Interreg Atlantic Area
European Regional Development Fund
EUROPEAN UNION

NEPTUNUS

PROJECT

Policy brief #1

Sustainability in seafood production

IPMA
ANFACO CECOPESCA
NUI Galway OÉ Gaillimh
universidade de aveiro
UC UNIVERSIDAD DE CANTABRIA

1. The Life Cycle Assessment methodology and its application in the seafood sector

What is LCA

The Life Cycle Assessment (LCA) is a powerful tool to assess the environmental impacts and resources used throughout a product's life cycle, i.e., from raw material acquisition, via production and use phases, to waste management (Finnveden et al. 2009). Figure 1 shows the evolution of the LCA concept from 1960s, when environmental degradation and limited access to resources became a concern, to 2006, when the ISO standards about LCA were adopted.

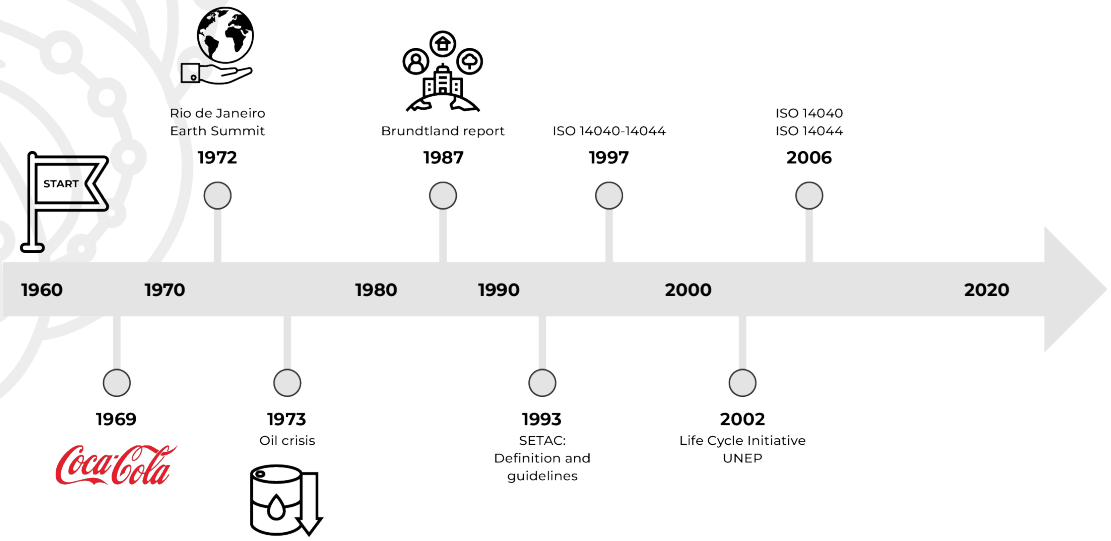


Figure 1. Timeline of the evolution of the Life Cycle Assessment concept adapted from Bjørn et al. (2018).

The LCA methodology structured according to the ISO framework and ILCD recommendations operates with four separate phases (Figure 2):

LCA PHASES			
Goal and Scope	**Life Cycle Inventory (LCI)**	**Impact assessment (LCIA)**	**Interpretation**
Definition of goal and scope	Inputs and outputs of the system unit processes	Selection of impact assessment method i.e. ReCiPe, EcoIndicator 99 etc	Interpretation of results and usability
Intended application audience, publicity, etc	Energy inputs	Selection of impact categories	Significance, limitations, comprehensive
Boundaries	Raw material inputs	Category indicators	Opportunities to improve
Functional unit	Other physical inputs	Characterisation models	Strategic decision making
Allocations	Products	LCI-results classification	Selecting indicators
Assumptions and limitations	Co-products and waste	Calculation of category indicator results i.e. characterization	Product and process development
Data quality requirements	Emissions to air	Grouping and normalization	Environmental information
Type of critical review	Discharges to water and soil	Weighting	Marketing

Figure 2. The four phases of LCA (based on ISO 14040 standard series).

LCA main applications

Policy formulation – the European Commission (EC) has promoted the Integrated Product Policy (IPP) to minimise environmental impacts of products by considering all stages of their life cycle, from the cradle to grave. This directive is an example of how life cycle thinking has guided policymaking within the EU, where the focus has shifted from manufacturing processes the use of products and their disposal. A major challenge to the application of LCA in these contexts is the communication of environmental performance of products. To facilitate the communication of reliable and reproducible information about the environmental performance of products and organisations, the EC launched the Single Market for Green Products Initiative with the aim of propose the Product Environmental Footprint (PEF) developing a common way of measuring environmental performance.

Decision-making support – LCA can be used as decision support to advice the introduction of novel technologies in the market or the selection of waste management systems. For instance, the EU Waste Framework Directive 2008/98/EC states that "to handle waste in a way that does not have a negative impact on the environment or human health".

Industry applications – LCA can be used in enterprises with different objectives: decision support in product and process development, marketing purposes, selection of suppliers and subcontractors and/or strategic planning. In addition, LCA has traditionally been used at product level, and is still used as such, but there is an increasing interest in using it at the corporative level to reflect the performance of the company or individual plants in a life cycle perspective.

Consumer perspective – LCA results can also serve as decision support for consumers to the private consumption of goods and services by means of ecolabels or other consumer information from producers. Consumer decisions that may be supported by an LCA can be, for example, in the choice of the product with the lowest environmental impact amongst a group of similar products.

LCA application in the seafood sector

Scientific LCA publication linked to the capture, farming and processing of seafood started in mid-2000 where the LCA-related publications strongly increased (Figure 3). Over the last decade there was an increasing publication of LCA studies, however, the seafood sector still represents a low percentage of LCA published studies focused on food.

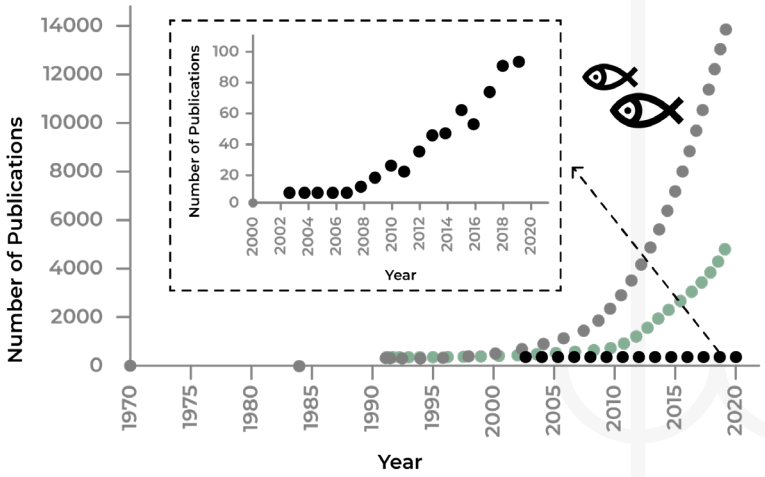


Figure 3. Number of publications per year in scientific journals that include the search terms "life cycle assessment" (●), plus "food" (●) or plus "fish" and "seafood" (●) (adapted from Ruiz-Salmón et al. (2021)).

Most LCA studies are focused on a single species or a group of species (i.e., tuna species). Typically, these species are emblematic of the regions analysed, such as Peruvian anchovy (Fréon et al. 2010), European anchovy (Laso et al. 2017), Galician mussels (Iribarren et al. 2010), and European sardine (Almeida et al. 2014). The main hotspot identified in the fishery stage is the production and direct combustion of diesel. However, this consumption depends mainly on the fishing gear. For example, small pelagic species captured by purse seining fisheries present a low fuel input fisheries and rank among the most efficient form of protein production, while fuel-intensive crustacean fisheries are among the least fuel-efficient fisheries (Parker and Tyedmers 2015). Differences can be found within the same species as when, for example, 0.7 kg diesel/kg octopus are needed to land octopus captured by traps and pots gears (Almeida et al. 2022), whereas using trawling gears these value increase to 1.7 kg diesel/kg octopus (Vázquez-Rowe et al. 2012). From an LCA impact categories perspective, the main challenges are linked to providing a more complete scope of environmental impacts related to the marine environment. The addition of impact categories linked to plastic debris in the ocean and stocks depletion would potentially enhance the utility and visibility of LCA.

Major findings about aquaculture evidenced that the feed production is a key driver for climate change, acidification, cumulative energy use and net primary production use, while the farming process is a key driver for eutrophication (Bohnes et al. 2019). The influence of the species farmed and the feed conversion ratio (FCR) was found particularly determinant for environmental performances of the systems since the nutritional needs of fed species range from largely herbivorous to almost exclusively carnivorous (Henriksson et al. 2021). In particular farming of extractive (non-fed) low trophic marine species (i.e., bivalves and macroalgae), can provide alternatives with lower environmental impacts (i.e., lower GHG emissions and reduced land and freshwater uses) (Gephart et al. 2021).

A drawback on an overview based on aquaculture LCA studies is that they offer limited coverage of production systems and species. For example, aquatic foods are generally overrepresented by Atlantic salmon farming which constitutes one of the most homogeneous and intensive aquaculture practices, while the omnivorous species and freshwater finfish (especially carps) represent the majority of aquaculture production globally are underrepresented in LCA literature (Henriksson et al. 2021). At global scale, Asian and African aquaculture systems are much underrepresented in past LCA studies, even though Asian aquaculture production accounts for more than 90% of global production and seafood as an important protein source participates to food security in those countries (Bohnes et al. 2019; Naylor et al. 2021).

In the processing stage, packaging has been identified as the main hotspot in the environmental impact of seafood products in LCA studies focused on canned seafood products (Hospido et al. 2006; Almeida et al. 2014; Laso et al. 2017). The studies have focused on the use of conventional packaging materials, but an investigation of these materials from a life cycle perspective including their production, recyclability prospects, or substitution by innovative packaging materials can help in reducing the environmental challenge associated with this stage of the product life cycle (Figure 4).

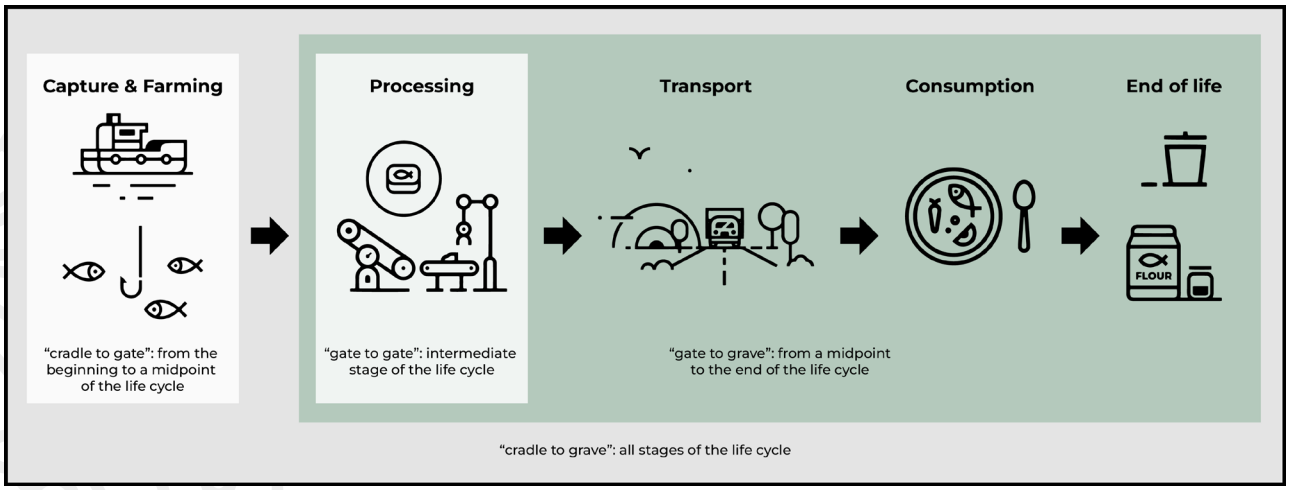


Figure 4. The life cycle of seafood (adapted from Ruiz-Salmón et al. (2021))

2. Environmental certification schemes for seafood

Environmental labels and declarations can help to identify those products or services proven "environmentally preferable". The approach aims to inform consumers about the environmental impact of their consumption patterns and encourage producers to improve the environmental sustainability of their products and services. As companies have come to recognize that environmental concerns may be translated into a market advantage for certain products and services, various environmental declarations, claims and labels have emerged. These have exerted a powerful attraction on consumers, but they have also led to some confusion and scepticism. The increasing proliferation of such labelling has led to concerns of 'greenwashing' and exaggerated marketing claims. Therefore, ISO International Standards plays a fundamental role on stablishing internationally agreed and harmonized criteria and methods of labelling to provide a credible playing field. At present, there are three main types of ecolabels stablished globally by ISO standards: Type I, Type II and Type III. Requirements of these ecolabels are not specific to seafood and they can be applied to any product.

Type I environmental labelling

The "classic" ecolabel that evaluates the environmental quality of a product compared with other products of comparable function. The objective of this type of environmental labelling programme is to contribute to a reduction in the environmental impacts associated with products, through the identification of products that meet the specific criteria of a Type I programme.
This type of ecolabel is:

- designed to be consumer-friendly and informative
- based on the fulfilment of a set of criteria in the environmental impact of a product and requirements are available to the public
- awarded by a certified third-party program
- voluntary and can be operated by public or private agencies at the national or international level
- defined by criteria and categories developed by independent experts, and can also include input from interest groups and technical experts
- granted for a specific time period after which the product/service needs to be recertified.

Type I is considered the so-called standard for consumers because there is an independent certifying body. The ISO 14020 refers to Type I environmental labelling programmes and establishes the principles and procedures. Common examples include the EU Ecolabel (can be applied only to farmed seafood), Marine Stewardship Council certification, and Fair Trade.

Type II self-declared environmental claims

The type II certification state the claims from manufacturers, retailers, or distributors about environmental characteristics of a product or service. This type of ecolabel is:

- self-declared
- focuses on a particular quality of a product (e.g. compostable packaging)
- not independently certified
- communicated by statements, symbols or graphics and may appear on the product package or in product literature

The ISO 14021 refers to Type II and identifies and clarifies a number of commonly used terms used in claims, whether they be on the product or elsewhere such as in product literature, advertising or reports. It also details the evaluation methods for each term in order to ensure they are valid and scientifically sound. Common examples include the Dolphin safe program, recyclability of materials, and carbon trust.

Type III environmental declarations

The type III certification are voluntary declarations of the sustainability of a product or service entire life cycle. Applicants need to carry out a LCA of the product or service and declarations enable comparisons between similar products. They are commonly known as Environmental Product Data (EPD) and represent the “nutrition labels for the environment”. This type of ecolabel is:

- independently verified, normally by a third-party and registered in an open EPD scheme
- often B2B (business-to-business) communication
- does not certify any specific quality of a product/service
- a way to draw independent conclusions about the sustainability of a product/service.

The ISO 14025 refers to Type III and establishes the principles and procedures for developing the data for such declarations and the requirements for declaration programmes, including the requirement that data are independently verified.

Certification schemes try to provide assurance about sustainability and help consumers in making more environmentally informed decisions when purchasing seafood products. The schemes can highlight the sustainability or environmental performance of seafood production activities under the different type of sources about issues such as pollution, overfishing, or climate change potential. Fisheries standards certify fisheries (which can entail a single fisheries company with several vessels or a group of companies working together). Aquaculture standards certify farms or groups of farms. Certified products available to the end-consumer carry a logo or a label and some standards charge a fee for using this logo, whilst others do not. At the same time, it is important to note that there are some costs associated with certification that can be high and some producers, particularly small farmers and small-scale fisheries, struggle to comply with certification standards due to the financial, organisational, and administrative burden of getting their operation certified. Sometimes processing plants are interested in supporting the certification of groups as this facilitates access to larger volumes of certified seafood for them.

The more widely recognised seafood labels are Marine Stewardship Council (MSC) and Aquaculture Stewardship Council (ASC) (Figure 5). More than 446 fisheries, representing 17% of global wild seafood, are certified by MSC[1]. The products awarded are sourced by fisheries that target healthy stocks, the stocks are well-managed and can be fished in the long-term, and fishing operations minimise their impact on other species and the marine ecosystem. The ASC certification is awarded to aquaculture producers/products that address the key environmental impacts of farming, requirements for workers' rights, and protect communities surrounding certified farm.

Figure 5. The Marine Stewardship Council (MSC) and Aquaculture Stewardship Council (ASC) logos.

There are other seafood sustainability labels such as Friend of the Sea and Dolphin Safe labels (Figure 6). The Global Sustainable Seafood Initiative (GSSI), a public-private partnership on seafood sustainability, developed a tool that benchmarks seafood certification schemes using the FAO Code of Conduct for Responsible Fisheries. GSSI-benchmarked certification standards are recognised by many retailers as being credible and trustworthy.

There is a gradual shift from retailers committing to selling seafood with specific ecolabels to committing to selling seafood that is certified by any GSSI-benchmarked certification standards. This provides an opportunity for other standards to increase and broadens the selection of standards to consider for the certification. There are also many initiatives that are invisible to the consumer. For example, in Fisheries Improvement Projects (FIPs) and Aquaculture Improvement Projects (AIPs) different actors in the supply chain work together to improve specific fisheries or aquaculture systems. They exist because in some areas fishers and farmers are not yet able to be certified, but they are working on improving their practices. Certification standards also implement improvement projects to help fishers and farmers work toward certification. Other examples are pre-competitive collaborations between companies, a collaboration between leading seafood companies seeking to lead a global transformation towards sustainable seafood production through time-bound commitments.

Figure 6. The Global Sustainable Seafood Initiative (GSSI), Friend of the Sea and Dolphin Safe logos

[1] https://www.msc.org/en-us/media-center/news-media/press-release/proposed-changes-to-msc-fisheries-standard-now-available-for-public-review

In the case of aquaculture, it is also possible to apply the principles of organic production in the EU to obtain organic certified seafood (Figure 7). The certification addresses issues related with the ecosystem balance and biodiversity stewardship, animal welfare, feeding requirements that respect the health of the organism, and feeding requirements along the sources of similar organic systems. However, technical barriers in developing organic finfish aquaculture exist related to the low availability of organic feed ingredients and higher production costs due to lower density or specialised production sites, which are not always compensated by the price premium. Bivalves (e.g. mussels) can be certified under the organic scheme of most of the EU production with no significant technical or economic barriers, apart from the quality of the water. The rules for producing organic seafood are more stringent than for sustainable seafood and the market for sustainable seafood in Europe is much larger than for organic seafood. On the other hand, producers tend to receive significant price premiums for organic seafood, whilst producers rarely receive price premiums for sustainable seafood.

Figure 7. The European Union organic logo gives a visual identity to organic products produced in the EU.

These schemes can be improved with the inclusion of specific environmental impact indicators or categories from LCA, to account for more holistic characterisation of the environmental impact of seafood production activities. LCAs can be used to estimate the impact of a product and can include carbon, water and energy footprints. The incorporation of LCA results would allow for more targeted interventions in improving environmental performance.Certification schemes such as Pescaenverde pair carbon footprints, energy footprints and the edible energy of the captured seafood (Figure 8)[2]. The end goal of this ecolabel is to increase the competitiveness of seafood products, as well as to help consumers to identify products with better environmental performance.

Figure 8. The Pescaenverde logo gives a visual identity to products produced in Galicia (Spain).

Additional efforts in expanding the scope of ecolabels and third-party certifications are ongoing with NEXUS methodology, which evaluates the integration of different footprints (carbon, water, energy and nutritional) in one final figure that represents a balance between the four perspectives. The NEXUS approach can demonstrate to consumers in a single score metric the complex interactions that footprints of seafood products can have.

[2] https://www.usc.gal/pescaenverde/

3. The PEF initiative

There are numerous ways of seafood certification that must be standardized for a consistent communication to the consumers, in addition to environmental product requirements. In 2013, the EC introduced the Product Environmental Footprint (PEF) initiative with the purpose of harmonizing the environmental performance of a product or organization across the EU. The main objective was to improve the reproducibility and comparability of products along the entire supply chain and to quantify the environmental impact associated with a product group or sector. The PEF is based on ISO standards, Life Cycle Assessment (LCA) methodology, Environmental Product Declaration (EPD) and other methods (e.g., Global Reporting Initiative (GRI), Environmental Management Systems (EMS), Green Public/Private Procurement (GPP)).

The main difference between the conventional LCA and the PEF is that the PEF reports results related to environmental impacts in an efficient and comparable way. To achieve assessment standards governed by common rules, the Product Environmental Footprint Category Rules (PEFCR) have been developed, which establish guidelines on the use of environmental information for the product category under assessment, making PEF studies easier, faster and less costly, including the establishment of benchmarks, databases and guidelines for reporting results.

Products in the same category must use the same functional unit (e.g., 1 kg of edible product) and must describe qualitatively and quantitatively the function and duration of the product category, according to the following four aspects:

· The function service provided: “What?”
· The extent of the function or service: “How much?”
· The expected level of quality: “How well?”
· The duration/lifetime of the product: “How long?”

The PEFCR should cover all stages of the life cycle of a functional unit and marine fish and can be divided into the following stages: i) fishing (raw material acquisition), ii) production (manufacturing), iii) distribution (manufacturing, packaging, retailing), iv) use (consumption), and v) end-of-life (waste management). The selected criteria should follow a transparent consultation process and involve all stakeholders. The main applications of a PEFCR can be internal: optimizing processes throughout a product’s life cycle, identifying environmental hotspots or improving environmental performance; and external, responding to customer and consumer demands, participating in third-party systems related to environmental claims or providing transparency to products that communicate their life-cycle environmental performance. The PEF methodology is still in the so-called “transition phase”, where it should provide a framework for monitoring the implementation of existing PEFCRs and developing new ones.

4. Sustainable seafood movement

A sustainable seafood movement began in the mid-1990s, raising the importance of consuming seafood that is caught or farmed using methods that do not harm single species or ecosystems. The movement encourage consumers to ask for sustainable seafood products as seafood consumers become more conscious of the environmental and social impact associated with seafood production. Recommendations about which seafood is “best” from the environmental point of view are difficult because there are a range of environmental aspects to account. However, some general differences can be taken for a sustainable seafood consumption globally:

1. *Blue food* - Discussions on sustainable food production focuses mainly on protein from meat (i.e. land-based animals) and vegetables, and usually misses seafood or aquatic-based animal production. However, small pelagic fish from fisheries and farmed shellfish have environmental

impacts lower than most animal-source proteins given their nutrient richness to meet dietary requirements (Koehn et al. 2022). From a climate perspective, seafood is overall better than red meat, and comparable to eggs and chicken (Figure 9). Plant-based options generally have a lower climate impact than seafood, but seafood has a more favourable nutritional composition.

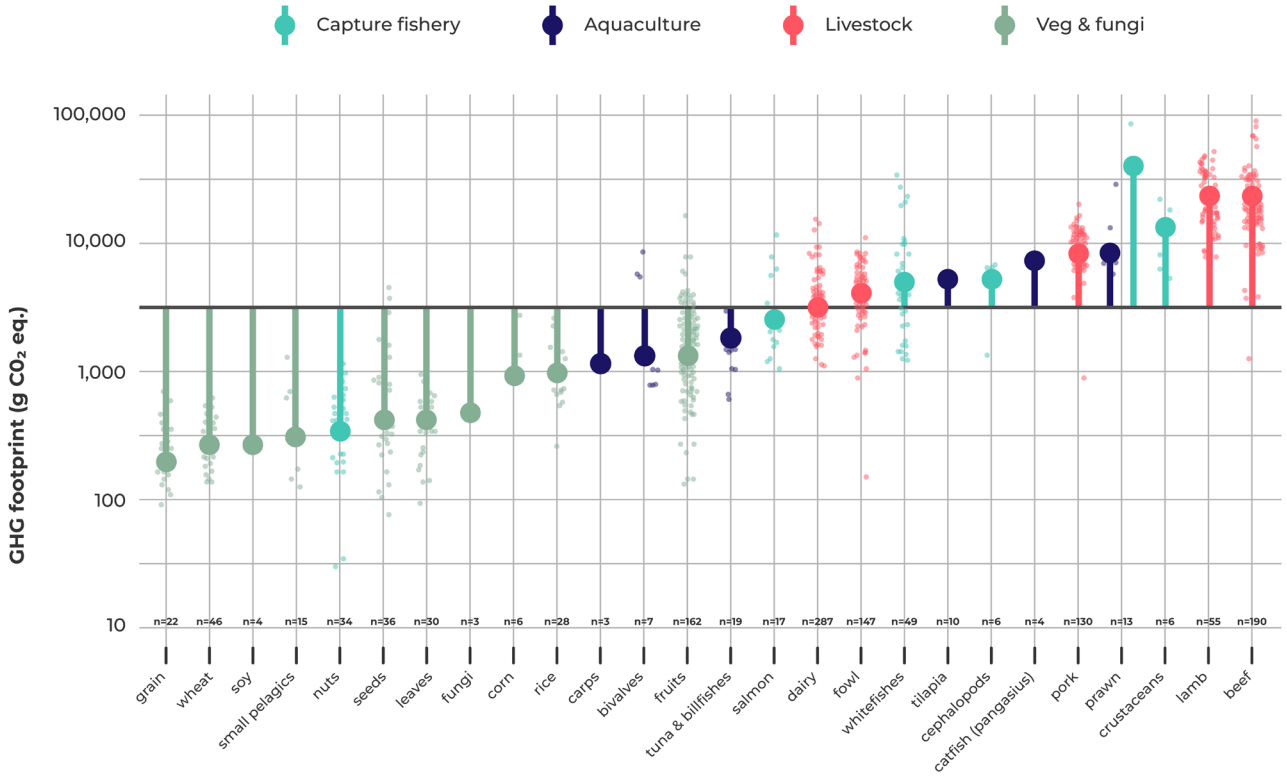


Figure 9. Greenhouse gas emissions relative to composite nutrient richness across major food groups. The gray horizontal line indicates the median for all observations across the food groups. The large points represent the median value across all species from that food group, whereas the vertical lines represent the distance from the median GHG footprint needed to meet 100% of the daily requirement across 12 nutrients. The y-axis is on a logarithmic scale.
(adapted from Koehn et al. (2022).

2. *Not one, but a highly diverse set of seafoods* - Seafood should not be treated as a single aggregated item, but rather as a set of different species based on varying production systems, edible yield rates, and nutritional profiles (Tlusty et al. 2019). As long as the seafood is not transported by air, it does not matter so much "where" the product was produced, but rather "how" (e.g., Ziegler et al. 2021). Regardless where the production happens, it should be prioritized the species, fishing gear, stock status, management effectiveness, indirect impacts on habitats, and when it comes to aquaculture, the type of system related to its intensity (i.e., extensive, semi-intensive and intensive), standards stablished, or type of feed used (Gephart et al. 2021; Ziegler et al. 2022) (Figure 10).

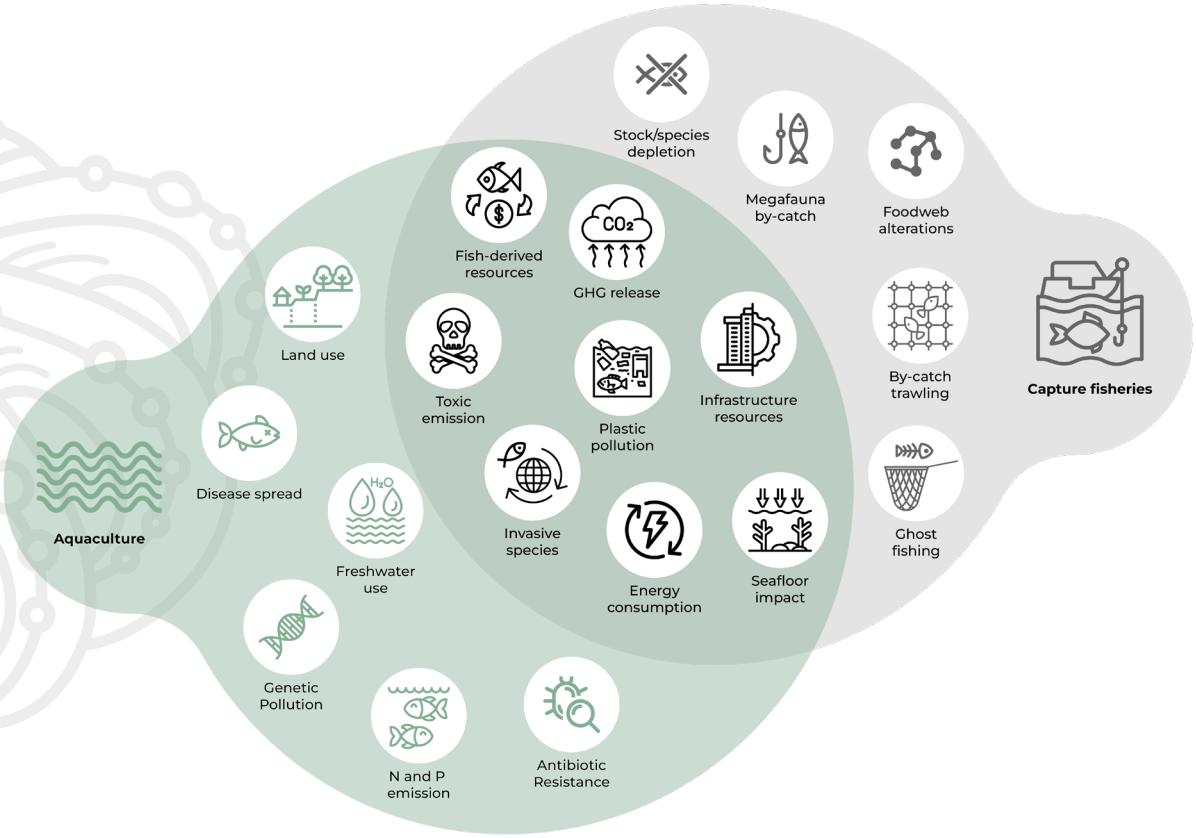


Figure 10. Major stressors stemming from aquaculture and capture fisheries (adapted from Gephart et al. (2021)).

3. *Local produced is not always better* - That a food is produced locally is none guarantee that has a low climate footprint. An imported product may actually have lower climate impact than a locally produced one. The best would be to choose from both sustainable and close production sources.

4. *Demand for not used seafood* - More fishing resources which otherwise go to feed or waste could be consumed directly or through innovative processing products. Therefore, more knowledge is needed about seafood waste along the supply chain to minimize losses, know where there is higher potential to avoid it and know the best options to reuse such waste.

5. *Simplify sustainable choices* - Making conscious choices in stores and restaurants when it comes to seafood is not always easy. Recommendations for a healthy reference diet consist of 28 g of fish or shellfish per day (range 0-100 g) which is about one or two servings per week, considering what else the diet consists of and if daily requirements of key macro and micro nutrients already have been reached (Troell et al. 2019). This can only be followed sustainably if we have good knowledge on how to choose species and/or products and information is available. The food chain has an important role to play in the shift to more sustainable seafood consumption and industries, grocery stores, and restaurants can be more transparent to help consumers.

6. *Use the tools available and contribute to improve them* - The ecolabels and seafood guides from NGO's are the most convenient tools to help consumers when choosing seafood. However, they are not always effective when it comes to reduce negative environmental impacts.

As an example, there is the risk of exclusion of small-scale fisheries or small aquaculture productions who may have difficulty in accessing a certification scheme or simply because there is no detailed information to determine their environmental impact. It is therefore important to keep tools updated and develop new tools to stimulate more sustainable choices as, for example, “nudging” (i.e., implement an aspect of the choice architecture that alters people’s behaviour in a predictable way without limiting any option).

5. Recommendations from NEPTUNUS project

- Shift towards food production with low environmental impacts and low carbon footprint. Every type of food production changes the environment. Therefore, an alteration of food systems toward net zero-carbon systems will require a pathway that focusses on environmental impacts being better than the alternative rather than elusively aiming for zero environmental impact. This needs to be supported by transdisciplinary research where consumers and wider public are included to accelerate opportunities.

- Support more LCA studies to cover more seafood products. The LCA results can play a key role in increasing producers and consumers awareness of the complex nature of seafood production systems and differing impacts across different environmental categories. Policymakers can also base their regulations on LCAs results to improve the environmental impacts of existing fisheries and aquaculture systems. Regulatory efforts should be complemented with initiatives that sensitize the public to sustainable seafood production, which may create market-driven for more sustainable production schemes.

- Integrate the climate impact into sustainability assessments. Today, climate impact is rarely included in environmental sustainability evaluations of seafood, such as certifications and NGO consumer guides. However, environmentally certified seafood can, for example, be transported by air which has the highest climate impact compared to slower types of transport, such as boat and train.

- Design instruments to reduce climate impact (i.e. carbon footprint) from seafood. These can be positive for the types of seafood that we want to benefit as well as negative for the types you might want reduce. Policy instruments can include different approaches from dietary advice to direct financial support or taxes.

- Rise awareness about the diversity of seafood species and production methods. Considering seafood or fish as a homogenous food overlooks the large differences between subsectors in terms of potential environmental benefits and its nutritional value, which includes many important nutrients in addition to protein.

Interested in learning more?

Almeida C, Loubet P, Laso J, et al (2022)
Environmental assessment of common octopus (Octopus vulgaris) from a small-scale fishery in Algarve (Portugal).
Int J Life Cycle Assess. https://doi.org/10.1007/s11367-022-02072-7

Almeida C, Vaz S, Cabral H, Ziegler F (2014)
Environmental assessment of sardine (Sardina pilchardus) purse seine fishery in Portugal with LCA methodology including biological impact categories.
Int J Life Cycle Assess 19:297–306. https://doi.org/10.1007/s11367-013-0646-5

Bjørn A, Owsianiak M, Molin C, Laurent A (2018)
Main Characteristics of LCA. In: Life Cycle Assessment. Springer International Publishing, Cham, pp 9–16

Bohnes FA, Hauschild MZ, Schlundt J, Laurent A (2019)
Life cycle assessments of aquaculture systems: a critical review of reported findings with recommendations for policy and system development.
Rev Aquac 11:1061–1079. https://doi.org/10.1111/raq.12280

Finnveden G, Hauschild MZ, Ekvall T, et al (2009)
Recent developments in Life Cycle Assessment.
J Environ Manage 91:1–21. https://doi.org/10.1016/j.jenvman.2009.06.018

Fréon P, Bouchon M, Domalain G, et al (2010)
Impacts of the Peruvian anchoveta supply chains: from wild fish in the water to protein on the plate.
Globec Int Newsl 16:22–26

Gephart JA, Henriksson PJG, Parker RWR, et al (2021)
Environmental performance of blue foods.
Nature 597:360–365. https://doi.org/10.1038/s41586-021-03889-2

Henriksson PJG, Troell M, Banks LK, et al (2021)
Interventions for improving the productivity and environmental performance of global aquaculture for future food security.
One Earth 4:1220–1232. https://doi.org/10.1016/j.oneear.2021.08.009

Hospido A, Vazquez ME, Cuevas A, et al (2006)
Environmental assessment of canned tuna manufacture with a life-cycle perspective.
Resour Conserv Recycl 47:56–72. https://doi.org/10.1016/j.resconrec.2005.10.003

Iribarren D, Vázquez-Rowe I, Hospido A, et al (2010)
Estimation of the carbon footprint of the Galician fishing activity (NW Spain).
Sci Total Environ 408:5284–5294. https://doi.org/10.1016/j.scitotenv.2010.07.082

Koehn JZ, Allison EH, Golden CD, Hilborn R (2022)
The role of seafood in sustainable diets.
Environ Res Lett 17:035003. https://doi.org/10.1088/1748-9326/ac3954

Laso J, Margallo M, Fullana P, et al (2017)
When product diversification influences life cycle impact assessment: A case study of canned anchovy.
Sci Total Environ 581–582:629–639. https://doi.org/10.1016/j.scitotenv.2016.12.173

Naylor RL, Hardy RW, Buschmann AH, et al (2021)
A 20-year retrospective review of global aquaculture.
Nature 591:551–563. https://doi.org/10.1038/s41586-021-03308-6

Parker RWR, Tyedmers PH (2015)
Fuel consumption of global fishing fleets: Current understanding and knowledge gaps.
Fish Fish 16:684–696. https://doi.org/10.1111/faf.12087

Ruiz-Salmón I, Laso J, Margallo M, et al (2021)
Life cycle assessment of fish and seafood processed products – A review of methodologies and new challenges.
Sci Total Environ 761:144094. https://doi.org/10.1016/j.scitotenv.2020.144094

Tlusty MF, Tyedmers P, Bailey M, et al (2019)
Reframing the sustainable seafood narrative.
Glob Environ Chang 59:101991. https://doi.org/10.1016/j.gloenvcha.2019.101991

Troell M, Jonell M, Crona B (2019)
The role of seafood for sustainable and healthy diets.
EAT-Lancet Comm 24

Vázquez-Rowe I, Moreira MT, Feijoo G (2012)
Environmental assessment of frozen common octopus (Octopus vulgaris) captured by Spanish fishing vessels in the Mauritanian EEZ.
Mar Policy 36:180–188. https://doi.org/10.1016/j.marpol.2011.05.002

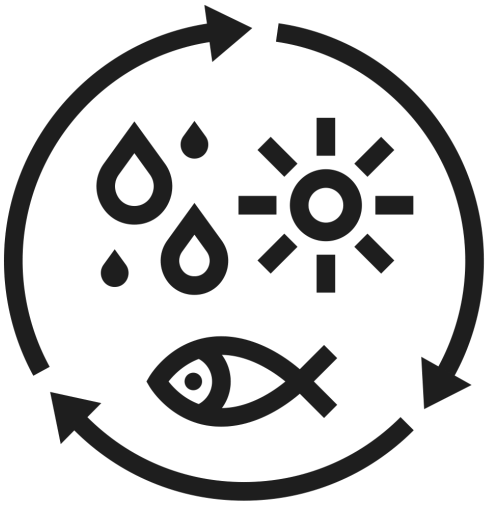
Ziegler F, Jafarzadeh S, Skontorp Hognes E, Winther U (2021)
Greenhouse gas emissions of Norwegian seafoods: From comprehensive to simplified assessment.
J Ind Ecol 1–12. https://doi.org/10.1111/jiec.13150

Ziegler F, Tyedmers PH, Parker RWR (2022)
Methods matter: Improved practices for environmental evaluation of dietary patterns.
Glob Environ Chang 73:102482. https://doi.org/10.1016/j.gloenvcha.2022.10248

Authors

Cheila Almeida[1], Jara Laso[3], Sandra Ceballos[3], David Alonso[4], Diego Mendez[4], Andrei Briones-Hidrovo[5], Paula Quinteiro[5], Ana Dias[5], Ronan Cooney[6,7], Eoghan Clifford[6,7], Maria Leonor Nunes[2], António Marques[1,2]

[1]**IPMA** - Instituto Português do Mar e da Atmosfera, Lisboa, Portugal
[2]**CIIMAR** - Centro Interdisciplinar de Investigação Marinha e Ambiental, Matosinhos, Portugal
[3]**Departamento de Ingenierías Química y Biomolecular**, Universidad de Cantabria, Santander, Spain
[4]**ANFACO-CECOPESCA**, Vigo, Spain
[5]**Centre for Environmental and Marine Studies (CESAM) & Department of Environment and Planning,** University of Aveiro, Aveiro, Portugal
[6]**School of Engineering**, NUI Galway, Ireland
[7]**Ryan Institute**, NUI Galway, Ireland



NEPTUNUS

PROJECT