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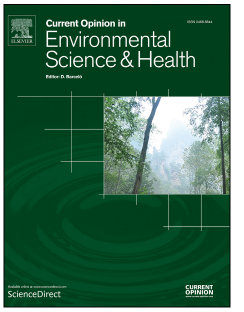


## Addressing challenges and opportunities of the European seafood sector under a circular economy framework

Israel Ruiz-Salmón, María Margallo, Jara Laso, Pedro Villanueva-Rey, Dolores Mariño, Paula Quinteiro, Ana Cláudia Dias, Maria Leonor Nunes, António Marques, Gumersindo Feijoo, María Teresa Moreira, Philippe Loubet, Guido Sonnemann, Andy Morse, Ronan Cooney, Eoghan Clifford, Neil Rowan, Diego Méndez Paz, Xesús Iglesias Parga, Clémentine Anglada, Jean-Christophe Martin, Ángel Irabien, Rubén Aldaco

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**Addressing challenges and opportunities of the European seafood sector under a circular economy framework**

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**Abstract**

The European seafood and aquaculture sectors are facing important challenges in terms of environmental threats (climate change, marine debris, resources depletion), social development (worker rights, consumer´s awareness) or economic growth (market and non-market goods and services, global competitiveness). These issues are forcing all stakeholders, from policy-makers to citizens and industries, to move to more sustainable policies, practices and processes. Consequently, an improvement in collaborations among different parties and beyond borders are required to create more efficient networks along the supply chain of seafood and aquaculture sectors. To achieve this, a "nexus thinking" approach (i.e. the analysis of actions in connected systems) combined with a life cycle thinking appears as an excellent opportunity to facilitate the transition to a circular economy.

**Keywords:** seafood, aquaculture, LCA, circular economy, climate change



## 1. Introduction

A growing 'green' awareness in societies is leading to a change in habits of the population, especially in developed countries with a sobering realisation that there is not a planet B to live [1]. What we produce, consume and how we do this is increasing interest to citizens and, therefore and as it usually occurs, economic sectors and politicians try to adapt themselves to new demands and requirements in order to maintain benefits and/or votes.

Notably, the seafood sector is facing important challenges: ensuring the survival of fishing grounds and guaranteeing nutritional quality [2], protecting worker's employment and social rights [3], obtaining benefits that make the sector viable over time [4], and preparing for climate change consequences and how these will affect the sector and other issues [5]. Nowadays, this "Blue economy" industry, (i.e. all the activities involving oceans, seas and coasts, which directly employed over 4 million people in the European Union (EU) and generated €658 billion of turnover in 2017 [6]), is facing different regulations to provide an answer to the current environmental challenges, promoting a circular economy strategy [7]. Within these directives and regulations, we found the EU's progressive landing of discards (unwanted catches returned to the sea) by species, from 2015 to 2020 [8], as well as the incoming ban (in 2021) of single-use plastics which can help to decrease the high impact of residues on ecosystems, biodiversity and fishing economy, including ocean marine litter [9].

All these measures will contribute to a more sustainable industry; however, to strengthen this sector in particular and the bio-economy in general, a life cycle thinking approach [10, 11] is required. Life cycle assessment (LCA) is an environmental tool to quantify the inputs, outputs and environmental impacts throughout the entire life cycle of products, processes and services. This methodology has been applied by the European Commission (EC) in the framework of the Single Market for Green Products Initiative [12] to develop methods and datasets to measure the environmental performance of products and organizations [13]. To simplify the communication of results the use of a widely recognized indicator, such as the environmental footprint, is broadly recommended.

For that, the release of the Product Environmental Footprint (PEF) and Organizational Environmental Footprint (OEF) methods aims at the harmonization of environmental footprint calculation and the communication of results to consumers. During the first stage (pilot phase), it was developed a methodological framework and Product Environmental Footprint Category Rules (PEFCRs) [14] covering products from different sectors: beer, dairy, pet food, IT equipment, metal sheets, wine and so forth. However, the development was delayed or discontinued for some products. In this sense, the pilot on marine fish was discontinued in June 2016 due to timing issues and a lack of background data to carry out a PEF study for products from different parts of the world [15]. Nonetheless, it is envisaged that PEFCRs for marine fish will be developed during the Environmental Footprint transition phase, providing valuable input to the development of the PEF and OEF methodologies by means of specific life cycle inventory datasets and calculation rules for products eco-labelling, which is the basis for better reproducibility and comparability of PEF studies.

In this brief timely review, some of the main challenges of the seafood sector are described, including the role of producers, consumers and policy-makers and opportunities given by new technologies and the circular economy.

## 2. Integrating the circular economy in seafood and aquaculture sectors

The main challenges of fisheries in the European framework are related to the circular economy transition, in particular: (i) the adaptation to climate change, and growing threats of (ii) marine debris and (iii) waste streams. Addressing these issues should not be seen only as a problem, but also as an opportunity to improve things from an intensive sustainable perspective:

i. Climate change can interact with fisheries in many different ways. For instance, salmon catches in the Atlantic have decreased by 90% since the early 1970s. These impacts are also seen in southern Europe, especially in the salmon rivers in northern Spain, such as in Cantabria, where the autonomous government started in 1997 a conservation programme to ensure the survival of the species through periodical repopulation in traditionally salmon rivers (namely, Asón, Nansa, Saja and Deva). This decline may have been impacted by climate change in the rivers, due to increased water temperatures, extreme water flow events (floods and droughts) and warming of maritime environments [16]. Smolt survival at sea depends on fish size, but also on sea surface temperature (SST) and food abundance. Climate change may also lead to earlier migration to sea. In the North Atlantic, cod fisheries have also seen collapses that may be related to increases in SSTs. These higher SSTs may also have an influence on the Allee effect (the ability for small populations and their fitness to effectively reproduce and recover stocks) [17] and on the certainty of population recovery. Moderate rises in SSTs may maintain current population dynamics but a SST rise of more than 4℃ would lead to the p opulation collapse of cod in the ocean regardless of other population pressures or resource management measures put in place.  Leitão et al. 2018 [18] confirmed that

Portuguese fish catches have seen increasing mean temperatures of catch (MTC), that have affected both the warmer and colder species and composition of catches due to climate change. MTC is derived from the average inferred temperature preference of exploited species weighted by their annual catch. Adverse weather conditions can have significant impacts on harvesting at sea, which is not well understood from socio-economic and decision-making perspectives. These storms and extreme weather events can also have disturbances on marine ecosystems [19]. Given the above, significant efforts must be made by European policy makers. The EU Common Fisheries Policy (CFP) is generally not evolving to cope with climate change despite climate proofing the CFP being part of the EU Strategy on Adaption to Climate Change. This may become even more crucial, for a range of reasons, if the United Kingdom does leave the EC through BREXIT [20].

ii. Marine debris is a global threat crossing country borders. There is evidence that micro and macroplastics are by far the type of debris most found on the sea surface, sea floor and beaches, pushing plastics on the spot of concerns [21]. A recent study has estimated that 4.8 to 12.7 million tons of plastic waste entered the oceans in 2010 [22], linking it to insufficient waste management, littering and consumption behaviour. From interfering with food webs, ghost fishing (i.e. lost or abandoned fishing gear catches fish that goes to waste) and transferring toxins up in the food chain, these marine debris significantly interfere with ecosystems and human health [23], and it also may harm activities such as tourism, fisheries and shipping. Therefore, there is a need to ensure that the sector should have a key role in the challenges of reducing, removing and recycling marine debris [24]. At the scientific level, there is a strong need to quantify marine debris through material flow accounting (MFA), and to integrate marine debris concerns into environmental impact evaluation tools such as LCA [25]. The fishery industry should better understand the reasons for gear loss and identify appropriate, fishery-specific preventive measures, as well as improving collection, disposal and recycling schemes for waste generated by the sector [26]. In this context, circular economy may contribute to decreasing marine debris and material extraction. Marine debris deteriorates the ecological state of marine and coastal ecosystems, disturbing the provision of market and non-market goods and services (provisioning, cultural and regulation services) needed to human well-being [27]. Besides, the implementation of a circular economy offers the opportunity to create a new value chain around the recycling of marine debris, generating new business opportunities and the creation of new jobs for local economies [28] making them more resilient [29]. Indeed, the production multipliers, estimating the ripple effects of fisheries to the other economic sectors within the local economy, are greater in circular economy. Instead of purchasing imported raw materials causing import leakage, fishing fleets could consume recycled material coming from the local recycling sector, in turn generating domino effects to the local economy [30].

iii. Aquaculture has several waste streams that have classically been regarded as of limited value and potentially harmful [31-33]. However, there has been an enhanced focus on valorising wastes from food production systems. For example, in the seafood/aquaculture sector, solid waste from finfish production has been identified as a potential substrate for anaerobic digestion with a secondary use as a fertiliser [33]. There is a pressing need to leverage emerging 'natural processes' in order to reduce operational cost and the environmental burden of food production for future sustainability and intensification of the aquaculture/seafood sector. This will require technical innovation along with a broader discussion across social and economic stakeholders – particularly regarding to wastewater treatment and water quality control [34]. Nutrient enriched effluent waters are also being treated by bacteria or used to culture vegetables in an integrated multi-trophic aquaculture (IMTA) approach [32, 35]. New IMTA concepts also apply to the use of microalgae and duckweed for waste treatment using organic principles. The potential to use IMTA to grow feedstocks for future bio-based products such as bioplastics and bio-fuels is also being investigated [36]. Fish trimmings and blood waters have been proposed as a source of bio-oil, amino acids and other bio-based products such as bio-inks and functional feeds [37, 38]. Bio-based feeds derived from insect larvae, algae and underutilized biological resources offer a means of valorising food waste, reducing nutrient emissions to the wider environment and a reduction pressure on wild fish stocks [39-41]. With 47% of global fish supply (53%, if non-food uses are excluded) coming from aquaculture [42] and the majority of wild fish stocks at or beyond their maximum sustainable yield [43, 44], the aquaculture sector will experience growth to match the growing demand for protein. Further research and innovation are needed to align aquaculture production and management systems with bio-economy and circular economy principles throughout their value chains. However, the sector is well placed to adapt and become a leader in sustainable food production.

## 3. Producers and consumers walking to utopia

In the last 10 years, the penetration of organic and environmental claims in food and drink launches has remained almost steady globally, except for North America and Europe, being the latter where the fastest growth has occurred: 17% of food and drink products launched in Europe between August 2018 and July 2019 carrying organic claims, compared to 9% in 2010. Besides, the claim 'organic' has overtaken 'no additives/preservatives' in European clean label demands [45].

As far as clean label and ethical criteria are concerned, their application has been brought to the next level, being the short ingredient lists, more sustainable packaging, local sourcing, and fair-trade practices, the most remarkable practices. Sustainable labels have a significant influence on fish and shellfish buying, underlining the need for companies to flag up their credentials in this area on the pack. In the UK, 30% adults purchasing a range of fish/shellfish consider sustainable labels important when buying, and the same percentage would be more prone to buy products from a brand that provided a sustainable rating on the package [46].

Packaging is one of the steps of the supply chain of seafood products because of its strong influence on the environmental footprint [47-49]. Packaging environmental burdens depend on impacts from packaging material production (e.g. aluminium, tinplate, glass, styrofoam, pouching and plastic trays for primary packaging; cardboard and plastic for secondary packaging) and end-of-life, including packaging recycling. Packaging environmental burdens also depend on indirect impacts caused by the influence of packaging on seafood product's life cycle, for instance seafood waste [50, 51].

There is an increasing awareness to apply a holistic approach to change packaging paradigm integrating eco-design that includes opportunities for protecting authenticity, traceability and avoiding counter fitting. Resource and raw materials reduction, recycling and development of renewable and biodegradable materials for seafood packaging from waste material and discards enable to implement packaging eco-design and strength seafood circular economy [52, 53]. Recyclability is highly desirable, but other packaging features should also be considered because seafood is highly perishable and sensitive to harmful microbial growth. Therefore, effective primary and secondary packaging is pivotal for preserving and preventing microbial contamination, ensuring that products reach consumers undamaged and in excellent conditions for keeping quality, reducing seafood spoilage, enhancing products shelf-life and supporting its logistic distribution [54]. Moreover, the packaging of a product is often the best way to engage and attract potential consumers visually. Consequently, by infusing eco-friendly methods into the design, retailers are able to creatively distinguish themselves from less eco-conscious brands and to promote innovative seafood products.

## 4. “Nexus thinking”: the most appropriate way to go ahead

Transitioning to a circular economy in a seafood context requires “nexus thinking”, implying that the action in one of the systems has impacts on the others and, therefore, unconnected systems may lead to acute unpremeditated consequences. Currently, there is no universally recognised methodology for nexus analysis. However, LCA is particularly important for understanding the interconnections in nexus, and it can be particularly applied to two kinds of seafood sector links. On the one hand, the water-energy-food nexus allows assessment of the lifecycle of seafood products in a holistic method considering the whole supply chain. On the other hand, the clustering concept approach that add value and cross-cut the former nexus, addressing barriers to strengthen this sector regionally and across jurisdictions in the European region.

This represents a good opportunity to contribute to the economic development of this area, but also implies a high responsibility that needs to be articulated through tangible midland long-term actions. It jointly addresses a global concern and interest in terms of policies and strategies aimed at climate change mitigation, energy and food security. To address the challenges, sustainable and multilateral research cooperation is needed to define integrated methodologies, policy tools and behavioural changes. The methodological challenge is to integrate environmental, nutritional and economic variables that meet regional needs through transnational strategies. The establishment of synergies in knowledge and, experiences and challenges at the local level will help overcoming challenges at a global level.

## 5. Conclusions

The sustainable development of the seafood sector in the European area requires a consistent methodology for products eco-labelling and defining eco-innovation strategies for production and consumption under a circular economy approach. Some plans and strategies involving blue economy have been already promoted in the EU context. However, more effort is required in European institutions, regional and local administrations, as well as producers and consumers' habits, leading to face real threats to ecological and socio-economic development, such as climate change and marine litter.

Life cycle thinking appears to be the most appropriate tool to adapt seafood and aquaculture sector to being more economically competitive, upholding worker rights, responsibly preserving fishing stocks, biodiversity and ecosystem services. A new transnational clustering concept approach combine with the water-energy-food nexus should be pursued to create synergies in the European area.

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The report presents the requirements and guidelines to conduct PEF studies aiming at comparability, reliability and reproducibility. Hence, comparability is possible when studies are based on the same product environmental footprint category rules (PEFCR) and, therefore, the development of PEFCRs shall be essential for PEF studies.

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The paper shows that climate change has impacted on salmon in both the terrestrial river and ocean environments and this is especially the case on salmon in northern Spain. The Atlantic salmon catch has fallen by about 90% in the last 40 years. Changes to the thermal and flow regimes of rivers can impact the survival of ocean returning smolts and govern their size. This is important as initial smolt survival at sea can be size dependent. Ocean fishing pressures also lead to ulcerative dermal necrosis and secondary bacterial and fungal infections within the adult population. One consequence of the possible loss of these southern populations will be to lead to a great reduction in the genetic diversity of the species.

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This report looks into the issue of microplastics from the fisheries and aquaculture perspective. It reports the potential impact of microplastics and related contaminants on fish consumers' health and the ecological implications for aquatic organisms based on existing literature. It also highlights the measures that should be taken to reduce plastics use, encourage recycling and better manage plastics pollution.

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The paper reviews and presents recommendations for the valorisation of one of the classical waste streams of seafood and aquaculture processing, blood waters. The authors summarise recent research activities into current and developing strategies for the recovery of blood-water proteins and the potential applications of the recovered product. While not explicitly explored in the article the use of such processes in seafood processing (along with others) can help to close the loop on the circular economy for seafood.

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The study presents a method based on life cycle assessment to reduce and simplify the decision-making process and to identify the best available techniques of a product, facilitating the selection of a technical alternative from an environmental point of view. In particular, the proposed method is applied to the Cantabrian anchovy canning industry, identifying the production of the aluminium can as the main hotspot of the process. Accoding to this result, the study proposed several improvements.

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Water-energy-food nexus allows assessment of the lifecycle of seafood products.

Clustering and knowledge transferring to add value in the European Atlantic region.

Eco-labelling and eco-design in fisheries under a circular economy approach.

**Declaration of interests**

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: