Can the transition from mono- to polyculture reduce aquaculture environmental footprint? An LCA approach proposed within the BLUEBOOST project

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1. Introduction

The increased intensive aquaculture production of recent decades raised concerns about its environmental effects, i.e., decreased water quality, depletion of natural resources, and greenhouse gas emissions. Aquaculture impacts are, however, frequently lower than those of other foods derived from animals [1]. Integrated Multi-Trophic Aquaculture (IMTA) combines fed aquaculture (e.g., fish) with non-fed aquaculture (e.g., shellfish). Its application aims at reducing nutrient and carbon emissions by using a circular approach: the combined production of higher-trophic and lower-trophic species might reduce waste released into the environment and increase the overall productivity of the system. The BLUEBOOST project will develop six monocultures to commercially scaled IMTAs that consider a wide range of low trophic species and environmental conditions. LCA will be used to evaluate and optimize the environmental sustainability of the systems. To date, only a few LCA studies have dealt with IMTAs [2-5], facing some methodological dilemmas related to modelling such multifunctional systems. We discuss possible methodological approaches for the environmental evaluation of IMTA systems.

2. Methods

The six IMTAs will be developed from existing monocultures by integrating species from different trophic levels (e.g., algae, invertebrates, detritivores and filter feeders, and fish), in both marine and freshwater (Figure 1). Challenges that arise when applying LCA methodology to IMTA systems include complex multi-species functional units, differing production cycles between species, and species having different needs in terms of material and energy inputs, which can be difficult to separate. An additional challenge will be providing a comprehensive picture of all aspects that contribute to increased circularity in aquaculture systems (e.g., product and waste circularity, nutrient and carbon charges), which are often not investigated by LCA applied to animal production. LCA will be used to first assess the impacts of the monocultures, and then quantify the effects and improvements of integrating low-trophic species in the implemented IMTAs. Finally, principles for upgrading an experimental case study into an optimized commercial production will be developed.

3. Results and discussion

The BLUEBOOST project poses some methodological issues and offers the opportunity for the development of various LCA approaches. The first choice is the functional unit, which has to consider the diverse co-products and their intended use (e.g., food, feed). Different approaches include multiple functional units for different co-products or a single unit for all (e.g., wet weight, protein content, or monetary value of the products). Second, the different production cycles of co-farmed species and their material and energy needs must be screened. Third, the allocation principle adopted. The pros and cons of such methodological choices will be weighed. The expected outcomes of the project will include the environmental footprint assessment of the monoculture and implemented IMTAs, as well as their Life Cycle Inventory. The impacts delivered by BLUEBOOST will hopefully aid the transition towards climate-neutral and sustainable aquaculture.

4. Conclusions

BLUEBOOST would fill knowledge gaps that exist in the conceptual development, practical implementation, and regulation of IMTAs.

5. Acknowledgements

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6. References

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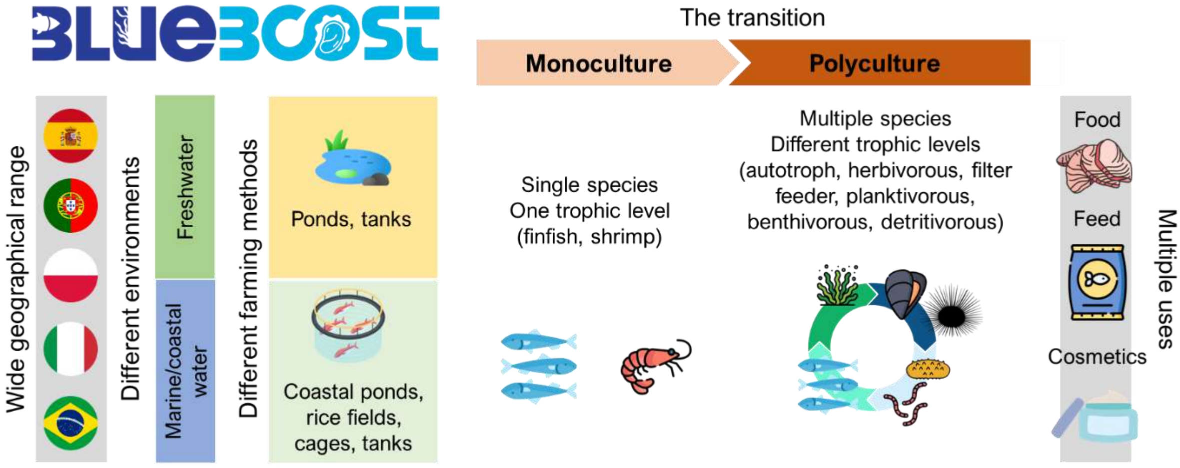

Figure 1. Transition from mono- to polyculture systems

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1 Introduction

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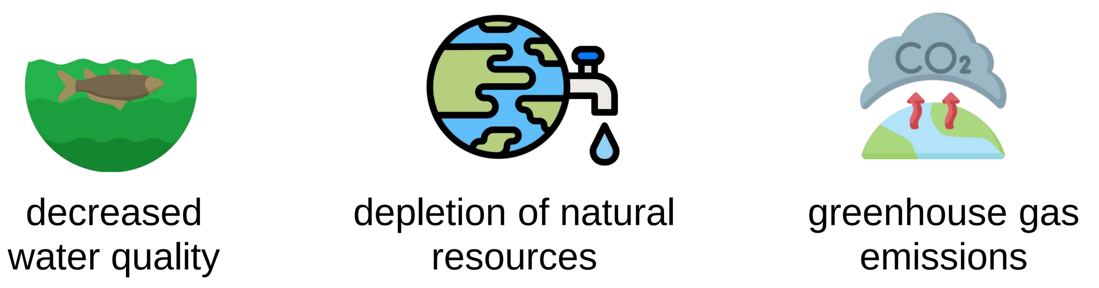


Aquaculture impacts are, however, frequently lower than those of other foods derived from animals [1].

Integrated Multi-Trophic Aquaculture (IMTA) combines **fed** (e.g., fish) with **non-fed** aquaculture (e.g., shellfish), which helps to **minimize** aquaculture **waste** and **enhance** system **circularity.**

IMTA systems could have lower environmental impacts and bring other benefits:

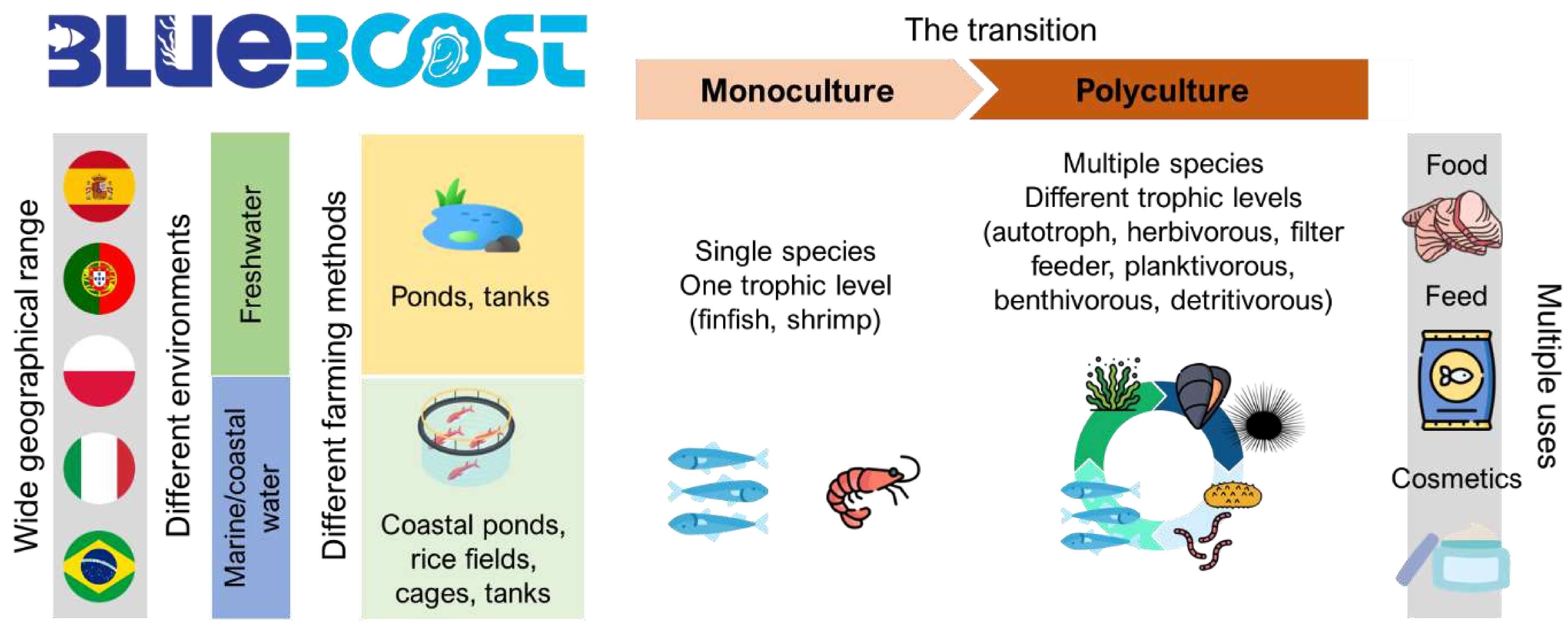
- ✓ **Reduced carbon** emissions
- ✓ **Reduced nutrient** emissions
- ✓ **Reduced wastes**
- ✓ **Increased productivity**
- ✓ **Decreased feed-food competition**

Aims of BLUEBOOST

To develop IMTAs from monocultures, considering a wide range of low-trophic species	To develop and implement methodological approaches to LCA, needed when dealing with complex systems	**To use the LCA to evaluate and optimize the sustainability of the systems**

2 Methodology

The **six** IMTAs will be developed from existing monocultures by integrating species from different trophic levels (e.g., algae, invertebrates, detritivores and filter feeders, and fish), in both marine and freshwater.



LCA will be used to first assess the impacts of the monocultures, and then quantify the effects and improvements of integrating low-trophic species in the implemented IMTAs.

Finally, principles for upgrading an experimental case study into an optimized commercial production will be developed.

Challenges that arise when applying LCA methodology to IMTA systems:

- multi-species functional units
- differing production cycles between species
- species having different needs in terms of material and energy inputs
- allocation
- system boundaries
- impact categories

An additional challenge will be providing a comprehensive picture of all **aspects that contribute to increased circularity in aquaculture systems**, which are often not investigated by LCA applied to animal production, using as much as possible data directly collected in the 6 IMTA systems.

3 Results

The BLUEBOOST project poses some methodological issues and offers the opportunity for the development of various LCA approaches:

Modeling approach	• **Attributional LCA**
Functional unit (FU) – co-products	• **Mass of biological product with an economic value (kg)** Choice is based on the fact that this FU incorporates the most relevant uses of the multiple products (food/feed and other) • **Multiple FUs will also be tested according to characteristics of specific systems**
System boundaries	• **Cradle-to-farm gate** The most practical choice, in view of the ongoing development of the IMTA systems. It can be modified if relevant processes outside the gate will be identified.
Allocation	• **Mass allocation** as the basis for co-product partitioning (products are defined as per the FU, used for different purposes)
Timeframe	For each system, the time coverage will be set according to the species with the **longest production cycle**.
Background data	**e.g., Ecoinvent** (V3.9.1)

The expected outcomes of the project will include the environmental footprint assessment of the monoculture and implemented IMTAs, as well as their Life Cycle Inventory.

4 Conclusions

BLUEBOOST would fill knowledge gaps that exist in the conceptual development, practical implementation, and regulation of IMTAs. The impacts delivered by BLUEBOOST will aid the transition towards climate-neutral and sustainable aquaculture.

ANY FEEDBACK FROM PAST EXPERIENCES WILL BE GREATLY APPRECIATED!

5 References

[1] Gephart, J.A., et al. 2021. Nature 597:360-365

6 Acknowledgements

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