

# Sailing Towards Sustainability: A Life Cycle Analysis of Mussel Farming in La Spezia

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## INTRODUCTION

The mussel farming is emerging as a low-impact food production activity. This farming method has experienced substantial growth in recent years, with a global production increase of 7 percent from 2011 to 2020 [1]. Proteins derived from mussels represent animal proteins with the lowest carbon footprint [2], partially thanks to the unique ability of bivalves to not require additive feeds for their growth. They naturally feed on phytoplankton in marine waters, eliminating the need for antibiotics. Moreover, as sessile organisms attached to solid substrates, they are typically cultivated within tubular nets that optimize space, significantly reducing the use of marine spaces.

Despite their intrinsic low environmental impact, this research proposes an assessment of the mussel farming life cycle as a guiding tool to identify and improve environmental production hotspots, aiming to minimize environmental impacts and integrate mussel farming into an even more sustainable process.

In fact, mussel farming lends itself to inclusion in virtuous and sustainable circular economies: one of the by-products of its production process is mussel shells, accounting for 56–61% of the dry weight of the organism [3]. These shells, primarily composed of calcium carbonate at a value of approximately 95% [4], are well-suited to be valorized as secondary raw material for various applications on both small and large scales, ranging from construction, agriculture, livestock, to design [5].

Examining the environmental impacts of this activity and integrating it into a circular economy perspective are key starting points for developing food production practices that align with the environmental challenges of our time and support sustainable diets.

## METHODOLOGY

Conducted through a Life Cycle Assessment (LCA) methodology following international ISO 14040 and ISO 14044 guidelines [6], this research analyzed the environmental impact associated with mussel farming. The study area is represented by cities of La Spezia, Lerici, and Portovenere (Liguria Region – IT), where, for the first time, a LCA analysis of bivalve farming is conducted. This approach allowed us to examine and quantify various life cycle stages, establishing boundaries 'from cradle to gate.' The considered stages include seeding, cultivation, monitoring, harvesting, selection, transportation to the processing plant, purification, and packaging.

The primary data for this study were obtained through direct interviews with the “Cooperativa Mitilicoltori Spezzini” and an analysis of the company databases. In cases where primary data were unavailable, secondary data from the Ecoinvent databases (version 3.8) were utilized.

The chosen functional unit is the annual mussel production of the 81 cooperative members in 2022; all input and output flows thus refer to this functional unit. For the analysis Simapro 9.5 software was employed to calculate potential environmental impacts through the CLM-IA baseline V3.07 characterization method. Careful consideration was given to 11 environmental impact categories to achieve a comprehensive and in-depth assessment of the environmental effects of mussel farming and production hotspots.

## RESULTS AND DISCUSSION

The results illustrated in Figure 1 reveal a pattern in which the predominant impact is consistently attributed to the agricultural phase. A subtle variation, in line with the general trend, is observed in terrestrial ecotoxicity. In this case, the purification phase exerts a more substantial influence on the overall impact compared to other categories. These results highlight the importance of the cultivation phase which includes refrigerated transportation for products imported from abroad. Consequently, it underscores the need for increased attention and targeted strategies to address the challenges posed by this specific phase.

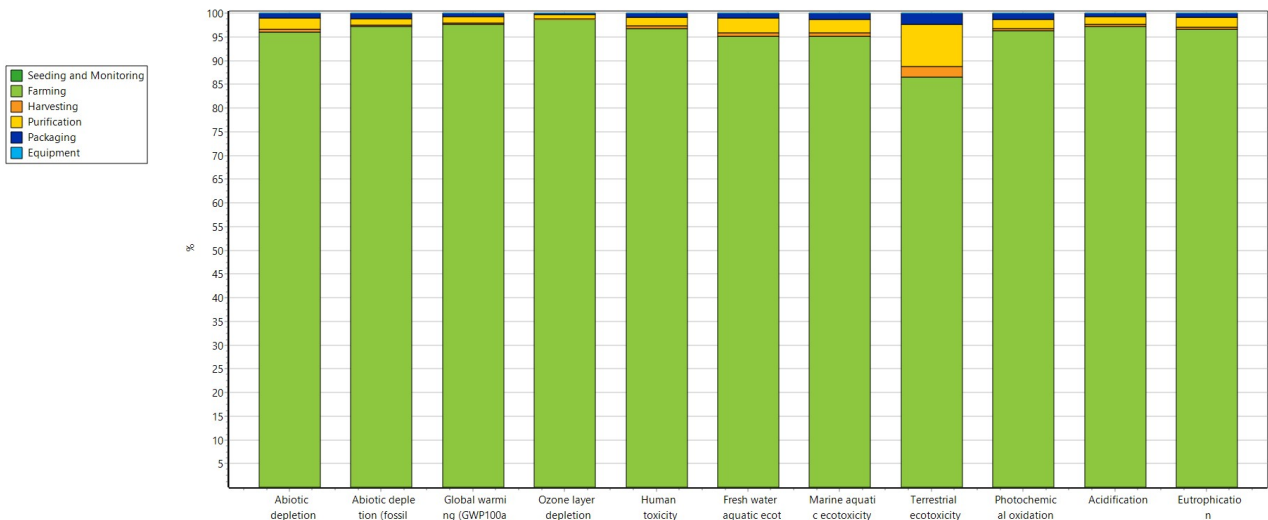


Figure 1 Life Cycle Impact Assessment. CLM-IA baseline V3.07 results

## CONCLUSIONS

The life cycle analysis (LCA) of mussel farming in La Spezia has delivered preliminary results that provide a starting point for quantifying the environmental impact of this practice and identifying potential improvement areas to make it more sustainable. Since further investigations are needed to gain a more comprehensive view, the next steps for this research will involve integrating our current analysis with the use and end-of-life stages, following the approach known as "cradle-to-grave." This will enable us to assess the impact, management, and potential valorization of waste generated from mussel farming. Among the most significant wastes from mussel farming are those related to shell production and the plastic material used for farming and distribution.

In the context of a circular economy, we are exploring solutions to valorize shell waste, such as using them as bio-fillers in bituminous compounds for permeable road pavements and as components in 3D printing blends to create artificial barriers for the restoration of marine habitats. Simultaneously, regarding waste related to plastic materials, research could focus not only on experimenting with valid alternatives, such as the use of natural fibers or bioplastics but also on implementing the LCA methodology, currently lacking an indicator, to quantify the potential impact of plastic and microplastics on marine ecosystems.

This holistic life cycle approach aims to influence the entire production cycle positively, facilitating a transition to a more circular and sustainable paradigm.

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