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Dual Land Use by Aquaculture and Photovoltaics in Vietnam

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- **Vietnam is a densely populated country with a relatively large contribution of agriculture and aquaculture to the BIP. Especially the expansion of shrimp farming is a strategic goal of the government.**
- **The demands for agricultural area and energy have been increasing heavily over the last decades due to population growth and economic development.**
- **Dual land use by photovoltaics and shrimp farming could reduce the competition for area without reducing the desired development of aquaculture and energy production.**

Background

In Vietnam, land scarcity is becoming increasingly acute, primarily due to rapid population growth and rising per capita economic growth. This leads to increased land consumption, especially for food and energy production, and has negative impacts such as deforestation, loss of biodiversity, and reduction of natural CO2 sinks. These issues require a rethinking of land use. To achieve the climate goals of the Paris Agreement, Vietnam is increasingly focusing on renewable energies, particularly photovoltaic systems. This is necessary as the country faces an annual increase in electricity demand of about 10%. Promoting renewable energy is a key aspect of addressing land use conflicts and climate change in Vietnam.

One strategy to alleviate the pressure on land as a resource is to double its use for food and energy production. The combination of aquaculture production and photovoltaic energy production on the same area (Aqua-PV) is a very recent development; to the best of our knowledge, there was no other Aqua-PV project for shrimp farming at the start of this project (Fig. 1). In shrimp aquaculture, the so-called biofloc system is increasingly being used, where light-dependent algae and microorganisms play an important role in water quality and shrimp nutrition (Fig. 2). Therefore, it is crucial to understand the impact of shading from PV systems on the biofloc system.

The SHRIMPS project aims to help reduce the future land requirements for aquaculture and PV ground-mounted systems in Vietnam. At the same time, it aims to increase the overall productivity of land areas. This way, land use and economic growth in Vietnam can be developed more ecologically and socioeconomically sustainably. In the subproject conducted by the Thünen Institute of Fisheries Ecology, we investigated the effects of shading of shrimp ponds by photovoltaic systems on the biological system of the ponds and shrimp production.

Figure 1: Schematic design of an Aqua-PV-facility with grid connection (Fraunhofer Institute for Solar Energy Systems (ISE), Freiburg, Germany).

Key Questions

1. How do different degrees of shading of aquaculture systems affect water quality, growth, and survival rates of shrimp?
2. How can the contribution of natural food to shrimp growth be determined under different shading conditions?

Methods

- Establishment of replicated model systems for shrimp production using the biofloc method employed in Vietnam in a temperature-controlled room at the Thünen Institute of Fisheries Ecology in Bremerhaven.

- Installation of LED lighting with photosynthetically active radiation corresponding to the light intensity determined in a simulation by Fraunhofer-ISE at 0%, 60%, and 90% shading by photovoltaic elements at a test site in Bac Lieu, Vietnam.
- Measurement of water parameters, growth, and survival rates of shrimp of different sizes in the experimental units with varying lighting.
- Calculation of the contribution of natural food to shrimp growth in the experimental units with different lighting using the ^{15}N tracer method (Fig. 2).

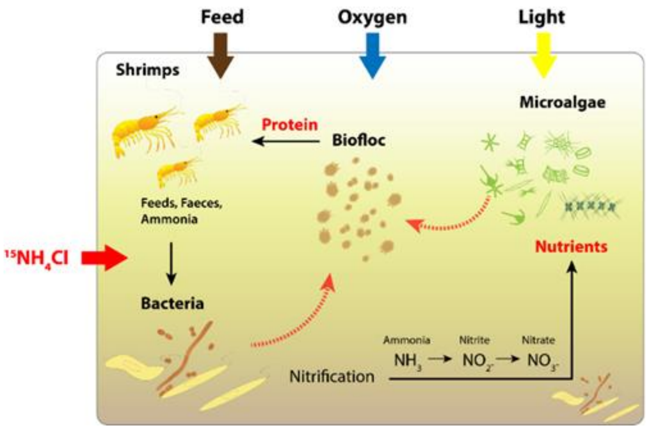

Figure 2: Principle of biofloc-based shrimp aquaculture (after Hermann et al. 2022). To identify the contribution of biofloc protein to shrimp nutrition. a ^{15}N-isotope tracer experiment was conducted. After the addition of ^{15}N-labeled ammonia chlorid ($^{15}NH_4Cl$) the enrichment of ^{15}N in biofloc and in the shrimps was measured (Source: Hermann et al., 2022).

Results and Conclusions

The Covid-19 pandemic significantly hampered project implementation in Vietnam. Therefore, for all experimental work, the light conditions in Vietnam had to be simulated in a model system at the Thünen Institute in Bremerhaven (Fig. 3).

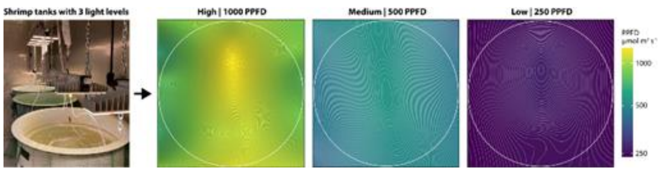

Figure 3: Left: Partial view of the experimental setup. Right: Light intensity at the surface (Source: F. Dahlke, Thünen Institute of Fisheries Ecology).

In this system, a series of experiments with shrimp of different sizes were conducted, while growth and survival rates of the shrimp were recorded in a conventional recirculation system. Regardless of light intensity, the biofloc mass (measured as sediment volume) increased rapidly in all systems (Fig. 4), and the concentrations of ammonium, nitrite, and nitrate remained low, indicating that the microbes in the biofloc quickly absorbed the nitrogen excretions of the shrimp. This was also confirmed by the tracer experiments. The addition of $^{15}NH_4Cl$ led to a rapid increase in the ^{15}N concentration in the biofloc material.

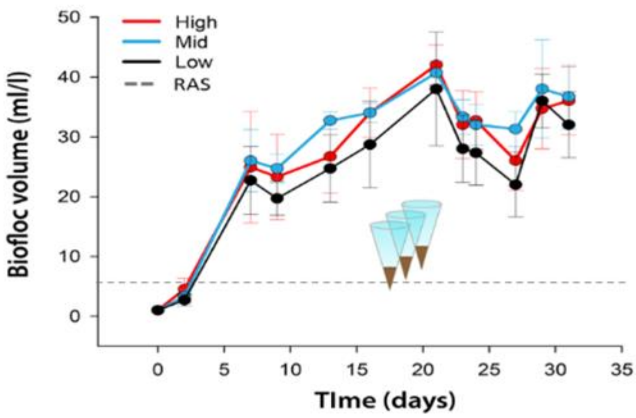

Figure 4: Settlement volume of water samples in dependance of the light intensities. The settlement volume is a parameter for the concentration of biofloc materials in the system, which is a potential food source for the shrimps (Source: F. Dahlke, Thünen Institute of Fisheries Ecology).

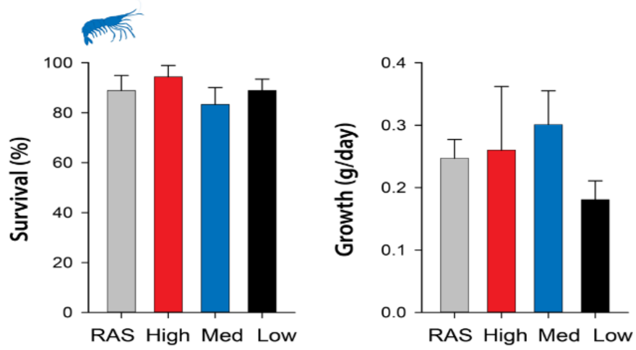

Figure 5: Survival and growth of the shrimp. – RAS = Shrimp in conventional recirculating aquaculture system, High, Med, Low = Shrimps is biofloc systems with high, medium and low light intensity (Source: F. Dahlke, Thünen Institute of Fisheries Ecology).

Regarding the growth and survival rates of the shrimp, there were no significant differences between the biofloc systems at different lighting intensities or between biofloc and conventional recirculation systems (Fig. 5). However, it is noteworthy that shrimp growth was more homogeneous at lower light intensity. Based on the laboratory experiments, the combination of shrimp aquaculture and photovoltaic energy generation appears to be feasible in principle. The results of the laboratory simulations still need to be confirmed by studies under real production conditions. Since the quantity and composition of natural food change depending on the light intensity (Fig. 4), it should also be examined whether shrimp growth can be further optimized by adjusting feed composition or feeding regimes. A more homogeneous growth would be advantageous for processing and marketing.

Further Information

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Partners

Fraunhofer Institute for Solar Energy Systems (ISE), Freiburg, Germany

Dornier Suntrace AG, Hamburg

SMA, Niestetal

Shrimp farm Viet-Uc , Bac Lieu, Vietnam

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Publications

Hermann C, **Dahlke FT, Focken U,** Trommsdorff M (2022) Aquavoltaics: dual use of natural and artificial water bodies for aquaculture and solar power generation. In: Gorjian S, Campana PE (eds) Solar energy advancements in agriculture and food production systems. London: Academic Press, pp 211-236

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