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Shrimp Breeding Grounds Detector

Group 27 Literature Review Document by

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1. Introduction

Aquaculture in Sri Lanka consists mainly of shrimp farming, accounting for around 90% of the total value of national production. Puttalam, Mannar, Trincomalee, and Jaffna are the major farming areas that provide very good conditions for shrimp breeding. Traditionally, this was done by farmers using their traditional knowledge about the breeding sites. In this process, data science and machine learning can play a very important role. This literature review throws light on four major factors affecting shrimp breeding: water quality, chlorophyll-a concentration, geospatial analysis, and historic breeding. It also underlined the need for predictive applications that can realize optimum shrimp farming practices for economic benefits to the country and shrimp farmers.

2. Relevant Work

2.1 Water Quality Analysis (Salinity, pH, Dissolved Oxygen, Temperature)

Water quality is important as shrimp require specific conditions to be able to survive and reproduce. Factors such as a stable pH, dissolved oxygen, etc. must be between specific ranges for shrimp breeding. Conditions such as pH not being in the right range can result in poor health for the shrimps and affect the growth rate.

(Tendencia, dela Peña, and Choresca 2005) covers the pH, salinity, and temperature of shrimp agriculture and how it affects shrimp diseases. It discusses how the variations in pH levels can affect the survival rates of luminous bacteria (for example, the *Vibrio* species) and consequently how the survival rates of those bacteria can increase the disease rates of shrimps. The temperature being ideal for the bacteria can therefore make them thrive. Deviations in salinity can promote bacterial growth. Once these luminous bacteria enter the body, the shrimp eats less and therefore it grows slower.

(Heenatigala and Fernando 2016) analyzes *vibrio* diversity, the effects of antibiotics in shrimp pond culture systems to control the disease that affects shrimp called vibriosis and the environmental conditions that are suitable for *vibrio*. It discovered that the overuse of antibiotics in shrimp farms lead to antibiotic resistance. From this it can be concluded that the use of antibiotics and especially relying on them is not the best way to control vibriosis but managing the environment is.

Salinity, pH, dissolved oxygen levels and temperature can be measured using satellite imagery, although some indirectly. Sea surface temperature can be measured using the MODIS (Moderate Resolution Imaging Spectroradiometer) on NASA's Aqua and Terra satellites, alternatives include VIIRS (Visible Infrared Imaging Radiometer Suite) on the Suomi NPP satellite or AVHRR (Advanced Very High-Resolution Radiometer) on NOAA satellites. Measuring the salinity from satellite imagery is more difficult than getting the temperature but it is feasible using microwave radiometry and with temperature, this data can be gathered from SMOS (Soil Moisture and Ocean Salinity); Historical data can be gathered from the retired NASA Aquarius. pH can't be directly measured from satellite imagery; however, Chlorophyll concentration can be used to estimate the pH. Dissolved Oxygen levels can't be measured directly like for temperature or chlorophyll concentration; however, they can be predicted using the relationship between salinity and temperature.

2.2 Chlorophyll-a Concentration (Phytoplankton Levels)

Chlorophyll-a is a surrogate of the phytoplankton, shrimp's primary food source, and thus a critical indicator of the health of a marine ecosystem so essential for shrimp farming. Measurement of chlorophyll-a has been considered important in the monitoring of water quality and ascertaining suitable conditions for shrimp in most studies.

(“Gunawardena, P.V.S.L.” 2009, #) conducted a study on the potential of mangrove wetlands in North-Western Sri Lanka for treating shrimp pond effluents. Although this study did not focus on chlorophyll-a concentrations, it highlighted how mangroves improve water quality by regulating nutrient levels, which affect phytoplankton growth and, in turn, chlorophyll-a levels.

(Tendencia, E. and Quitor, G.C. 2021, #) examined factors that lead to the deaths of shrimp due to bacterial infections, which cause a disease called AHPND. Also, they emphasize the importance of maintaining good water quality and phytoplankton levels to reduce shrimp mortality.

(“Peng Y, Sengupta D, Duan Y, Chen C, Tian B” 2022, #) used satellite images from Sentinel-2 to analyze coastal aquaculture ponds in China, focusing on biophysical factors like chlorophyll-a concentrations. This study suggests that similar methods could be useful in Sri Lanka for mapping shrimp farms and monitoring water quality.

Moreover, remote sensing technology most importantly satellite imagery proven effective for identifying chlorophyll-a levels over large areas (“Q., Peng, H.C., Yao, Y., Wang, R., Ma, W.Y., Shi, J.R., Ren” 2023, #). Although tools like Google Earth Engine and Sentinel-3 have been used to monitor chlorophyll-a in coastal waters their application for shrimp breeding in Sri Lanka is still limited. Second, such methods have been perfected over the years, whereby a result ("Hu, C., Feng, L. and Guan, Q" 2020, #) developed a machine learning approach to estimate surface chlorophyll-a concentrations in global oceans from satellite measurements, thus making the tracking of the phytoplankton level easier. It is with such improvements that can be used to keep a better eye on Sri Lankan coastal waters for predicting shrimp breeding areas using the abundance of the phytoplankton.

Another of the major methods of calculation of chlorophyll is by using Landsat satellite images. The Landsat satellites are specifically designed to provide multispectral images that could be used for several land analyses, including vegetation and water quality analyses, such as the calculation of chlorophyll-a concentration. Specifically, the spectral bands in the visible and near-infrared (NIR) regions are useful for chlorophyll assessment. Normalized Difference Chlorophyll Index (NDCI): This index is specifically designed to assess chlorophyll-a concentration.

$$\mathbf{NDCI=(Band5-Band4)/(Band5+Band4)}$$

This index uses the Red and NIR bands from Landsat 8 and 9.

Chlorophyll-a Algorithms: You can also use empirical or semi-empirical algorithms developed for chlorophyll-a concentration estimation, which have been tailored for different water bodies. Also, to access these data USGS would be a great help.

Landsat 8 has several spectral bands, and for chlorophyll-a assessment, the following bands are typically used: **Band 2 (Blue)**: Useful for water bodies and detecting chlorophyll in shallow waters. **Band 3 (Green)**: Sensitive to chlorophyll absorption. **Band 4 (Red)**: Also sensitive to chlorophyll content in water and vegetation. **Band 5 (NIR)**: Helpful in identifying biomass and vegetation but can also contribute to water body analysis.

2.3 Geospatial Analysis (Satellite Imagery and Terrain Data)

In other terms, the prime features of geospatial analysis for shrimp breeding include monitoring the area of production, sustainable control of aquaculture expansion, and environmental impact monitoring.

One of the most important features of this analysis is that it was, for the first time, in a position to use satellite data to its full advantage for the purpose of continuously monitoring aquaculture areas. This would allow for accurate estimations of changes in pond size, distribution, and environmental conditions from year to year. This is important for any trends in shrimp farming and the purposes of decision-making on sustainability management. (Xia et al., 2018; Ottinger et al., 2017).

The application of geographic analysis can vastly help in the assessment of environmental impacts related to shrimp breeding. This could allow for land degradation, water quality, and the emphasis of the impacts from aquaculture operations on nearby ecosystems. Some literature has shown that pollution by effluents from shrimp farming and loss of biodiversity should be addressed with specific mitigation strategies promoted by researchers. (Martínez-Durazo et al., 2019; Páez-Osuna et al., 2021).

Besides environmental monitoring, geospatial analysis helps optimize production. Integrating landscape information with satellite images allows stakeholders to choose proper sites for new shrimp farms with appropriate topography, availability of water, and proximity to markets. This strategic planning may beget better use of resources and higher yields, thereby reducing the risks in economic viability. (Prasad et al., 2020; Bangladesh study, 2019).

Geospatial research also illuminates the socioeconomic concerns about shrimp aquaculture. All stakeholders can work toward promoting more equitable and ecologically sound aquaculture development by framing farming practices within community subsistence and market access. Such a holistic approach benefits producers and local communities. (PLOS ONE, 2019; Xia et al., 2018)

It helps farmers and policymakers make an informed decision to arrive at a balance between environmental sustainability and productivity with the help of geospatial data-based decision support systems. This would confer the requisite capacity to reach the objectives of sustainable development inclusive of food security, conservation as pointed out by (Ottinger et al., in 2017, and Bangladesh research in 2019.)

It is, therefore, conclusive that geospatial analysis has tended to be instrumental in bringing efficiency and sustainability into shrimp breeding by enabling comprehensive insights that benefit the cause of environmental health and output.

2.4 Historical Shrimp Breeding Patterns

The shrimp farming system affects Sri Lanka's coastal economy very closely, especially in lagoons, where locating exact breeding sites for shrimp is a great challenge. Records of historical observations of breeding movements done using the manual observation method influenced by several environmental factors such as water quality, temperature, salinity, and other natural features such as mangroves were faced with problems.

Several studies have significantly contributed to understanding shrimp breeding patterns in Sri Lanka. (Hettiarachchi and Edirisinghe, 2016) theoretically explored the captive breeding of *Lysmata debelius*, giving valuable information on how environmental conditions influence reproductive success. Being specific to only one species, the findings may also be generalizable to shrimp farming in Sri Lanka, being informative on breeding conditions.

(Jayawardane, McLusky, and Tytler, 1999) published their work on the reproductive biology of *Metapenaeus dobsoni* in the western coastal waters of Sri Lanka. Monthly data were collected from lagoons and the offshore areas from September 1998 to December 1999. Their findings helped to estimate fecundity, reproductive size, sex ratios, and the timing of spawning events, thereby contributing in a significant way to the knowledge of breeding seasonality and success rates of shrimp.

(Bandara, 2009), in his Master's thesis, has used historical breeding data of the perfect life stages from various coastal lagoons to explore shrimp breeding patterns. By using statistical and time series analysis, breeding success was tested against seasons and different locations, and it gave a long-term perspective of environmental influence on breeding.

The studies and research of (Ofori, Kodikara, and Jayatissa, 1993-2020) on mangrove ecosystems in the Pambala-Chilaw lagoon complex provided an ecological insight into the impact of shrimp farming. Using aerial and satellite imagery from 1973 up to 2020, their research showed there had been a 45% decrease in mangrove coverage, while it also reveals a decline in shrimp farming activities in 2001; thus, the environmental impacts of shrimp aquaculture were highlighted.

The insights provided would be great for a better understanding of shrimp breeding characteristics and marine environmental influences in Sri Lanka. Through the combination of historical data and present technologies, such research in the future can provide enhanced shrimp farming practices which would be both successful and environmentally friendly in coastal areas of Sri Lanka.

3. Comparison Table of Relevant Work

Research	Author	Year	Dataset	Model Used	Metric
Water Quality Analysis (Salinity, pH, Dissolved Oxygen, Temperature)					
Effect of shrimp biomass and feeding on the anti-Vibrio harveyi activity of Tilapia sp. in a simulated shrimp–tilapia polyculture system	Eleonor A. Tendencia, Milagros R. dela Peña, Casiano H. Choresca	2005	Water samples and bacterial isolate from shrimp farms	pH, temperature, and salinity analysis	PO4-P (ppm), NO2 -N (ppm) NH 3 -N (ppm) Bacterial count (cfu/g) Presumptive Vibrio Weight of feces (g/g intestine)
Occurrence of bacteria species responsible for vibriosis in shrimp pond culture systems in Sri Lanka and assessment of the suitable control measures.	P.P.M. Heenatigala, M.U.L. Fernando	2016	Biweekly samples of water, sediments and hemolymph from the Western and Northwestern coastal belt of Sri Lanka covering Chilaw, Puttalam and Kalpitiya.	water, sediments and hemolymph analysis	Morphological and biochemical characteristics of identified Vibrio isolates, Water quality parameters, Antibiotic Resistance

Chlorophyll-a Concentration (Phytoplankton Levels)					
Research	Author	Year	Dataset	Model Used	Metric
Potential of mangrove wetlands as biofilters to treat shrimp pond effluents	Gunawardena, P.V.S.L., Epa, U.P.K., Hettiarachchi, M.	2009	Shrimp pond effluents in North-Western Sri Lanka	Mangrove wetlands as biofilters	Improved water quality, controlled nutrient levels
Ammonia, Phosphate, Total Suspended Solid and Chlorophyll a Removal in Mangrove Habitat Receiving Shrimp Pond Effluents	Tendencia, E. and Quitor	2021	Two experiments were done using earthen ponds and Water nutrient levels were analyzed using ANOVA and repeated measures using SPSS V 23.	Experimental analysis	Reduced shrimp mortality with better water quality
Accurate mapping of Chinese coastal aquaculture ponds using biophysical parameters based on Sentinel-2 time series images	Peng, Y., Sengupta, D., Duan, Y., Chen, C., Tian, B.	2022	Sentinel-2 Satellite data (Chinese coastal aquaculture ponds)	Sentinel-2 based biophysical parameter analysis	High accuracy mapping of aquaculture ponds
A machine learning approach to estimate surface chlorophyll a	Hu, C., Feng, L., Lee, Z., Franz, B.A., Bailey, S.W.	2020	Satellite data (global chlorophyll-a)	Algorithm refinement for satellite data recovery	Enhanced accuracy in chlorophyll-a measurements

concentration in global oceans from satellite measurements					
Suitability of Sentinel-3 chlorophyll products based on optical water types.	Zhou, Y.T., Shen, Q., Peng, H.C., Yao, Y., Wang, R., Ma	2023	Sentinel-3 Satellite data	Satellite remote sensing	Large-scale chlorophyll-a level monitoring
Geospatial Analysis (Satellite Imagery and Terrain Data)					
Research	Author	Year	Dataset	Model Used	Metric
Estimating shrimp farm production and future growth prediction using remote sensing.	Sáenz-Romero et al.	2023	Sentinel-2 satellite imagery, shrimp farm locations (Gulf of California)	Random Forest for classification and growth prediction	Accuracy, Precision (for classification), and production estimates
Mapping aquaculture and environmental effects	Ottinger et al.	2016	TerraSAR-X, SPOT-5, RapidEye for Vietnam and China	Object-based image analysis (OBIA)	Aquaculture pond detection and classification accuracy
Use of remote sensing for aquaculture detection	Xia et al.	2018	Landsat 8 OLI for Jiangsu Province, China	Decision tree classifier, NDWI, MNDWI	Mapping aquaculture areas, land-use change detection accuracy
Environmental impacts of aquaculture expansion	Quoc Vo et al.	2015	SPOT-5 for Ca Mau Province, Vietnam	Maximum likelihood classification	Maximum likelihood classification

High-resolution mapping of aquaculture ponds	Stiller et al.	2019	Sentinel-1, Landsat archive for Vietnam	Random Forest classifier	Mapping aquaculture and temporal change detection
Sustainable aquaculture and socio-economic analysis	Hossain et al.	2013	Literature review and field data for Bangladesh	Geospatial analysis and socio-economic assessment	Impacts of shrimp farming on coastal environment and livelihoods
Historical Shrimp Breeding Patterns					
Research	Author	Year	Dataset	Model Used	Metric
Captive breeding of fire shrimp (*Lysmata debelius*) under Sri Lankan conditions	H.A.S.U.Hettiarachchi, U.Edirisinghe	2016	Data on captive breeding conditions of fire shrimp in Sri Lanka	N/A	Breeding success under different environmental conditions.
Reproductive Biology of *Metapenaeus dobsoni* (Miers, 1878) from the Western Coastal Waters of Sri Lanka	P.A.A.T.Jayawardane, D.S.McLusky, P. Tytler	1999	Monthly catch data from lagoons and offshore areas (September 1998 - December 1999)	Empirical data analysis	Estimated fecundity, reproductive size, sex ratio, timing of spawning events
MSc Thesis on Shrimp Breeding in	Bandara, R.C.	2009	Dataset based on historical	Statistical Methods, Time Series	Historical trends, breeding

Sri Lanka: A study on breeding Patterns			shrimp breeding patterns from various coastal lagoons in Sri Lanka		success across different seasons and locations
Ecological impact of shrimp farming on mangrove ecosystem in Sri Lanka	Samuel A. Ofori, Sunanda K.A. Kodikara, Loku P. Jayatissa, et al.	1993 - 2020	Aerial and satellite imagery data from 1973 to 2020 (Pambala-Chilaw lagoon complex)	Geospatial analysis	Mangrove extent decrease (45%), shrimp farm decrease (since 2001), ecological footprint analysis of shrimp farming

4. Summary and Research Gaps

Our project objective is to create a real-time prediction system for the identification of shrimp breeding grounds using satellite images, environmental sensor data, and historical breeding patterns. With an analysis based on key parameters (water quality, chlorophyll-a concentration, geospatial features, and historical shrimp breeding patterns), it will yield accurate prediction about the breeding grounds that shrimp will choose for themselves in Sri Lanka. Inevitably there exist gaps, including those solutions under the gambit of aquaculture fall short in not employing lagoon ecosystem dynamics, real-time prediction is lacking, and not combining satellite data with locally recorded environmental information. Importantly, so far, there is no dedicated app to locate shrimp breeding sites, representing a substantial gap for potential marketing. This effort aims at enabling the shrimp farmers to adopt more sustainable aquaculture practices with the best insights available.

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