



Improving the potential success of a new technology

Trial-and-error implementation of a new technology can be economically and environmentally costly, which highlights the value of planning and innovative forecasting. Our spatial bio-economic analysis provides a cost-efficient method for addressing the uncertainty inherent in offshore aquaculture production. Current research is assessing the environmental impacts of offshore aquaculture and our research complements these efforts and provides a framework to integrate social, environmental and economic considerations into the development of offshore shrimp aquaculture. The set of modeling and planning tools we have provided will assist our client in establishing successful Aquapod operations and ultimately help transition local communities from a dependency on destructive aquaculture and capture fisheries to a model of economic and environmental sustainability.

We would like to take this opportunity to thank the Environ Foundation as well as all the people at the following organizations that generously donated their time and resources for the sake of this project.



Recommendations to Olazul

Focus future research and pilot trials in La Paz. Based on the spatial bio-economic analysis of the three study areas, La Paz has the most potential for successful and profitable Aquapod operations.

Conduct on-site research to increase the probability of successful placement. Collection of in-situ data to parameterize our model will increase the validity of our results and more accurately represent environmental conditions.

Investigate environmental impacts of Aquapods. Further research needs to be done to evaluate the environmental sustainability of offshore aquaculture operations.

Collaborate with local stakeholders to gain a better understanding of competing uses and risks. Our maps can be used to communicate with stakeholders and to investigate how Aquapod deployment may interact or conflict with existing uses and potential threats.

Research the feasibility of implementation of alternative management scenarios. The alternative management scenarios we evaluated can be used to improve the efficiency and profitability of Aquapod operations.



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Aquapods Project Brief



Spatial Planning and Bio-Economic Analysis for Offshore Shrimp Aquaculture. A Project at the Bren School of Environmental Science and Management, UCSB



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Shrimp: Small animal, Big problems

Shrimp is one of the most highly demanded seafood commodities around the world. Approximately six million tons of shrimp are traded annually and shrimp is the highest valued internationally traded fishery commodity (Gillett, 2008). In Mexico, it is the most valuable seafood export, with shrimp industries providing many regional jobs and economic benefits. However, current harvesting practices of bottom trawling and traditional shrimp farming through land-based aquaculture are frequently environmentally and economically unsustainable. Shrimp trawling causes seafloor habitat damage and results in high levels of non-target species bycatch (Conapesca, 2007). Land-based aquaculture often degrades valuable coastal habitat and results in the discharge of excess nutrients, antibiotics and other pollutants into the environment (Paez-Osuna et al., 2003).

Olazul is a non-profit organization that aims to assist coastal communities with their transition from a dependency on destructive seafood farming and trawling practices to more ecologically and financially sound livelihoods. Olazul is interested in exploring offshore shrimp aquaculture as an alternative to trawling and

land-based aquaculture, as it shows promise for reducing or eliminating many of the problems embedded in these practices.

Aquapods: An emerging alternative to meet increasing shrimp demand

Offshore aquaculture shows promise for reducing or eliminating many concerns embedded in existing capture fishery and aquaculture practices. Offshore operations result in little habitat destruction and may benefit from strong offshore currents, which could flush out wastes and bring in nutrients and oxygen for the shrimp. Aquapods are a new offshore aquaculture cage system that could provide a path to sustainable shrimp production, but little is known regarding the optimal placement strategy or economic viability of this new technology. As an emerging use in crowded coastal waters, there are potential user conflicts, as well as uncertainty about how location may affect the economic viability of Aquapod operations. Without proper planning, trial and error implementation of offshore aquaculture could incur unnecessary environmental and financial costs and increase the likelihood of user conflicts.

Project Objectives

- Identify suitable deployment sites for Aquapod implementation in three study areas.
- Determine how spatial variability, biological growth, and socioeconomic parameters affect profitability of Aquapod operations.
- Inform future research priorities and best management practices for Aquapod operations.

Developing a strategic plan for Aquapod implementation

We used an innovative spatial bio-economic model to provide a strategic framework for implementing offshore shrimp aquaculture with greater certainty of success. To better inform the planning, management and research priorities of Aquapod operations in Northwest Mexico, this project couples marine spatial planning with bio-economic modeling and sensitivity analyses to identify suitable sites for Aquapod implementation and evaluate the economic viability of Aquapod operations in the Bay of La Paz, Magdalena Bay, and Guaymas Bay.

Step 1. Site-Suitability Analysis

We identified five spatial parameters that constrain Aquapod siting: (1) depth, (2) seafloor slope, (3) marine reserves, (4) shipping lanes, and (5) incompatible existing uses. We used GIS spatial planning tools to develop a site-suitability model and maps of the suitable zones for each study area based on these five spatial constraints.

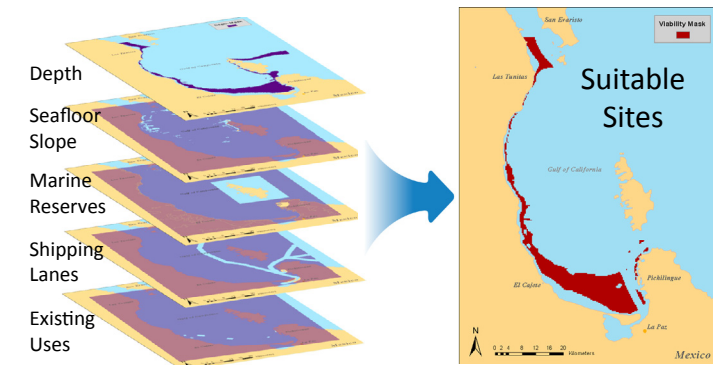


Figure 1. The five spatial parameters that constrain Aquapod siting.

Step 2. Spatial Bio-economic Analysis

Our spatial bio-economic model determined how Aquapod profitability would vary across space within the suitable area in each bay. Profitability in our model was measured as net present value (NPV), or discounted profits over time. Profits from Aquapod operation are dictated by revenues and costs, which are driven by operational, biological, and spatial factors.

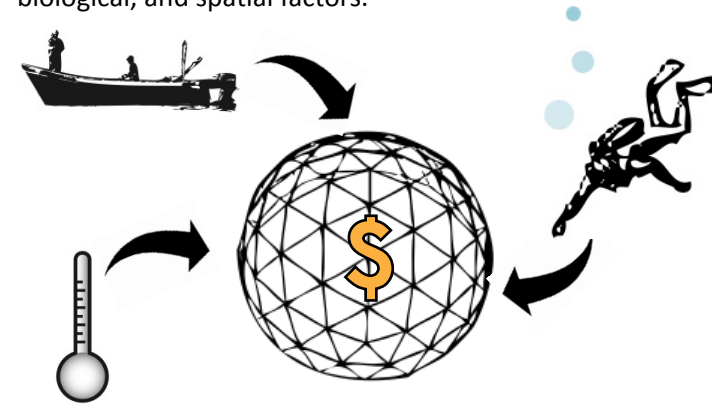


Figure 2. Image that represents a few of the many factors (boat costs, dive costs, and ocean temperature) that influence Aquapod profitability.

Revenues in our model are a function of price and shrimp biomass at harvest, both of which depend on shrimp growth rate. Costs in our model consist of capital startup costs, operational costs, and costs associated with risk. To account for uncertainty in our model parameters, we performed a Monte Carlo simulation over multiple iterations, to generate a distribution of NPVs from which we calculated an expected NPV for each suitable location with each bay.

Step 3. Sensitivity Analyses

To inform research priorities for Olazul, we performed two different sensitivity analyses on model parameters to determine 1) which parameters most impact profit, and 2) which parameters cause the most uncertainty in the model output. An elasticity analysis measured the relative response of the model output (NPV) to a percent change in individual parameters. A “parameter value range” sensitivity analysis measured the range in NPV values that result from evaluating the minimum and maximum values for each parameter.

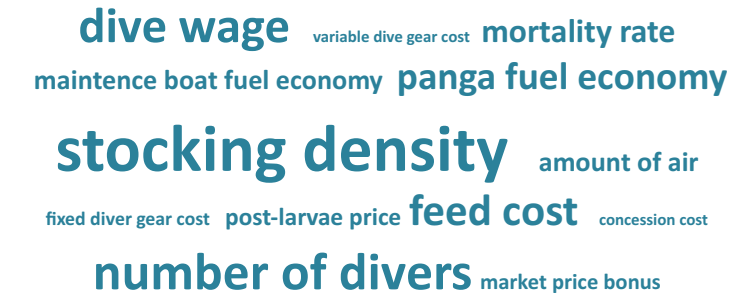


Figure 3. A word cloud, which reveals the importance of a given parameter to the profitability of Aquapods, through the font size of that word.

Results

Our site-suitability analysis found that only a small proportion of La Paz, Guaymas and Magdalena Bays are suitable for Aquapod siting: 7%, 11% and 16%, respectively. The resulting maps from our site-suitability analysis illustrated that depth was the most important

environmental driver in all three bays in determining the suitable area for Aquapods.

Our spatial bio-economic model, which is based on current Aquapod pilot operations, found that none of the Aquapod sites within the suitable areas are expected to be profitable under a 20 year time horizon, ultimately highlighting inefficiencies in the current pilot management process. However, NPV was not homogenous across each of the suitable areas, indicating that spatially-dependent variables, such as travel costs and temperature, played a large role in the profitability of Aquapod operations. Proximity to launch sites is one of the primary spatial factors influencing profitability, however positioning Aquapods adjacent to aquaculture and pollution outflows can negate the benefits of having a launch site close by.

Results from our sensitivity analyses were used to inform several alternative management scenarios we explored in our artisanal model. Feed and labor costs were two of the top ranking results in both our elasticity analysis and parameter value range analysis as outlined in the case study below. Reduction of feed and labor costs in the model to mimic management decisions (e.g., installing an automatic feeder, using alternative feed sources) increased the number of profitable sites by 100%. The location of the operation is still an important determinant of profitability due to spatial variability. By reducing feed and labor costs and utilizing the spatial bio-economic results map to research suitable locations close to shore, Aquapod operators can maximize their chance of securing positive profits.

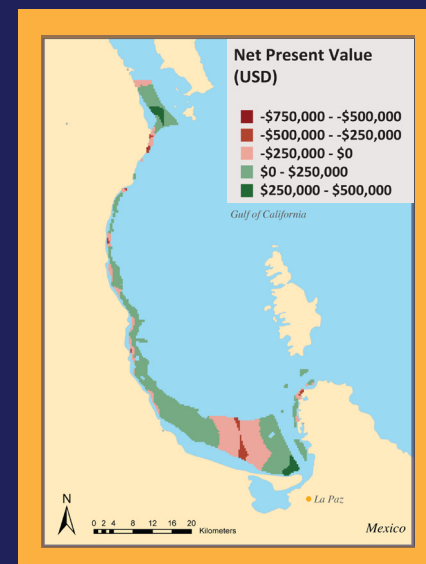
Case Study: Improving Operational Efficiency to Increase Economic Viability of Aquapods

While seven percent of the study area in La Paz is suitable for Aquapod siting, none of the suitable sites are expected to be profitable under a “business as usual” scenario. Consequently, we explored several alternative management scenarios that reduce costs to improve the economic viability of Aquapod operations. Feed and labor costs are major drivers of profitability in our model and may be reduced by decreasing the amount of artificial feed used, utilizing by-product feed sources, or installing automatic feeders.

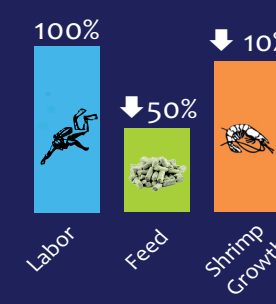
Reduced Feed Cost



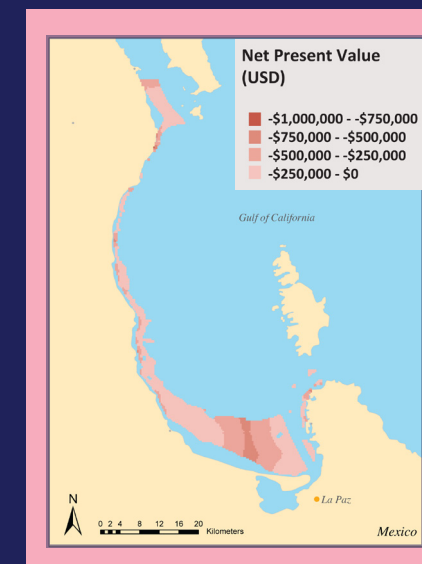
Feed costs could be cut by using cheaper by-product feed sources. A 50% reduction in feed costs resulted in 66% of the suitable sites being profitable.



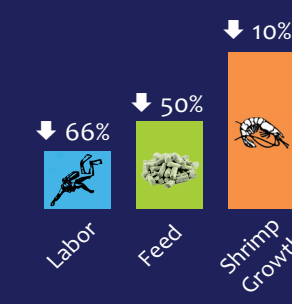
Reduced Feed Quantity



Feed costs could also be cut by reducing feed quantity, but this option may negatively impact shrimp growth rates. A 10% reduction in shrimp growth rates caused all the suitable sites to become unprofitable once again.



Reduced Labor and Feed Quantity



Reducing the the amount of feed or installing automatic feeders could reduce the required number of diver hours, thereby decreasing labor costs. With a 66% reduction in labor costs, 100% of the suitable sites became profitable.

