

*Research article*

## **Productive zone mapping of the Swandip Coast, Bay of Bengal: A geospatial analysis to suggest potential mariculture hotspots**

*Antar Sarkar<sup>1</sup>, Shahida Arfine Shimul<sup>1</sup>, Angan Sen<sup>2</sup>, Saifuddin Rana<sup>1</sup>, and Sk. Ahmad Al Nahid<sup>1\*</sup>*

<sup>1</sup>Department of Fisheries Resource Management, Faculty of Fisheries, Chattogram Veterinary and Animal Sciences University, Khulshi-4225, Chattogram, Bangladesh.

<sup>2</sup>Faculty of Fisheries, Chattogram Veterinary and Animal Sciences University, Khulshi-4225, Chattogram, Bangladesh.

### ARTICLE INFO

Article history:

Received:01/10/2024

Accepted:02/04/2026

*Keywords:*

Swandip island, Bay of Bengal, marine productivity, mariculture, geospatial planning

*\*Corresponding author:*

Cell: +8801712505698

E-mail:

[nahid83bau@gmail.com](mailto:nahid83bau@gmail.com)

### ABSTRACT

Bangladesh has abundant marine resources in the Bay of Bengal but lacks comprehensive evaluations of hydrology and productivity. Geospatial technologies can direct sustainable management of marine resources and find productive hotspots. In order to suggest possible mariculture locations, this study concentrated on locating productive zones within a 7 km buffer surrounding Swandip Island of the Bay of Bengal. Three important hydrological indices were mapped using ArcGIS analysis of Landsat-8 data from July 2023 to July 2024: sea surface temperature (°C), turbidity (Nephelometric turbidity unit), and Ch-a concentration (mg/m<sup>3</sup>). The data underwent atmospheric and radiometric corrections before overlay analysis. The sea surface temperature ranged from 19.83 to 33.64°C. Findings showed that 50–60% of the eastern and northeastern sections had colder waters (19–24°C) and 30–40% had moderate temperatures (25–30°C). The concentrations of chlorophyll-a varied from 0.2 to 0.48 mg/m<sup>3</sup>, with the north and southwest having the highest concentration. Turbidity ranged from 0.0446 to 0.0808 NTU (Nephelometric Turbidity Unit). In 60–70% of the northern, western, and southwestern regions, there was considerable turbidity (0.070–0.0808 NTU). The productive zones were predominant from northwestern, western to southwestern regions and suggested for mariculture pursuits such as shellfish culture, cage culture of fish, and seaweed culture. The Bay of Bengal's sustainable economic exploitation of marine resources can be optimized with the help of these insightful findings and insights. The study recommends geospatial analysis and marine spatial planning of more marine productive areas.

**To cite this paper:** A. Sarkar, S. A. Shimul, A. Sen, S. Rana, S. A. A. Nahid, 2025. Productive zone mapping of the Swandip Coast, Bay of Bengal: A geospatial analysis to suggest potential mariculture hotspots. *Bangladesh Journal of Veterinary and Animal Sciences*, 13(1& 2):08-16.

### 1. INTRODUCTION

Bangladesh is enriched with its diversified marine fisheries resources. The recent increase in the country's maritime area from its

neighboring states, India and Myanmar, has opened a new window for fostering marine fisheries production in Bangladesh. Many economically significant resources are supported by Bangladesh's vast marine water

region, which spans 118,813 square kilometers. These include 475 species of finfish, 36 species of shrimp, 16 species of crab, and 165 species of seaweed. 15% of all fisheries production is derived from maritime fisheries. However, Bangladesh faces significant challenges in maintaining the sustainability of its maritime fishing resources. The main challenges to preserving the sustainability of marine fisheries have been pollution, climate change, and several other natural and man-made problems. (Tora et al., 2022). An emerging concept for the sustainable use of marine resources in the nation is the "blue economy." Sustainable use, management, and conservation of these marine resources are essential to the growth of the blue economy. Nevertheless, scientific management techniques, hydrological monitoring, productivity assessment, and stock assessment are lacking (Ahmad et al., 2023).

The Swandip coast, located along the northeastern part of the Bay of Bengal, represents a region of immense ecological and economic importance. The abundant biodiversity of its coastal waters supports a wide variety of marine creatures, which is vital to the local fishing communities' ability to sustain livelihood. These waters play a pivotal role in the regional fishing industry and are closely associated with the overall health of the Bay of Bengal ecosystem. Maintaining the biological diversity that sustains regional fisheries depends critically on the productivity of this marine habitat, which is influenced by many oceanographic and environmental variables (Estes et al., 2021). Maintaining the long-term sustainability of marine resources requires an understanding of and mapping of the geographical distribution of productivity. Chlorophyll-a (Ch-a) concentration, sea surface temperature (SST), and turbidity are some of the connected elements that can indicate marine productivity (Kay et al., 2018; Moradi and Moradi, 2020). Mapping of these important marine production indicators has been made possible by recent developments in remote sensing technology and geospatial analysis. Through the integration of data obtained from satellites into Geographic Information Systems (GIS), researchers are now able to visually represent and measure spatial differences in

production over extensive coastal regions. By identifying productivity "hotspots" and their seasonal variations, this geospatial method offers important insights into the dynamic characteristics of marine ecosystems (Schwartz-Belkin and Portman, 2023). The ability to map and monitor marine productivity over time is crucial for fisheries resource management, as it informs decisions related to sustainable exploitation, conservation zoning, and the mitigation of overfishing (Shamsuzzaman et al., 2017). Given the rising pressures on marine habitats caused by overfishing, habitat degradation, and the effects of climate change, it has become critical to use modern analytical methods for spatial planning in fisheries management. The Swandip coast, with its unique hydrodynamic features, serves as a microcosm for understanding the broader productivity trends in the Bay of Bengal.

Therefore, the study aimed to create a detailed productivity map of the Swandip coast by applying geospatial technologies. Three indicators, sea surface temperature (SST), Ch-a, and turbidity, were analyzed to create the productivity mapping. The insights gained from this analysis will not only contribute to our understanding of marine ecosystem dynamics but also offer practical applications for enhancing fisheries management strategies and ensuring the sustainable use of marine resources. The findings from this study will also serve as a critical reference point for policymakers seeking stewardship of the marine resources of the Bay of Bengal. By focusing on the Swandip coast as a case study, this study underscores the potential of applying geospatial technologies in managing vast marine areas and resources of Bangladesh. Through a combination of advanced remote sensing tools and spatial analysis, this study will pave the way for assessing the spatial patterns of marine productivity and ensure more informed and sustainable fisheries governance in Bangladesh.

## 2. MATERIALS AND METHODS

### Study area and data collection

The study area includes a 7 km buffer zone around the Swandip island of the Bay of Bengal

(Figure 1). Landsat-08 images from 1<sup>st</sup> July, 2023 to 1<sup>st</sup> July, 2024 were acquired from USGS (United States Geological Survey) database. Table 1 gives an overview of the data used in this research. The satellite images were

imported and reprojected to the Universal Transverse Mercator (UTM) for further processing in this research.

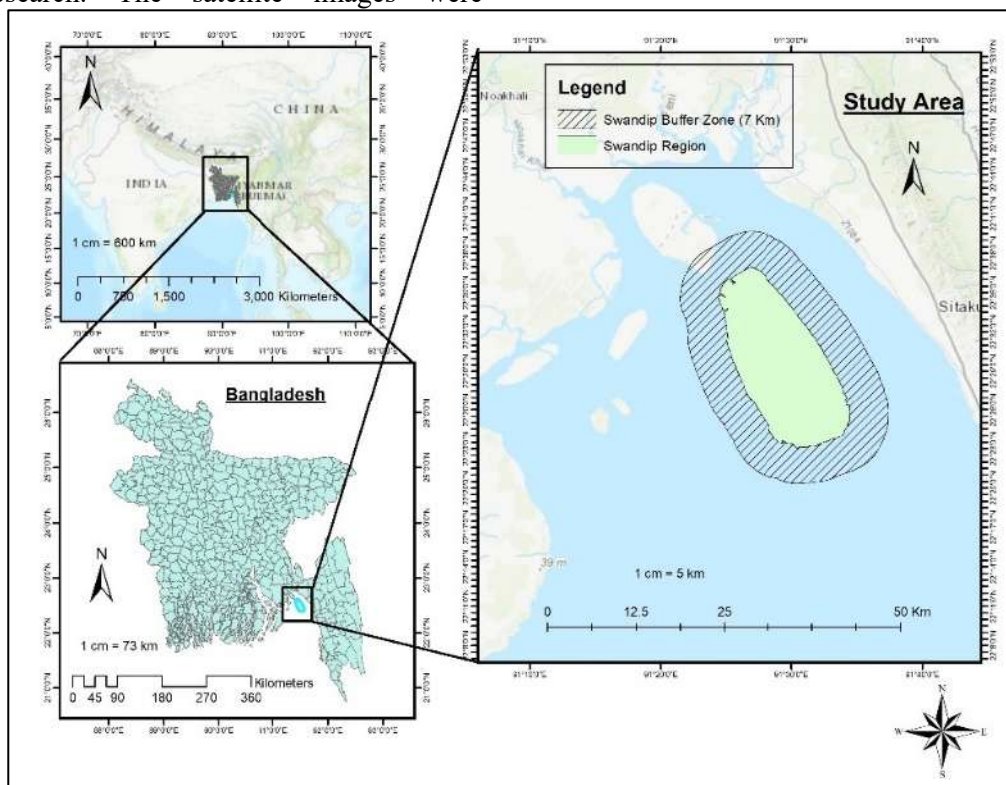


Figure 1. Study area map showing 7 km buffer zone of the Swandip island, Bay of Bengal, Bangladesh

**Image processing and variable analysis**

The satellite images were processed using ArcGIS software (10.8). Sea surface temperature, Ch-a content, and turbidity data were retrieved following image correction procedures including radiometric calibration and atmospheric adjustment for cloud filtering (0–20%). The Landsat 8 Thermal Infrared Sensor (TIRS) provided the estimated data of these variables. Landsat 8 provided the metadata of the bands such as thermal constant and rescaling factor value. The image processing and mapping were performed with the following steps and formulas:

Table 1: Satellite (Landsat 08) datasets for mapping of the productivity variables of the study area

Data Type	Sensor	Band	Wavelength	Resolution (meters)	Purpose
Satellite image	Landsat 8	Band 3	0.53 – 0.59	30	Turbidity data extraction
		Band 4	0.64 – 0.67	30	Turbidity & Chl-a data extraction
		Band 5	0.85 – 0.88	30	Chl-a data extraction
		Band 10	10.6 – 11.19	100	Sea surface temperature (SST) data extraction

First, the digital number (DN) of band 10 was converted to radiance by using Formula (1);

$$L_{\lambda} = M_L * Q_{cal} + A_L - O_i$$

Where,  $L_{\lambda}$  is the top of the atmosphere spectral radiance;  $M_L$  is the radiance multiplicative band 10;  $Q_{cal}$  is the quantized and calibrated standard product pixel values;  $A_L$  is the radiance additive

Band 10;  $O_i$  is the correction value for Band 10 (0.29).

Then,  $L_{\lambda}$  was converted to the brightness temperature (BT) with Formula (2);

$$\text{Kelvin (K) to degree Celsius (}^{\circ}\text{C)} \text{ BT} = K_2 / \ln(K_1 / L_{\lambda} + 1) - 273.15$$

Where,  $K_1$  and  $K_2$  are the thermal conversion constants from metadata.

Normalized differential vegetation index (NDVI) was calculated with formula (3).

$$\text{NDVI} = (\text{Band 5} - \text{Band 4}) / (\text{Band 5} + \text{Band 4})$$

Proportion of vegetation (PV) was computed with Formula (4) to estimate the emissivity using the maximum and the minimum values NDVI:

$$\text{PV} = ((\text{NDVI} - \text{NDVI}_{\min}) / (\text{NDVI}_{\max} - \text{NDVI}_{\min}))^2$$

Emissivity was computed using Formula (5):

$$E = 0.004 * \text{PV} + 0.986$$

The value 0.986 corresponds to the correction value of the equation and 0.004 is a constant as illustrated by USGS website.

Then, the SST map was obtained using Formula (6):

$$\text{SST} = \text{BT} / (1 + (\lambda * \text{BT} / c_2) * \ln(E))$$

Here,  $c_2$  is the radiation constant (14,388  $\mu\text{m}$ ) and  $\lambda$  represents the wavelength of the emitted radiation.

Ch-amap was extracted using band 4 and band 5 of Landsat 8 image with Formula (7):

$$\text{Ch-a} = ((\text{Band 5} + \text{Band 4}) / (\text{Band 5} - \text{Band 4}))$$

Turbidity map was extracted using band 3 and band 4 of Landsat 8 images with Formula (8):

$$\text{NDTI} = ((\text{Band 4} + \text{Band 3}) / (\text{Band 4} - \text{Band 3}))$$

Finally, overlay analysis of the Chl-a, SST, Turbidity and NDVI maps was conducted to create the potential productivity map of the 7 km buffer zone around the Swandip island.

### 3. RESULTS

#### Sea surface temperature

The sea surface temperature (SST) map around Swandip Island reveals varying water temperatures within the 7 km buffer zone. The upper limit of SST was 33.64°C and the lowest limit was 19.83°C within the study period of 1<sup>st</sup> July, 2023 to 1<sup>st</sup> July, 2024. Warmer waters (bluish to pink, 30°C to 33°C) dominate the northern to northwestern regions, covering about 20-30% of the buffer zone, indicating high surface temperatures. The southwestern to western areas show moderate temperatures (yellow to green, 25°C to 30°C), occupying around 30-40% of the area. The northeastern, eastern, and southeastern regions exhibit cooler waters (blue to purple, 19°C to 24°C), accounting for 50-60% of the buffer zone (Figure 2).

#### Chlorophyll-a

The Ch-a map around Swandip Island showed varying levels of phytoplankton concentration.

Ch-a concentrations ranged from 0.20 to 0.48 mg/m<sup>3</sup>. Moderate to high (0.30–0.39 mg/m<sup>3</sup>) Ch-a levels (green to blue) were dominant in the northern, northwestern to southwestern regions, covering about 40-50% of the buffer zone. In contrast, the northeastern, eastern to southeastern regions displayed low to moderate (0.20–0.29 mg/m<sup>3</sup>) Ch-a concentrations (yellow to green), covering 50-60% areas (Figure 3).

#### Turbidity

The turbidity map around the 7 km buffer of Swandip Island showed varying distributions ranging from 0.0446 to 0.0808 NTU

(Nephelometric turbidity unit) within the study 0.056 NTU: blue to yellowish) zones were primarily found in the eastern and southeastern regions, covering 20-30% of the buffer area. In contrast, the northern, western to southwestern

period. Low to moderate turbidity (0.0446–0.070–0.0808 NTU: yellowish to red), covering about 60-70% of the buffer zone (Figure 4).

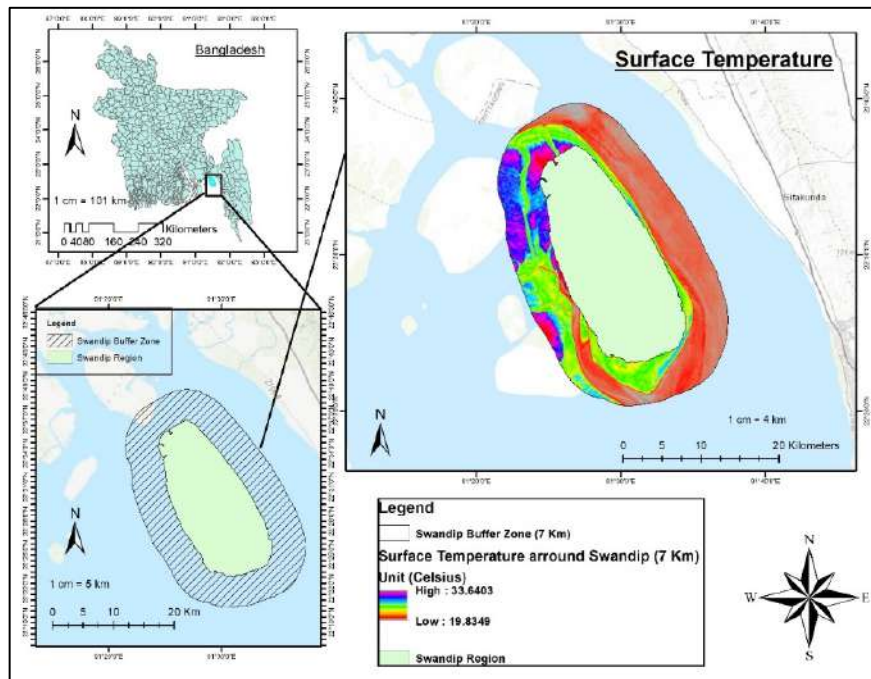


Figure 2. Status and distribution of sea surface temperature (SST) from July 2023 to July 2024 across the 7 km buffer zone of the Swamp Island, Bay of Bengal, Bangladesh.

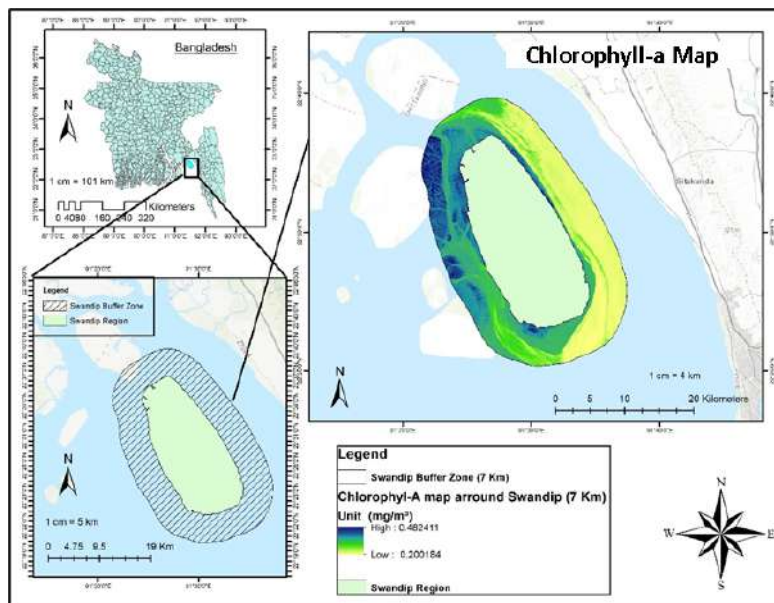


Figure 3. Status and distribution of Chlorophyll-a (Ch-a) from July 2023 to July 2024 across the 7 km buffer zone of the Swamp Island, Bay of Bengal, Bangladesh.

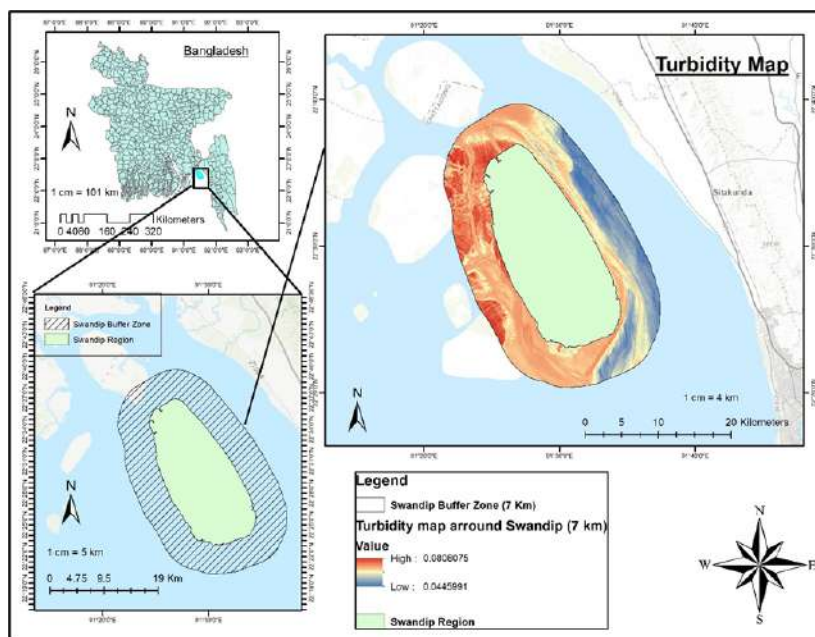


Figure 4. Status and distribution of turbidity from July 2023 to July 2024 across the 7 km buffer zone of the Swandip Island, Bay of Bengal, Bangladesh.

### Potential productive zone

The final integrated productivity map was developed by overlaying SST, Ch-a, and turbidity data to highlight regions with favorable conditions for marine productivity (Figure 4). The integrated productivity map, combining SST, Ch-a, and turbidity data, highlighted several key zones with high marine productivity. The spatial overlay analysis identified areas where ST ranged between 26°C and 28°C, Ch-a concentration exceeded 0.3 mg/m<sup>3</sup>, and turbidity values were moderate to high (0.056–0.070 NTU). The map illustrated various productivity zones surrounding the island, categorized into less productive, moderately productive, productive, and highly productive areas. The less productive zones (green) dominated in the northern, northeastern, and southeastern to south directions, covering approximately 50–60% of the total area. The moderately productive zones (blue) were concentrated primarily along the northwestern, western to southwestern coasts, with smaller stretches in the northeast, accounting for around 20–30% of the total area. The productive zones (orange) appeared in small patches, mainly in the northwestern, somewhat in the western, and to a small extent in the northeastern regions, covering about 5–10%

of the buffer area. Lastly, the highly productive zone (pink) is limited to small areas, concentrated primarily in the northwest, comprising roughly 1–2% of the total area (Figure 5).

This spatial distribution of productive zones reflected the potential for different activities based on the resource availability in these zones. The map highlighted various productivity zones that can be used for mariculture activities like fish culture in cages, shellfish culture, and seaweed culture. The highly productive and productive zones, located primarily in the northwest to southwest regions, would be the most preferable for intensive mariculture activities, such as fish culture in cages, and shellfish culture using methods like longline, bag, and raft culture. These areas could be appropriate for less intensive mariculture activities as well, such as seaweed farming but might require careful management to ensure sustainability. Finally, the less productive zones, covering much of the northeast, eastern to southeastern regions, may not be ideal for commercial mariculture due to lower productivity and the absence of suitable hydrological conditions.

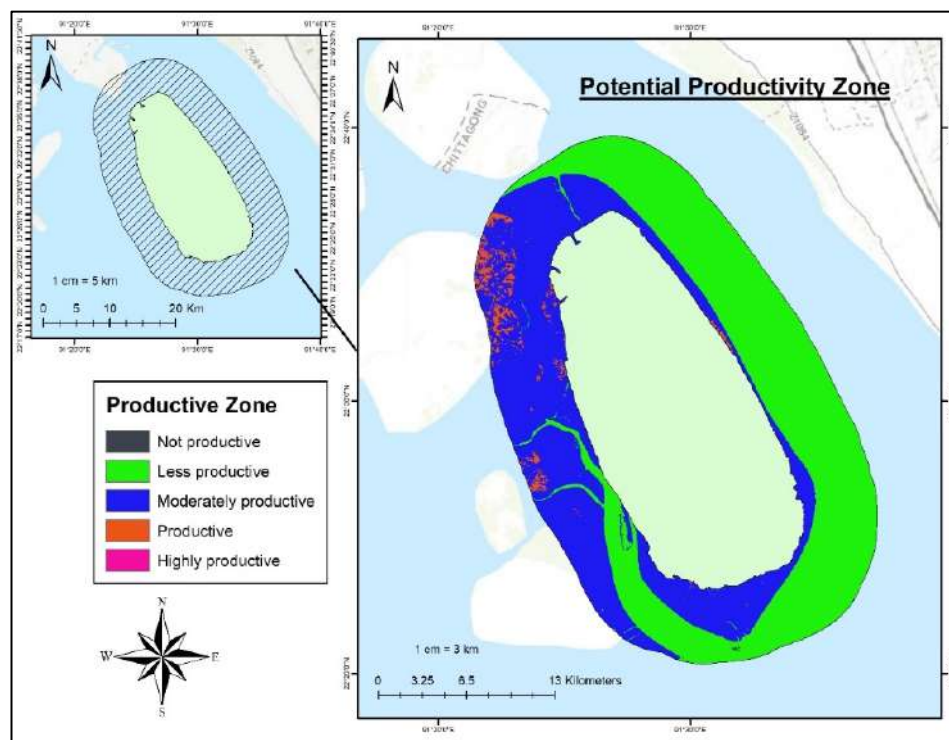


Figure 5. Productivity hotspots mapping obtained from overlay analysis of SST, Ch-a and turbidity across the 7 km buffer zone of the Swandip Island, Bay of Bengal, Bangladesh.

#### 4.DISCUSSION

The productivity mapping of the Swandip coast in the Bay of Bengal, as explored in this study, provides crucial insights into the spatial distribution of marine productivity zones, leveraging advanced geospatial analysis and remote sensing techniques. With the integration of data on turbidity, sea surface temperature (SST), and Ch-a concentration, the study offers a holistic view of the dynamic processes regulating marine productivity in the region. Understanding the interaction among these environmental factors is critical for identifying potential productivity zones, which are essential for effective fisheries management and conservation efforts (Behrenfeld & Boss, 2018). The surface temperature analysis revealed notable variations across the study area, with moderate temperatures closely associated with upwelling zones, where nutrient-rich and cooler waters rise to the surface, significantly enhancing primary productivity. This upwelling phenomenon, driven by the seasonal monsoon winds in the Bay of Bengal, plays a pivotal role in marine productivity, replenishing the surface layers with nutrients necessary for phytoplankton growth (Hou et al., 2016;

Valavanis et al., 2004) This aligns with previous studies indicating that optimal productivity often occurs in regions where nutrient upwelling coincides with favorable temperature conditions (Largier, 2020).

Another important measure studied was the concentration of Ch-a, which serves as an indicator for phytoplankton biomass. In the marine environment, places with elevated concentrations of Ch-a as a result of specific oceanographic phenomena, such as upwelling, cyclonic gyres, fronts, and eddies are referred to be productivity hotspots (Agostini and Bakun, 2002). The spatial distribution of Ch-a in this study identified critical productive zones, notably those near coastal areas. Moderate to high ( $0.40\text{--}0.48\text{ mg/m}^3$ ) quantities of Ch-a were found in locations with regular phytoplankton blooms, which are essential for supporting higher trophic levels, including commercially significant fish populations. The well-established relationship between Ch-a and fisheries productivity supports these findings, as regions with high Ch-a concentrations are often linked to abundant fish stocks (Behrenfeld & Falkowski, 1997; Cai et al., 2022; Gao et al., 2022). The variability in Ch-a concentrations

found in this study highlights the dynamic character of coastal productivity, which is impacted by both natural processes like tidal mixing and human activities like nutrient runoff. Turbidity, a gauge of the concentration of suspended particles in the water column, has a twofold impact on marine production (Ramsey et al., 2025). Moderate turbidity levels (0.0446–0.056 NTU), especially in nearshore locations, are indicative of nutrient-rich environments where suspended sediments contribute to nutrient availability for primary producers (Cloern, 1987).

However, excessively high turbidity can reduce light penetration, limiting the photosynthetic activity of phytoplankton and thus reducing primary productivity (Cloern & Jassby, 2008). In this study, the moderate to higher (0.056–0.080 NTU) turbidity levels were recorded near coastal regions, which also corresponded to areas with higher Ch-a concentrations (0.40–0.48 mg/m<sup>3</sup>), confirming their role as productive zones. The correlation between turbidity and productivity highlights the complexity of these environments and their capacity to support both primary production and fisheries resources (Sarma et al., 2013).

The study on the Swandip coast aligns with prior research in identifying productive marine zones using remote sensing and GIS techniques. Nath et al. (2000) used GIS to evaluate potential mariculture sites in India, employing a multi-criteria decision approach similar to this study, but with a broader environmental focus, while the Swandip study uniquely emphasized the role of SST, Ch-a, and turbidity in coastal productivity. Similarly, Jha et al., (2017) identified mariculture hotspots using SST and Ch-a data. Vivekanandan & Krishnakumar (2010) also confirmed the link between Ch-a and fisheries productivity, paralleling the findings of this study. These pieces of evidence and comparisons underscore the importance of GIS and remote sensing in sustainable fisheries management and mariculture development

## 5. CONCLUSION

The findings of this study underscore the variability in semen quality across different

cocks, but overall, the results demonstrate that the majority of the cocks produced high-quality semen with excellent motility and favorable biokinetic characteristics. The total motility, progressive motility, and other sperm parameters were generally well within the desirable range for successful fertilization. This study clearly indicates that the abdominal massage method is an effective and reliable technique for collecting RJF semen. Not only does this method ensure optimal semen quality, but it also provides a sufficient quantity for semen storage and artificial insemination. These advancements offer a promising approach for increasing the population of RJF through more efficient breeding practices.

## REFERENCES

- Agostini, V. N., & Bakun, A. (2002). “Ocean triads” in the Mediterranean Sea: Physical mechanisms potentially structuring reproductive habitat suitability (with example application to European anchovy, *Engraulis encrasicolus*). *Fisheries Oceanography*, 11(3), 129–142. <https://doi.org/10.1046/j.1365-2419.2002.00201.x>
- Ahmad, H., Jose, F., Islam, M. S., & Jhara, S. I. (2023). Green energy, blue economy: Integrating renewable energy and sustainable development for Bangladesh. *Marine Technology Society Journal*, 57(4), 52–69. <https://doi.org/10.4031/MTSJ.57.4.4>
- Behrenfeld, M. J., & Boss, E. S. (2018). Student’s tutorial on bloom hypotheses in the context of phytoplankton annual cycles. *Global Change Biology*, 24(1), 55–77. <https://doi.org/10.1111/gcb.13858>
- Behrenfeld, M. J., & Falkowski, P. G. (1997). Photosynthetic rates derived from satellite - based chlorophyll concentration. *Limnology and Oceanography*, 42(1), 1–20. <https://doi.org/10.4319/lo.1997.42.1.0001>
- Cai, L., Tang, R., Yan, X., Zhou, Y., Jiang, J., & Yu, M. (2022). The spatial-temporal consistency of chlorophyll-a and fishery resources in the waters of the Zhoushan Archipelago revealed by high-resolution remote sensing. *Frontiers in Marine Science*, 9, 1022375.

- Cloern, J. E. (1987). Turbidity as a control on phytoplankton biomass and productivity in estuaries. *Continental Shelf Research*, 7(11–12), 1367–1381.
- Cloern, J. E., & Jassby, A. D. (2008). Complex seasonal patterns of primary producers at the land–sea interface. *Ecology Letters*, 11(12), 1294–1303.
- Estes Jr, M., Anderson, C., Appeltans, W., Bax, N., Bednaršek, N., Canonico, G., ... & Weatherdon, L. V. (2021). Enhanced monitoring of life in the sea is a critical component of conservation management and sustainable economic growth. *Marine Policy*, 132, 104699. <https://doi.org/10.1016/j.marpol.2021.104699>
- Gao, S., Ren, S., Xie, B., Zhang, S., Lu, J., & Fu, G. (2022). Interaction between sea surface chlorophyll-a and seawater indicators in the sea ranching area: A case study in Haizhou Bay. *Regional Studies in Marine Science*, 56, 102687.
- Hou, X., Dong, Q., Xue, C., & Wu, S. (2016). Seasonal and interannual variability of Ch-a and associated physical synchronous variability in the western tropical Pacific. *Journal of Marine Systems*, 158, 59–71. <https://doi.org/10.1016/j.jmarsys.2016.01.008>
- Jha, D. K., Rajaprabhu, G., Kirubakaran, R., Sendhil Kumar, R., Dharani, G., Das, A., Gopinath, G., & Santhanakumar, J. (2017). Estimation of potential zones for offshore mariculture in the Indian Sea using geographical information system as a management tool. *Journal of Coastal Conservation*, 21(6), 893–902. <https://doi.org/10.1007/s11852-017-0556-y>
- Kay, S., Caesar, J., & Janes, T. (2018). Marine dynamics and productivity in the Bay of Bengal. *Journal Name, Volume (Issue)*, 263-275.
- Largier, J. L. (2020). Upwelling bays: How coastal upwelling controls circulation, habitat, and productivity in bays. *Annual Review of Marine Science*, 12(1), 415–447.
- Moradi, M., & Moradi, N. (2020). Correlation between concentrations of Ch-a and satellite derived climatic factors in the Persian Gulf. *Marine Pollution Bulletin*, 161, 111728. <https://doi.org/10.1016/j.marpolbul.2020.111728>
- Nath, S. S., Bolte, J. P., Ross, L. G., & Aguilar-Manjarrez, J. (2000). Applications of geographical information systems (GIS) for spatial decision support in aquaculture. *Aquacultural Engineering*, 23(1–3), 233–278.
- Ramsey, R. D., Brothers, S. M., Cobo, M., & Wurtsbaugh, W. A. (2025). Spatiotemporal patterns of chlorophyll-a concentration in a hypersaline lake using high temporal resolution remotely sensed imagery. *Remote Sensing*, 17(3), 430.
- Sarma, V. V. S. S., Sridevi, B., Maneesha, K., Sridevi, T., Naidu, S. A., Prasad, V. R., Venkataramana, V., Acharya, T., Bharati, M. D., Subbaiah, Ch. V., Kiran, B. S., Reddy, N. P. C., Sarma, V. V., Sadhuram, Y., & Murty, T. V. R. (2013). Impact of atmospheric and physical forcings on biogeochemical cycling of dissolved oxygen and nutrients in the coastal Bay of Bengal. *Journal of Oceanography*, 69(2), 229–243. <https://doi.org/10.1007/s10872-012-0168-y>
- Schwartz-Belkin, I., & Portman, M. E. (2023). A review of geospatial technologies for improving marine spatial planning: Challenges and opportunities. *Ocean & Coastal Management*, 231, 106280. <https://doi.org/10.1016/j.ocecoaman.2022.106280>
- Shamsuzzaman, M. M., Xiangmin, X., Islam, M. M., Alam, M. W., & Karim, E. (2017). Sustainable marine fisheries resources of Bangladesh: A strategic response for economic security.
- Tora, A. T., Hasan, J., & Shaha, D. C. (2022). Marine fisheries resources in Bangladesh: Present status and future prospects. *Frontiers in Marine Science*, 134, 66-67.
- Valavanis, V. D., Kapantagakis, A., Katara, I., & Palialaxis, A. (2004). Critical regions: A GIS-based model of marine productivity hotspots. *Aquatic Sciences*, 66, 139-148. <https://doi.org/10.1007/s00027-003-0669-2>
- Vivekanandan, E., & Krishnakumar, P. (2010). Spatial and temporal differences in the coastal fisheries along the east coast of India. *Indian Journal of Marine Sciences*, 39, 380–387.