# CLASSIFICATION AND IDENTIFICATION OF MARINE ALGAL DIVERSITY IN MUMBAI

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## *Abstract*

This study explores the biodiversity of marine algae along the coastal areas of Mumbai, India. Algae, as primary producers, play a critical role in marine ecosystems, supporting the food chain and contributing to carbon fixation and oxygen production. Samples were collected from six locations, including Manori Beach, Juhu Koliwada, and Marine Drive, to assess the diversity and abundance of algal species. The study identified six main divisions of algae, with Bacillariophytes (diatoms) being the most dominant group. Quantitative methods such as Simpson's Diversity Index and Shannon-Wiener Diversity Index were employed to analyse species richness and evenness. Results showed moderate to high algal diversity across the studied sites. Despite urbanization and pollution, certain algal species have adapted to thrive in challenging environments. The findings underscore the ecological importance of algae and highlight the impact of human activities on marine biodiversity. This research provides essential insights for biodiversity conservation and marine ecosystem management.

***Keywords: -***
Marine algae diversity, Classification and Identification, Simpson's Diversity Index, Shannon-Wiener Diversity Index, Mumbai coast, pollution impact.

## Introduction

The study of algae is referred to as the Algology of Phycology. Algae are considered to have evolved early on earth based on fossil records from Precambrian periods and also from Proterozoic and Cambrian periods (Ambhore & Whankatte, 2016). Algae are the simplest chlorophyllous forms found on the Earth. They belong to a division called Thallophyta of the plant kingdom. They are simple creatures, without differentiation into roots, stems, and leaves. Their sexual organs are not enclosed within protective coverings. Algae are the most common marine vegetation commonly called "Seaweeds". They are classified into Blue-green (Cyanophyta), Green (Chlorophyta), Brown (Phaeophyta) and Red (Rhodophyta). Seaweeds play an important role in marine food chains (Patil, 2024).

They exist in different sizes and shapes. The size of marine algae varies from microscopic cells to huge plants more than 700 feet as in the case of Laminaria and Macrocystis. Algae represents more than any other aquatic plant species with about 1,50,000 of algal species found in the intertidal zones and tropical waters of the oceans and other freshwater resources (Gouda et al., 2015). The ocean covers about 70% of earth surface and therefore marine algae are primary producer, sustain the entire ecosystem. The occurrence of algae could vary at different locations due to change in seasons or the number of pollutants let out through the different sources.

Tropical conditions as the one existing in India are favourable for their growth (Handa & Jadhav, 2016). Algae is many times responsible for water pollution, water reservoirs caution of phosphate and other pollutants has the rich amount of domestic sewage result in algal blooms containing species of Oscillatoria, Chlorella, Microcystis, Closterium and Diatoms, and other planktonic algal wise a dusty water smell in the water (Rathod et al., n.d.). Hence, they are very useful pollution indicators. (Ambhore & Whankatte, 2016).

Marine algae produce biogenic compounds (such as halogenated compounds, alcohols, aldehydes, terpenoids) with pharmacological importance. Seaweeds are the only source for the production of phytochemicals such as agar (China grass), carrageenan and algin. The phytochemicals from seaweeds were used as gelling, stabilizing and thickening agents in food, pharmaceutical, confectionary, dairy, textiles, paper, paint, varnish industries, etc. (Pawar, 2017).

The diversity of algae, encompassing a wide range of morphological, physiological, and ecological characteristics, reflects their adaptability to various environmental conditions. This diversity is not only crucial for the stability and resilience of aquatic ecosystems but also for supporting the biodiversity of other organisms, including fish, invertebrates, and microorganisms that rely on algae as a food source or habitat. Fish communities serve as indicators of ecological changes due to their specific habitat needs and reliance on various aquatic conditions for survival (Surya et al., 2018).

This research focuses on the diversity of algal diversity in marine samples collected from coastal areas in Mumbai. The study aims to assess the composition, abundance, and distribution of different algal divisions within this specific marine environment. Quantitative methods, including Simpson's Index (D) and Shannon Wiener Diversity Index were employed to evaluate species richness, evenness, and dominance. By analysing the abundance and distribution of various algal divisions, this study seeks to highlight the ecological significance of algae and the potential implications for ecosystem health and biodiversity conservation. Understanding algal diversity is not only important for maintaining the integrity of aquatic ecosystems but also for assessing the impacts of environmental changes and human activities on these vital biological communities.

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## Materials and Methods

### Study site:

Mumbai, located along the western coast of India, is bordered by the Arabian Sea, giving it a diverse range of coastal landscapes. The coastline of Mumbai is approximately 150 kilometres long and features a mix of beaches, rocky shores, mangrove forests, estuaries, and tidal flats**.** The sampling areas were Manori beach, Juhu Koliwada, Bandra carters, Bandra bandstand, Dadar beach and Marine drive **(Fig.1)**.

**A. Manori beach:** Manori Beach, located in the northwestern part of Mumbai, offers a relatively less urbanized coastal environment. It is positioned between latitude 19°12' to 19°15' N and longitude 72°46' to 72°49' E. This sandy beach, with its adjacent mangroves and tidal flats, supports a variety of marine algae. The less polluted waters and the natural habitat of this area provide an ideal environment for the study of algal biodiversity, although occasional pollution events may still occur due to nearby human activity.

**B. Juhu Koliwada:** Juhu Koliwada, located in the western part of Mumbai, is a traditional fishing village known for its close connection to the Arabian Sea. This area is situated between latitude 19°05' to 19°10' N and longitude 72°45' to 72°50' E. The coastal stretch, with its nature of sandy beaches and intertidal zones, is suitable for the growth of different algae. However, because of proximity to urban centres, it is afflicted by the consequences of pollution, which may influence algal blooms and marine biodiversity.

**C. Bandra Carters:** Bandra Carters, located along the western coastline of Mumbai, is a rocky shore area exposed to strong tidal influences. The site is positioned between latitude 19°02' to 19°06' N and longitude 72°48' to 72°52' E. The diverse substrate types, such as rocky pools and sandy stretches, offer varied habitats for marine algae.

**D. Bandra Bandstand:** Bandra Bandstand is another prominent coastal area in the western suburbs of Mumbai. It lies between latitude 19°02' to 19°07' N and longitude 72°49' to 72°53' E. Bandstand is characterized by its rocky outcrops and boulder formations, making it a unique environment for algal growth. Tidal action and wave exposure play a significant role in shaping the distribution of algal species.

**E. Dadar Beach:** Dadar Beach is a lesser-known beach located in central Mumbai. It lies between latitude 19°01' to 19°04' N and longitude 72°48' to 72°51' E. This beach is a mix of sandy and rocky areas, providing an environment conducive to the growth of various algae species. Like other urban beaches, Dadar Beach is impacted by runoff and waste from nearby residential areas, which affects the local marine ecosystem and algal communities.

**F. Marine Drive:** Marine Drive, situated in the heart of South Mumbai, is a coastal promenade stretching along the Arabian Sea. It is located between latitude 18°55' to 18°58' N and longitude 72°48' to 72°51' E. The rocky and concrete embankments of Marine Drive support the growth of hardy algal species adapted to harsh, polluted environments. Despite being a highly urbanized area, certain resilient species of marine algae can still be found here, though anthropogenic factors significantly influence their population dynamics.


**Fig.1:** -Location of Sampling Areas on Map

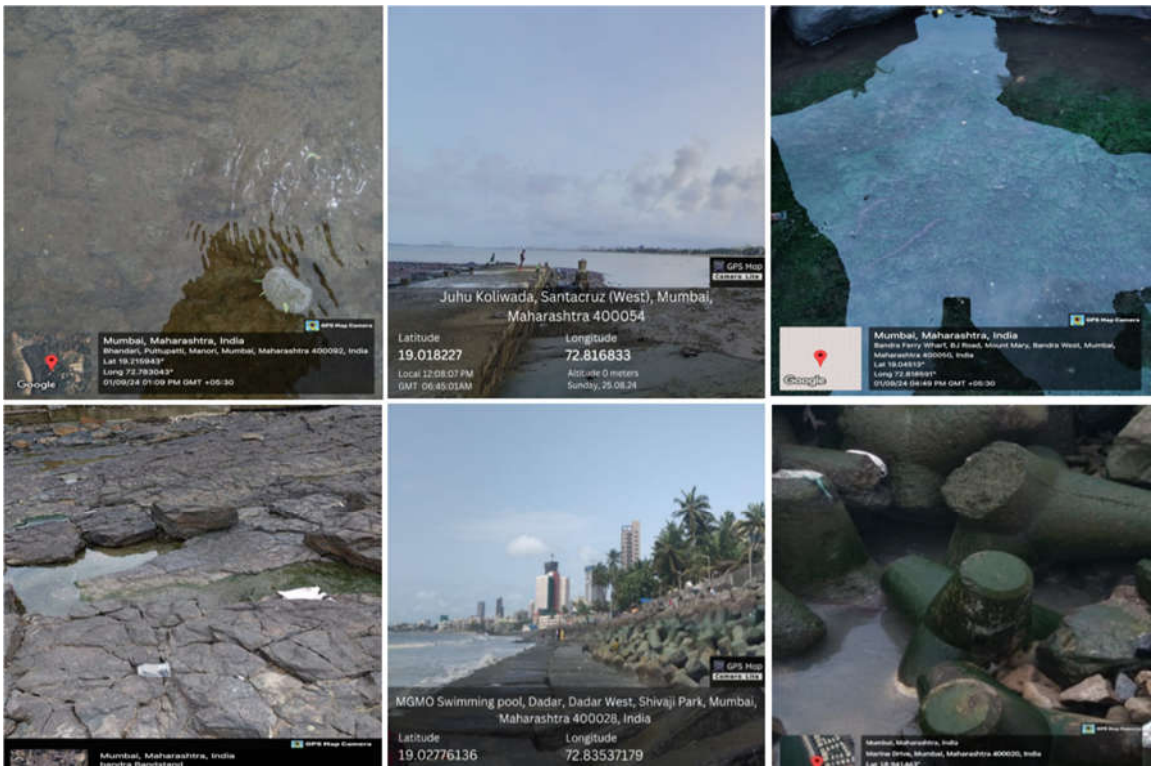


**Fig.2: -** Geotag images of all the sampling areas

**Materials: -**

The materials used for sample collection:

1.Clean transparent plastic containers
2. Clean Scalpel
3. Gloves
4. 4% Formalin (Preservative)
5. Compound Microscope
6. Clean and grease free glass slides
7. Coverslips
8. Forceps
9. 100 fields square sheets
10. Identification manual

**Sample collection method: -**

The sampling was done from various coastal areas of Mumbai such as Manori beach, Juhu Koliwada, Bandra carters, Bandra bandstand, Dadar beach and Marine drive. Random sampling method was used to collect the sample. The sample was scraped using scalpel from the wet rocks and the pathway. The sample was collected in the thoroughly cleaned transparent plastic container which was labelled with the name of the sample collector, the date and the location.

**Preservation: -**

The samples were fixed using formalin. The formulation used to preserve the to preserve their natural colour was Cupric sulphate (0.5gm) + water (38ml) + Glacial acetic acid (4ml) + 4% Formalin (8ml) + 95% Ethyl alcohol (50ml) (Patil, 2024).

**Sample Analysis: -**

Collected samples were examined using a compound microscope for taxonomic identification. The sample was observed under microscope at 10x and 45x by preparing a wet mount. The sample was observed for 100 fields to check the occurrence of the diverse algae in the sample.

**Occurrence pattern: -**
The abundance pattern of the algal sample was marked in the field of view. Hundred fields were observed. Each time the algae was observed and noted. The frequency of occurrence of a particular division at different locations was analysed. Mean values of the samples occurring frequently from all the stations were taken and then calculated with Simpson's Index (D).

**Diversity Index**

**a. Simpson's Diversity Index**
Simpson's Diversity Index is a measure of diversity which takes into account the number of species present, as well as the relative abundance of each species. The value of *D* ranges between 0 and 1. With this index, 1 represents infinite diversity and 0, no diversity.
The formula to calculate Simpson's index is: $\boldsymbol{D = 1- \Sigma n_i(n_i-1) / N(N-1)}$
where:
**$n_i$:** The number of organisms that belong to species *i*
**N:** The total number of organisms (Handa & Jadhav, 2016)

**b. Shannon Wiener Diversity Index**
Shannon diversity index (H) is another index that is commonly used to characterize species diversity in a community. Like Simpson's index, Shannon's index accounts for both abundance and evenness of the species present.

The formula to calculate Shannon Wiener Diversity Index: $H = -\sum[(pi) \times \log(pi)]$

where:
**H:** Shannon diversity index;
**pi:** proportion of individuals of i-th species in a whole community;

∑: sum symbol; and

**Log:** usually the natural logarithm, but the base of the logarithm is arbitrary (10 and 2 based logarithms are also used). (Handa & Jadhav, 2016)

**Results and Discussion**

**Identification and classification of species identified according to their division**

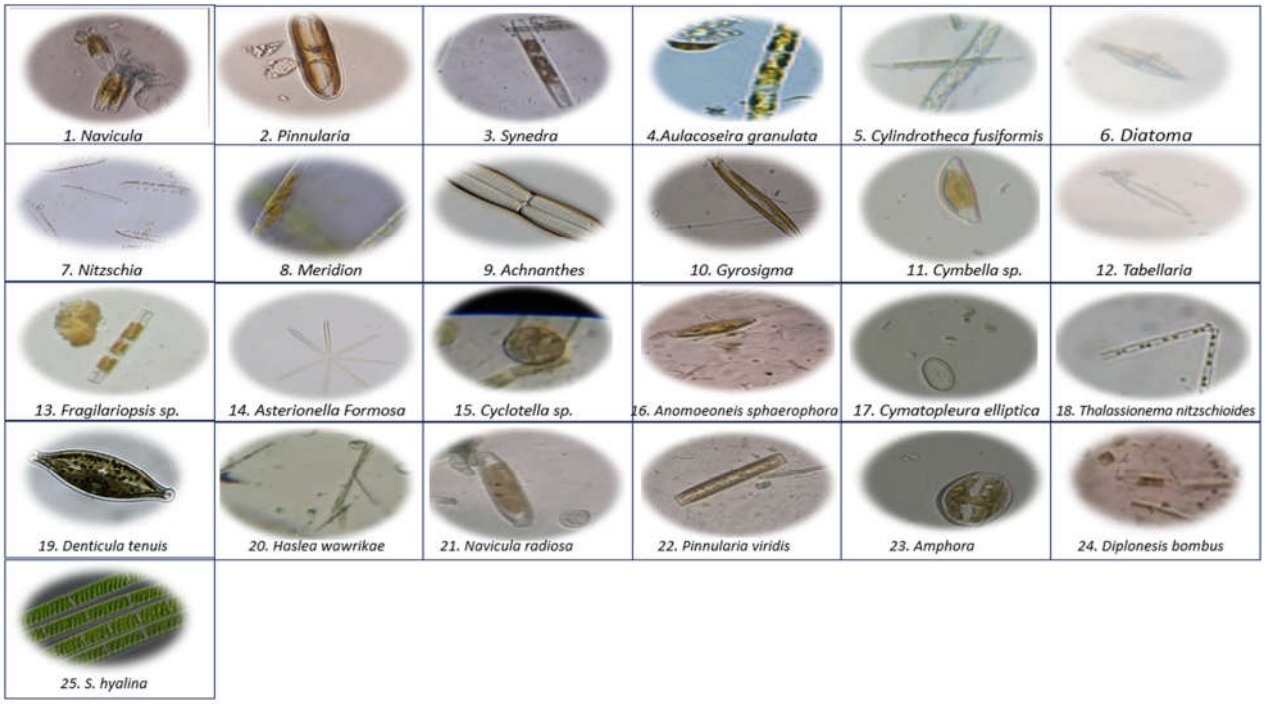


**Fig.3: -** Bacillariophyta (Diatoms)

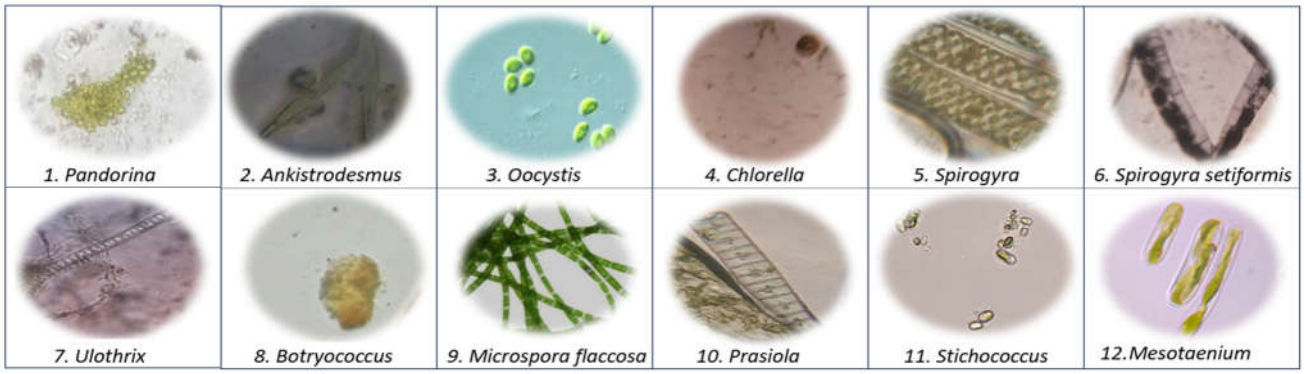


**Fig.4: -** Chlorophyta (Green Algae)

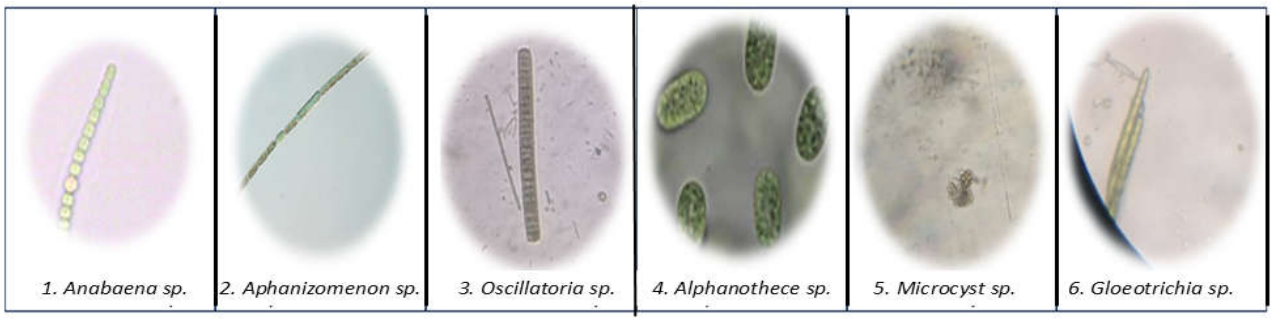


**Fig.5:** -Cyanophyta (Blue Green Algae)

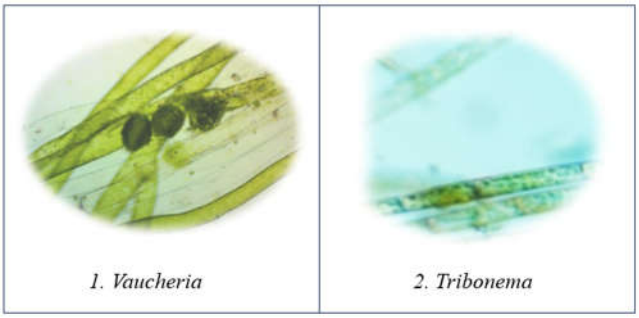


**Fig.6: -** Xanthophyta (Yellow Green Algae)


**Fig. 7: -** Phaeophyta (Brown Algae)

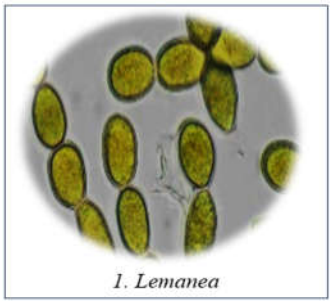


**Fig.8: -** Rhodophyta (Red Algae)

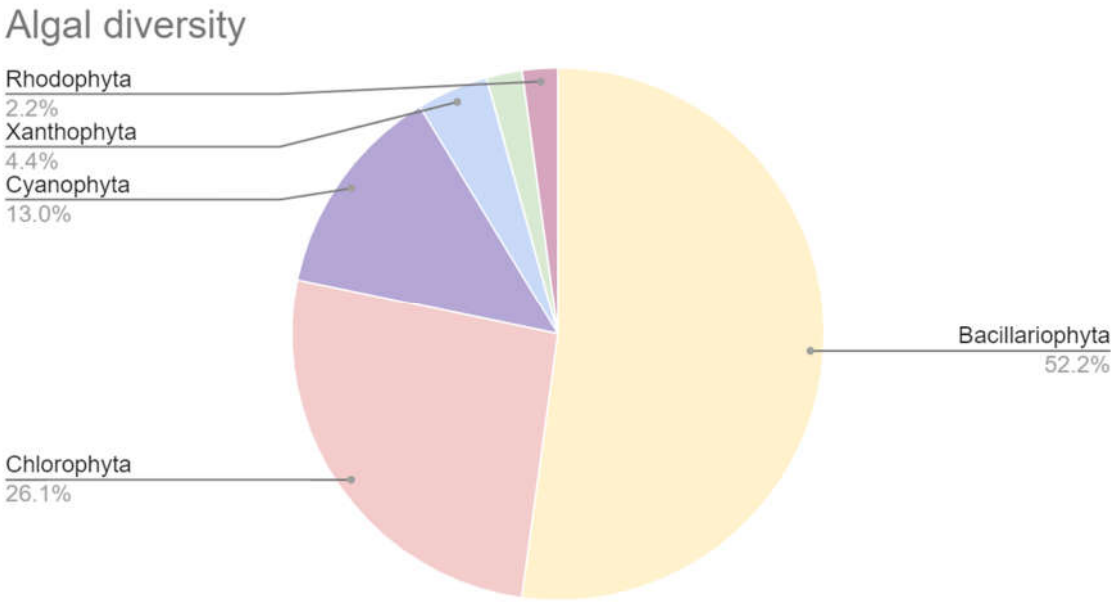


**Fig 9: -** Pie chart containing algal diversity in each division.

**Table1: -** The Names of species observed in each division

| Division of Algae | Bacillariophyta (Diatoms) | Chlorophyta (Green algae) | Cyanophyta (Blue Green algae) | Xanthophyta (Yellow green algae) | Phaeophyta (Brown Algae) | Rhodophyta (Red algae) |
|---|---|---|---|---|---|---|
| **Name of the species** | *1.Navicula* | *1. Pandorina* | *1. Anabaena sp* | *1. Vaucheria* | *1. Dictyota dichotoma* | *1. Lemanea* |
| | *2. Pinnularia* | *2.Ankistrodesmus* | *2.Aphanizomenon* | *2. Tribonema* | | |
| | *3. Synedra* | *3. Oocystis* | *3. Oscillatoria sp.* | | | |
| | *4. Aulacoseira granulata* | *4. Chlorella* | *4.Alphanothece* | | | |
| | *5.Cylindrotheca fusiformis* | *5. Spirogyra* | *5. Microcysts* | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | *6. Diatoma* | *6. Spirogyra setiformis* | *6.Gloeotrichia* | | | |
| | *7. Nitzschia* | *7. Ulothrix* | | | | |
| | *8. Meridion* | *8.Botryococcus* | | | | |
| | *9. Achnanthes* | *9.Microspora flaccosa* | | | | |
| | *10. Gyrosigma* | *10. Prasiola* | | | | |
| | *11. Cymbella perfossitilis* | *11.Stichococcus* | | | | |
| | *12. Tabellema* | *12. Mesotaenium* | | | | |
| | *13.Fragilariopsis sp.* | | | | | |
| | *14.Asterionella formosa* | | | | | |
| | *15. Cyclotella sp* | | | | | |
| | *16.Anomoeoneis sphaerophora* | | | | | |
| | *17.Cymatopleura elliptica* | | | | | |
| | *18.Thalassionema nitzschioides* | | | | | |
| | *19. Denticula tenuis* | | | | | |
| | *20. Haslea wawrikae* | | | | | |
| | *21. Navicula radiosa* | | | | | |
| | *22. Pinnularia viridis* | | | | | |
| | *23. Amphora* | | | | | |
| | *24. Diplonesis bombus* | | | | | |
| | *25. S.hyalina* | | | | | |

**Calculations of Simpson's Diversity Index and Shannon Diversity Index**

**Table 2:** Calculation of Simpson's Diversity Index

| Divisions of algae | Number of species (n) | n-1 | n(n-1) |
|---|---|---|---|
| Bacillariophytes | 25 | 24 | 600 |
| Chlorophytes | 12 | 11 | 132 |
| Cyanophytes | 6 | 5 | 30 |
| Xanthophytes | 2 | 1 | 2 |
| Phaeophyta | 1 | 0 | 0 |
| Rhodophyta | 1 | 0 | 0 |
| | Total number of species | | |
| Total(N)= | 47 | ∑ | 764 |
| N(N-1)= | 2208 | | |
| | Simpsons Diversity Index | | |
| | D= | 0.654 | |

**Table 3:** Calculation of Shannon Diversity Index

| Divisions of Algae | Number of species | pi | ln pi | pi* ln pi |
|---|---|---|---|---|
| **Bacillariophytes** | 25 | 0.53191 | -0.6313 | -0.3358 |
| **Chlorophytes** | 12 | 0.25532 | -1.3652 | -0.3486 |
| **Cyanophytes** | 6 | 0.12766 | -2.0584 | -0.2628 |
| **Xanthophytes** | 2 | 0.04255 | -3.157 | -0.1343 |
| **Phaeophyta** | 1 | 0.02128 | -3.8501 | -0.0819 |
| **Rhodophyta** | 1 | 0.02128 | -3.8501 | -0.0819 |
| | 47 | 1 | | -1.2453 |
| | | | **H'=** | **1.2453** |
| | | | **Effective number of species (ENS)= EXP(H')** | 3.47399 |

**Table 4: Calculated values of Simpson's Diversity index and Shannon Diversity index**

| Division of algae | No. of species observed |
|---|---|
| **Bacillariophyta (Diatoms)** | 25 |
| **Chlorophytes (Green algae)** | 12 |
| **Cyanophytes (Blue Green algae)** | 6 |
| **Xanthophyta (Yellow green algae)** | 2 |
| **Phaeophyta (Brown Algae)** | 1 |
| **Rhodophyta (Red algae)** | 1 |
| **Simpson's Diversity index** | **0.654** |
| **Shannon diversity index** | **3.473** |

The study identified six main divisions of algae: Bacillariophytes, Chlorophytes, Cyanophytes, Xanthophytes, Phaeophyta, and Rhodophyta. Among these, Bacillariophytes showed the highest diversity, with 25 species observed, followed by Chlorophytes with 12 species.

Quantitative analysis using Simpson's Diversity Index yielded a value of 0.654, indicating moderate diversity. The Shannon-Wiener Diversity Index resulted in a value of 3.473, suggesting a relatively high species richness and evenness across the sampled sites.

The study underscores the role of algae in maintaining the health of marine ecosystems, serving as primary producers and habitat-forming organisms. The presence of pollution and human activities was noted as a factor influencing algal diversity in urbanized coastal areas. This research contributes to the understanding of marine biodiversity and helps in assessing the environmental impact of human activities on these vital ecosystems.

## Conclusion

The conclusion of the research paper on the "Classification and Identification of Marine Algae Diversity in Mumbai "emphasizes the ecological importance of algae in sustaining marine ecosystems. The study found significant diversity among different divisions of algae, with Bacillariophytes (diatoms) being the most dominant group, followed by Chlorophytes (green algae) and Cyanophytes (blue-green algae).

The unique organisms with industrial applications found during this research from various locations in Mumbai were *Diplonesis bombus, Cylindrotheca fusiformis* (from Bandstand), *P. abaujensis and B. braunii* (from Marine lines), *M. floccose and L. fluviatilis* (from Carters Beach), *A. granulata and T. nitzschiodes* (from Juhu Beach), *H. wawrikae and Flagiriopsis sp.* (from Dadar beach) and *T. minus and Mesotaeniun sp*. (from Manori beach).

Using Simpson's Diversity Index and Shannon-Wiener Diversity Index, the study demonstrated a moderate to high diversity of algal species across various coastal regions of Mumbai. The analysis highlights the role of algae as primary producers, contributing to both marine food chains and environmental health. Despite the resilience of algae in urbanized areas, pollution and human activities have negatively impacted their diversity, especially in heavily urbanized and polluted locations.

This research provides valuable insights into the biodiversity of marine algae and stresses the need for conservation efforts to protect these critical ecosystems from environmental degradation. Understanding the diversity and abundance of algae is crucial for monitoring ecosystem health and for implementing strategies to mitigate the impact of human activities on coastal marine life.

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