SmartChain
Blue Bioeconomy Solutions

BlueBio SMARTCHAIN Project

Evaluation of circularity and sustainability in seafood value chains: A simulation-based analysis

Research Findings Brief

September 2024

Simulation framework

SMARTCHAIN focuses on developing a simulation framework to assess the end-to-end effects and potentials of improving processes, logistics, and information flows to enhance sustainability and circularity.

This framework is built on conceptual supply chain mapping, supply chain optimization model, and sustainability and circularity indicators. The generated simulation scenarios are expected to provide decision support to enhance the sustainability performance of seafood supply chain.

The complexity in the aims and objectives for achieving sustainable and circular seafood value chains is immense. Ensuring the sustainable use of resources, minimizing loss and waste, and maximizing profits all place an enormous burden on decision-makers. Traditional linear supply chains, which often prioritize efficiency and profit, typically result in significant environmental degradation, resource depletion, and unsustainable practices. Excessive fishing, the unintentional capture of non-target species, degradation of marine habitats, and inefficient resource utilization during seafood processing and transportation all contribute to the increasing burden on ocean ecosystems. Therefore, addressing sustainability and circularity simultaneously in seafood value chains is vital for mitigating the sector's contribution to climate change, reducing pollution, and conserving biodiversity. The shift towards sustainable and circular seafood value chains is not only a matter of environmental responsibility but also an essential strategy for ensuring the long-term viability and profitability of the seafood industry. As seafood becomes an increasingly important source of protein for a growing global population, the need to develop resilient, sustainable, and circular systems is more pressing than ever (Cooney et al., 2023[1] ; Clair et al., 2023 [2]).

Considering these challenges, there is a growing need to develop a comprehensive framework that facilitates the evaluation of sustainability and circularity within seafood value chains. Such a framework must take into account the interconnected processes and interactions across the entire end-to-end supply chain, from harvesting, production and processing to distribution, consumption, and loss and waste management. By considering these interactions holistically, this framework would enable decision-makers to better assess the environmental, economic, and social implications of different strategies, helping them to balance various sustainability goals. Moreover, this type of framework would make it easier to assess scenario-based analyses, allowing stakeholders to explore potential outcomes of different approaches under various conditions, such as changing regulatory, consumer preferences, or technological advancements.

Our approach in the SMARTCHAIN project tackles these complex challenges by employing a System Dynamics (SD) approach to comprehensively evaluate the interconnections within the seafood value chain. By utilizing SD, we can simulate the impacts of various sustainability and circularity strategies, capturing feedback loops and nonlinear interactions throughout the entire supply chain. This method allows us to explore how different policies and innovations influence both environmental and

[1] Cooney, R., de Sousa, D. B., Fernández-Ríos, A., Mellett, S., Rowan, N., Morse, A. P., Hayes, M., Laso, J., Regueiro, L., Wan, A. H., et al. (2023). A circular economy framework for seafood waste valorisation to meet challenges and opportunities for intensive production and sustainability. Journal of Cleaner Production, 392, 136283.

[2] Clair, R. S., Pappas, D., Fletcher, C., & Sharmina, M. (2023). Resilient or environmentally friendly? both are possible when seafood businesses prepare for long-term risks. Journal of Cleaner Production, 408, 137045.

System Dynamics

A simulation approach that models complex systems using feedback loops, incorporating stocks, flows, and auxiliary variables. System boundaries, interactions between modules, and exogenous variables influence the overall system behavior.

Causal loop diagram

Our causal loop diagrams, representing different steps within the fish value system, are rooted in the concept of integrated supply, value, and decision chains. Through the provision of a causal modeling framework, this methodology takes into consideration both linear and non-linear relationships, conducting an analysis of variables' endogenous behavior.

By adopting this comprehensive approach, it effectively meets the fundamental requirements for tackling policy and decision-making challenges in the realm of sustainable fish value chains.

financial outcomes, providing a holistic framework to address the evolving needs of the fisheries sector as it transitions toward more sustainable and circular practices.

System dynamics model

The simulation framework aims to identify key intervention points to enhance the efficiency and circularity of the seafood system. Our goal is to create a model capable of predicting how various factors such as government policies, customer behaviors, and technological innovations affect sustainability within a circular economy context. Focusing on critical points where losses and waste occur within blue bioeconomy value chains, and utilizing the mapping of the seafood supply chain, our SD model is being developed based on a generic seafood value chain structure and sustainability metrics. This model can be customized and tailored for specific scenario analyses, and it allows for the assessment of additional sustainability measures by incorporating more specific features, as illustrated in Figure 1.

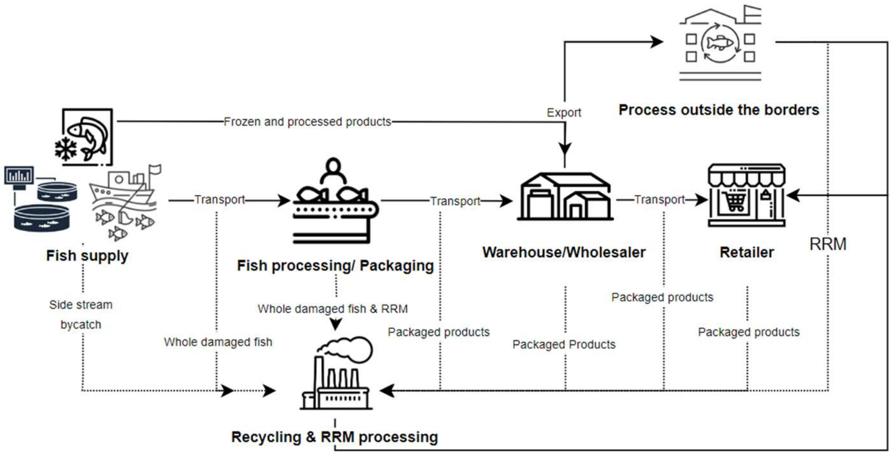

Figure 1 Generic seafood value chain

We are developing a simulation framework using SD modeling. An overview of interactions across the seafood value chain has been taken into account, as illustrated in Figure 2. This figure will serve as the foundation for developing the causal loop diagram, given in Figure 3. Considering these interactions and system boundaries, the simulation framework is being developed to assess how sustainability indicators may evolve under various scenarios. The SD simulation model, depicted in Figure 4, is supported by numerous equations that are formulated to define and adjust the interactions within the system. Afterward, the framework is being validated and verified and then scenarios are being developed based on expert opinions to examine how changes in key variables, which could reflect real-life situations, might affect sustainability measures.

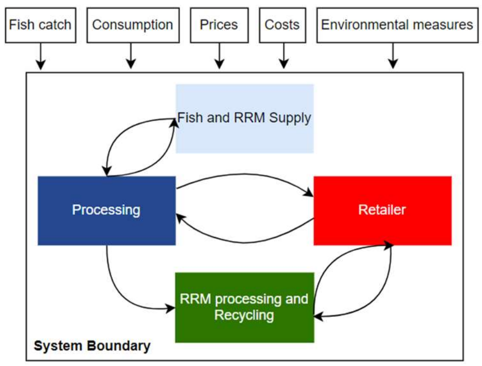

Figure 2 Overview of interactions between different modules in the seafood value chain

Model validation

Validation involves presenting the framework to experts and practitioners in the seafood industry to gather feedback and ensure its relevance.

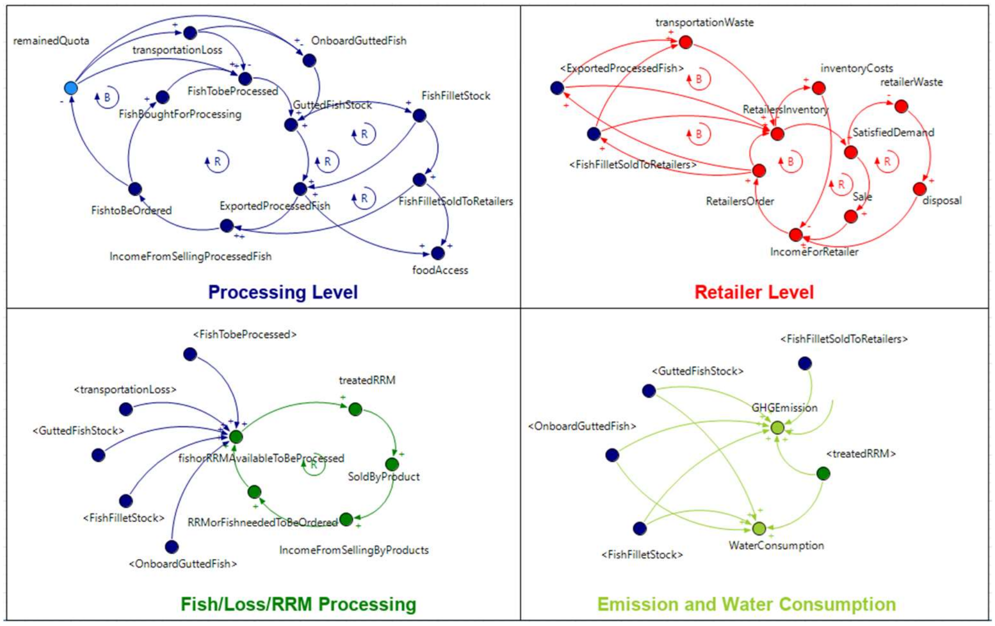

Figure 3 The causal loop diagram

Preliminary findings from the scenario analyses

Here's a concise overview of the scenarios examined using data for cod species, obtained from various sources, along with the initial findings:

Scenario analyses

Based on expert viewpoints, several predictive scenarios are being identified and investigated. To run the SD model, we collected data from expert interviews, online databases, and landing data from the largest sales organization in Norway, covering the majority of white fish landings.

Initial results on Scenario 1: Potential impact of advanced preservation technology on fish quality

This scenario explores how implementing advanced preservation technologies on vessels could improve fish quality and reduce spoilage compared to traditional methods. Early findings suggest that using high-tech preservation may lead to better fish utilization for human consumption, reduce reliance on by-products, and lower energy and water consumption in processing. The analysis indicates that improved fish quality could reduce the need to catch more fish, as more of the catch would be suitable for human consumption, contributing to better environmental sustainability. While the initial investment in onboard technology may impact short-term economic sustainability, in the long term, this could be offset by selling higher-quality fish to end consumers and making more efficient use of the catch.

Initial results on Scenario 2: Balancing processed fish and by-product production through enhanced RRM landings

This scenario explores the potential effects of increasing the ratio of rest raw material (RRM) landings. Preliminary results suggest that while higher RRM landings could enhance by-product production, they may also reduce the amount of processed fish due to storage limitations. Bringing in more RRM could result in fewer fish landings at the harbor, but utilizing RRM efficiently for high-value by-products like collagen and fish oil could offset this reduction. Ongoing work seeks to determine the optimal balance between fish quality and by-product production to improve economic and resource efficiency. In addition, combining this scenario with the earlier one where advanced preservation technologies improve fish quality could help compensate for the potential reduction in landed fish. The higher quality of the fish would allow for more efficient use in human consumption, balancing the decrease in fish landings while enhancing overall economic and resource efficiency.

Ongoing work on results

The preliminary results, while promising, require further examination through additional potential scenarios and broader engagement with experts across the field. By sharing these findings and incorporating expert feedback, we aim to further validate the results, ensuring they are closely aligned with the practical challenges faced by the seafood industry. This approach will strengthen the project's relevance and applicability, driving more sustainable and effective solutions.

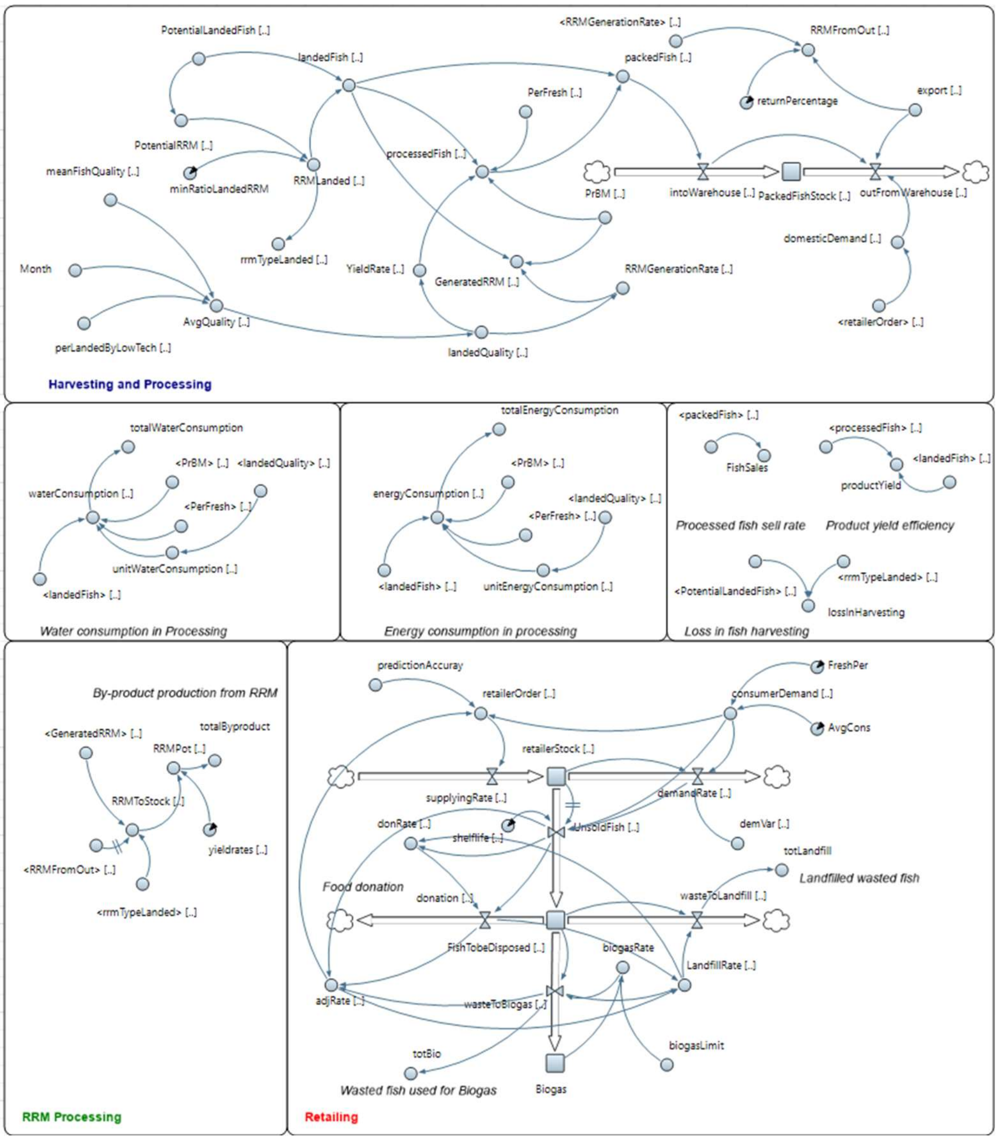

Figure 4 The SD simulation framework, referred to as a stock and flow diagram

Initial results on Scenario 3: Impact of consumer behavior on food loss and sustainability

This scenario assesses how changing consumer preferences from fresh to frozen fillets might influence food waste at the retail level. Initial findings suggest that shifting demand to frozen fillets could reduce unsold fish but might increase energy and water use. However, combining this with the earlier scenario of improved fish quality from advanced preservation technologies, the increase in energy and water consumption could be offset by the higher quality of landed fish, leading to less waste overall and better resource efficiency. Further exploration is needed to fully understand the trade-offs between reducing food waste and managing resource consumption.

Initial results on Scenario 4: Potential effects of retailer overordering penalties

This scenario examines the potential impact of penalizing unsold fish sent to landfills. Preliminary analysis suggests that such penalties could incentivize better inventory management, reducing food waste and increasing the use of fish for biogas production. However, convincing retailers to avoid overordering could be challenging. Offering incentives, such as tax adjustments for increased donations or diverting unsold fish to biogas instead of landfills, could motivate retailers to adopt more sustainable waste management practices. Further work will refine these outcomes and assess the effectiveness of such regulatory measures.

Simulation-based analysis in seafood supply chain – Recommendations

The initial findings from the scenario analyses suggest the potential to address key trade-offs in the seafood value chain, enhancing sustainability and circularity. Each scenario indicates opportunities for reducing food loss and waste, though challenges in implementation highlight the need for technological innovations to overcome these barriers. Additionally, some scenarios show promise for improving circularity, but further exploration is required to balance sustainability goals with resource efficiency. To fully realize these opportunities, the seafood industry could explore the potential of both data-driven and advanced technological innovations, such as more efficient fishing techniques, improved preservation methods, and automated processing systems. These innovations have the potential to address the implementation challenges. Policymakers might play a pivotal role by promoting the adoption of such technologies and encouraging shifts in consumer behavior toward more sustainable choices. Close collaboration among stakeholders, with a focus on integrating cutting-edge technologies and data insights, could be key to driving meaningful progress in fishing, processing, and sustainability practices across the seafood value chain.

Key sources for further information

To discuss the research presented in this brief, please contact: Allan Larsen alar@dtu.dk and Ali Ghavamifar aghava@dtu.dk, DTU Management, Technical University of Denmark.

Scientific dissemination:

Ghavamifar, A. Larsen, A. Evaluating sustainability and circularity in the seafood value chain: A system dynamics perspective. Manuscript in preparation

Deliverables:

Ghavamifar, A. Larsen, A. (2023). Simulation model framework. The SMARTCHAIN project co-funded by ERA-NET, EU Horizon 2020 G.A. No 817992, and Norges forskningsråd (RCN), Innovation Fund Denmark (IDF), and The Icelandic Centre for Research (RANNIS) / Technical Development Fund (TDF). Deliverable: D5.1, Technical University of Denmark, Lyngby, 13 pages.

Ghavamifar, A. Larsen, A. (2024). Report on scenarios for analysis. The SMARTCHAIN project co-funded by ERA-NET, EU Horizon 2020 G.A. No 817992, and Norges forskningsråd (RCN), Innovation Fund Denmark (IDF), and The Icelandic Centre for Research (RANNIS) / Technical Development Fund (TDF). Deliverable: D5.2, Technical University of Denmark, Lyngby, 13 pages.

Ghavamifar, A. & Larsen, A. (2024). Simulating the end-to-end supply chain. The SMARTCHAIN project co-funded by ERA-NET, EU Horizon 2020 G.A. No 817992, and Norges forskningsråd (RCN), Innovation Fund Denmark (IDF), and The Icelandic Centre for Research (RANNIS) / Technical Development Fund (TDF). Deliverable: D5.3, Technical University of Denmark, Lyngby, 12 pages.

Conference presentation:

Ghavamifar, A., & Larsen, A. (2024). Towards a sustainable circular seafood value chain: A system dynamics perspective. Paper presented at the 11th EurOMA Sustainable Operations and Supply Chains Forum conference, Hamburg, Germany.

Ghavamifar, A., & Larsen, A. (2024). Enhancing sustainability and circularity in seafood value chains using system dynamics. Production and Operations Management Society (POMS) Conference, Istanbul, Turkey.

SMARTCHAIN – Smart solutions for advancing supply systems in blue bioeconomy value chains

https://bluebioeconomy.eu/smart-solutions-for-advancing-supply-systems-in-blue-bioeconomy-value-chains/
https://www.sintef.no/en/projects/2021/smartchain/

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