are no such general rules. But when looking at the most fuel-efficient fisheries, they are often coastal fisheries for pelagic species with passive fishing gear and the least energy efficient often high sea demersal trawlers.

There is also one important property in addition to those mentioned above: It is proven that there is a connection between the fuel efficiency and how well the targeted stock is monitored and managed. The connection is simple: The more scattered the fish species is and/or the less its occurrence is known, the more fuel is spent finding it and catching it.

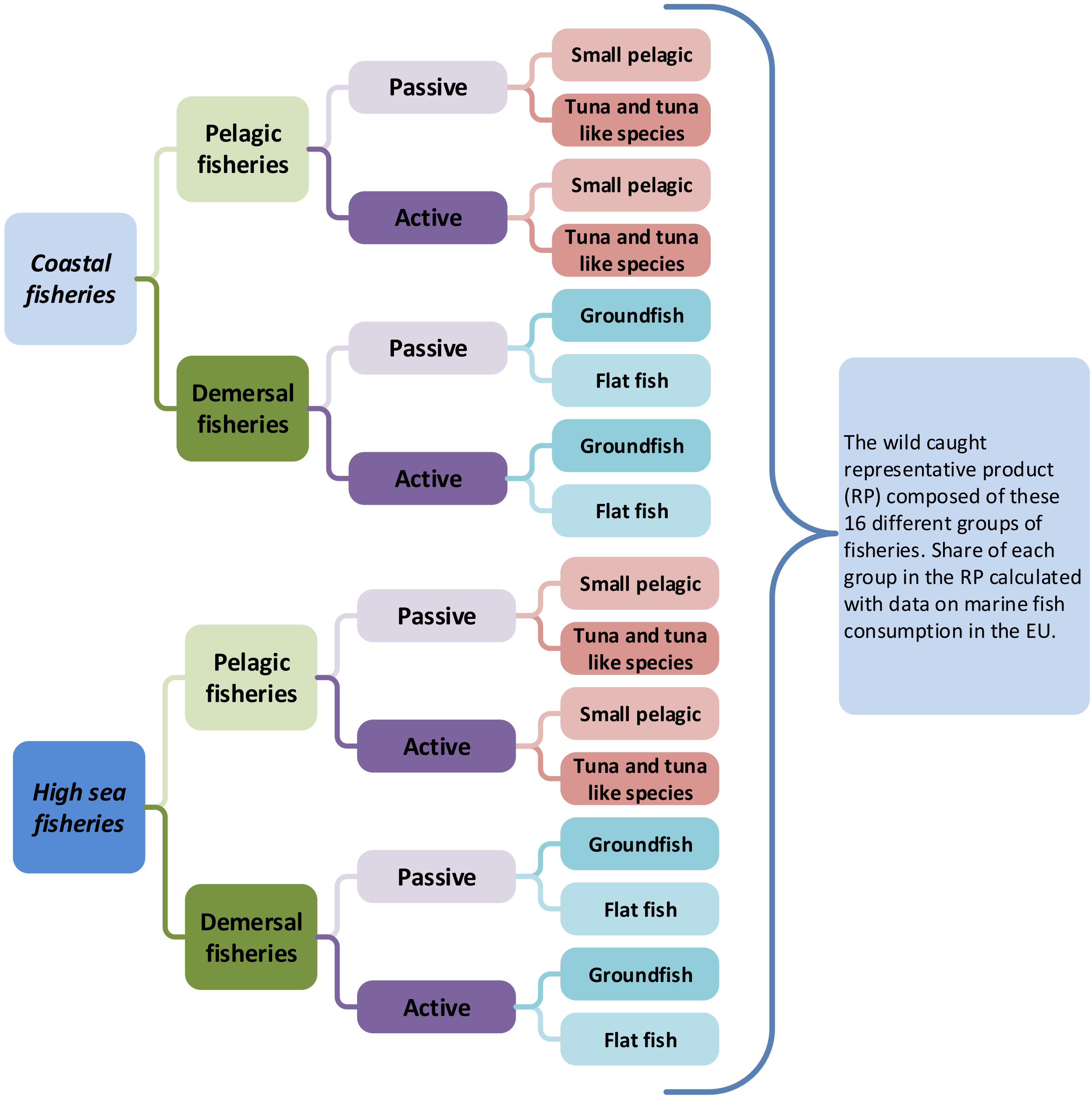

Figure 4-3 Approach and model for the wild caught fish representative product. Figure illustrates how the representative product will be composed of up to 16 different combinations of fisheries according to where and how the fish is fished.

4.4.2 The marine aquaculture representative product

Compared to wild caught marine fish products the marine aquaculture fish RP is easier. There are far less species and basically only one method: Open net pen aquaculture. Thus, the marine aquaculture fish RP is a product from an open net pen system.

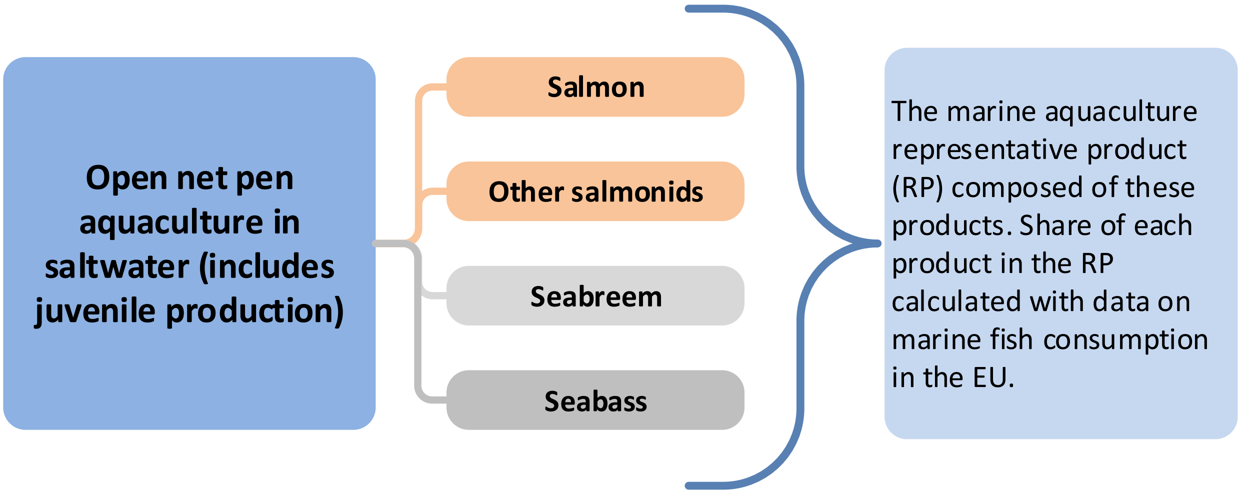

Figure 4-4 Model for the representative product for the marine aquaculture representative product

4.5 EU Seafood consumption

The EU is the largest trader of fishery and aquaculture products in the world in terms of value. In 2016, the trade flow grew to EUR 54,3 billion and 14,1 million tonnes. More than 50% of the seafood consumption was supplied through imports. In 2015 EU imported 8,68 million tonnes of fish (live weight, for food use only) (EUMOFA, 2017). Norway is the main source of EU fish-product imports, 1,5 million tonnes in 2016 with a value of EUR 6,3 billion – that is 17% of the total mass of seafood imported to the EU.

In 2015 the seafood consumption I the EU was 25,11 kg per capita. The most consumed species are tuna, cod and salmon. Salmon registered a 4% increase in 2015 compared with 2014.
Consumption of wild products represented 74% of total fish consumption in 2015 and still dominates the EU fish market.

According to Eurostat the landing of marine fish from the North East Atlantic (NEA) in 2016 was just above 3 million tonne live weight. Norwegian fisheries landed 1,8 million of this, almost 60% of all landing of marine fish from the NEA. The remaining was mainly landed by Icelandic fisheries, 1 million tonnes.

Table 4-2 presents what commodity groups composed the EU seafood consumption in 2015, how much of this that was sourced from fishery or aquaculture.

Table 4-3 presents examples of species for each commodity group.

Table 4-2: EU seafood consumption. All numbers in tonne.

Commodity group	EU consumption 2015 total - tonne and %share of marine fish consumed	Fishery vs Aquaculture	Species Examples from EU consumption, percentage of total marine fish consumption
Flatfish	279 058 (3,1%)	95,7% vs. 4,3%	
Groundfish	3 231 712 (35,8%)	99,6% vs. 0,4%	Hake 5%, Cod 11%, Alaska pollock 8%
Other marine fish	846 155 (9,4%)	75,0% vs. 25,0%	
Small pelagics	1 878 495 (20,8%)	100,0% vs. 0,0%	Herring 7%, Mackerel 5%, Sardine 3%
Tuna and tuna-like species	1 455 579 (16,1%)	98,9% vs. 1,1%	Tuna, mostly canned 14%
Salmonids	1 341 692 (14,9%)	0,7% vs. 99,3%	Salmon 11%

Table 4-3 Examples of species in each commodity group, species specified. FAO 3-alpha species codes (ASFIS).

Commodity-group	Species
Wil caught marine species	
Groundfish	COD - Atlantic cod - Gadus morhua
	POK - Saithe(=Pollock) - Pollachius virens
	HAD - Haddock - Melanogrammus aeglefinus
	LIN - Ling - Molva molva
	REB - Beaked redfish - Sebastes mentella
	ARG - Argentines - Argentina spp
	USK - Tusk (=Cusk) - Brosme brosme
	HKE - European hake - Merluccius merluccius
	POL - Pollack - Pollachius pollachius
	MON - Angler(=Monk) - Lophius piscatorius
	GDG - Silvery pout - Gadiculus argenteus
	WHG - Whiting - Merlangius merlangus
	BLI - Blue ling - Molva dypterygia
Small pelagics	HER - Atlantic herring - Clupea harengus
	MAC - Atlantic mackerel - Scomber scombrus
	WHB - Blue whiting (=Poutassou) - Micromesistius poutassou
	CAP - Capelin - Mallotus villosus
	NOP - Norway pout - Trisopterus esmarkii
	SPR - European sprat - Sprattus sprattus
	HOM - Atlantic horse mackerel - Trachurus trachurus
	PIL - European pilchard - Sardina pilchardus
	ARY - Argentine - Argentina sphyraena
Marine aquaculture species	
Salmonids	SAL - Atlantic Salmon - Salmo salar
Salmonids	TRR - Rainbow trout - Oncorhynchus mykiss
Groundfish	BSS – European Seabass - Dicentrarchus labrax
Groundfish	SBG – Gilthead Seabream - Dorade royale

4.6 Scope: NACE/CPA classification

With reference to the NACE/CPA classification, the PEFCR shall cover the following classes.:

- 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, also the following classes under C Manufactured products 10.20 Processed and preserved fish, crustaceans and molluscs will 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 <u>not</u> 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

See chapter 4.2 for more details on the separation between preparation and processing.

4.7 Data strategy for screening analysis

The development of the PEFCR for marine fish will use data on seafood production systems from literature, industry data and research projects.

4.8 Allocation, waste and end of life treatment

In the screening studies, for processes with multiple outputs, allocation will be performed using economic allocation (mass allocation as a basis with market process for each output). Allocation will also be discussed and investigated according to the PEFCR that now exist for biological resources.

For outputs that are not in any kind utilized the allocation will be set to zero. This is then considered to be waste. Here waste is defined as something that is not used, and by-product/co-product is defined as something that is somehow utilized. Thus, what is waste end what is by-product/co-product is defined by what the producer actually chooses to do with these resources. It is not possible to predefine what is what is what; it is up to the decision of those that generate the product/by-product/waste.

For the screening analysis it will clarified what is assumed to be utilized (considered a by-product/co-product) and what is considered not to be utilized (waste).

For outputs that go to energy or material recovery the end of life formula presented in the PEFCR Guidance (v6.3) will be used.

The following presents examples of outputs from important processes in seafood production systems (this list is not a complete list of all known outputs).

Table 4-4 Examples of multiple outputs from seafood life cycle stages that will be addressed in the PEFCR

Life cycle stage	Example of outputs from stage
Fishing	- Bycatch, non-targeted species - Guts, blood etc from processing e.g. gutting, filleting, - Products that do not have the required quality for intended use - Packaging materials and equipment
Aquaculture	- Dead fish - Escapees - Products that do not have the required quality for intended use - Packaging materials and equipment - Sludge
Preparation	- Cut offs, blood, water with proteins, guts - Packaging materials - products that does not have the required quality for intended use

4.9 Capital goods

The PEFCRs are required to include capital goods in the assessment process. For seafood, capital goods are items such as aquaculture equipment and facilities, fishing vessels and the infrastructure that the seafood industry relies on, harbours, roads, airports etc. Capital goods will be included in the screening analysis.

4.10 Modularity

The Marine Fish PEFCR will be produced for final products, marine fish for human consumption. The Marine fish PEFCR will however work as a module for other systems that uses by-products/co-products from marine fish or marine fish as input to processing , as an ingredient in mixed food products as well as for processing comprised by the definition of "processing" given in *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).*

4.10.1 Existing modules to be used with the Marine Fish PEFCR

Feed production for marine fish aquaculture will not be covered by the Marine Fish PEFCR, but rather by the “PEFCR Feed for food producing animals”[10]. At the same time the Marine Fish PEFCR will work as a module for the Feed PEFCR to cover the input of marine raw materials directly processed for that purpose or of marine by-products coming from the preparation of caught as well as farmed marine fish. See Figure 4-5 for an illustration of flow of marine raw materials from marine fisheries to feed production.

As a consequence of the cradle to gate approach chosen for the Feed PEFCR, the ‘on farm’ feed efficiency will have to be measured when conducting the LCA of animal products.

[10] Link to PEFCR: http://ec.europa.eu/environment/eussd/smgp/pdf/PEFCR_feed.pdf

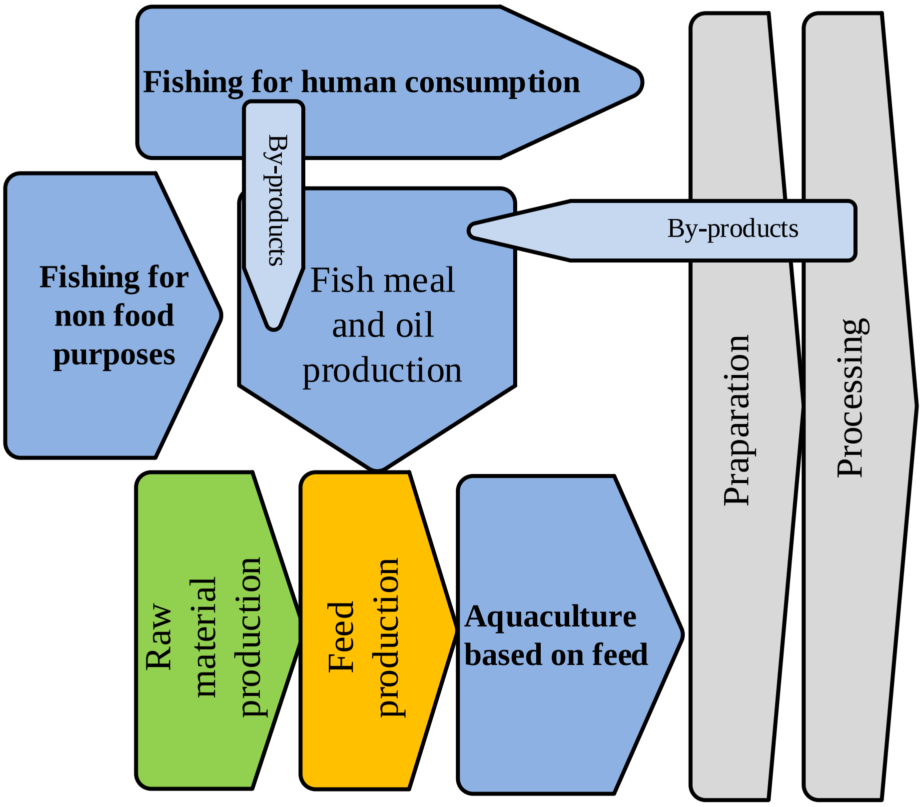

Figure 4-5 Flow of marine raw materials from marine fisheries to feed production

Table 4-5Documents containing rules or guidelines for environmental assessment of seafood products

Document	**Type of document**
BSI PAS 2050-2:2012 Assessment of life cycle greenhouse gas emissions10.	This Publicly Available Specification (PAS), PAS 2050-2, contains requirements for the assessment of life cycle greenhouse gas (GHG) emissions specifically associated with seafood and other aquatic food products. The requirements are supplementary to those specified in PAS 2050:2011, which provides a generic method for assessing the life cycle GHG emissions of goods and services [14].
NS 9418:2013 Carbon footprint for seafood - Product category rules (CFP-PCR),	Developed by Standards Norway [15]. This is the only one published in Norwegian.
PRODUCT CATEGORY RULES ACCORDING TO ISO 14025:2006. PRODUCT GROUP: UN CPC 2124 FISH, OTHERWISE PREPARED OR PRESERVED; CAVIAR AND CAVIAR SUBSTITUTES11	This is a PCR document developed in the framework of the International EPD System, operating in accordance with ISO 14025:2006; 9001; 14001; 14040 and 14044. The International EPD® System is a system of voluntary environmental declarations applicable to any type of goods and services.

5. On the production systems and environmental footprint of seafood products

5.1 Summary of screening results

As a part of the former and discontinued Marine Fish PEFCR development, a screening assessment was performed [13]. This assessment, and the model in which the analysis was done, was reviewed by two different external experts appointed by the European Commission.

The goal of that screening was to identify environmental hot spots and study methodical choices to provide recommendations for a product environmental footprint category rules (PEFCR) for marine fish products.

The assessment was performed from fishing and growing of crops for feed and up to where the fish is delivered to retailer - a cradle to gate assessment. The functional unit was 1 kg of edible fish. The impact assessment method used was the latest ILCD method.

The former screening confirmed existing knowledge from LCAs and PEFs performed on seafood products:

- All life cycle stages in the marine fish life cycle are relevant for the calculation of their PEF
- For fished products the most important environmental aspect is the fuel use in the fishery followed by use of refrigerants (in some cases) and the distribution, this including transport and packaging. These results are the same as the body of existing LCA on wild caught seafood products [4]–[12]
- For aquaculture the most important environmental aspect is how the feed is produced, the feed efficiency that is achieved and the distribution (transport and packaging) [14]–[21].
- Preparation is also important, through the energy used by the preparation plant, but especially through the yield that is achieved from round fish to edible product and by how by-products are utilized.
- The report from the former screening process highlighted the need for development of better impacts assessment methods. As of today, the established impact assessment methods are weak at covering emissions to the marine environment and most important there are no established impact assessment methods to cover the different types of biotic impacts associated with marine fish production systems.

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7. Suggested approach to integrate biotic impacts in marine fisheries PEFs

This text is originally a work by Sara Hornborg & Friederike Ziegler at RISE (Gothenburg, Sweden) that was produced as a deliverable to the Marine Fish Pilot [13]. The text presented here is modified by the authors of this report.

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 the first part, examples on how to perform the impact assessment are given. The last part comprise of response to the comments given by the EU commission on the methods provided.

7.1 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.

7.2 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.

7.3 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:

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

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

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).

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.

7.4 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).

7.5 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)**

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.

7.6 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.

7.7 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).

Proposed method for assessing impact on ecological communities:

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

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

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).

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).

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7.9 Examples 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.

7.9.1 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 7-1 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[11]	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.

7.9.2 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)***

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.*

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

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.

7.9.3 Habitats

The general BENTHIS-model is as follows:

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**

7.9.4 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:

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

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	

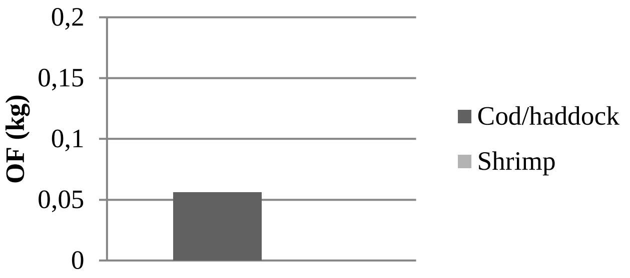
Total		5 225 305	724 811 284	**139**

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.

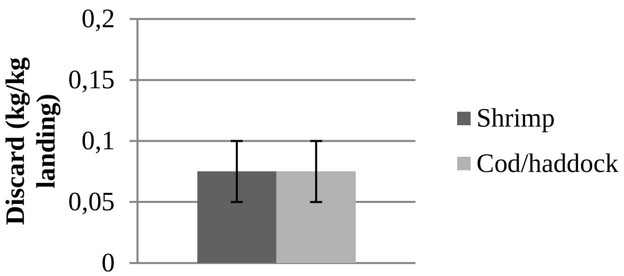
Overall results



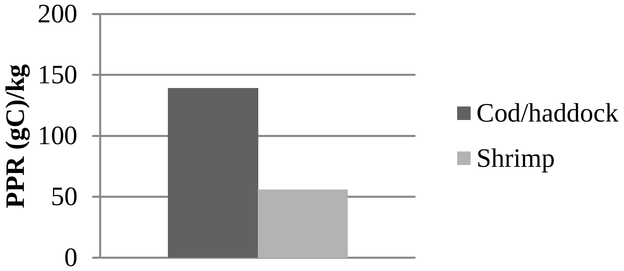
Overfishing is low in the cod and haddock fishery and there is no overfishing in the shrimp fishery.

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

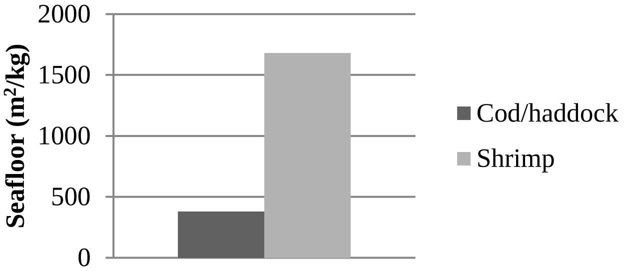
Landing of threatened species is low in the cod and haddock fishery and none in the shrimp fishery.



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.

7.9.5 References examples

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