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BIOSCIENCE

Seafood Life Cycle Inventory database

Methodology and Principles and Data Quality Guidelines

Version 1, January 2018

Erik Skontorp Hognes, Peter Tyedmers, Christoffer Krewer, Jasper Scholten, Friederike Ziegler

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Sammanfattning

En växande insikt om betydelsen av livsmedel för global miljöpåverkan, särskilt animaliska livsmedel inklusive sjömat, har lett till ett behov hos producenter såväl som handeln att kommunicera miljöpåverkan av råvaror och produkter genom livsmedelskedjan. Detta visar sig i form av nya krav på att dokumentera produkters miljöavtryck, t ex vid certifiering och i regelverk. EU initiativet inom hållbar utveckling med en ”inre marknad för gröna produkter” är ett exempel, med målet att dokumentera miljöavtrycket av produkter på EU marknaden enligt metoden Product Environmental Footprinting (PEF). Målet är att göra det möjligt för konsumenter, handel, producenter och lagstiftare att göra medvetna val och att etablera drivkrafter mot reducerad miljöpåverkan i produkters värdekedja.

För att kunna leva upp till dessa nya krav, krävs tillgång på representativ data av hög kvalitet, något som i stort sett har saknats för sjömatsprodukter. För att göra högkvalitativa, representativa data kring resursåtgång och miljöpåverkan av sjömatsprodukter (inklusive biomassa som direkt eller indirekt används till foder) tillgängliga, initierade den norska sjömatsbranschen ett pilotprojekt. Projektet definierade en rekommenderad metod och struktur för datainsamling och använde denna metod för att samla in tillgängliga data för ett antal pilotfall. Metoden för datainsamling presenteras i detta dokument och kan, tillsammans med pilotdataseten som gjorts tillgängliga i projektet, användas av näringen som grund för en bredare datainsamling för att skapa en utbyggd sjömats-LCI-databas.

Summary

An increasing awareness about the important role of food, in particular animal-based foods including seafood, for global environmental impacts has led to a need of producers as well as retailers to communicate environmental impacts of raw materials and products through the food chain. This is demonstrated by new requirements to document the environmental footprints of products, e.g. by certification schemes and policies. The EU policy for sustainable development with its “single market for green products” is one example, aiming for documenting the environmental footprint of products on the EU market according to the Product Environmental Footprint (PEF) method. The goal is to enable consumers, retailers, producer, regulators and policy makers to make conscious choices and establish drivers for reducing environmental impacts throughout product supply chains.

To be able to live up to these new requirements, representative data of high quality is needed, something which has largely been missing for seafood products. To make high-quality, representative data on the resource use and environmental impacts caused by seafood products (including biomass used directly or indirectly for feed) available, the Norwegian seafood industry initiated a pilot project. The project defined a recommended method and structure for data collection and used this method to collect available data for a number of pilot cases. The method for data collection is presented in this document and can, together with the pilot data sets made available through the project, be used by the industry as a basis for a broader data collection to create an expanded seafood LCI database.

List of terms used

Term	Description
Activity	
Attributional LCA	Also sometimes referred to as back-casting LCA modelling in which average production or estimated average future production inputs and outputs of activities are used to characterize impacts
Background/secondary data	This data is often provided in LCA databases and is used e.g. when calculating footprints of products. Examples of background data are those associated with electricity production, transports etc. It is used when the data are considered not to contribute significantly to overall impacts and/or when preexisting background data are considered robust. Where one of both of these conditions are absent, they can be modified to better fit to the context when it is needed.
By-catch	Here defined as part of catch landed, but not one of the target species
By-product	The EU definition (EC Reg No 1069/2009) is used here: 'Animal products that do not go directly to human consumption'. This includes entire production systems when the purpose is to produce e.g. feed such as many Anchoveta fisheries etc. Other definitions would not consider these dedicated feed production systems as producing by-products.
Consequential LCA	Also sometimes referred to as change-oriented LCA is practice in which impacts are modelled based what are seen as marginal or projected future implications of changes to systems occur rather than modelling impacts of average resource use
Co-product	Various edible and non-edible products from the same process, e.g. seafood preparation. Sometimes used as a synonym to by-product, but not when using the definition above.
Discard	Part of catch returned to sea
Dummy process	An empty process used to describe desired flows from suitable background data, had it existed. The rationale is

	that the end user or database provider can use the dummy process information to replace it with the best available background data available to them. The reason why a process has to be created is that SimaPro is used in phase 1 and that SimaPro does not support the creation of flows without output processes.
Emission model	A model that represents the relationship between an input material/resource use, technology (activity specific context e.g. management practice, weather conditions etc.) and the resulting emissions.
Fish meal and oil plant	A processing plant that uses grinding, pressure and heat to reduces aquatic raw material into meal and oil.
Generic process	An ‘average process’, average on the level that often background/secondary data is.
Grow-out	Growth phase in aquaculture, typically encompassing the period from when juveniles become available to animals are ready for slaughter
Hatchery	Aquaculture activity producing juveniles that are transferred to a different system for grow-out
Landings	Landed part of catch (target and by-catch species), i.e. catch minus discard
Marine net-pen aquaculture	Farming fish in semi-rigid pens in the ocean
Material process	Activity/process where the output are material flows. Fisheries are, for example, modelled using first a Processing process (Fishing by fishing fleet x) where the output is a tonne of fish, then using a Material process as the second step, in which the catch composition per species is added as multiple outputs.
Model	A model can be said to consist of variables (dependent parameters), constants (input parameters) and their dependencies. To the degree it is possible the project will deliver models that allow for maximum modelling flexibility for users. It means that functions and calculations will be inserted in the datasets if possible, and that the datasets will also contain constants. The models, i.e. single or interlinked datasets, variables and constants will represent a certain (average of specific)

	product system that can be adapted to user needs.
Process	A dataset that describes one or many activities. The words process and activity are used interchangeably.
Processing process	Activity/process where the output is a 'service'. Fisheries are e.g. modelled using first a Processing process (Fishing by fishing fleet x) where the output is a tonne of fish, then using a Material process as the second step, in which the catch composition per species is added as multiple outputs (see Material process)
System process	A 'black box' process that in itself describes the product system (usually the upstream activities). It can be considered to consist of aggregated unit processes.
Target species	One or more species that are the primary economic aim or legal basis for a fishing activity
Trimmings	Fish processing by-products, typically composed of offal, heads, bones, skin, etc that historically my have been treated as waste but are increasingly being directed to secondary markets including conversion to fish meal and oil, but also to food ingredients after processing
Unit process	A process that describes an individual activitiy in a product system. Togehter with other linked unit processes it describes the whole product system. A unit process is often modelled as a 'gate-to-gate' activity.

1 Introduction

Despite recent interest in single dimension environmental assessments (single in terms of environmental aspects covered or in steps of a products supply chain included), more complete understanding of the environmental performance of products remains critical. Environmental legislation[1], product labels, investors, supplier policies and environmentally conscious consumers all demand a more holistic understanding of a wide range of environmental attributes for the whole life cycle of a product or service. Life Cycle Assessment (LCA[2]) is an established methodology widely used for this purpose and is, together with the related Product Environmental Footprints (PEFs[3]) increasingly required by markets. Given the role that food systems play in global environmental change and growing attention of consumers on how their food is sourced, there is need to assess and communicate the environmental performance of products in a transparent, credible way. Within the broader context of food systems, seafood products from fisheries and aquaculture, are of particular interest in this regard due to their major potential to contribute to future sustainable food security in combination with a lack of available LCI data to model their inclusion in diets. Consequently, there is considerable interest in, and need for, standardized approaches to data collection and analysis based on LCAs of seafood products. Potential uses of these data includes: benchmarking of seafood systems for comparison with each other or other foods, for comparison over time, and for comparison and communication of products or processes with respect to their environmental performance.

To implement life cycle based innovation in the seafood sector the following steps need to be taken by industry and regulating governmental bodies:

1. Implementing guidelines/standards on quantifying and documenting the environmental impacts of seafood, to ensure transparent assessments. One such example is the development of Product Environmental Footprint Category Rules (PEFCRs) to be used in the EU market.

2. Such implementation requires that life cycle inventory (LCI) data[4] for seafood products is made available.

3. A governance structure to develop, implement and maintain 1 and 2 including the financial mechanism to fund the necessary investments.

[1] The Single Market for Green Products Initiative (link) and upcoming environmental life cycle legislation from the European Parliament. See the following article in The Guardian for more information:
"*The European parliament is set to call for binding lifecycle reporting on virtually every product we buy*".
[2] Wikipedia page on the LCA method: https://en.wikipedia.org/wiki/Life-cycle_assessment
[3] Link to more information on the PEF method: http://ec.europa.eu/environment/eussd/smgp/dev_methods.htm
[4] Data on the in- and outputs from the processes building the production system/life cycle. This will be input of resources and commodities (e.g. materials, chemicals and energy) and outputs of emissions to ground, water and air, other types of environmental impacts, waste flows and products.

The present methodology is intended to constitute a foundation for making more seafood LCI data available within established or future LCA databases. The main purpose of the methodology is more specifically to enable the building of a public database with consistent seafood datasets which are user-friendly for LCA practitioners. Consistency regarding the following principles is needed:

- A common methodology
- A common structure of the datasets
- A common naming strategy

This document is intended to guide those who:
a) wish to contribute data to the database
b) wish to access/use data from the database and need to understand the data, what it represents and how is can be used

This document defines:

- The goal and scope of the database
- Guidelines for methodological choices in the data sets
- How processes in the LCI database shall be modelled and what data quality should be aimed for.
- How modelling and data shall be documented
- Rules for naming of processes
- Procedure for data quality assessment
- Procedure for review and quality assurance of data by third party

This document was prepared using the following documents as starting points:

- ISO 14040 / 14044 (ISO, 2006a, 2006b).
- Ecoinvent: Data quality guidelines (Weidema et al., 2013).
- GLAD (UNEP/SETAC, 2011).
- Marine Fish PEFCR: Screening and recommendations (Hognes, 2014) .
- Agri-footprint methodology report (Blonk Agri-footprint BV, 2015a, 2015b).
- GFLI procedure for data collection *(under publication)*.
- PEF guidance version 6.0 *(latest version)* (European Commission, 2016).
- Compliance rules and entry-level requirements, v1.1 (ILCD) (JRC, 2012).
- Specific guide for Life Cycle Inventory data sets, first edition (JRC, 2010).
- Dataset Documentation for ecoinvent database version 3, v1.0 (ecoinvent, 2012)

1.1 Change log

Date	Version number	Change description
2018-01-31	1.0	First released version

1.2 Background

Why a database?

The concept of life cycle thinking and the tool or accounting framework of LCA is increasingly used to understand and inform potential improvements across food systems (from production through retail and consumption). Consequently, there is increasing need for reliable data and methods. Guidelines and standards for environmental assessment of some aspects of seafood production have been developed (e.g. BSI 2012), but their use has been limited by the availability of reliable and transparent data on products from marine biotic resources. The need for a database of life cycle inventory data of seafood products and other marine resources has therefore been pointed out.

Various initiatives have led to the need for a seafood LCI database:

- Adoption of the concept of LCA by governments and international organisations with major influence on the sector, including the Food and Agriculture Organisation of the UN (FAO)
  and the EU sustainability single market policy[5] that lead to the development of product/sector specific rules for how an environmental footprint of products and organisations should be performed, documented and communicated (Product Environmental Footprint- PEF).
- Certification schemes that require undertaking LCAs or carbon footprints (e.g. the Aquaculture Stewardship Council-ASC)
- Retailer requirements
- Use of LCA and GHG assessment in environmental management systems

Seafood compared to other production systems

Seafood product systems derive raw materials from fisheries and aquaculture, and while they share certain characteristics with other food systems (e.g. in being tightly coupled industrial-biological systems, relying on inputs of energy, resulting in products intended directly or indirectly for human nutrition), in other important ways, fisheries and aquaculture systems differ from agricultural food production:

- Fishing relies on the extraction of largely wild resources from ecosystems and landings are often highly variable due to spatial and temporal heterogeneity of the resource leading to variability in the efficiency of extracting these resources.
- Though fishing is often carried out with a target species identified, often, multiple species are caught, some of which will be landed with the rest being discarded.
- Fishing is conducted using an enormous range of methods (von Brandt 1984) with highly different efficiencies, even to catch the same species. Somewhat similarly, aquaculture is conducted using an enormous range of technologies in a wide range of settings (Troell et al. 2004).

[5] Single Market for Green Products Initiative (http://ec.europa.eu/environment/eussd/smgp/index.htm)

- Both fishing and aquaculture is conducted across the full range of intensities from artisanal to industrial scale. For example, commercial fishing encompasses non-motorized vessels up to super trawlers of over 140 metres in length, which contributes to variability of inputs, outputs, and impacts.
- The number of species harvested or farmed (~2500 species fished and ~600 species farmed globally) is much larger than the number of species produced commercially in agriculture
- Seafood is also one of the most traded commodities globally, leading to complex supply chains with many opportunities for intentional or unintentional mischaracterization and labeling of products (Jacquet and Pauly 2008)
- Breeding certain desirable characteristics such as productivity or stress tolerance has advanced further in agriculture than in aquaculture
- Both fishing and aquaculture lead to environmental impacts not covered by traditional LCA methodology, e.g. marine biotic depletion, seafloor disturbance, transmission of disease and genes to wild populations
- Although aquaculture is more similar to agricultural production than fisheries, when aquaculture is done in open systems, the aquatic environment leads to efficient dispersal of both nutrients and escaped fish that potentially affect wild populations.
- There are fewer routinely compiled statistics available for key activities associated with seafood production compared to agriculture, and the availability of statistics differs between nations.

Table 1. The project team

Name	Organization	Expertise
Erik Skontorp Hognes	SINTEF Ocean (current affiliation: Asplan Viak)	Fisheries and aquaculture, seafood LCA
Peter Tyedmers	Dalhousie University	Fisheries and aquaculture, seafood LCA
Christoffer Krewer	Research Institutes of Sweden (RISE)	LCI data and databases
Jasper Scholten	Blonk Consultants	LCI data and databases
Friederike Ziegler	Research Institutes of Sweden (RISE)	Fisheries and aquaculture, seafood LCA

The project had a reference group which was consulted regularly throughout the project (Table 2)

Table 2. The reference group

Name	Organization	Type of activity
Erik Gracey	BioMar AS	Aquafeed production
Trygve Berg Lea	Skretting Group	Aquafeed production
Dave Robb	Cargill Aqua Nutrition	Aquafeed production
Neil Auchterlonie	IFFO	Marine meal and oil producer organisation
Courtney Hough	FEAP	European aquaculture producer federation
Nicolas Martin	FEFAC	European feed producer federation and representing GFLI
Henrik Stenwig	Norwegian Seafood Federation	Norwegian organisation including marine meal and –oil producers, fish feed producers, aquaculture producers and seafood processors.
Berit Anna Hanssen	FHF	Fisheries and Aquaculture Research Fund

2 Goal of database

2.1 Intended applications and users

This database is intended to be used by professionals familiar with the LCA methodology, what is considered best available practise and able to evaluate the needed data quality in relation to their goal. While the data in the database will be well documented, it is expected that the users of this database also secure a working level of understanding of seafood production systems and the marine biotic resources that seafood systems depend on.

Four main uses of this methodology are identified:

- As a guide to continue to develop datasets in the Global Feed LCA Institute (GFLI) (GFLI 2017)
- To understand data in the database and modify/adapt datasets to users specific needs
- As a guide for anyone wishing to contribute with data to GFLI
- For others wanting to develop seafood LCI data and databases

The intended application of the data assembled in the database is in LCAs where the professional consideration of the practitioner is that secondary data, such as those provide in the database, is sufficient to meet the data quality requirements to achieve the goal of the assessment. However, data complied in the database will, to the extent possible, be developed in a way that enables users to adapt it to their specific needs.

A non-exhaustive list of stakeholders of the database and potential uses includes:

- Feed producers wanting to be able to calculate the environmental impact of their feed products and in the context require data on the feed ingredients they purchase
- Scientists modelling e.g. new feed (or other) products
- Business associations wanting to promote and communicate the environmental performance of seafood products in a variety of forms
- Retailers wanting to choose suppliers and inform customers about their products
- Consumers wanting to know the environmental footprint of products they buy
- The public sector wanting to set criteria for green public procurement
- The seafood industry wanting to improve or communicate the environmental footprints of their products

Given that the main use of the methodology is to publish data in GFLI and to meet the needs of all stakeholder groups the methodology work will focus on describing how to assemble data on fisheries and data are foreseen to be representative for a year or longer time periods (rather than e.g. per fishing trip). The methodology shall support development of data that these stakeholders need, with special emphasis on the needs of feed producers, seafood producers, as well as consumers.

Finally, the use of data can be divided into users that use the data as it is, e.g. comparing different foods with each other, and users that intend to undertake their own studies and adapt the data to their need. The latter will need both cradle-to-gate LCI unit activity data, but also gate-to-gate activities.

2.2 Maximize the use and impact of data

The long-term aim is that the database shall cover as many products as possible, with the best available data. This will result in variable data quality in the database, and not all best available data will fulfil the requirements specified in this methodology. An important criterion is *that the data are presented transparently so that the user can assess its fitness for purpose*. In other words, the motto is that data that for some purposes may be of too low quality, or too old, etc. for other purposes may be sufficiently representative or in the absence of other data be better than no data at all, as long as the data are well described in terms of what it represents. Therefore this document describes a certain ideal goal and scope for the data to be contained in the database. However, other data that does not meet all requirements may still be published, as long as deviations are clearly described in the datasets. The aim is that eventually, stakeholders will prioritize and finance extending and updating data contained.

Based on the experience of the database design team, we have identified a hierarchy of importance for attributes of data, for those data to be included in the database. The word 'shall' is used when a requirement must be fulfilled for data to be included. The word 'should' is used where it is highly desirable that a requirement should be fulfilled. Finally, 'may' is used where it is recommended to fulfil a requirement.

3 Database methodology

This chapter describes the guiding principles for how data in the seafood LCI database shall be modelled and documented. Chapter 4 follows with more specific guidelines and requirements for specific processes and life cycle stages of seafood products.

3.1 Products in scope

The database will include data on seafood products and other aquatic resources that are used for human consumption directly or indirectly through feed ingredients.

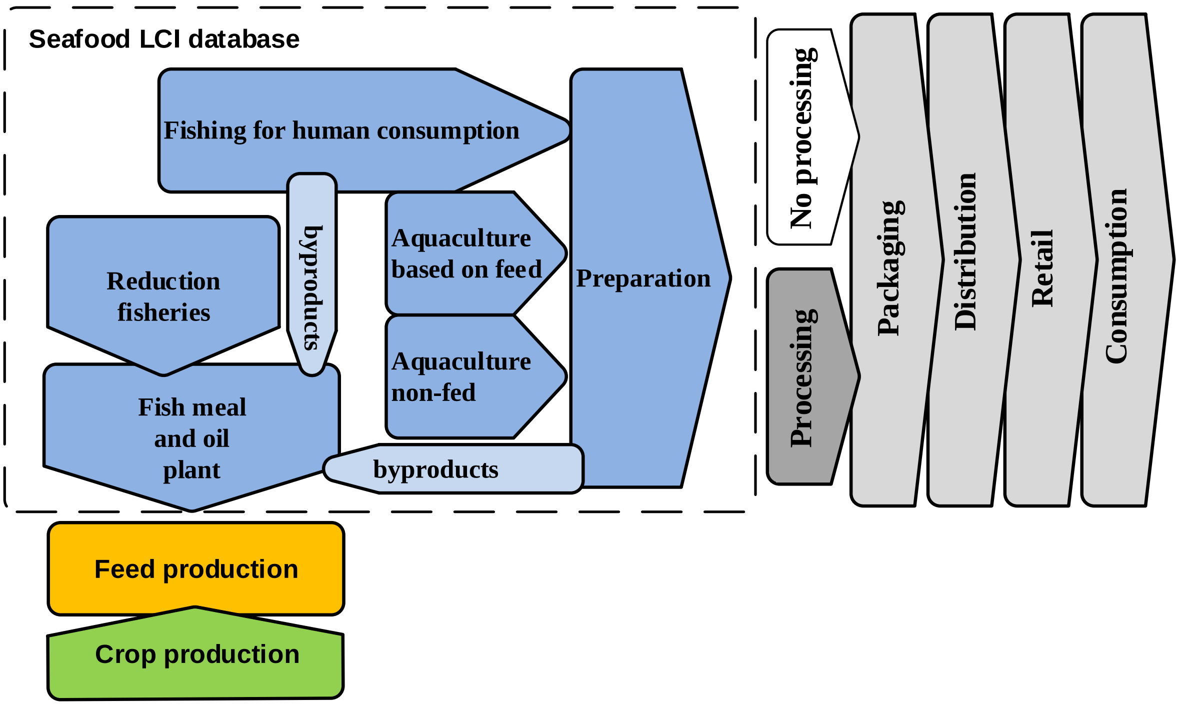
3.2 System boundaries and life cycle stages

When fully developed, the database will cover:

- Fisheries:
    - Fisheries for products intended for direct human consumption as well as those intended for meal and oil production (often referred to as either industrial fisheries or reduction fisheries)

- Aquaculture, from both fed and non-fed culture, including:
    - Juvenile acquisition through production in hatcheries (or from wild) to a size/state where animals can be transferred to a grow-out environment
    - Grow-out phase. Typically the longest phase in which the farmed species reaches marketable size
    - In cases where life histories are fully in culture, broodstock production and maintenance
- Slaughter and preparation: One or more processes used to convert animals from their live form to seafood products (forms typically made available for final human consumption such as fillets). Preparation[6] includes only mechanical transformation of the fish and cooling, e.g. bleeding, gutting and filleting, and freezing and chilling.
- Processing[6], on the other hand, refers to transformation of seafood, e.g. through canning, smoking, salting, drying, marinating or used as an ingredient in a mixed food product.
- Transports: The seafood LCI database will only cover transport processes that are unique for the seafood sector and not found in existing LCI databases.

Figure 3-1 illustrates what life cycle stages the database will cover. The other stages are not specific to seafood and can be found in other databases.



[6] Regulation (EC) No 853/2004 of the European Parliament and of the Council of 29 April 2004 laying down specific hygiene rules for food of animal origin (OJ L 226, 25.6.2004, p. 22)

Figure 3-1 Simplified figure of system boundaries for the Seafood LCI database (and map of important life cycle stages in seafood production systems)

3.3 Impact Assessment methods

The seafood database should be in line with the ReCiPe and the ILCD impact assessment methods and inventories should preferably cover the impact categories of these methods.

The database will not contain LCIA methods, which means that it is either the user or the database provider (of other databases) that ensures that the same elementary flows/substances are used.

Established impact assessment methods (as of 2017) do not cover all inventory flows and type of impacts, e.g. ecosystem impacts. Still, a methodology can provide guidance on how to collect and assemble also data not currently handled by existing LCIA methods. The reason for doing so is to highlight these impacts and resource use, even if data cannot be characterised using current methods. This can encourage the development of such characterisation methods, examples include marine plastic waste, loss of gear and biodiversity/marine depletion.

3.4 Database modelling principles

The general guiding principles for how to model data are:

- The database shall, as a general rule, be built around unit processes, avoiding aggregated system processes as much as possible (chapter 3.5).
- Where possible, processing steps (e.g. processes converting a resource or material from one form to another) shall be modelled as a discrete activity or system (chapter 3.6).
- Background data, e.g. inputs and impacts of energy and materials that are widely and commonly used across human activities (e.g. steel) are not covered by the seafood database and are modelled with dummy activities and will have to be replaced by data from other databases (chapter 3.9)

3.5 Unit process in contrast to system process modelling

The database should consist of mainly unit processes[7], i.e. activities shall be broken down to the smallest possible dataset in which it can be presented and shared publicly. This is to make data as transparent and useful as possible. If there is not enough detailed data available or if sensitive data need to be protected by aggregation, data can also be presented as a system process[8]. The main benefits of unit modelling are:

- The potential to trace back the source of each emission and resource use. This is important to be able to interpret and evaluate the robustness of results
- The potential to modify individual unit processes to specific needs/situations

In contrast, the main benefit of modelling system processes is that sacrificing details reduces complexity, which for very large models can reduce impact calculation times. In the chapters on the modelling of specific activities (e.g. fishing, aquaculture grow-out) more specific recommendations and requirements are provided. Multi-output processes shall not be pre-allocated and/or shall be modelled as independent single output processes. For more information on unit processes see the ecoinvent methodology, level of detail[9].

3.6 Modelling of processing processes

Processes converting a resource/material into a set of new flows shall, as far as possible, be modelled as isolated processes where the output is the "service" of processing the materials/resources rather than the actual product. This is conceptually presented in

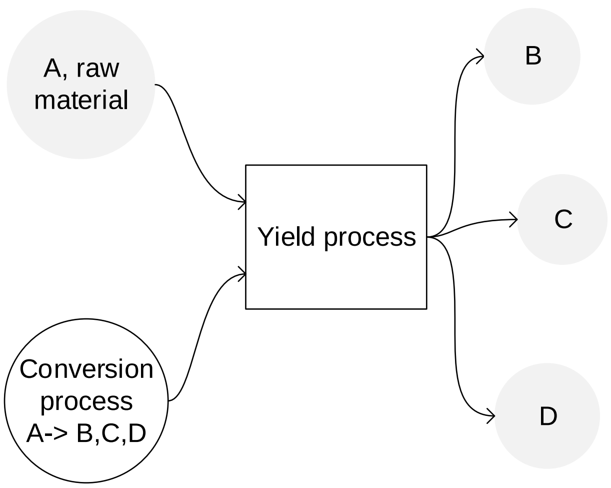


Figure 3-2: The dataset describing the processing of an input A into the products B, C and D is modelled as an independent processing activity simply providing the service of converting the input. With this approach the products B, C and D will be outputs of a

[7] See ISO 14040, ISO. (2006b).
[8] See the 'Shonan guidelines', UNEP/SETAC. (2011).
[9] ecoinvent: Data quality guidelines (Weidema et al., 2013).

compilation process that combines the input (A), the independent processing activity, and delivers outputs (B, C, and D) depending on the specific product yield values used.

This approach is especially relevant where the same processing data can be used for different materials/resources, e.g. freezing. The benefit is that it simplifies building of new production systems in which the same processing step can be used. For processing that is only relevant for one specific input, this approach does not have such clear benefits.

Examples:

- Conversion/processing process: Processing of a unit of landed fish or fish trimmings to meal and oil. This dataset only includes the necesary inputs to do the conversion, but not the input of raw materials or output of products. The process can include emissions and other outputs related to the inputs of supply materials or energy.
- Yield/material process: Production of fish meal and oil e.g. from a unit of landed herring. This combines the conversion/processing process with a specific raw material input and the product outputs according to a specific yield.
- Note that care must be taken so that all outputs (emissions, products and waste flows) are covered, but only in one of the processes to avoid double-counting. The two processes can be aggregated in different ways to become more easy-to-use for non seafood experts.

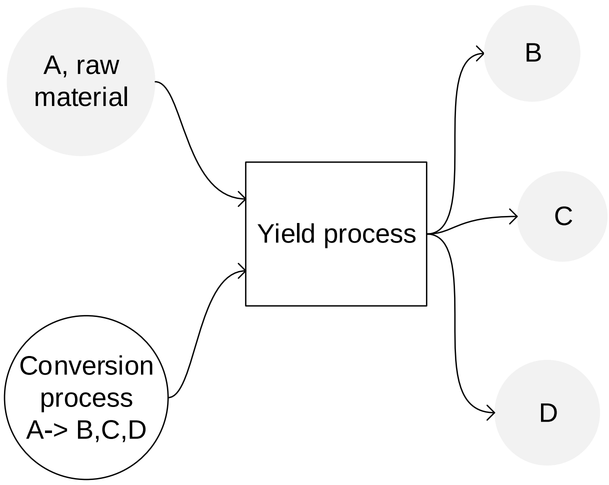


Figure 3-2 Conceptual description of isolation of processing step, here called conversion process. The alternative would be to include the conversion process in the yield process.

3.7 Naming conventions

In this chapter, the naming of flows/exchanges and activities (also referred to as nomenclature) is structured and described.

Names shall be generally understandable by people from many different fields. Abbreviations shall be avoided and a common language shall be strived for, e.g. use of the phrase 'live weight' instead of 'round weight' to describe whole fish.

Singular is used as far as possible, e.g. fillet and not fillets.

The product and activity naming conventions in ecoinvent[10] are adopted here:

- Product names begin with the most generic form of the product that is generally recognized as a product, e.g. "cod, headed and gutted" rather than "headed and gutted cod", but avoiding artificial names, e.g. not "feed, Tilapia" but "Tilapia feed"."
- Processing processes are preferably named by using the activitiy form of the associated verb (i.e. the "…ing" form), for example. fishing.
- Material processes are preferably named by using the word 'production' together with the reference product, e.g. fillet production, fish production etc.
- Processing activities should follow order [process], [raw material], [detail of process].

Wild caught fish can before catch be considered as an elementary flow. Thus wild caught fish can be considered first an elemerntary flow and then a product. This should be considered according to the requirements of the data/database format that is used.

3.8 Good practice for documentation and meta-data

Meta data can be explained as "data that describes the data". Consistent and detailed inclusion of meta data helps ensecure that users can easily evaluate if the data is fit for the intended purpose. Meta data typically includes information about the time frame covered by the data, the geographic context of the data, the number of operating units represented by the data, etc.

Various formats for documentation of LCI data exist. The Seafood LCI database will function with at least the ecospold and the ILCD format:

- When using the ecospold format, ecoinvent guidelines[11] should be used, together with the documentation guidelines in this methodology.
- When using the ILCD format the ILCD guidelines[12] should be used, together with the documentation guidelines in this methodology.

The data documentation guidelines in ecoinvent[13] are adopted:

- Informative explanatory comments shall generally be provided for all values
- Information that is relevant for several datasets shall not be documented in the dataset but instead be linked to from the dataset
- Literature and other sources shall be referenced, and links (URI) to the sources provided if available

[10] Overview and methodology, (Weidema et al., 2013).
[11] Dataset Documentation for ecoinvent database version 3, (ecoinvent, 2012).
[12] Documentation of LCA data sets, (JRC, 2011)
[13] Overview and methodology, (Weidema et al., 2013).

- Comments and references that are general to more than one entry in the dataset are provided in the comment field most relevant for the nature of the value
- All datasets for activities and products shall make reference to an established system for trading codes, ISIC and CPC are suggested as a starting point
- All datasets developed in this project shall be made open, and when integrated in other databases it shall be stated that FHF and the data owner has made these data publicly available
- British English is the default language

3.9 Background/secondary processes and dummy input flows

The Seafood LCI database does, in general, not contain data on energy, materials and infrastructure used as inputs to the processes covered by the Seafood LCI database. Thus the Seafood LCI database is dependent on other data sources to cover these parts of the system. The reason to exclude these more generic types of data is that such data are already available in existing LCI databases.

Examples of data frequently used as inputs in seafood systems, but for which data will be taken from other databases include inputs and impacts of:

- Production and distribution of fuels and electricity
- Production of materials such as metals, plastics, concrete and cardboard
- Production of chemicals like refrigerants and anti-fouling paints
- Production of infrastructure: Roads, airports and harbours, buildings.

Such inputs that are used, but not part of the database, will be modelled with what is referred to as empty "dummy" processes. The function of these dummy processes is to maintain a flow that the user can link to the generic background database. The dummy processes and their flows should be documented so that users and database providers can link the data to their own background data. If possible, the same practice for documentation as in chapter 3.8 should be used. If secondary data is found in existing databases, reference shall be made to it by stating the product name, database version and its UUID (if such exists). If the found secondary data is an approximation, the characteristics of the required product shall be clearly documented as well as where the secondary data deviates from it.

3.10 Attributional or consequential modelling

The database will, as a general rule, only include attributional data due to the goals of the database and the uncertainties involved when making assumptions about future market conditions.

3.11 Multi-functionality and allocation

Processes with multiple outputs shall be modelled as unit processes securing a clear understanding of whatever allocation method and ratios used. It shall be possible to use the data with another allocation method.

3.12 Data quality requirements and assessment

Data quality requirements from the PEF guidance version 6.0 will be implemented. Data will not be assessed by using DQR, but rather documented so that DQR can be applied, when needed. The reason why DQR is not applied in the database from the beginning is because it is designed only with the PEF use cases in mind. As a result some criteria are intrinsic to the DQR, e.g. DQR rates the most recent data with the highest score while a data user might want older data that fits better with her or his specific scope. However, the procedure of documentation might also need to be adapted to also cover other needs that are identified along the way.

3.13 Data review

Before data are entered into the database, a procedure for data review shall be in place, either internally and/or externally and shall be clearly explained.

4 Description of data

This chapter describes what type of data should be aimed for including and how to organise it in the database for seafood LCIs in order to be most useful for future users. The resolution and structure suggested to be used will not fulfil every possible goal, the aim is to fulfil the needs of most potential users. Data are described per major life cycle step specific for seafood, i.e. fishing, aquaculture, fish meal production, preparation and processing. It is also described how to document available data. Data not listed here can still be part of the Seafood LCI database.

4.1 Fishing

Modelling

A fishery is the human directed activity of fishing that extracts aquatic animals from largely wild ecosystems. Data associated with a specific fishery for potential inclusion in the database typically (though does not have to) involves one or many fishing vessels, licensed by one country (in rare cases an international organization), using one fishing method to target the same target species in a more or less localized or describable area. Fisheries are to be modelled as two activities, where the first activity is a **processing process** and represents the type of fishery with respect to *what fishing gear is used and the fishing nation and fishing area*. Its output is the quantity of fish that is landed, without differentiating the species. The second activity, a **material process**, adds information regarding *what species are caught*. This approach with two activities used to understand a fishery reflects a guiding principle that we have adopted, rather than a requirement. The advantage of approaching database construction in this way is that it makes it easier to use data from one fishery as a proxy for a fishery of the same type for which primary data are not available. Another advantage is that the processing activity of a given fishery can be used to obtain the environmental impact of that fishery per quantity of fish, regardless of species.

Importantly, in some fisheries, processing of fish into some form of derived products can take place aboard the fishing vessels. Where this occurs, if possible, this activity should be separated from the fishing activity. Where this is not possible, it is very important that it is clearly stated that processing is included and that it is clearly stated in what form products are landed.

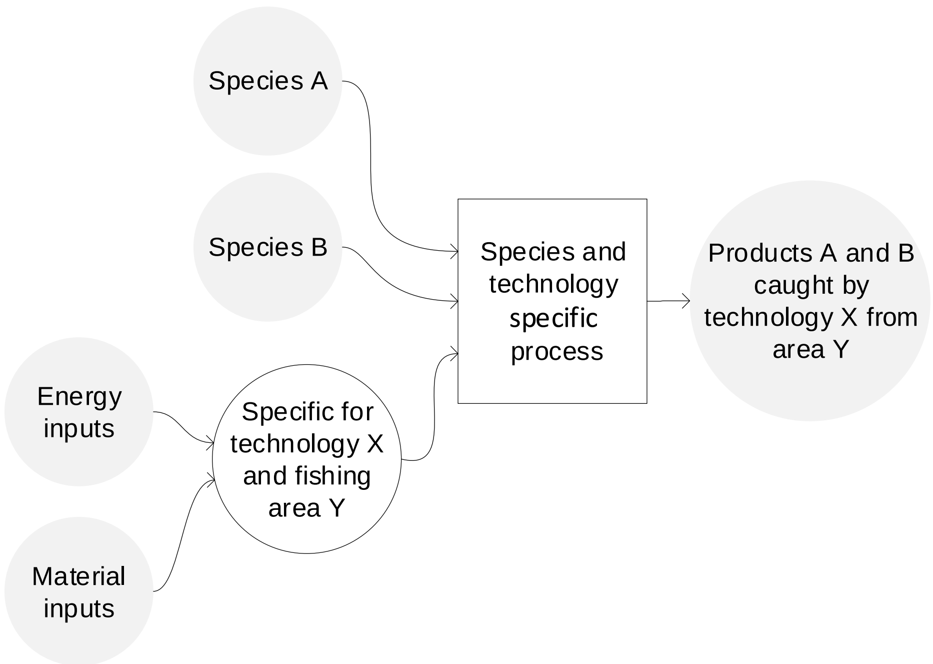


Figure 4-1 Conceptual figure of fishing modelling

Conceptual description of data requirements

Data required for fisheries, example units and degree of importance are found in Table 4-1 and explained briefly below. All energy used to maintain fishing activities shall be included: Steaming of vessels to and from fishing grounds, fishing operations, use of re-supply or support vessels or other vehicles, maintenance, electricity use in port, and in some cases onboard processing. In general, activities that are excluded include those associated with state management and oversight of the fishery itself. The energy use shall be the sum of all fuels (including lubricants) utilized by fishing vessels, or otherwise used in direct support of the fishing activity, over a time period that includes all of these activities. Ideally, data will encompass a minimum of one year of operations to capture seasonal variation. This of course implies that the database will *not* be useful to analyse seasonal differences of fisheries. If vessels are engaged in several fisheries over a year, only data associated with the fishing season/activities in the fishery studied shall be included. If the fishing season is shorter than one year, ideally at least two years of data (two fishing seasons) should be encompassed by the data provided. Fuel used for maintenance in such cases needs to be added if it does not take place during the season studied, either as a proportion of fuel use added or as an absolute amount distributed equally over the fishing year, depending on data availability. In any case, it needs to be clearly described how this is done. Ideally, all forms of fuel or other energy inputs will be directly quantifiable from fishing company records or similar private or public systematic data collection efforts. In some cases though, it may be possible to robustly estimate fuel or other key inputs indirectly from fishing effort or other data (see Tyedmers 2000, Bastardie 2010, 2013). Where this occurs, the same principles in terms of temporal coverage of data (ideally full year, or multi-year if fisheries operate sesonally) apply. Both production and combustion of the fuel shall be modelled and it is critical that all types of resource use, including fuel, are related to the volume of landings ***in the same period of time***.

Replacing losses of refrigerants from refrigeration systems on the fishing and other support vessels should be included, in particular if HCFCs or HFCs are used. This should include refilling during planned service and when refrigeration system failures have occured. It should be clearly documented what refrigerant is used, and the volume refilled and over what time period (e.g. per year).

Material inputs to capital goods (the fishing vessel, fishing gear) are optional to include and are likely to be more important (i.e. play a greater role in life cycle impacts of resulting products) in less resource-intensive fisheries, rates of capital good expenditure are unusually high or when resource-intensive materials, such as aluminium, are used.

Data

Table 4-1 LCI data for fisheries

FISHING				
Data	**Type of data (Metadata / Quantitative)**	**Description and comments**	**Example unit**	**Importance (Shall, should or may)**
Species targeted	Metadata	English and scientific name of species targeted (e.g. found in fishbase.org). Note that more than one species can be targeted by a fishery (e.g. Atlantic cod, *Gadus morhua* and Haddock, *Melanogrammus aeglefinus*)	n/a	Shall

FISHING				
Stock	Metadata	Name of stock of target species (e.g. Northeast Arctic cod)	n/a	May
Fishing area	Metadata	FAO catch zones and subdivisions (e.g. FAO 27/IIIa or Northeast Atlantic/Kattegat)	n/a	Should
Fishing gear	Metadata	Name of fishing technique used (e.g. purse seine, long-line, demersal trawl, gillnet)	n/a	Shall
Vessel characteristic s	Quantitative	Vessel size (m), vessel age (yr), primary engine power (kW), engine age (yr)	m, Years, kW	May
Vessel characteristic s	Metadata	Description of propulsion and energy system (combustion, , diesel-electric, hybrid…)	n/a	Shall
Fishery characteristic s	Metadata	Coastal or offshore, demersal or pelagic	n/a	May
Time period	Metadata	Time for which data is representative, one or several years or a specific fishing season during a year (e.g. March-April)	n/a	Shall
Fishing nation	Metadata	Country or international body licensing the fishing vessel, managing the fishery and/or distributing the fishing quota used by the vessel	n/a	Shall
Landing location	Metadata	Name of country or port where fish/seafood is landed	n/a	May
Product form landed	Metadata	Description of the form and mode of conservation of product that are delivered to port. For example, liveweight (i.e. round weight), gutted, headed and gutted or fillets Fresh or frozen	n/a	Shall
By-product fate	Metadata	By-products in onboard processing (guts, heads, skin, bones) landed or discarded?	n/a	Should (if no information is given assume by-products are discarded)
Composition of landings	Quantitative	Mass of landings (per species and per year) (e.g. 100 tonnes cod, 10 tonnes redfish) Mass per species and size group of landings (e.g. 50 kg cod 2-5 kg, 20 kg cod 1-2 kg)	Tonnes or Kg Tonnes or Kg	Shall May
Composition of discards	Quantitative	Mass or number of individuals discarded (per species) per unit landed	Kg or numbers/kg landed	May
Fuel use	Metadata	Type of fuel used (e.g. marine gas oil, diesel fuel)	n/a	May
Fuel use	Quantitative	Amount of fuel consumed per unit of mass landed during a defined time period (e.g. a year), including fuel used for non-fishing activities such as steaming to and from fishing fields, port activities and maintenance. Mass landed includes all biomass that is landed and further utilised. (see section 5.1 for more specific guidance for data collection/description)	litres fuel/tonne landed	Shall

FISHING				
Refrigerant use	Metadata	Type of refrigerant used (natural: e.g. CO_2, NH_3 or synthetic e.g. HCFCs like R22 or HFCs like R134a, R507)	n/a	Shall
Refrigerant use	Quantitative	Amount of refrigerant refilled in onboard cooling system per year.	Kg/year (then related to the landings during same time period)	Should Shall if refrigerant of HCFC or HFC type is used
Ice use	Metadata	Produced onboard or brought from land?	n/a	May
Ice use	Quantitative	Amount of ice used per amount of fish landed	Kg ice/kg fish landed	May
Packaging materials	Metadata	Types of packaging materials used on fishing vessel	n/a	May
Packaging materials	Quantitative	Amount of each packaging material used per amount of fish landed	Kg/kg fish landed	May
Vessel construction	Metadata	Types of materials used in fishing vessel	n/a	May
Vessel construction	Quantitative	Amount of each material used in vessel and their lifetime	Tonnes, years	May
Gear construction	Metadata	Types of materials used in fishing gear	n/a	May
Gear construction	Quantitative	Amount of each material used in gear and their lifetime	Kg, years	May
Bait use	Metadata	If bait is used, what types are used and where does it come from(species and country) ?	n/a	Should
Bait use	Quantitative	How much of each bait type is used per amount of fish landed?	Kg/kg	Shall
Anti-fouling	Metadata	Type of anti-fouling agents used (active ingredient/s)	n/a	Should
Anti-fouling	Quantitative	Amount of anti-fouling and content of active ingredient/s	Liters and mass %	Should
Loss of fishing gears	Quantitative	Units of gear lost per year	Number	May

Naming

Processing process

In the first step above, the recommendation is to name the process ‘Fishing (defined by target species, fishing method, fishing nation, fishing area)’.

The output of this process is volume of landed fish and can be interpreted as the fishing activity needed to land a certain volume of fish under the given conditions (gear, target species, fishing nation and fishing area).

Material process

In the second step, the recommendation is to name the process ‘Fish landed (defined by species, , product form, landing location)

Output flow / Intermediate exchanges / Products

The recommendation is to name the flow ‘Species, product form, landed’.

Elementary flows / Elementary exchanges / Exchanges from and to the environment

The recommendation is to name the flow ‘Species (English and scientific name), stock’.

4.2 Marine feed ingredients production

Modelling

Fish meal and oil production from whole fish or other aquatic animals (e.g. krill, shrimp), or from by-products of seafood processing as well as soluble proteins/hydrolysates, is typically known as reduction and is one way to refine and stabilize the nutritional attributes of aquatic animal tissues for use in other industries. Other ways of stabilizing these materials is by treatment with formic acid to produce a fish slurry, also called silage. Silage can then later be used as an input to meal/oil production.

Fish meal and oil production most often takes place in a land-based plants. The primary outputs of the reduction process typically include a stable, low moisture content, protein-rich meal, and an oil that typically is nearly 100% lipid. Other products can include soluble proteins that have been filtered or otherwise extracted from the liquid pressed from the fish tissues. These can be added back into the meal to increase protein content or stabilized and sold separately. Fish meal and oil have been used historically in a wide range of applications but currently, most are destined for further use as feed ingredients in aquafeeds, and to a lesser extent, in livestock production. The process of reduction is done through mechanical, thermic and chemical treatment of the raw material.

Fish meal and oil processing shall be modelled as a processing data set, independently of species and yields. The reduction plant is modelled as a processing activity delivering the service of reducing raw material to meal and oil. It will, in the same way as in the fishery, be connected to material processes that uses the service and contains data on yields, raw materials and allocation, illustrated in *Figure 4-2*.

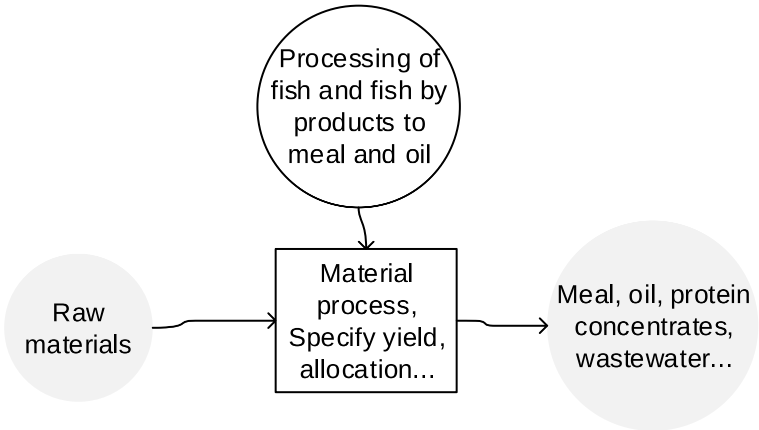


Figure 4-2 Modelling of a fish meal and oil production illustrating combination of processing and material data sets.

Conceptual description of dataset requirements

Data describing the process of reducing wet fish material to fish meal and oil should ideally encompass at least one year. Input and process-related data that play a critical role in life cycle impacts of fish meal and oil production include: direct inputs of energy (both electricity and/or fossil fuels for raising steam), emissions of waste water, and the species-specific yield rates of meals and oils per unit of raw material processed. All energy use at the fish meal and oil plant shall be described and quantified. Water use and waste water production, including composition of waste water, e.g. level of nutrients and chemicals, shall be quantified and included. This is particularly important when life cycle impacts of concern include eutrophication. The yield of meal and oil per tonne of raw material processed is highly important as it differs widely and has a major influence on the environmental assessment of the products (Cashion et al. 2016, 2017).

As was the case with the fishery process, material inputs to capital goods associated with the operation of a reduction plant are optional to include as they are very unlikely to affect resulting life cycle impacts given the typically long life span of reduction plants and associated buildings and their typical enormous annual throughout.

Table 4-2 LCI data for production of marine feed ingredients

Fish meal and oil processing				
Data	**Type of data (Metadata**	**Description and comments**	**Example Unit**	**Importance (Shall, should or may)**

Fish meal and oil processing				
	/ **Quantitative)**			
Process flow	Metadata	Describe: What raw materials are used, what processing that is perfomed and what products that are delivered. Specify quality parameters for raw material input and products, e.g. water and protein content etc.	n/a	Shall
Electricity use	Metadata	Describe where electricity is sourced from. Can be described through what grid (geographic) it is sourced from or what production technologies the grid mix is composed of. Describe if it is low, medium or high voltage electricity.	n/a	Shall
Electricity use	Quantitative	Document for a time period of one year or longer.	kWh/tonne raw material into processing	Shall
Heat use	Metadata	Describe source and at what temperature the heat is used (input temperature)	n/a	Shall
Heat use	Quantitative	Document amount for a time period of one year or longer	kWh/tonne raw material into processing	Should
Fuel use	Metadata	Describe what type of fuel is used. Document sulphur content.	n/a	Shall
Fuel use	Quantitative	Document amount for a time period of one year or longer	Liter/ tonne raw material into processing	Shall
Chemicals	Metadata	Describe what chemicals are used., e.g. formic acid used to preserve the products and raw materials and chemical used for extraction. Antioxidants used to stabilise the fishmeal is also important.		Shall
Chemicals	Quantitative	Quantify input of each chemical	Liter/ tonne raw material into processing	Should
Water use	Metadata	Describe what water that is used, specify source (geographical and type of water, municipal, lake, ocean etc.) Describe how water is treated before and after use, e.g. waste water tretament	n/a	Should
Water use	Quantitative	Quantify fresh water input and waste water output	Liter/ tonne raw material into processing	Should
Water use	Quantitative	Quantify content of nutrient and dissolved organic content in waste water	Gr/liter waste water	Should

Fish meal and oil processing				
Yield	Quantitativ e	Specify the total yield of marine ingredients per tonne of raw material processed	Kg/tonne of raw material processed	Shall

Naming

Processing process

In the first step above, the recommendation is to name the process 'Fish meal and oil processing (defined by country and specific technology used at plant)'.

The output of this process is the annual production of fish meal and oil of the plant and can be interpreted as the processing activity needed to produce a certain amount of fish meal and oil at the plant.

Material process

In the next step, the recommendation is to name the process 'Fish meal (defined by species, whole fish/trimings, country of production)'

Output flow / Intermediate exchanges / Products

The recommendation is to name the flow 'Fish meal, species, whole fish/trimmings, country of production'.

4.3 Aquaculture

Aquaculture encompasses an enormous range of activities, and resulting life cycle impacts will depend considerably on the nature of animals in culture, the portions of their life histories included in culture, the duration of culture, the physical and technological setting of culture and other supporting system employed, the extent to which growth is based on feed inputs, etc. Here we have simplified the scope of potential systems to be modelled to three sub-systems: juvenile acquisition or production, grow-out and where applicable, broodstock production and maintenance.

4.3.1 Juvenile Acquisition or Production

Modelling

Despite the great diversity that exists within aquaculture, at its core, all forms involve the sheltering and rearing of animals from a younger/smaller state (for simplicity, hereafter referred to simply as juveniles) to an older/larger state that is harvested. Originally, most forms of aquaculture started out with juveniles sourced from largely wild populations. Over time, most forms of aquaculture have been able to shift to the artificial propagation and rearing of juveniles in what are typically called hatcheries. This, however, is only possible where reproduction and early life history rearing can be reliably and reasonably inexpensively replicated in a controlled environment.

Contemporary examples of this include production of all salmonids, many varieties of seabass and sea bream, catfish, etc. for culture. However, some contemporary aquaculture systems still source juveniles from the wild, for example eel, mollusc and some shrimp culture systems as well as tuna fattening systms (when the catch is not actually juvenile).

The acquisition of juveniles for culture from the wild should, where possible, be modelled as if it were a standalone fishery as described above. Challenges in doing so may arise, however, when juvenile harvesting occurs informally (e.g. without official permits or monitoring), and at relatively small scales in contrast to more typical directed fisheries. Furthermore, some fisheries for juveniles for culture do not employ equipement typically associated with a fishery (e.g. a fishing vessel). Nonetheless, where possible, life cycle inventory data for activites that extract juveniles from the wild should be modelled as a fishery.

When juveniles are produced in hatcheries, where possible, they should be modelled as two activities, where the first activity is a **processing process** and represents the type of juvenile hatching and rearing that is occurring with respect to *type of animal being produced (e.g. mollusc, finfish, etc)* and *the extent of feeding that occurs*. Its output is the quantity of juvenile animals produced. The second activity, a **material process**, adds information regarding *what species are produced*. This approach, with two activities used to understand hatchery operations, reflects a guiding principle that we have adopted, rather than a requirement. Indeed, this level of process disaggregation may not be possible in many settings. There can be important differences between freshwater and seawater systems due to different energy use based on how they are located in relation to the source of water used resulting in varying need for pumping and energy use. Also aquatic emissions and their impacts will vary depending on the technology used and water recipient. The advantage of approaching database construction in this way is that it makes it easier to use data from one hatchery system as a proxy for a hatchery of a similar type for which primary data are not available. Another advantage is that the processing activity for a type of hatchery can be used to obtain the environmental impact of that hatchery per quantity of animals produced, regardless of species.

Conceptual description of dataset requirements

This specification is intended to describe data required and desired to characterize juvenile production in enclosed on-shore hatchery systems regardless of species. Until the database is further developed this description is also valid for enclosed on-shore systems that also include the grow-out of fish to market size. Juvenile production is here the process of growing fertilized eggs to a size the fish or other organism is ready to be transferred to larger systems for grow-out to a harvestable size. For some systems, juvenile production and grow-out may not be easily distinguishable, e.g. for production in some land based systems.

Critical input parameters of enclosed on-shore aquaculture systems like hatcheries include all energy inputs, feed inputs if brought in, use of bottled or liquid oxygen if supplied from offsite, water inputs, refrigerants and chemicals. Energy inputs shall include all electricity used, including that for water pumping, filtering/treatment, heating and chilling along with general operations. Where sludge from juvenile production is handled and treated on site, electricity used for these purposes shall be included along with data on resulting residual emissions to water and air. If the sludge treatment includes material and/or energy recovery this shall be included according to the Resource Use and Emissions Profile (RUaEP) as presented Annex V in the PEF guide (. In addition to electricity, all forms and amounts of fuels used to operate or support hatchery operations should be included.

Material inputs shall include quantities and types of water (e.g. fresh and saltwater) inputs for regular hatchery operations as well as for cleaning shall be included and categorized according to the water impact assessment methods used. This shall also include make up water used in recirculating hatchery production systems. In addition, where feed are provided and are produced offsite, quanties and types of feeds used shall be recorded. When oxygen is provided and not produced onsite, quanties and forms used (e.g. bottled, liquid) shall be included. When refrigerants are used quantities and types of losses shall be included. Finally, quantities and types of chemicals used to adjust water chemisty, clean infrastructure and treat animals (veterinary medicinal products -VMPs) should be included.

Given the production capacity that is typical for modern enclosed hatchery systems infrastructure plays a minor role in the overall environmental impact at the level of the final consumer product and as such can be excluded.

Output measures that shall be quantified include some measure of the quanity and type(s) of juvenile animals produced. In addition, wastewater discharge quanties and qualities shall be included, particularly when there is limited or no onsite treatment.

When juvenile production typically takes less than a year, data will encompass a minimum of one year of hatchery operations to capture seasonal variations. Where juvenile production (or land-based grow-out) requires more than one year, data shall reflect a minimum of one full production cycle and ideally should reflect two or more complete cycles to minimize the effect of variability between cycles.

Table 4-3 LCI data for juvenile production in hatcheries.

Aquaculture enclosed system production of juveniles and/or grow-out				
Activity or input to document	**Type of data (Metadata / Quantitative)**	**Description and comments**	**Example Unit**	**Importance (Shall, should or may)**
Process description	Metadata	Describe system. What is produced. Water treatment technologies applied.		Shall
Electricity use	Metadata	Describe where electricity is sourced. Can be described through what grid (geographic) it is sourced from or what production technologies the grid mix is composed of. Describe if low, medium or high voltage electricity.		Shall
Electricity	Quantitative	Document for a time period of 1 year or longer.	kWh/tonne	Shall

Aquaculture enclosed system production of juveniles and/or grow-out				
use			fish produced	
Heat use	Metadata	Describe source and at what temeprature the heat is used (input temperature)		Should
Heat use	Quantitative	Document for a time period of 1 year or longer	kWh/tonne fish produced	Shall
Fuel use	Metadata	Describe what type of fuel that is used. Document sulphur content.	Litre/tonne fish produced	Shall
Chemicals	Metadata	Describe what types of chemicals that are used. Known chemicals could include cleaning products and chemicals used to adjust water chemistry, etc.		Should
Chemicals	Quantitative	Quantify input of each chemical	Litre/tonne fish produced	Should
Oxygen	Metadata	Describe if/how oxygen is used. Sourced externally or produced at the plant? How is it transported?		Shall
Oxygen	Quantitative	Quantify mass of oxygen used.	Kg/tonne fish produced	Shall if supplied from offsite
Water use	Metadata	Describe what water that is used, specify source (geographical). State if there are resiculation of the water and if so the resiculation rate. Describe how water is treated before and after use, e.g. wastewater tretament		Shall
Water use	Quantitative	Quantify fresh water input and waste water output	Litre/tonne fish produced	Should
Water use	Quantitative	Quantify content of nutrient and disolved organic content in waste water	g/litre wastewater	Shall

Naming

Processing process

In the first step above, the recommendation is to name the process ‘Juvenile production (defined by country and specific technology used)’.

The output of this process is the annual production of juveniles from the hatchery and can be interpreted as the processing activity needed to produce a certain amount of juveniles.

Material process

In the next step, the recommendation is to name the process ‘Juveniles (defined by species, country of production)’

Output flow / Intermediate exchanges / Products

The recommendation is to name the flow ‘Juveniles, species, country of production’.

4.3.2 Aquaculture Grow-out

Modelling

All forms of aquaculture include some form of grow-out during which animals are, at a minimum, provided with some degree of shelter and protection and in many instances, their growth is accelerated through the provision of feeds and/or efforts to enhance feed availability within the culture environment (e.g. inducing algae blooms through fertilization). Grow-out also includes efforts to maintain water quality parameters within acceptable, if not optimal ranges, to maximize growth, and may also involve treatment of animals in culture to address disease (includes parasites) issues when they arise. Grow-out can occur in a wide variety of settings including in pens, cages, ponds, raceways, tanks, and in the case of mollusc culture systems, in unenclosed waters on natural surfaces in the intertidal zone or suspended from rafts, or other structures. Data associated with a specific form of grow-out for potential inclusion in the database should generally relate to activities that co-occur in a specific region (though this can be difficult to define), that use a single specific culture technology in a specific aquatic environment (e.g. marine based net-pen, freshwater raceway, marine raft-based culture, etc.) to grow-out one species (though in some settings, two or more species are commonly grown out together).

As was the case with fisheries and juvenile production of fish for aquaculture, grow-out is to be modelled as two activities, where the first activity is a **processing process** and represents the type of grow-out with respect to *the type of culture technology used (e.g. net-pen, raceway, etc), physical setting,* and *the extent to which feeds are used to grow animals*. Its output is the quantity of fish that is produced, without identifying the species. The second activity, a **material process**, adds information regarding *what specie(s) are produced*. This approach with two activities used to understand a grow-out system reflects a guiding principle that we have adopted, rather than a requirement. The advantage of approaching database construction in this way is that it makes it easier to use data from one grow-out system as a proxy for an aquaculture activity of the same type for which primary data are unavailable. Another advantage is that the processing activity of a given grow-out operation can be used to obtain the environmental impact of that aquaculture operation per quantity of fish, regardless of species.

Conceptual description of dataset requirements

Aquaculture grow-out includes all processes used to enhance growth and secure and protect animals in culture until they are harvested. Given the diversity of grow-out settings, technologies and species, in this version of the specification, we describe the data needed to characterize inputs to a typical intensive, fed aquaculture grow-out system such as a marine-based, net-pen aquaculture system, regardless of the species being farmed. Critical inputs that are known to drive many life cycle impacts associated with intensive, fed net-pen based culture, include feed inputs, and direct and supporting energy inputs. In some instances, where chemotheraputants and/or other chemicals are used commonly, they shall also be quantified. With respect to feed inputs, the following data shall be included:

- The coarse composition, source location, and transport mode(s) used to move feed to the farm site(s).
- The economic (also known as the gross) feed conversion efficiency (eFCR). Typically expressed as a ratio, this represents the total mass of feed used on farms, relative to the total live weight mass of animals harvested for human consumtion from those farms. The EFCR shall include also the feed used for fish that do not end up as a consumer products. Importantly, ALL feed fed on farms, regardless of whether some was eaten by animals that subsequently escaped or died before harvest must be included. The eFCR shall encompass a minimum of one full grow-out cycle for the animals being cultured.
- Emissions of Phosphorus and Nitrogen from the fish farm that result from all excretions and from degradation of uneaten feed shall be included. These emissions shall be calculated based specifically on: the use and fates of feed in the production of the fish being characterized; content of N, P and C in the feed; spillage and retention in the fish, etc. For Atlantic salmon in culture this mass balance calculation is demonstrated by Wang et al [17, 24].

All energy use on farms and to support farm related activities shall be specified. This includes fuels used in for aggregates that supply electric power to the feed system, the crew quarters etc. and fuel used for service vessels, other vessels and well-boats used to transfer fish to, from and between farm sites, as well as any fuel or electicity used on farm sites directly. This should include fuel used on sub-contractor vessels, etc. With respect to emissions of chemicals (e.g. antifouling paints, veterinary substances, etc.) used on farm sites, all forms and quantities of active substances that are emitted to the water, either directly or through fish excreta or wear and tear of materials shall be quantified relative to the total live weight mass of fish harvested. In many instances, some of these quantities can only be estimated (e.g. loss of anti-foulant paints through flaking and erosion). Where farm maintenance is conducted by sub-contractors (e.g. net washing, etc.), emissions from these activities shall be included. If these emissions are not covered by elementary flows covered by the default impact assessment method (e.g. ILCD method) they shall still be documented and quantified.

Given the production capacity that is typical for modern grow-out systems, infrastructure (e.g. nets, anchoring systems etc.) typically plays a minor role in the overall environmental impact at the level of the final consumer product and as such can be excluded.Outputs that shall be quantified include the total live weight mass of all species harvested for potential human consumption from the grow-out system. In addition, the mass of all culled animals and all animals that died pre-maturely and were collected for disposal shall be quantified along with their fates (e.g. sent to compost on land, disposed of at sea, etc.) To cover seasonal differences and the different activities performed between grow-out cycles and maintenance, data shall as a general rule cover longer time periods, preferably several production cycles to make sure all start up, shut down and maintenance operations are included. Where a production system to be characterized is well established and involves multiple farm sites in an area, data should ideally encompass a representative proportion (>30%) of total farming activities in an area.

Table 4-4 LCI data for marine net-pen based grow-out

Aquaculture enclosed system production of juveniles and/or grow-out				
Activity or	**Type of**	**Description and comments**	**Example Unit**	**Importanc**

Aquaculture enclosed system production of juveniles and/or grow-out				
input to document	**data** **(Metadata /** **Quantitative)**			**e** **(Shall, should or may)**
Process description	Metadata	Describe system, including: location, technology used, what species are produced, the time period represented by the data, how many total farms are involved in the area and how many farms are represented by the data.		Shall
Material flow	Metadata	Document the mass flow of fish from when it enters the system (e.g. as juvenile fish) to the different ways it leaves. That would be as fish forhuman consumption, dead fish, escapes etc. Also document what the dead fish and other fish not for human consumption is used for. If it is utilized or becomes a waste flow.		Shall
Material flow	Quantitative	Quantify the flows of fish	Kg/year for each product	Shall
Describe and document mass flow	Metadata and quamtitative			Shall
Feed use	Metadata	Describe where feed is sourced from (country), describe its composition at least roughly (e.g. proportion marine inputs or nutritional content) and how the feed is transported to the farm sites *Detailed feed composition requirements are provided in the Feed PEF-CR*		Shall
Feed use	Quantitative	Document number of farm sites and production cycles represented.	Economic feed conversion rate (e.g. tonnes of feed fed: live weight tonnes of animals harvested for intended consumption	Shall
Feed use emissions to water	Quantitative	Document the sources of data and the source of the equations used to quantify N, and P emissions to water	Kg of N and kg P emitted to water/live weight tonne of fish produced	Shall
Fuel use	Metadata	Describe what types of fuel that are used and for what activities (e.g. fish transfer, feed supply, etc). Document sulphur content.		Shall
Fuel use	Quantitative	Describe the period and activities the data represent	Litre/tonne fish produced	Shall
Electricity use	Metadata	For farm sites that use electricity directly, describe where electricity is sourced from. Can be described through what grid (geographic) it is		Shall

Aquaculture enclosed system production of juveniles and/or grow-out				
		sourced from or what production technologies the grid mix is composed of. Describe if it is low, medium or high voltage electricity.		
Electricity use	Quantitative	Document for a time period of 1 year or longer.	kWh/tonne fish produced	Shall
Chemicals	Metadata	Describe what types of chemicals that are used. Known chemical could include anti-foulant paints along with active ingredients, and chemotheraputants (veterinary medical products, VMPs) used along with their active ingredients, etc.		Shall
Chemicals	Quantitative	Quantify input of each chemical	Kg or litre/tonne fish produced	Shall

Naming

Processing process

In the first step above, the recommendation is to name the process 'Aquaculture (defined by country and specific technology used)'.

The output of this process is the annual production of animals produced at the farm and can be interpreted as the processing activity needed to produce a certain amount of farmed seafood.

Material process

In the next step, the recommendation is to name the process 'Farmed *species*, country of production)'

Output flow / Intermediate exchanges / Products

The recommendation is to name the flow 'Farmed *species*, country of production'.

4.4 Seafood preparation

Modelling

Preparation and processing refer to one or more processes used to convert animals from their live form into seafood products (forms typically made available for final human consumption such as fillets). Preparation[14] includes mechanical treatment of the fish and cooling, e.g. bleeding, gutting and filleting, and freezing and chilling. Processing[14], on the other hand, refers to transformation of seafood, e.g. through canning, smoking, salting, drying, marinating or use as an ingredient in a mixed food product and is not included here.

Just like earlier, in the fishing phase, preparation is modelled as a process independent of the input of raw material and products. The preparation process is then used as an input to a material process where the raw material use and product yield is taken into account.

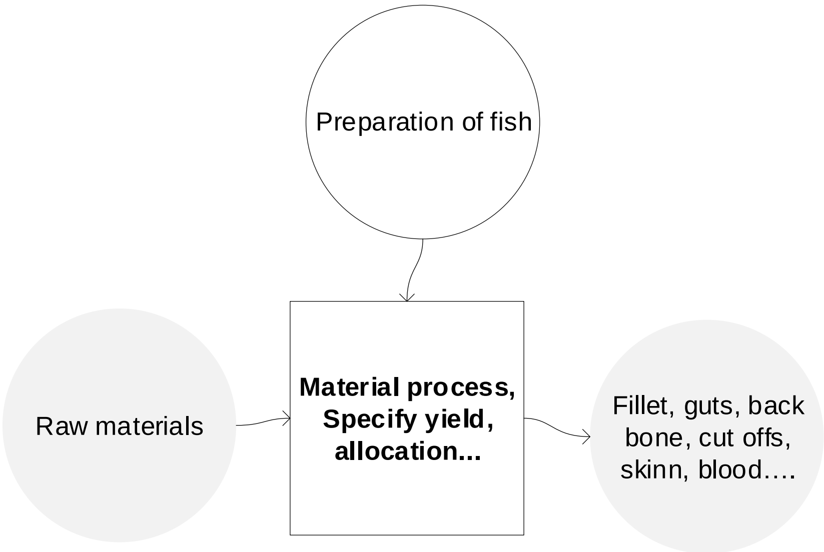


Figure 4-3 Preparation of fish modelling

Conceptual description of dataset requirements

When modelling preparation of seafood, important parameters are the use of energy and coolants, the raw material use and product yield. It is also important to describe clearly in what form the raw material enters the plant, whole, gutted, headed etc. A common situation is that different types of seafood products (e.g. fresh, frozen and smoked) are produced in the same industry and therefore a comprehensive description of what kind of preparation the dataset describes is needed including location of the plant. If possible, different production lines should be separated to avoid the need to allocate resource use and impacts between co-products. For example, energy use for e.g. canning should be taken out from the total value if the product studied is fresh. A detailed description of all products and co-products is needed, in terms of species, product form and product yield from raw material used. It is important to specify whether they go to direct human consumption, to further processing to be used in feed or if they become a waste flow etc. The economic value of the different outputs should

[14] Regulation (EC) No 853/2004 of the European Parliament and of the Council of 29 April 2004 laying down specific hygiene rules for food of animal origin (OJ L 226, 25.6.2004, p. 22)

also be documented. All types of energy used are quantified. Almost without exceptions, seafood industries have refrigeration systems and their use of refrigerant is crucial both in terms of what substance is used and how much is emitted per year (normally equal to the amount refilled during annual service). The total volume of refrigerant used in the refrigeration systems should also be documented. The documentation of use and emissions of refrigerants is especially important if coolants of CFC, HCFC or HFC type are used. Water use and chemicals used for cleaning, are additional data that can be important, depending on the impact categories analysed.

Naming

Processing process

In the first step above, the recommendation is to name the process 'Freezing or Filletting (defined by country and specific technology used)'.

The output of this process is the annual production of frozen fish at a plant and can be interpreted as the processing activity needed to produce a certain amount of frozen fish.

Material process

In the next step, the recommendation is to name the process '(species, product form, country of production)'

Output flow / Intermediate exchanges / Products

The recommendation is to name the flow 'Species, product form, country of production'.

Table 4-5 LCI data for preparation

Preparation				
Data	**Type of data** **(Metadata / Quantitative)**	**Description and comments**	**Example unit**	**Importance (Shall, should or may)**
Material flow	Metadata	Describe what types of preparation are done at the plant, that is what are the main products produced in terms of species and product form (fresh, frozen canned and whole or fillets)		Shall
Material flow	Quantitative	Document the mass balance from raw materials, including specifying the product form of the	Kg/year for each product	Shall

Preparation				
		incoming raw material, to all co-products		
Outputs	Quantitative	Price of outputs(products	EUR/kg	May
Electricity use	Metadata	Describe where electricity is sourced from. Can be described through what grid (geographic) it is sourced from or what production technologies the grid mix is composed of.	NA	Shall
Electricity use	Quantitative	Document for a time period of one year or longer.	kWh/tonne raw material into processing	Shall
Refrigerant use	Metadata	Type of refrigerant used (natural: e.g. CO2, NH3 or synthetic e.g. HCFCs like R22 or HFCs like R134a, R507)	n/a	Shall
Refrigerant use	Quantitative	Amount of refrigerant refilled in cooling systems per year.	Kg/year	Shall
Refrigerant use	Quantitative	Volume of refrigerants used the in refrigeration systems.		Should
Heat use	Metadata	Describe source and at what temperature the heat is used (input temperature)	n/a	Shall
Heat use	Quantitative	Document amount for a time period of one year or longer	kWh/tonne raw material into processing	Should
Fuel use	Metadata	Describe what type of fuel is used.	n/a	Shall
Fuel use	Quantitative	Document amount for a time period of one year or longer	Liter/ tonne raw material into processing	Shall
Chemicals	Metadata	Describe what chemicals are used., e.g. for cleaning		Should
Chemicals	Quantitative	Quantify input of each chemical	Liter/ tonne raw material into processing	May
Water use	Metadata	Describe what type of water is used, specify source (geographical and type of water, municipal, lake, ocean etc.) Describe how water is treated before and after use, e.g. waste water tretament	n/a	Should
Water use	Quantitative	Quantify fresh water input and waste water output	m^3/ tonne raw material into processing	Should
Water use	Quantitative	Quantify content of nutrient and dissolved organic	g/liter	Should

Preparation				
		content in waste water	wastewater	

4.5 Other important seafood-specific data

4.5.1 Fuel: Use and production

Fuel use is an important environmental aspect of several processes and shall be included using data that are specific for the fuel that is used and the engine technology using it. Specifications:

- Production and distribution of the fuel shall be included. Loss of fuels/emissions during distribution and loading shall be included. Production and distribution of the fuel can be included with generic data.
- For assessments that only include a carbon footprint it is sufficient to use fuel specific emission factors
- SOx, NOx an particulate matter emissions shall be included with reference to how these emissions are calculated (or measured). Preferably with reference to methods presented in the MARPOL convention[15]

4.5.2 Refrigeration systems

For processes that use refrigeration shall be included with the following details:

- Type of refrigerant used
- Emissions of refrigerants to air
- The energy used to run the refrigeration system.
- production of the refrigerant, this can be included with generic data

Regarding the energy used to operate the refrigeration systems, it shall be explicitly documented if the energy to run the refrigeration systems is already included in the energy included for the life cycle stages where the refrigeration is used. E.g. the reported fuel use of fishing vessel shall include all on board systems, including refrigeration systems. Equally for preparation the energy used associated with the preparation factory shall include all refrigeration systems. A common example of situations where energy used by refrigeration systems are not included, is in transportation where refrigeration aggregates can have their own fuel tanks.

[15] http://www.imo.org/en/OurWork/Environment/Pages/Default.aspx

Energy use and emissions from refrigeration systems used in transport systems shall be documented so that it can be modelled for the specific time/duration of the transport, as explained below.

4.6 Distribution, transport

Transports shall be included with the following details:

1) Transport mode (e.g. train, ship, truck)
2) Transport mode type (e.g. vessel size in TEU or DWT, truck size in tonne etc.)
3) Fuel type
4) Specific fuel consumption of the transport vehicle (units of fuel per kilometre)
5) Load capacity utilization. The theoretical or allowed max load shall be documented along with the average load of each transport unit
6) Distance of the transport
7) Duration of transport (total time including loading, redistributing and offloading)
8) Data on the use of refrigeration; cooling agent and leakage rate

(Cooling for truck, aircraft, train, barge, transoceanic or reefer ship)

4.7 Biogenic carbon

Biogenic carbon contents of unit process outputs will be part of the meta-data. So biogenic carbon sequestration is not included as parameter in the dataset. This is in line with PEF guidance 6.0 and Agri-footprint 3.0. Users can easily include biogenic carbon when they want to include it.

4.8 Antifouling

Production of antifouling paints is currently not included in Agri-footprint but this will be developed for the seafood database. The most common antifoulant used is copper and to include toxic antifouling emissions, it is necessary to know the bran used and its content of active ingredient, e.g. CuO or CuO_2. The amount of paint applied annually together with the copper content and data or assumptions on leakage then gives the amount of active ingredient emitted (to water when leaking from the hull, to soil if left on the hull and later scraped off). See also the seafood PEFCR regarding how antifouling use and emissions shall be modelled (Hognes 2014).

4.9 Capital goods

Capital goods such as construction of port facilities and vessels and gear are not mandatory to include due to their repeatedly demonstrated low importance for total life cycle impacts of seafood products (Hognes 2014), but if data is available, these flows can be added.

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