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REVIEW ON SHIP SHAPED FISH FARMS

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ABSTRACT

This paper presents a review on ship shaped fish farms as a first step in the research and developing of a modular floating aquaculture platform based on inland river cargo barge design to be exploited under biosecurity and sustainability conditions in the Lower Danube region, aligned with the current sustainable development strategies of the blue economy outlined by the European Union.

KEYWORDS: fish farm, aquaculture platform, river barge

1. Political context

The present paper supports and promotes fundamental, multidisciplinary, interdisciplinary and transdisciplinary scientific research and started from four current strategic development directions of the European Union:

- European Green Deal
- Strategy for a Blue Economy
- "Farm to Fork" Strategy
- Common Fisheries Policy

The European Green Deal is the European Union's (EU) new growth strategy and is a set of strategies with the main goal of the EU green transition toward climate neutrality by 2050 [1]. The interconnected transition directions like climate, transport, environment, industry, energy, agriculture are leading to the transformation of the EU member states economies into modern and sustainable ones, with zero target greenhouse gas emissions. The European Green Pact prioritizes the protection of biodiversity and ecosystems; reducing air, water, and soil pollution; the transition to the circular economy; improving waste management as well as guaranteeing the blue economy and aquaculture sectors sustainability.

The European Union's Strategy for Blue Economy can contribute to this dual challenge: if set on a more sustainable trajectory, it will become a source of action and ideas to create innovation, stimulate a rapid and sustainable recovery and protect the planet [2]. Biodiversity conservation and protection are considered fundamental principles of aquatic economic activities. From the point of view of the strategy, aquatic biodiversity represents an elementary condition necessary for the development of economic activities such as fishing, biotechnology, and tourism. By making better use of water resources and choosing alternative sources of food and animal feed, the blue economy can help alleviate the pressure on the climate and natural resources for food production. One of the sectors responsible for carbon dioxide emissions, pollution and biodiversity loss is the current food production and consumption system. Placing the system on a sustainable path is the objective of the Commission's Farm to Fork strategy, with a comprehensive approach that intersects with many aspects of the blue economy. These include responsible fishing to bring stocks to sustainable levels, sustainable aquaculture to supplement the natural limits of wild catches, and seaweed production as an alternative to agriculture.

According to Green Deal policies, the "Farm to Fork" Strategy is a central element of the Commission's Agenda for achieving the United Nations' Sustainable Development Goals. All citizens and operators in all value chains, in and outside the EU, should benefit from a fair transition, especially because of the COVID-19 pandemic and the slowdown in economic growth. Shifting to a sustainable food system can bring environmental, social and health benefits, generate economic gains and ensure that over-coming the crisis is equivalent to embarking on a sustainable trajectory. Ensuring sustainable livelihoods for primary producers, who are still lagging in terms of in-come, is critical to the success of the crisis and transition [3]. The COVID-19 pandemic has made society extremely aware of the interconnectedness of health, ecosystems, supply chains, consumption patterns and the limits of the planet. The increasing frequency of droughts, floods, wildfires, and new pests are a constant reminder that

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our food system is under threat and must become more sustainable and resilient. The European Green Deal and the Farm to Fork Strategy highlight the potential of aquaculture food as a source of protein for food and feed with a low carbon footprint, which plays an important role in building a sustainable food system.

In the vision of the Common Fisheries Policy [4], aquaculture creates jobs and eco-nomic development opportunities in the EU's coastal and rural communities. With a long-term strategy this sector can also contribute to the de-carbonization of the economy; combating climate change and mitigating its impact; reducing pollution; better conservation of ecosystems and can be part of a more circular management of resources. According to [5], the self-sufficiency rate for fishery and aquaculture products was around 42% in 2018. The self-sufficiency rate is defined as the ability of EU member states to meet demand from their own production and can be calculated as the ratio of domestic production to domestic consumption. In terms of resilience, two aspects are particularly challenging for the aquaculture sector: managing animal and human health risks and the impact of climate change. Particularly for freshwater aquaculture, predators and drought also pose a challenge to profitability. Water is becoming a limited resource due to climate change. There is also increasing competition for both space and access to water between different economic activities, including aquaculture.

2. Offshore fish farms

Moving fish farms to offshore locations can be a sustainable alternative to farmed fish production. Floating farms utilize the water surface, allowing for efficient utilization of space without occupying land and can be moved to more suitable locations as needed, adjusting to changing environmental conditions or optimizing for better water quality and fish health. They enable better control over water quality parameters by positioning in areas with cleaner water or equipped with filtration systems to maintain optimal conditions for fish growth. Properly designed floating fish farms can minimize the impact on the surrounding environment by employing systems to manage waste and prevent the release of excess feed or pollutants into the water. Being elevated on water, floating farms can offer protection from some ground-based predators, reducing risks to the fish stock. With proper management and monitoring, floating fish farms can potentially increase productivity due to controlled environments and optimized conditions for fish growth. Floating farms can be more adaptable to changes in water levels due to factors like seasonal variations or climate change, compared to fixed land-based farms.

The potential of offshore fish farms was identified by [6] who presented the development of offshore aquaculture from economical perspective. The economic potential for offshore aquaculture is dependent by growing population, the relative cost of offshore aquaculture and the relative values of competing uses of potential inshore farming areas will increase.

According to [7] the farming concepts must enable the fish to get the required water exchange and prevent high current velocities from being exposed directly to the fishes. The farming concept shall be proactive by design-out potential failures, predictive to detect unexpected failures, easy to be maintained and preventive for bio-fouling communities. These design requirements aim to cut-off the maintenance cost. One of the most critical criteria is the escaped fish rate. There is a Norwegian Standard 9415 for cage farming equipment to prevent fish escape. However, farming concepts might differ in their mechanism to avoid or mitigate any escaping events.

A comprehensive review was performed by [8] on the existing design standards and procedures issued by classification societies (Det Norske Veritas or Bureau Veritas) and/or national or international technical guidelines with applicability to offshore fish farming installations. Marine loads as currents, waves, wind and mooring of fish farms were found to be the main challenges to offshore fish farming.

As per Bureau Veritas vision about future of offshore fish farming, it's estimated that by 2050, global population growth will require 60% more sustainably produced food. At the same time, the impacts of climate change will be felt across all agricultural sectors. The aquaculture – also called fish farming – could rise as one of the most efficient forms of food production on the planet. Already, it's one of the fastest-growing food production sectors, and its further expansion could help ease pressure on wild fish stocks [9]. The main risks of fish farming are the diseases, pollution, and fish escape, while the main operational challenges are the open water, waves, winds and water currents.

As stated by [10] the continuously demand of fish is leading to disease and environmental challenges and in the lack of space onshore it is expected a migration of fish farming offshore. This trend is also highlighted by OECD [11] and FAO [12] studies. With a forecast of more than 100 million tons in growth of fish farming production by 2027, clean waters, constant water temperatures and low risk of diseases can be the key factors contributing to migration offshore of the fish farms.

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3. Ship shaped fish farms

Starting from the current development strategies of the EU and from the difficulties of terrestrial fish farms such as the lack of water and the high price of land but also the lack of labour force, the development of a modular floating fish farm systems is proposed.

As presented by [13], in 2018, Chinese shipyard CIMC Raffles started the construction the first Havfarm fish farm design for Norwegian fish farming company, Nordlaks. With a capacity of 10000 tons of salmon per production cycle, the fish farm, Havfarm 1, entered in operations in 2020 as moored structure at 5 km offshore.

A numerical investigation on the mooring of a vessel-shaped floating fish farm in open sea application was performed by [14]. The largest tension was observed when the current and waves are 90 degrees misaligned.

In 2019 started the construction of the first movable fish farm ship shaped of 100 thousand tons of the fifty such ships [15]. The annual production is estimated at approx. 200 thousand tons of sea fruits or fish. According to design, it is a structure 250 meters long, 45 meters wide, and can reach a speed of 10 knots for relocation or avoiding exceptional severe weather conditions.

Culturing tests were conducted from May to August 2021 on a test aquaculture vessel in the sea regions of Zhejiang, China [16]. The growth rate of *Pseudosciaena crocea* reaches 100 g per month, and the survival rate gets to 95 %, which proves the feasibility of the Shipborne mariculture system.

Recently, a semi-submersible vessel-shaped fish farm platform was proposed by Pang *et al*. The diving the main hull through the water it is conducting to improvement of seakeeping performance. Therefore, the small waterplane area provided a reference for the design of a large fish farm platform [17].

Wang et al. investigated the effect of the interaction among the ship shaped floating fish farm, disturbed wave field and hydrodynamic loads on the steel frames and nets under irregulars waves. Combining the global response of the cage and velocity, the disturbed irregular wave field is rebuilt to calculate the hydrodynamic forces on slender structures in time domain. Also, the global response is updated by solving the motion equation of the cage in time domain [18].

The idea of a vessel shaped fish farm for maritime exploitation is not new. Instead, for inland rivers and channels the available data is rather poor. Contrary to maritime fish farms, the inland rivers and channels offers to fish farms, either moored or anchored, a more protected area. In this case the wave loads are negligible and in the case of farms with large superstructures the influence of the wind loads must be investigated.

4. Conclusions

Designing a modular floating fish farm for inland rivers and channels offers several advantages and considerations. Inland rivers and channels might have limited available space along their banks for traditional fish farms.

From modular point of view the cargo hold of one barge can be separated into small modular tanks or more barges can be exploited side by side in modular system. From a constructive point of view, the barge can be equipped with alternative energy recovery systems: wind, flow currents, and solar energy, but also with greenhouses with an aquaponic operating principle. The aquaponic system combines the aquaculture of fish in limited spaces with hydroponics, the cultivation of plants in a liquid environment, and its use starts from the constant need to filter water with nitrites and nitrates from fish tanks and implicitly meaning energy consumption. Instead of classic mechanical filters, aquaponics involves filtering water through vegetable growing beds. From an economic point of view, at the same energy consumption, the fish farm can also produce fresh vegetables, bringing additional income but also fitting into the European paradigm of sustainable and sustainable development. If the aquaculture system allows development without the administration of drugs or chemical feeds, the plants grown with fish water can be considered ecological, bringing added value. Such a barge can be purchased at a scrap price and repaired and customized with minimal expense respecting at the same time the decarbonization strategy of the European Green policy by considerably reducing CO_2 emissions from the steel production process. Also, in case of severe weather conditions these fish farms cand be moved easily to a safer position with the help of a river tug or pusher, either single or multiple combination as convoy.

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