Algae Assemblages of Andaman and Nicobar Islands

EH-612: Project Report

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1 Introduction

The Andaman and Nicobar Islands, in the Bay of Bengal, are known for their rich terrestrial and marine Biodiversity. Andaman and Nicobar Islands are a broken row of continuous islands from north to south with latitudes varying between 6° and 14° North and longitudes varying between 92° and 94° East. Among the various forms of marine life, algae play an important role in the ecosystem dynamics of these islands. Algae contain a wide array of photosynthetic organisms, varying from the microscopic scale (single-celled forms) to large, multicellular seaweeds. They refer to an assemblage of polyphyletic organisms that conduct oxygen-evolving photosynthesis other than land plants. They are omnipresent in the sea, freshwater, and moisture-rich land environments. They are essential components of marine ecosystems, contributing significantly to primary production, nutrient cycling, and habitat formation.

1.1 Diversity of Algae:

The Andaman and Nicobar Islands harbour a diverse array of algal species due to the favourable environmental conditions prevalent in the region. The warm tropical waters, high levels of sunlight, and nutrient-rich marine currents create an ideal habitat for the growth and proliferation of various algal taxa. These include but are not limited to:

- Macroalgae: Large seaweeds such as kelps, red algae (Rhodophyta), brown algae (Phaeophyta), and green algae (Chlorophyta) are commonly found along the rocky shores and coral reefs of the islands.

- Microalgae: Microscopic algae such as diatoms, dinoflagellates, and cyanobacteria thrive in the nutrient-rich waters surrounding the islands, contributinging significantly to primary production and serving as food sources for various marine organisms.

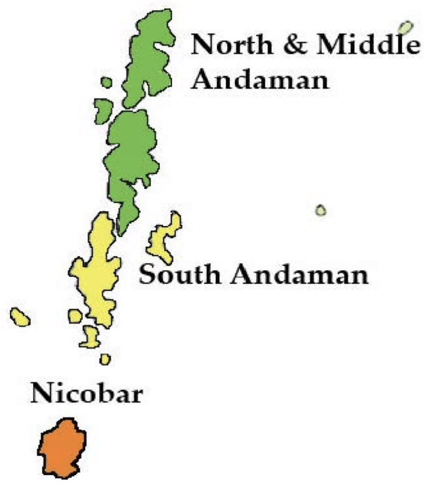

Figure 1: Andaman and Nicobar islands

1.2 Ecological Significance:

Algae have a crucial role in maintaining the ecological balance of marine ecosystems in the Andaman and Nicobar Islands. They serve as primary producers, converting solar energy into organic matter through photosynthesis, forming the marine food web base. Additionally, certain algal species provide habitat and refuge for many marine organisms, including fish, invertebrates, and other algae.
Algae also contribute to nutrient cycling by absorbing and recycling essential nutrients like nitrogen and phosphorus, which are crucial for the growth of other marine organisms. Algal blooms, although sometimes detrimental due to excessive growth, also serve as indicators of water quality and can help in identifying environmental changes and potential threats to marine ecosystems.

1.3 Economic Importance:

Algae have significant economic importance for the local communities in the Andaman and Nicobar Islands. Certain species of seaweeds are harvested for various purposes, including:

- Food: Edible seaweeds such as Nori (Porphyra) and Sargassum are consumed by local populations and also have commercial value.
- Pharmaceuticals: Algae are a potential source of bioactive compounds with pharmaceutical applications, including antibacterial, antiviral, and anticancer properties.

- Agar and Carrageenan: Some species of red algae are cultivated to extract agar and carrageenan. They are used as gelling agents in the food and pharmaceutical industries.

1.4 Conservation Challenges:

Despite their ecological and economic importance, algae in the Andaman and Nicobar Islands face various conservation challenges, including habitat degradation, overexploitation, and climate change. Coastal development, deforestation, and unsustainable fishing practices can destroy algal habitats and loss of Biodiversity. Additionally, rising sea temperatures and ocean acidification in relation to climate change pose significant threats to the certain algal populations and coral reefs.
Pollution is another critical issue facing algae in these islands. Industrial discharge, sewage runoff, agricultural runoff, and plastic pollution introduce harmful substances and debris into marine environments. These pollutants can harm algal communities directly, disrupt their growth and reproduction, and contribute to algal blooms that can have detrimental effects on marine life and water quality.

2 Methods

Research on algae in the Andaman and Nicobar Islands typically involves a multifaceted approach encompassing field surveys, specimen collection, laboratory analysis, and data interpretation. Scientists utilize various techniques, including microscopy, DNA sequencing, and ecological modelling, to comprehensively study algae populations and their environmental interactions.

- Field Surveys and Specimen Collection: Field surveys serve as the foundation for algae research in the Andaman and Nicobar Islands. Scientists conduct extensive surveys along the coastlines, coral reefs, and mangrove ecosystems to document the diversity and distribution of algal species. During these surveys, researchers collect specimens representing different algae taxa, including macroalgae (seaweeds) and microalgae (phytoplankton), using various sampling methods such as quadrats, transects, and plankton nets. Careful documentation of environmental parameters such as water temperature, salinity, pH, and nutrient levels accompanies specimen collection to provide context for subsequent laboratory analyses.

- Laboratory Analysis: Upon collection, algae specimens undergo rigorous laboratory analysis to characterize their morphological, physiological, and genetic traits. Microscopic examination of algae samples allows scientists to identify species based on morphological features such as cell shape, size, pigmentation, and reproductive structures. Additionally, molecular techniques such as DNA sequencing elucidate algal taxa's genetic diversity and phylogenetic relationships. Chemical analysis of algae samples may also be conducted to assess their biochemical composition, including the presence of secondary metabolites with potential pharmaceutical or industrial applications.

- Data Interpretation and Ecological Modeling: Data generated from field surveys and laboratory analyses are integrated and interpreted to gain insights into the ecology and dynamics of algal communities in the Andaman and Nicobar Islands. Researchers use statistical methods to analyze species abundance, distribution patterns, and environmental correlations. Ecological modelling techniques, such as species distribution modelling and food web analysis are employed to simulate and predict the responses of algal populations to environmental changes, including anthropogenic impacts and climate variability. These modelling efforts contribute to our understanding of algae's roles in marine ecosystems and their resilience to environmental stressors.

3 Algae Diversity in Andaman

The Andaman and Nicobar Islands is a beacon of remarkable Biodiversity, with a rich tapestry of algae species adorning its coastal waters. This diversity encompasses a spectrum of green, red, and brown algae, each contributing uniquely to the marine ecosystem dynamics of the region. The confluence of diverse environmental factors, such as warm tropical waters, nutrient-rich currents, and complex geological formations, fosters an environment conducive to the proliferation of a multitude of algae taxa, thereby enriching the marine Biodiversity of the islands.

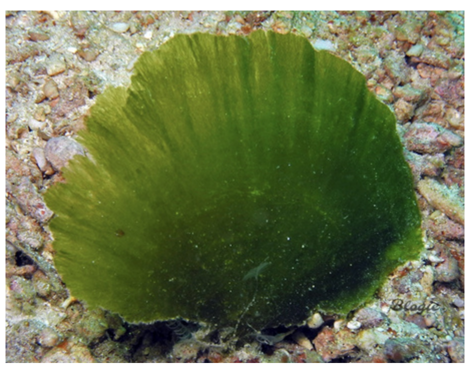

Figure 2: Green Algae

- Green Algae (Chlorophyta): Green algae, characterized by their chlorophyll-rich chloroplasts, thrive in the sunlit waters surrounding the Andaman and Nicobar Islands. Members of the Chlorophyta phylum, such as Ulva, Enteromorpha, and Codium, are commonly found along the islands' rocky shores and intertidal zones. These macroalgae form extensive mats and tufts, providing habitats for diverse marine organisms and contributing to the coastal ecosystem's productivity.

In 2019, Indian scientists stumbled upon a novel discovery in the waters surrounding the Andaman and Nicobar Islands: a previously unknown species of green algae. This newfound organism, dubbed "Acetabularia jalakanyakae", derived its name from Sanskrit, translating to "mermaid," owing to the uncanny resemblance of its umbrella-like algae to delicate parasols. What sets this species apart is its biological makeup: each. An umbrella-shaped structure represents a single colossal cell housing a solitary nucleus at the base of its root-like appendages. This intriguing find sheds light on the remarkable diversity of marine life in the Andaman Sea.

Figure 3: Acetabularia jalakanyakae

- Red Algae (Rhodophyta): The vibrant hues of red algae paint the underwater landscape of the Andaman Sea, adding splashes of colour to coral reefs and rocky substrates.

Figure 4: Red Algae

Species belonging to the Rhodophyta phylum, such as Gracilaria, Gelidiella, and Laurencia, are prevalent in the region. These red algae exhibit a wide range of morphological forms, from delicate filamentous species to robust calcareous encrusting forms, each having a significant job in many processes, such as nutrient cycling and sediment stabilization.

- Brown Algae (Phaeophyta): Brown algae, renowned for their characteristic brown pigments and complex thallus structures, form an integral part of the Andaman and Nicobar Islands' algal community. Members of the Phaeophyta phylum, including Sargassum, Padina, and Turbinaria, dominate the subtidal zones and shallow reef areas. These macroalgae possess unique adaptations to turbulent wave action and fluctuating environment conditions, contributing to the resilience and stability of nearshore ecosystems.

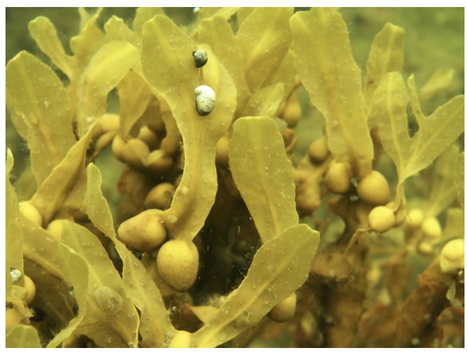

Figure 5: Brown Algae

The diversity of algae in the Andaman and Nicobar Islands serves as a testament to the region's ecological richness and underscores the importance of conserving these invaluable marine resources. Efforts to understand and preserve algal diversity are crucial for maintaining the integrity of coastal ecosystems and sustaining the livelihoods of local communities dependent on marine resources.

4 Factors Influencing Algae Growth

Climate change is a global phenomenon that poses a significant threat to marine ecosystems. Consequences of climate change include ocean acidification and increased seawater temperatures, which can have profound effects on marine life.

4.1 Ocean Acidification

Ocean acidification poses significant challenges to algae, impacting their growth and photosynthesis efficiency. While initially benefiting from increased CO2 availability, prolonged exposure to lower pH levels can disrupt enzyme activities crucial for photosynthesis, affecting carbon uptake and metabolic processes. Calcifying algae, like coralline algae, may suffer reduced calcification rates, altering their structural integrity and habitat suitability.

However, it's important to note that not all algae respond equally to ocean acidification. Some species, especially those adapted to highly variable environments, demonstrate relative resilience to changes in pH and temperature. Studies have shown that certain macroalgae can maintain their physiological functions and even show increased quantum yield under extreme acidification conditions, such as a pH decrease of -0.9. For instance, Tricleocarpa cylindrica exhibited higher Fv/Fm values under extreme acidification, indicating a potential adaptation to acidified waters.

Despite these findings, the overall impact of ocean acidification on algae populations and marine ecosystems remains a complex and ongoing area of research. Understanding how different algal species respond to acidification and other environmental stressors is crucial for predicting future ecological shifts and implementing effective conservation and management strategies.

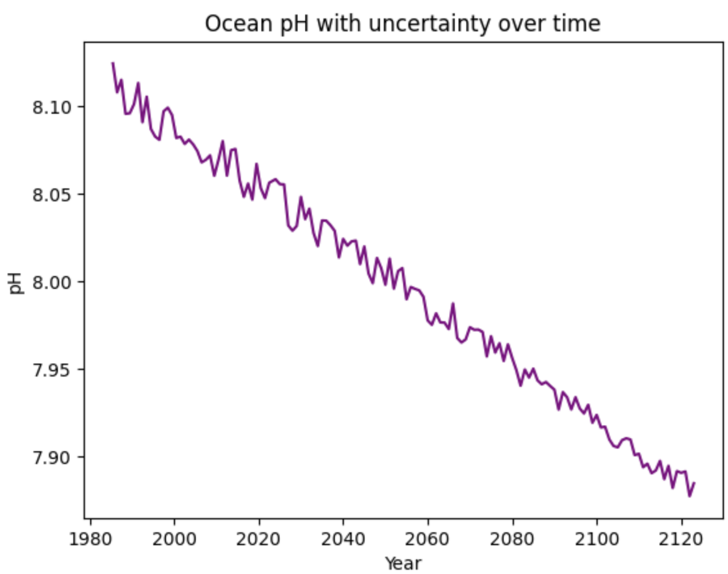

Figure 6: Predicted Ocean pH with uncertainty using the copernicus marine dataset and Linear Regression model.

The parameters Fv/Fm (maximum quantum yield of photosystem II) and Max ETR (maximum electron transport rate) are key indicators of photosynthetic efficiency in algae, directly influencing their growth and overall productivity. Fv/Fm represents the maximum efficiency at which algae can convert light energy into chemical energy during photosynthesis.It represents the ratio

of variable fluorescence (Fv) to maximum fluorescence (Fm) emitted by chlorophyll molecules in response to light stimuli. A higher Fv/Fm value indicates that algae are effectively utilizing light energy for photosynthesis, while a lower value may suggest stress or limitations in photosynthetic activity.
Max ETR measures the maximum rate at which electrons are transferred through the photosynthetic electron transport chain, reflecting the capacity of algae to convert light energy into biochemical energy. Algae with higher Max ETR values can efficiently utilize available light energy for photosynthesis and metabolic processes, leading to enhanced growth rates and productivity.
Results showed an increase in optimum quantum yield in T. cylindrica under extreme acidification (-0.9 pH), while coralline algae experienced a decline in this parameter. Following are the results for different species of algae.

- Coralline Algae: Showed lower Fv/Fm values at extreme acidification (T(-0.9)) compared to other treatments.
- Tricleocarpa cylindrica: Presented higher Fv/Fm values at extreme acidification (T(-0.9)) compared to normal pH (T(0)).
- Frondose Algae (Halimeda cuneata and Padina gymnospora): Did not show significant effects on Fv/Fm values under different pH treatments.

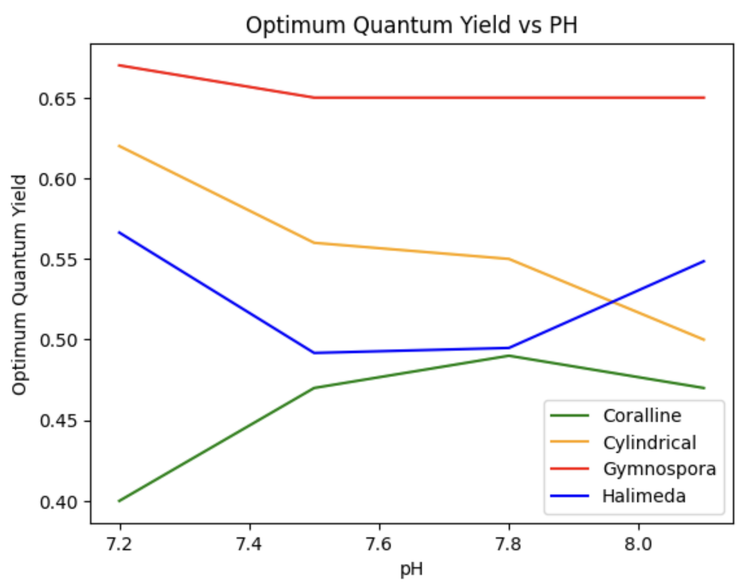

Figure 7: Variation of Optimum Quantum Yield (Fv/Fm) with uncertainty and varying pH.

Resilience in marine organisms can vary based on their structural composition and physiological mechanisms. Phytoplankton, with their shell or tests made of carbonate, tend to have lower resilience compared to algae in the context of ocean acidification. The carbonate shells of phytoplankton, such as foraminifera or coccolithophores, are directly exposed to seawater chemistry changes. As ocean acidity increases, these carbonate structures can dissolve or become more vulnerable to damage, affecting the organisms' survival and population dynamics.

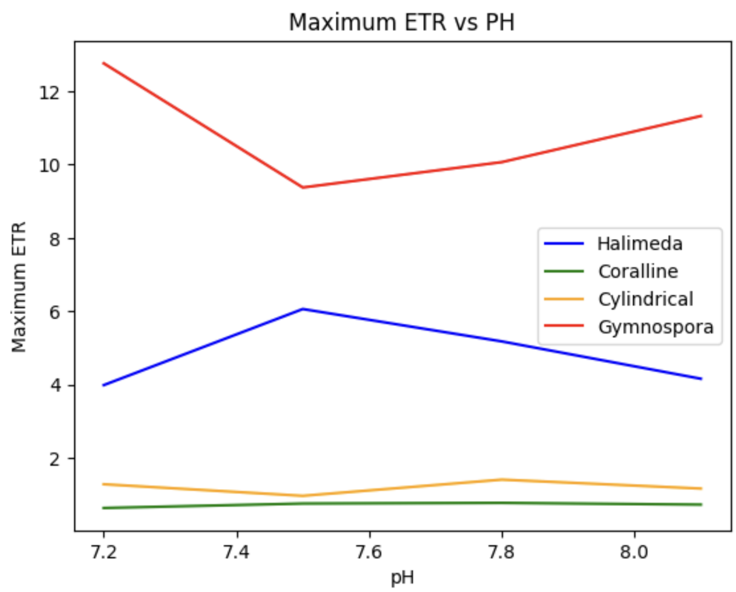

Figure 8: Variation of Maimum Electron Transport Rate (ETR) with uncertainty and varying pH.

On the other hand, algae, especially calcifying macroalgae like Halimeda cuneata and Padina gymnospora, have a different resilience mechanism. Their carbonate structures are embedded within their tissues, providing a certain level of protection against external changes in seawater chemistry. While they can still be impacted by ocean acidification, their internal carbonate structures are less directly exposed compared to phytoplankton shells. This structural difference contributes to the relatively higher resilience of calcifying macroalgae compared to carbonate-based phytoplankton in the face of ocean acidification.

4.2 Changes in different sources of carbonates with varying pH

Carbonate species, including bicarbonate (HCO3-) and carbonate (CO32-), play a crucial role in regulating pH and carbonate chemistry in seawater. As pH decreases (becomes more acidic), the distribution of these carbonate species

shifts, affecting the availability of carbonate ions that are essential for calcifying organisms and certain algal species.
For algae, especially those that rely on carbonate ions for calcification or as a carbon source for photosynthesis, changes in carbonate chemistry due to lower pH can have significant implications. Reduced availability of carbonate ions can hinder the ability of calcifying algae, such as coralline algae, to build and maintain their calcium carbonate structures, impacting their structural integrity and habitat suitability. This can indirectly affect the overall ecosystem as these algae provide important habitats for other marine organisms.

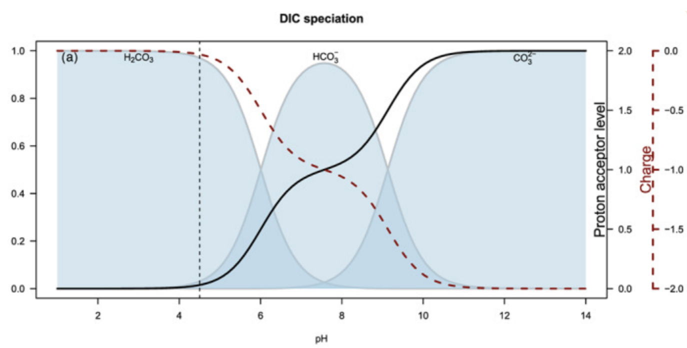

Figure 9: Bjerrum plot showing the distribution of carbonic acid, bicarbonate, and carbonate as a function of pH

The Bjerrum plot can also illustrate how changes in carbonate chemistry can influence the seawater's buffering capacity. A decrease in pH shifts the equilibrium towards more dissolved CO2 and bicarbonate ions, which can affect the balance of ions and nutrients crucial for algal growth and metabolic processes. Algae rely on a stable chemical environment for efficient photosynthesis, and disruptions in carbonate chemistry can lead to physiological stress and reduced photosynthetic efficiency.

4.3 Rising Seawater Temperatures

While certain species such as H. cuneata may respond sensitively to temperature changes within specific ranges, others like coralline algae, T. cylindrica, and P. gymnospora demonstrate resilience or insensitivity. This diversity highlights how habitat and adaptation mechanisms play a crucial role in how algae manage climate variations. The following figure shows variation of seawater temperature over the years.

Following are the results for the different species of algae.

- Coralline Algae: Photosynthetic Response to Temperature: Showed no significant effects on Fv/Fm values with higher temperatures during the

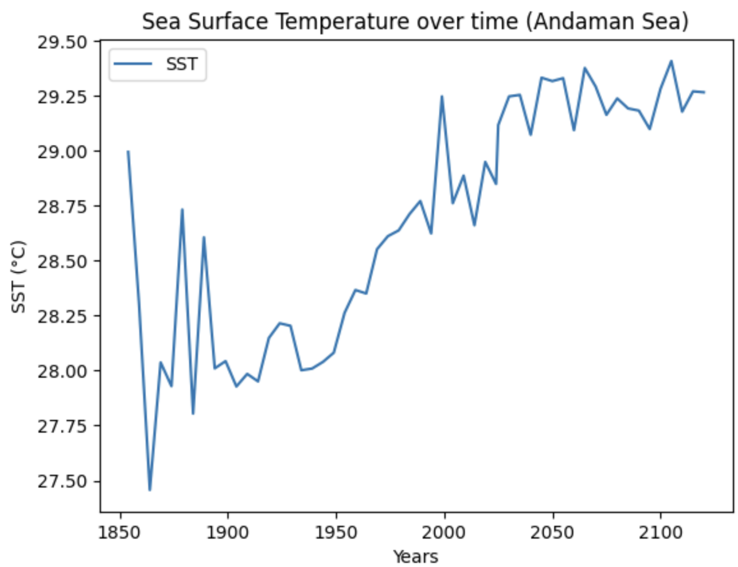

Figure 10: Predicted rise in Sea surface Temperatures over the years using the NOAA ERSST dataset and Autoregressive Integrated Moving Average model.

experimental period. Coralline algae demonstrated adaptability to variations in temperature, showing no significant photosynthetic responses to temperature rises, in line with other studies. Their physiological robustness may be due to adaptation to highly variable environments like rocky pools.

- Tricleocarpa cylindrica: Photosynthetic Response to Temperature: No significant effects on Fv/Fm values were observed with higher temperatures. T. cylindrica displayed resilience to temperature changes, aligning with the adaptability of many species to temperature variations.

- Padina gymnospora: Photosynthetic Response to Temperature: Similar to T. cylindrica and coralline algae, showed no significant effects on Fv/Fm values with higher temperatures. P. gymnospora exhibited insensitivity to temperature variations, likely indicating adaptation or acclimation to the intertidal region's variable environment.

- Halimeda cuneata:

  Photosynthetic Response to Temperature: Presented significantly higher Fv/Fm values at +1°C compared to control and +4.5°C treatments. H. cuneata showed enhanced photosynthetic responses at modest temperature increases, reflective of its affinity to tropical conditions. However, excessively high temperatures led to lower Fv/Fm values, suggesting a reversal of positive responses. This indicates that biogeographical shifts

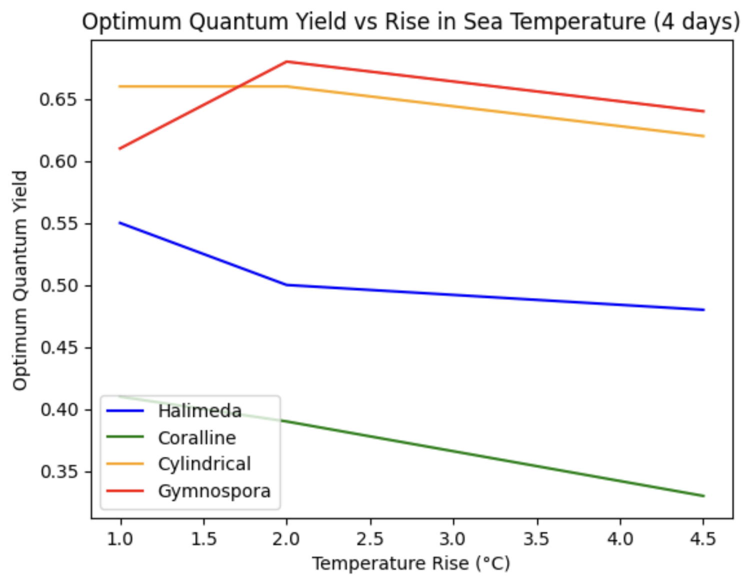

Figure 11: Variation of Optimum Quantum Yield vs Rise in Seawater Temperature after 4 days from the experiment.

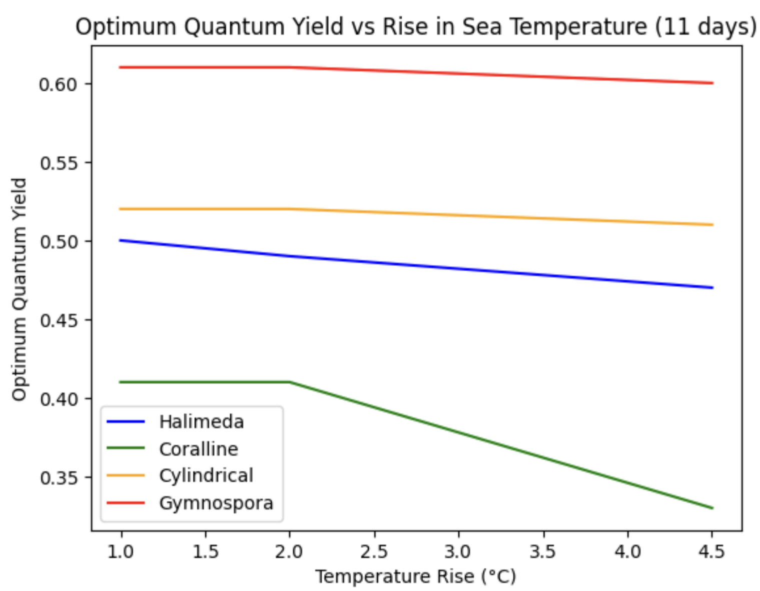

Figure 12: Variation of Optimum Quantum Yield vs Rise in Seawater Temperature after 11 days from the experiment.

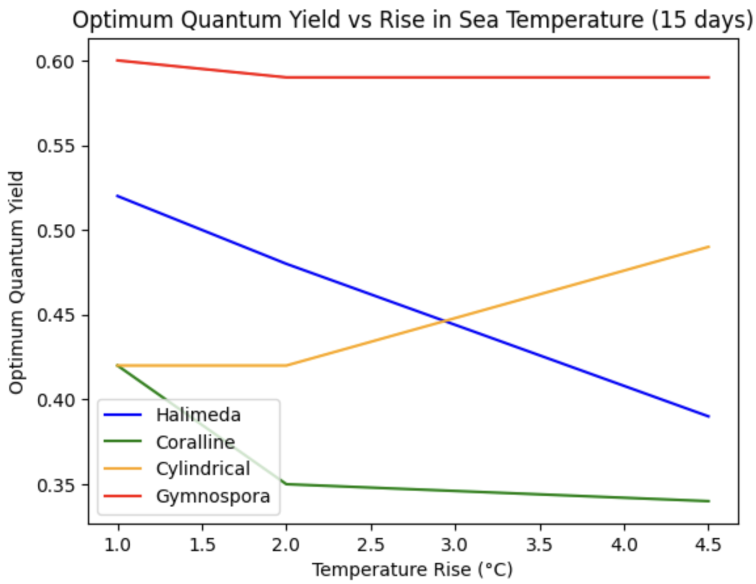

Figure 13: Variation of Optimum Quantum Yield vs Rise in Seawater Temperature after 15 days from the experiment.

may occur if temperature increases exceed species limits for physiological performance.

5 Algal Blooms and Harmful Algal Species

Algal blooms are a recurring phenomenon in the Andaman Sea, influenced by seasonal changes and anthropogenic activities. These blooms are often fueled by an influx of nutrients, primarily nitrogen and phosphorus, from sources such as agricultural runoff, sewage discharge, and natural upwelling events. The nutrient enrichment leads to rapid algal growth, particularly of phytoplankton species like diatoms, dinoflagellates, and cyanobacteria. While some blooms are part of the natural ecological cycle, others can become detrimental, causing "red tides" or discoloration of water due to the proliferation of certain pigmented algae species. These blooms can deplete oxygen levels in the water column as algae undergo rapid photosynthesis, leading to hypoxic conditions that stress marine organisms and may result in fish kills and coral reef degradation.

Harmful algal species (HABs) pose significant challenges in the Andaman Sea, with several species known for their toxin production and ecological disruptions. Dinoflagellates like Karenia brevis and Alexandrium spp. can produce potent neurotoxins causing paralytic shellfish poisoning (PSP) and other seafood-related illnesses such as ciguatera poisoning. Diatoms such as Pseudo-

Figure 14: Example of Harmful Algae found in Andaman and Nicobar Islands

nitzschia can produce domoic acid, leading to amnesic shellfish poisoning (ASP). These toxins can bioaccumulate in shellfish and other marine organisms, posing risks to human health when consumed. Monitoring programs in the Andaman region often employ phytoplankton sampling and toxin analysis to detect the presence of harmful species and assess potential risks to seafood safety. Additionally, research efforts focus on understanding the environmental factors that trigger toxin production in HABs, including nutrient levels, water temperature, and salinity gradients.

6 Conclusion

Conclusively, the varied responses of algae species to environmental stressors like acidification and temperature rises provide crucial insights into the adaptability and resilience of algae assemblages, including those in the Andaman region. The observed differences in sensitivity among species, such as the notable changes in H. cuneata compared to the resilience of coralline algae, T. cylindrica, and P. gymnospora, highlight the intricate dynamics within these assemblages.

From a conservation perspective, understanding these nuanced responses is vital for guiding conservation efforts in the Andaman region and similar coastal ecosystems. It underscores the significance of protecting diverse algae species assemblages due to their substantial contributions to marine biodiversity and ecosystem functions. Conservation strategies should take into account not only the broader impacts of climate change but also the specific vulnerabilities and adaptations of individual species within these assemblages.

Moreover, these findings stress the ongoing necessity for monitoring and research to track long-term changes in algae populations and their responses to ongoing environmental changes. This knowledge is critical for informing adaptive management strategies aimed at preserving the ecological integrity and resilience of marine ecosystems, particularly in regions like the Andaman Islands where diverse and unique algae assemblages flourish.

7 References

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