Title
Sea Cucumber Aquaculture at Kaua'i Sea Farm

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Abstract/Executive Summary

Integrated multi-trophic aquaculture, or IMTA, attempts to reduce or eliminate nutrient loading by introducing lower trophic organisms to consume waste matter. These organisms should be capable of consuming bottom detritus with dissolved and particulate organic matter such as feces and unconsumed feed from upper trophic species. The viability of sea cucumber integration into land-based aquaculture production facilities was investigated and discussed. The focus of the study was on the role of the sea cucumber as an ecosystem service. Consumption of nutrient-loaded waste is essential in reducing eutrophication and maintaining an ecological balance. I worked with Kauai Sea Farm's (KSF) Dave Anderson (MAS MBC '16), investigated and compiled the most recent findings in integrating sea cucumbers into their aquaculture farm at Nomilo Fishpond with a focus on sediment analysis and comparison of biomass of sea cucumbers used in this study.

The primary goal of this preliminary study was to investigate the potential benefit of integrating sea cucumbers into existing aquaculture systems to clean up and reduce waste and at the same time improve environmental outcomes. This study highlights the viability of sea cucumber integration into land-based aquaculture farms, which addresses the value of waste reprocessing, and will significantly impact the future success of aquaculture farms.

Background/Problem Statement

Monoculture aquaculture refers to cultivating a single species of fish or shellfish in a confined environment, such as ponds, tanks, or cages. While it can be efficient in terms of production, it poses several ecological problems, such as nutrient pollution. Uneaten feed, feces, and other waste products accumulate in aquaculture environments, contributing to nutrient pollution. This excess of nutrients can lead to eutrophication, harming aquatic ecosystems by causing algal blooms and oxygen depletion. Addressing these ecological problems in monoculture aquaculture requires sustainable practices such as implementing better waste management strategies and incorporating ecosystem-based approaches that consider the interactions between aquaculture and the surrounding environment.

Polyculture, such as integrated multi-trophic aquaculture, offers several advantages over monoculture aquaculture. IMTA can mimic natural ecosystems by diversifying species interactions and nutrient cycling. This enhances ecological resilience, making these systems more resistant to diseases, fluctuations in environmental conditions, and other disturbances.

Sea cucumbers have a vital ecological role in cleaning up organic-rich sediments. Most deposit-feeding or burrowing sea cucumbers contribute to the bioremediation of sediments by moving through them and releasing processed sediments in the form of feces (Slater et al., 2011). Bioturbation, a form of bioremediation, is accomplished by removing the upper layers of the sediment, promoting mineralization (Levin, 1999). Overexploitation has led to the depletion of sea cucumber populations in various parts of the world. Many species are harvested at unsustainable levels, with fishing efforts often exceeding natural replenishment rates. This has resulted in population abundance and size decline due to unsustainable harvesting as a food resource worldwide (Purcell et al., 2013).

Cultivating sea cucumbers in aquaculture systems faces various challenges, including suboptimal growth rates, disease susceptibility, environmental impacts, and limited integration into existing aquaculture practices. The potential for integrating sea cucumber aquaculture in an aquaculture setting is mainly unexplored and still in the experimental stages. There is a need to address these issues and develop sustainable approaches for sea cucumber aquaculture and its integration into polyculture or multi-trophic systems. Marine macroinvertebrates, such as mussels and abalone, have been investigated and found to be more suitable for coculture and integration success because of natural benthic interactions (Navarro et al., 2013).

Specific Objectives

1. Identify the role of sea cucumbers in enhancing the sustainability of fish farms through waste management.
2. Investigate and document further research and collaboration to support viability and sustainability studies for integration to aquaculture systems.

    a. *Stichopus horrens* (dragonfish)
    b. *Holothuria whitmaei* (white teatfish)

3. Generate a graph or table of growth and survival rates of the above species with factors such as bioremediation and sediment uptake/consumption.
4. Develop a plan of action and recommendations to investigate new methodologies to integrate sea cucumbers in IMTA, knowing that this is still in experimental stages and not yet in commercial production.

Deliverable

Story Map: https://storymaps.arcgis.com/stories/13539350ebe648baa3b3ab1a1fb61e8a

Methodology

1. A total of four cages were constructed and deployed at the shallow end of the Nomilo Fishpond. Sediment samples were taken before the two different sea cucumber species were weighed and released inside the cages. Sediment samples were collected five weeks later and sea cucumbers were weighed again and released back into the holding tanks at KSF's hatchery.
2. A comparative sediment analysis was performed and data was compared to biomass or weight of sea cucumbers before and after they were released in the cages at the Nomilo Fishpond.
3. Sediment analysis used was difference on ignition. Four to five grams of sediment samples were initially weighed then dried at 60 degrees C for 48 hours, it was then weighed again after 30 minutes in the desiccator, Weight was dry weight.
4. Sediment samples were baked at 500 degrees for 4.5 hours, cooled, placed in the desiccator then weighed again for ash weight.
5. Data was tabulated for the two sample dates, April 8, 2024 and May 15, 2024.
6. Pictures were taken to document sea cucumber species used at the Nomilo Fishpond at KSF, which is part of the story map deliverable.

Results and Discussion

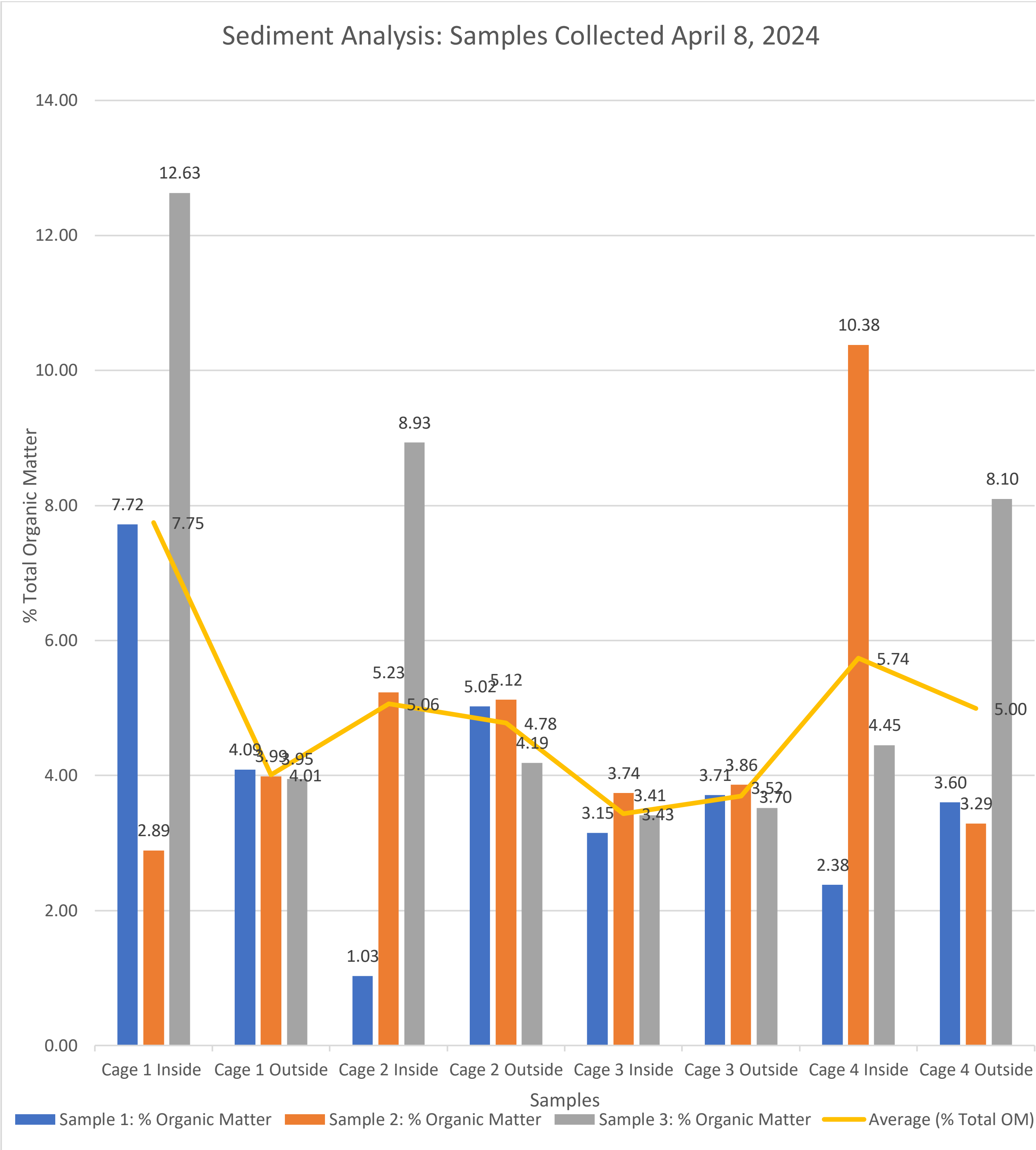


Figure 1. Sediment analysis results of samples collected during April 8, 2024

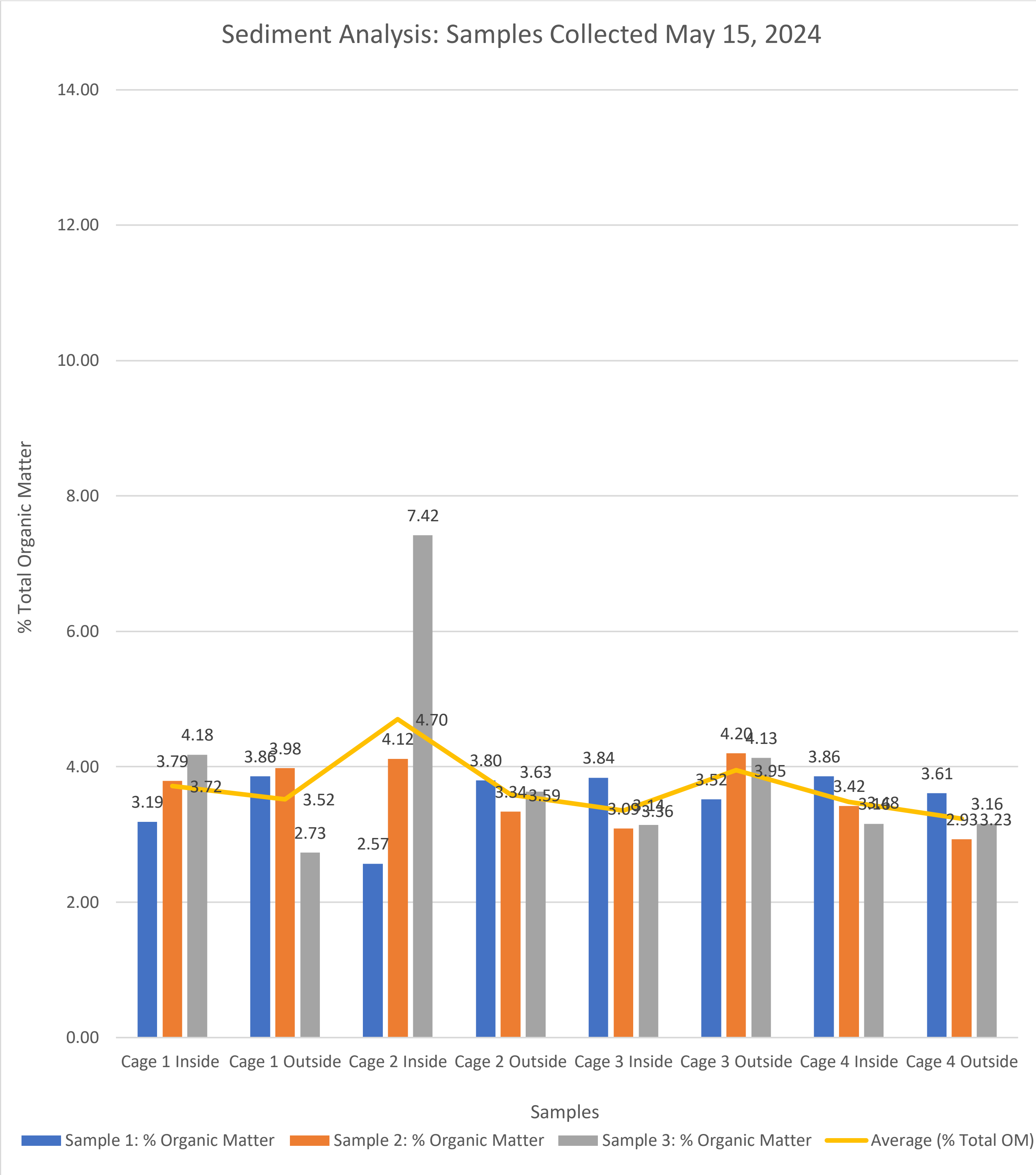
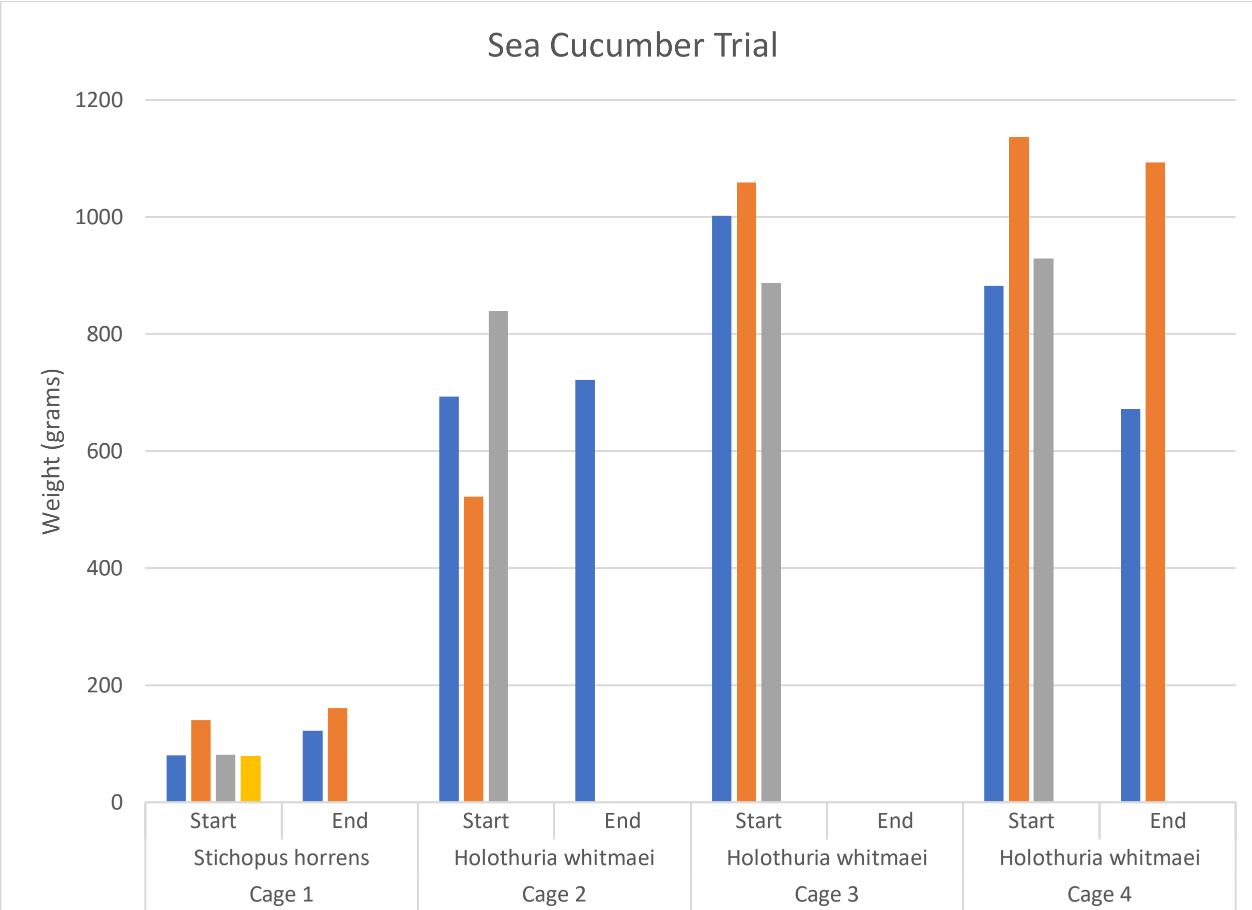


Figure 2. Sediment analysis results of samples collected during May 15, 2024

Figures 1 and 2 shows the results of the sediment analysis. There was a slight decrease of percent total organic matter (%TOM) after five weeks when sea cucumbers were kept inside the cages.



	Stichopus horrens Cage 1 Start	Stichopus horrens Cage 1 End	Holothuria whitmaei Cage 2 Start	Holothuria whitmaei Cage 2 End	Holothuria whitmaei Cage 3 Start	Holothuria whitmaei Cage 3 End	Holothuria whitmaei Cage 4 Start	Holothuria whitmaei Cage 4 End
■ (blue)	80.5	122	693.9	722.3	1002.4		882.8	672.1
■ (orange)	140.5	161.2	522.9		1058.9		1136.9	1093.4
■ (grey)	80.8		838.9		887.3		929.6	
■ (yellow)	78.5							

Figure 3. Summary of results for the sea cucumber trial

Although the results are inconclusive (Figure 3) due to more than half of the sea cucumbers escaping, it is clear that the *Stichopus horrens* in Cage 1 had an increase of biomass. Based on the weights of the *Holuthuria whitmaei*, there was very little increase in biomass in Cage 2 and a decrease in biomass in Cage 4.

Conclusion and Findings

1. Although the data collected and findings were not conclusive, it was observed that the sea cucumbers used in this study gained biomass and that some of the organic matter was consumed based on the results of the sediment analysis.

2. Organic and particulate matter intake contributed to the increased weight or biomass of the sea cucumbers. Thus, sea cucumbers may have a potential benefit in IMTA.

Recommendations

1. A second sediment analysis to include sulfide content since the pond is an old inactive volcanic crater. Also, an analysis of the sediment at the pond's deeper end (center) to validate results from the initial baseline sediment analysis.

2 An analysis of variance (ANOVA) should also be performed using independent and dependent variables such as species used and how much total organic matter remained in the sediment samples after a period of time. This could indicate whether the results were significant or random.

3. Further studies or investigations are recommended to include putting sea cucumbers in fully enclosed cages on the bottom underneath the mesh nets where clams are currently raised in the pond to prevent escape.

References

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