STUDIES ON MANGROVE-ASSOCIATED DIATOMS IN THRISSUR DISTRICT, KERALA

DISSERTATION

Submitted to the University of Calicut in partial fulfilment of the requirement for the award of degree of

MASTER OF SCIENCE IN BOTANY

UNIVERSITY OF CALICUT

Submitted by

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Kodungallur, Thrissur

2022-2024

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2024

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This is to certify that the project report entitled **"STUDIES ON MANGROVE ASSOCIATED DIATOMS IN THRISSUR DISTRICT, KERALA"** Submitted by **Ms. ASWINI S GUPTHA** in partial fulfilment for the Degree of **Master of Science** in **Botany** of M.E.S. Asmabi College in the University of Calicut is a bonafide work carried out by her during the fourth semester of the course under the supervision and guidance of **Dr. V.B. Sreekumar, Principal scientist, KSCSTE-Forest Botany Department, Kerala Forest Research Institute, Thrissur**, during the academic period of 2024.

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DECLARATION

I hereby declare that the dissertation entitled '**STUDIES ON MANGROVE-ASSOCIATED DIATOMS IN THRISSUR DISTRICT, KERALA**' is a bonafide work for the partial fulfillment of the requirements for the award of the Degree of Master of Science in Botany under the co-guidance of **Dr. Girija T.P, Head of the Research Department of Botany, M.E.S. Asmabi College, P. Vemballur, Thrissur.** I also declare that this work has not been submitted for the award of any other Degree/ Diploma/ Fellowship/ Associateship of any other similar title of any University or Institution and it represents the original work done by me under the supervision of **Dr. V.B. Sreekumar, KSCSTE-Forest Botany Department, Kerala Forest Research Institute**.

Place: Kodungallur ASWINI S GUPTHA

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ABSTRACT

The mangrove ecosystem stands out as a uniquely productive environment, boasting a diverse array of small microscopic organisms. Among these, Diatoms, and cyanobacteria have a remarkable ability to flourish within this habitat. Diatoms are widely distributed and play a significant role in aquatic ecosystems. Their distinguishing feature lies in their silicified walls, setting them apart from other algal groups. However, in this present study, deals with the taxonomical study of diatoms collected from three different mangrove sites of Thrissur district. The study reported a total of about 51 diatom taxa under 30 genera belonging to 23 families. Among these Naviculaceae was the dominant family consisting of 10 species followed by six species from Bacillariaceae, five species from Surirellaceae, three species reported from Diplonidaceae, Pinnulariaceae, and Gomphonemataceae, two species from Cymbellaceae, Catenulaceae, Fragilariaceae one species reported from Rhopalodiaceae, Pleurosigmataceae, Stauroneidaceae, Plagiotropidaceae, Anomoenoidaceae, Mastogloiaceae, Achnanthidiaceae, Eunotiaceae. The study also identified 11 pollution-tolerant species comprising 7 *Navicula* sps, 3 *Gyrosigma sps*, and 1 *Cyclotella sps.*

Key words: Diatoms, Taxonomic study, Thrissur District, Mangrove habitat.

1. INTRODUCTION

The mangrove habitat provides a unique and specialized type of coastal habitat. It is distinguished by its specific combination of salt-tolerant vegetation, tidal influence, and diverse array of organisms specially adapted to thrive in challenging conditions of brackish water. This ecosystem plays an important role in supporting and providing valuable ecological services. Mangroves exhibit remarkable resilience across varying levels of salinity, tidal fluctuations, wind speeds, temperature, and anaerobic muddy conditions enabling their robust growth and property. Their adaptability to these dynamic surroundings fosters an abundance of inhabitants within the mangrove forest. Mangroves are commonly referred as sea lungs. Tomlinson, (1986) distinguished between two different kinds of mangroves. The initial category is termed as true mangroves, and that species has a complete loyalty to that environment. The second group is known as secondary constituents of mangals that are less prevalent in mangrove habitats and they might favour peripheral regions commonly the edges of that mangrove habitats. Li and Lee, (1997) identified truly mangroves and mangrove associates within the ecosystem. The mangrove ecosystem indeed supports a diverse range of floral, faunal, and small microscopic organisms. Mangroves have become a vital biodiversity component of coastal areas. Their adaptive features in root systems, stem, leaves and canopy development greatly enhance the resilience of coastal regions. This resilience is crucial for mitigating erosion, providing habitat for various species, and buffering coastal communities against the impacts of storms and rising sea levels. Mangroves provide a diverse array of valuable forest products while also playing a vital role in preserving estuarine water quality and supporting the life cycles of many fish and shellfish species. Some of the forest products derived from mangroves include timber, firewood, and charcoal. Additionally, mangroves contribute to the ecological balance of estuarine ecosystems by filtering pollutants, trapping sediments, and providing essential nursery habitats for various marine organisms, including fish and shellfish. This makes them indispensable for the overall health and productivity of coastal environments. Mangroves provide essential habitat for creatures like birds that roost in their dense canopy. Indeed, viviparity (the ability to give birth to live offspring) and various dispersal mechanisms are reproductive adaptations that significantly enhance the survival chances of mangroves. Viviparity allows mangroves to germinate and establish themselves while still connected to the parent tree, increasing their chances of survival in challenging coastal environments.

Additionally, dispersal mechanisms such as buoyant seeds and propagules enable mangroves to colonize new areas and maintain genetic diversity, further contributing to their resilience and long-term survival. ln addition to fish species, certain algae also attach to the roots and stems of mangroves. Mangroves play a crucial role in stabilizing the soil and creating an environment utilized by numerous other organisms. They form the foundation of a complex and productive ecosystem as photosynthetic primary producers. Residents of the mangrove ecosystem are well-adapted to the challenging conditions, including regular tidal immersion and exposure, fluctuating salinity, low water oxygen concentrations, and high temperatures. This resilience allows them to thrive in an otherwise harsh environment, contributing to the overall diversity and productivity of mangrove ecosystems. More significantly, aquatic organisms, crucial to human reliance, inhabit the intricate roots of the mangroves. Numerous juvenile fish from neighbouring coral reefs, like snapper, seek shelter among the tangled roots of the mangroves. In this environment, young fish can thrive with reduced competitive interaction and predatory behaviour. Mangrove marshes serve as crucial habitat for young fish species, as documented by Boulon, (1992). They can act as nursery areas for both estuarine and reef fishes. Additionally, crustaceans namely shrimp, crabs, and lobster thrive and mature in these ecosystems. Certain smaller fish species never venture far from the tangled root systems of the mangroves. The mangroves are mangroves are favoured hunting habitat for fish like tarpon, rays, and lemon sharks. Mangroves possess a unique stability to nurture diverse flora and fauna, setting them apart from many other ecosystems. Mangroves act as a green bio shield, forming a natural barrier against various disasters like storm surges, tsunamis, and hurricanes. Their dense roots and sturdy vegetation help absorb and dissipate energy of waves, and reducing their impact of such events on coastal communities and ecosystem. Mangrove are regarded as ideal nursing area is due to highly productive ecosystem, intricate structure of mangrove like canopy formation and the ecosystem offers a secure environment for retention of larvae that preclude them from being dragged away by coastal currents. The water saturated or submerged sections of mangroves roots, stems serve as heaven accommodating a broad spectrum of epiphytic floral and faunal population, including bacteria, fungi, macroalgae, microalgae etc. pneumatophore and root system of mangrove act as a solid substrate that facilitates the thriving of photosynthetic organism such as diatoms and cyanobacteria.

Cyanobacteria are a group of photosynthetic prokaryotes, are essential component of the mangrove ecosystem. According to studies conducted by Ram, (2021) identified that cyanobacteria and mangrove association are mainly due to the presence of heterocyst that can fix nitrogen. They are highly adapted to grow in hypersaline conditions. The cyanobacterial association can be visible clearly in pneumatophore and root systems. According to Kathiresan and Bingham, (2001) is that they exist in various forms single cell colonies to filamentous heterotrichous structures. Cyanobacteria contribute significantly to enhancing the habitat of mangrove ecosystem. Another type of algae associated with the mangrove ecosystem is diatoms, which are commonly known as tiny glasshouses and are identified 150 years. They are also known to be jewels of the plant kingdom. These are the members of the class Bacillariophyceae and are characterized by unicellular golden-brown algae with silicious skeleton made up of two halves and can live either solitary or in colonies. About 20-25% of oxygen in the atmosphere are produced by diatoms. The formation of diatom frustules is the basis of diatom classification. In 1767, Linnaeus categorized diatoms under Vermes, within zoophytes in the 12th edition of Systema naturae. In 1824, Agardh spearheaded diatom taxonomy by grouping them as a single order of algae in systema Algarum, it is the foremost classifications of diatoms. Another kind of classification put forward by Kützing, (1834) released the synopsis diatomearum, wherein he divided diatoms into two main categories, Diatomaceae Liberae and Diatomaceae Inclusae. He documented a total of 16 genera, with 10 allocated to the former category and the remaining species assigned to the latter category. Pfitzer in 1871 derived a new system of classification for diatom based on the plastids. He established two main divisions namely Coccochromaticae and Placochromaticae. Smith, (1872) also proposed a novel type of classification that centered around the cell wall of diatoms, specifically emphasizing the presence of raphe on their valve face. Diatoms were split into two factions by Schütt, (1896). Following this classification Bessey, (1900) proposed a new classification along with phylogenetic aspects. The categorization of diatoms are bolstered in 1930s by the invasion of electron microscopy, which enables for the elaborate examination and identification of diatom fine structures present in valves. Many eminent scientists came forward for the systemic categorization of diatoms. Round *et al.*, (1990) divide the diatoms into radial bilateral symmetry. They organized diatoms into 11 subclasses and 3 classes that comprise Coscinodiscophyceae, Fragilariophyceae, and Baccillariophyceae. The most accepted and widely studied classification of diatoms proposed by Cox, (2015). In this classification diatoms are categorized into four classes that integrated with phylogenetic studies, valve characteristics, and cytoplasmic specializations. The four classes that comes under this classification are Coscinodiscophyceae, Mediophyceae, Fragilariophyceae, and Bacillariophyceae. Cox,

(2015) classification is widely used in nowadays for diatom taxonomy and identification studies. These organisms are autonomous photosynthetic or non-pigmented heterotrophs, or symbiotic photosynthetic partners. In 1981, Round categorized diatoms based on their attachment into different groups such as epipelic, epispammic, epilithic, epiphytic, epizoic, and planktonic. They are ubiquitous, because they occur in a diverse range of habitats, including extreme conditions such as hot springs and low pH environments. The diatom cell wall is composed with silica dioxide, and exhibits various patterns of ornamentation like round, spherical, oval, lanceolate, elliptical, sigmoid, rhomboidal, and more. In some endosymbiotic species and *Phaeodactylum tricornutum,* siliceous cell wall is absent. Diatoms are grouped into centric and pennate diatom forms based on their shape and exhibits both radial and bilateral symmetry. The diatom cell wall, which is multipartite, consists of two large intricately sculptured units known as valves. These valves are named the epivalve and hypovalve, while the siliceous parts of the cell wall are collectively called the frustule and are identified by Round *et al*., (1990). The frustules look like a box with a smaller half hypotheca inserted within a larger half epitheca. Girdle is positioned between these two walls, which are the silica-based shells that encase the diatom. The girdle can indeed be categorized into two overlapping portions epicingulum and hypocingulum. According to Bold and Wynne, (1985) the fusion of epivalve and epicingulum forms epitheca, while hypovalve and hypocingulum compose the hypotheca. These components assist the diatoms for regulating the buoyancy and maintaining their shape. Diatoms can be visualized in both valve view and girdle view. In many pennate diatoms a longitudinal slit called raphae present in the middle of theca. Bold and Wynne, (1985) identifies that raphae constitutes an aperture or cleft that runs through the apical axis. Based on these raphae system diatoms can be raphid, araphid, and pseudo raphid diatoms. Along with raphae diatom wall also consists of numerous striae which are arranged parallelly on the valve surface. There are two types of wall perforations observed by Lee, (2008) in diatoms that are complex areolae and simple pore. In some diatoms extracellular mucilage or slime pores also known as mucilage secreting pores have been documented. The release of mucilage through various substance in the cell wall of diatom which helps in locomotion and aid for the establishment of various diatom colonies. The protoplast found within the cell wall comprises of nucleus, mitochondria, endoplasmic reticulum, golgi bodies, and chloroplast with or without pyrenoids in photosynthetic diatoms. Additionally, one or two large central vacuole is also present. The placement of nucleus differs in both Centrales and Pennales type of diatom. The chloroplast is enclosed by two membranes and the exterior layer of the chloroplast endoplasmic reticulum is connect seamlessly with the nuclear outermost membrane. Pyrenoids are positioned centrally on the chloroplast. Chloroplast appears as brownish or greenish in color. The major photosynthetic pigments are chlorophyll a, c1, c2, c3 and fucoxanthin. These pigments are responsible for imparting the golden-brown coloration to diatoms. The major reserve food materials within the diatom cell are in the form of oil and polysaccharides mainly chrysolaminarin. Diatoms are often moved as circular gliding and also in a series of curve and zigzag direction, propelled by a secretion of mucilage from their cells. This movement allows them to navigate in their aquatic environment. Diatoms generally have restricted mobility, but certain varieties show varied types of motion. Araphid pennate diatoms may show constrained mobility, while certain centric diatoms show rotational movements. Raphid diatoms exhibit gliding motion and centric diatoms which have characteristic labiate processes that produce mucilage at their central region and assist in locomotion Hoek *et al.*, (1995).

Diatoms often exhibit a bloom and bust life cycle pattern. During favorable conditions, such as ample nutrients and sunlight, diatoms can rapidly reproduce leading to a bloom where their population density increases significantly. However, once nutrients are depleted or conditions become unfavorable the bloom can collapse resulting in a bust phase where the diatom population declines sharply. This cycle is common in many aquatic ecosystems and can have significant ecological impacts. Diatoms undergo two primary distinct yet interlinked phases i.e. vegetative phase and a sexual phase. The vegetative phase encompasses cellular proliferation through mitosis, leading to an augmentation in cell count and biomass. Conversely, the sexual phase involves meiosis and genetic recombination. During meiosis cells divide to produce gametes, each containing half the chromosome number of the parent cell. These gametes subsequently fuse during fertilization, facilitating genetic diversity through recombination. The vegetative phase in the diatom includes cell division and resting spore formation. During cell division, each valve of the parent diatom serves as the epitheca for one of the newly formed daughter cells. Additionally, a new hypotheca will be formed in each of the divided daughter cells. This process ensures that each cell inherits one valve from the parent diatom, maintaining the characteristic shape and structure of the diatom cell. The process of creation of Resting spore is another type of division in some diatoms. During unfavorable conditions such as nutrient depletion or changes in environmental factors certain diatom species form resting spores. These spores are specialized structures with thickened cell walls, allowing them to withstand adverse conditions such as desiccation, extreme temperatures, and low nutrient availability. During favorable conditions resting spores germinate and resume their life cycle. The development of Resting spores is far more common in centric diatom, such as nutrient depletion, which typically occurs after diatom blooms, serves as the main trigger in marine waters, where light, temperature, and salinity are stable parameters compared to freshwater environments where frequent environmental changes make it particularly conducive for resting spore formation (Lee, 2008). Sexual reproduction in diatoms is mainly by auxospore formation. Diatoms mainly undergo sexual reproduction for renewal or restoration of their size. The gamete characteristics of diatoms are male gametes of centric are motile and female gamete are motile whereas in pennate forms gametes lack flagella. These gametes unite to generate a zygote called auxospore. The specialized feature of auxospore is larger in size and encased inside a two piece of silicified wall called perizonium. This perizonium replaces the thin zygotic membrane during their growth phase. These auxospores mature into new diatoms. Auxospores can occur in three different forms: isodiametric auxospores, properizonial auxospore, perizonial auxospores. Auxospore formation in pennales primarily occurs through isogamy, anisogamy, oogamy, autogamy and parthenogenesis. In these isogamy, anisogamy and oogamy are the predominant mechanisms in auxospore formation whereas autogamy and parthenogenesis are infrequent methods in Pennales diatoms. Sexual reproduction in Centrales is mainly by oogamy and autogamy type. Throughout the life cycle of diatoms, the balance between asexual and sexual reproduction as well as the formation of resting stages allows them to adapt to the changing environmental conditions and persist in various ecosystems and also promote their long-term evolutionary success. Amato, (2010) provides a extensive study of the sexual reproduction in pennate and centric diatoms, covering both morphological, behavioural and ecological aspects in their review. Compared to marine waters, freshwater environment experiences frequent environmental changes, making them more suitable for resting spore formation.

In sexual reproduction species lifecycle is primarily diplontic mode, presence of resting stages during unfavorable conditions etc. These features help them to thrive in any environment conditions. Diatoms mainly serves as indicators in various environmental assessments due to their sensitivity to change in water quality and environmental conditions. Their abundance and composition provide a valuable information about water quality. They are frequently employed for bio mineralization, platinum and cadmium metal production, nanoparticle synthesis, producers, diatomaceous earth is widely used for the production of toothpaste, sugar filtration, abrasives etc.

Their high capability to flourish in saline condition of mangrove ecosystem due to their silicious cell wall which protect them from osmotic shock in the hyper saline environments. Sethi *et al*., (2020) elucidated the contribution of diatoms as a natural carbon sink during photosynthesis, assist in carbon sequestration within coastal ecosystems. Mangroves, renowned for their carbon sequestration capabilities, heavily rely on this process for survival within their ecosystem. This shows the interconnectedness of diatom and mangrove carbon sequestration, emphasizing the vital role both play in maintaining the ecological balance and resilience of coastal habitats. Mangrove soil is usually without oxygen content. Mangroves, with their pneumatophores, encounter limitations in oxygen respiration and diatoms that also maintain the sand stability through oxygen production. Sylvestre *et al*., (2004) observed that the indigenous epipelic community could serve as a biological indicator of the stability of fluid mudflats. The association between mangroves and diatoms contributes significantly to maintaining water quality. Mangroves act as natural filters, trapping sediments and pollutants, while diatoms play a crucial role in nutrient cycling and water filtration. Together, they help improve water quality

Since Kerala has not been conducted any studies on mangrove associated diatoms diversity. The diversity list of diatoms can also be enhanced by cataloguing diatoms in our environment. Diatoms are referred to be as pollution indicators, so the pollution status of mangrove ecosystem can also be analyzed in future. By identifying mangrove associated diatom diversity, can be utilized for the advancement of aquatic inhabitants and other applications. Since diatom play a sufficient role in mangrove ecosystem vitality and maintenance due to their purpose in aquatic food chain, so it was planned to explore mangrove associated diatom diversity.

OBJECTIVES

- To gather information regarding the diversity of diatoms in the mangrove ecosystem of Thrissur up to the species level.
- To prepare a detailed taxonomic description of each taxon.
- To study the physio-chemical factors (pH, & Temperature) which affecting the distribution of diatom.

2. REVIEW OF LITERATURE

2.1 Taxonomic studies in Diatom

Diatoms, commonly referred as tiny glasshouses. Taxonomic studies in diatoms provide us with a deeper understanding of their distribution patterns, ecological roles, and evolutionary relationships. Diatom taxonomy involves organizing diatoms, belonging to the phylum Bacillariophyta, into hierarchical categories based on their characteristics, including morphology, ecology, and genetic relatedness. Diatoms are characterized by their unique cell walls made of silica and their diverse shapes and sizes. Nowadays, numerous studies are conducted in the field of diatom taxonomy, focusing on advancements in molecular techniques, morphological analyses, and ecological applications and also field of medicine. These investigations enhance our comprehension of diatom diversity, evolution, and ecological roles, underscoring their significance in environmental surveillance and conservation endeavours. Comprehensive record of diatom taxa within the region offers valuable insights into the fluctuating degrees of organic pollution present within the ecosystem.

2.1.1. Diatom study in India

Hemendra Kumar Prithviraj Gandhi is commonly known as the father of Indian freshwater diatom science. Gandhi has made two major contributions to the field of taxonomy of diatoms and treating diatoms as a pollution indicator. About 299 diatom taxa are documented and more than 35 publications. He also published a book for diatom study. Venkataraman, (1939) documented 98 forms across 33 genera. Among these, 67 forms were previously unrecorded in India. Additionally, the research unveiled 3 new species, 6 new varieties, and 6 new forms from South Indian diatoms. Subrahmanyan, (1946) a comprehensive study on the marine plankton diatoms found along the Madras coast documented a total of 171 different forms. These included representatives from 15 families, 64 genera, and 134 species. Notably, Subrahmanyan identified 9 new species, 17 new varieties, and 4 new varieties, along with 7 additional forms. Chacko, (1950) study delves into the findings of a plankton investigation conducted in the waters surrounding Krusadai

Island in the Gulf of Mannar. Spanning from September 1940 to August 1943, the research involved the collection of 436 samples thrice a week. Through qualitative and quantitative analyses, approximately 65 species were identified and examined. Roy, (1954) documented the phytoplankton community of Chilika Lagoon that contains marine, brackish and freshwater taxa and contains all 4 algal groups. Among these, diatoms prevailed, comprising 79 species, with 41 belonging to the Centrales group and 38 to the Pennales group. Nautiyal and Nautiyal, (1996) conducted a study on pennate diatom flora of cold water in Alaknanda, a cold- water mountain river. Their research identified 173 pennate taxa across 23 genera, which were categorized into 7 families within 4 suborders.

Studies on estuarine and marine diatoms in Karaikal coast by Natanamurugaraj, (2008) documented 79 species belonging to 33 genera of diatoms. D'Costa and Anil, (2010) enlisted 86 diatom species belonging to 35 genera in which 18 species belongs to centric and 17 species belongs to pennate were recorded. Their study is based on the diatom community structure and dynamics in the West Coast of India. A study conducted by Pareek *et al*., (2011) investigating the freshwater diatoms of Galta Kund, Jaipur enlisted a total of Twenty-Four diatom species. The research findings also suggest that diatoms experience peak growth in winter season and progressively diminish during summer season, reaching their lowest levels in the rainy season. Another study by Mohan *et al*., (2011) enumerated the diatoms on surface sediments. The analysis examined surface sediment samples taken from the Enderby Basin in the Southern part of Indian Ocean. It aimed to the proportional prevalence and spatial arrangement of seven pivotal indicator diatom species. The study discovered a connection between nutrient concentrations and the distribution and richness of these diatom species.

Karthick *et al*., (2011) analyzed the nestedness patterns of stream diatom assemblages across 24 sites in the Central Western Ghats. It identifies a total of 98 different taxa present in streams within this region. Karthik *et al*., (2011) identified a new genus *Gomphonema ehrenberg* in India, also documented a Checklist and also gave an account about three new species. George *et al*., (2012) documented 34 species of diatoms based on Examining the correlation between hydro-chemical parameters and the phytoplankton distribution pattern in the Tapi estuarine area of the Gulf of Khambhat. Alakananda *et al*., (2012) enlisted two new species of *Nitzschia* from shallow wetlands of Peninsular India. A new species of *Pleurosigma* from Western Ghats, South India by Karthick and Kociolek, (2012). The recently identified species exhibits transverse striae on its external valve surface, while internal valve regions show oblique type of striae patterns. It is currently categorized under the genus Pleurosigma because of these oblique striations. Karthick *et al*., (2012) detected some *Surirella* taxa from peninsular India. They show different levels of endemism such as locally endemic, regionally distributed and cosmopolitan distribution. Satheesh and Wesley, (2012) examined the establishment of diatom groups on acrylic panels sunken in the coastal waters of Kudankulam, located on the coastline of Eastern India. They identified a total of 19 genera of diatoms during the study. Venkatachalapathy *et al*., (2013) recorded a total of 21 diatom species from 13 genera. The paper focuses on the examination of diatoms and the evaluation of water quality in Yercaud Lake, located in Salem district, Tamil Nadu. Minu *et al*., (2014) conducted a study on the characteristics of phytoplankton communities in the waters along the southeastern Arabian Sea. They identified and listed 54 species of diatoms. In a study conducted by Meeravali *et al*., (2015), an investigation into the freshwater diatoms inhabiting three distinct aquatic environments, namely waterfalls, check dams, and community water tanks, in the Ananthapuramu district was undertaken. A total of thirty-nine species were enlisted. Kumar, (2015) study focused on assessing the diversity and abundance of freshwater diatoms as gauges of water quality in the Gorgianga River, fed by glaciers in India. The study compiled about 27 diatom species. Keshri *et al*., (2016) identified four new diatom taxa. These taxa are previously undocumented in Eastern India. Baliarsingh *et al*., (2016) study extensively investigated the phytoplankton communities vary seasonally and their correlation with environmental factors in two different types of local waters, particularly a coastal site in the north-western Bay of Bengal. They listed around 140 species of diatoms. Nashima and Palanisamy, (2016) investigated the plentiful of diatoms in various paddy fields within the Rasipuram area of Namakkal District, Tamil Nadu, India and enlisted 18 diatom genera. About 92 species of diatom were recorded by Murugan and Usha, (2016) based on study on analyzing the physical and chemical parameters and phytoplankton diversity in the Netravathi-Gurupura Estuary located in Mangalore, on the South West shoreline of India.

Another study investigated in the coastal waters of Malvan, on the west coast of India, Hardikar *et al*., (2017) based on seasonal variations of phytoplankton and its correlation with physico-chemical parameters; around 40 species of diatom were recorded. Balasubramaniam *et al*., (2017) Documented about 41 diatom taxa which includes 27 pennate diatoms and 14 centric diatoms based on their study about spatial and temporal arrangement patterns of microphytobenthos in Andaman Archipelago. Shah *et al*., (2017) study focused on diatoms, their spatial distribution, and the physicochemical properties of sediment in Wular Lake, located in Kashmir Valley, Jammu and Kashmir. They discovered 48 diatom species in 26 sediment samples. The dominance of diatom species like *Cymbella, Cyclotella,* and *Tabularia* suggests that Wular Lake is experiencing notable organic pollution and has an alkaline freshwater environment. Srivastava *et al*., (2017) identified a total of 100 diatom taxa from 40 different genera in their study on the Applicability and efficacy of diatom indices in water quality evaluation of the Chambal River in Central India. In a study conducted by Aher *et al*., (2017) on diatoms from haranbari dam of Maharashtra, revealed twenty-three distinct algal taxa spread across forty-five genera of diatoms. Roshith *et al*., (2018) documented 195 species of diatoms through their research on the phytoplankton composition in the Hooghly estuary. The Hooghly-Matla estuarine system is a significant biodiversity hotspot globally, serving as a crucial nursery area for various fish and shellfish species. Sharma and Singh, (2018) conducted a study on the water quality and phytoplankton diversity in the high-altitude wetland Dodi and listed 20 genera of diatoms. Diatoms represent the most dominant group. Manju and Ramjan, (2018) conducted research on the range of the Purna River Basin parbhani district and identified 20 species of diatoms. Purushothaman and Anupama, (2018) investigated the phytoplankton diversity and ecological aspects in four lakes situated in K.R. Nagar Taluk, Mysuru. Their findings underscored the significance of diatoms as vital bioindicators for evaluating the ecological well-being of these lakes. Kumar *et al*., (2018) focused on the temporal phytoplankton makeup and diversity changed over time in association to the water's physical and chemical properties within the major dol net fishing zones of two nearby tidal creeks. In Mahul, researchers identified 55 diatom species, while in Naigaon, they found 47 diatom species. Mishra *et al*., (2018) cataloged 81 diatom species which includes 51 centric and 27 pennate diatoms from Mahanadi estuary.

Borse, (2019) conducted a study on *Navicula* genus from Girna river Maharashtra and about thirteen species are reported. The study of sediment by Humane *et al*., (2019) from Ghodajhari Lake in Chandrapur District, Maharashtra, has unveiled a diverse array of diatoms and documented about 50 species from 23 genera. The findings reveal a variety of diatoms in Ghodajhari Lake, including typical planktonic types like *Aulacoseira granulata*, *Discostella stelligera*, and *Cyclotella meneghiniana*, alongside benthic species such as *Nitzschia microcephala*, *Amphora ovalis*, and *Pinnularia*. Variations in the assortment of diatoms in Ghodajhari Lake are probably shaped by the alternating dry and wet periods occurring in its watershed throughout time. Ramanujam *et al*., (2020) studied the impact of human activities on the diatom community in Umiam Reservoir and enlisted 53 species of diatoms. Another study conducted by Parihar and Pareek, (2022) reported thirty-seven diatom taxa which comprises common diatoms and site-specific diatoms. A study conducted by Das *et al*., (2022) delves into understanding diatom communities within some freshwater ponds in Kolkata and their fluctuations in different seasons. Tiwari *et al*., (2023) analyze the diatom response of different climatic conditions in the Western coastline of india. Venkatachalapathy and Madhankumar, (2023) assessed the environment impact assessment using diatoms in Thamirabarani River, Tamil Nadu. The analysis revealed around 55 distinct diatom species falling into 25 different genera were discovered. Recent studies were conducted by Singh *et al*., (2023) documented 63 diatom species from the wetlands of Punjab, in which it consists of 39 different genera comprising 25 different families and 14 orders. Out of these 58 taxa were newly reported. The study indicating the diatom diversity in the wetland was relatively low, with dominant genera including *Navicula, Cymbella, Gomphonema,* and *Nitzschia*

2.1.2. Diatom study in Kerala

In Kerala Diatom research started in 1945. First study on Diatom was done by Menon, (1945) on his work seasonal distribution of plankton on Trivandrum coast and identified 43 diatom species. The plankton productivity along this coast is primarily influenced by the monsoon seasons. During these times, the organic and inorganic materials carried by the Karamana River to the South and the Veli bar to the North of Trivandrum beach play major role in supporting the plant and animal life in the coastal waters. Gopinathan, (1975) on qualitative research on diatoms in the Cochin backwaters and reported 88 different species of diatoms. Joseph and Pillai, (1975) study on the seasonal and spatial dispersal of planktonic algae in the Cochin backwaters found that phytoplankton were mainly comprised of diatom species belonging to genera such as Chaetoceros, Coscinodiscus, Skeletonema, Pleurosigma, and Nitzschia. A systematic description of the littoral diatoms of the South Western shoreline of India was studied by Gopinathan, (1984) and reported 109 diatoms. The research encompasses the description of 109 diatoms, which include 10 varieties and a newly discovered species, representing a diverse range of 40 genera. Among these, 17 species from 8 genera are classified under the group Centrales, while the remaining 92 species from 32 genera fall under the Pennales category. Jose and Patel, (1989) on contribution to the freshwater diatom flora of Kerala and reported a total of

29 taxa of freshwater diatoms representing 9 genera, *Eunotia* (9), *Cocconeis* (1), *Stauroneis* (2), *Neidium* (3), *Navicula* (3), *Cymbella* (2), *Gomphonema* (3), *Pinnularia* (4), and *Surirella* (2). Bindhu, (2006) conducted research on diatoms along the South Western coastline of India, specifically investigating their correlation with hydrological factors and listed about 43 diatom species. The study of Marry *et al*., (2008) evaluated the dispersion and diversity of phytoplankton in correlation with the water quality of the Alappuzha Changanassery canal within the Kuttanad wetland ecosystem of Vembanad Kol Ramsar site in Kerala and identified 15 species of diatoms. Based on the study the diatom exhibits a higher positive correlation with nitrate concentration.

Tessy and Sreekumar, (2008) conducted a survey on algae at 4 locations within the Kol wetlands of Thrissur. This survey focuses on assessing the pollution levels of algae specifically in the Thrissur Kole Wetlands and reported 188 species of algae belonging to 64 genera. Based on the study diatoms are less common at all sites comprising only 13 species across 11 genera. Sanilkumar *et al*., (2009) documented the distribution of planktonic microalgae in estuarine and coastal regions, identifying a total of 175 species. Nasser and Sureshkumar, (2014) conducted an assessment of seasonal Fluctuations and ecological richness of phytoplankton in the Parambikulam Reservoir located in the Western Ghats. Their study identified and documented 42 species of diatom reservoir and the dominant species are *Pinnularia* and *Navicula* inhabiting the reservoir. Binoy and Ray, (2016) investigated the variety and environmental roles of diatoms in *Oxic Dystrudepts* soils across three distinct vegetation types in the Western Ghats. The study focused on the ecology and range of diatoms in the Western Ghats of South India, a renowned biodiversity hotspot. Soil samples were compiled from various vegetation types including forests, rubber plantations, and teak plantations across three different seasons. Diatoms were observed directly in field soil samples and also cultured in nutrient media for further examination. Identification relied on morphological characteristics, employing both ordinary microscopic and scanning electron microscopy techniques.

Sreenisha and Paul, (2016) reported 39 diatoms species based on study of pollution studies of phytoplankton diversity of Tirur River, Malappuram District, Kerala. Throughout the study period, the class Bacillariophyceae emerged as a diverse group of algae in all three venues of the Tirur River. Diatoms, being ecologically resistant and highly adapted to riverine environments, were prominently featured. Human interventions were identified as the primary cause of spoilage in the river. Paul and Anu, (2016) reported 6 species of diatoms from Guruvayur temple pond. This study investigates the diversity of algae in the Guruvayur temple pond, located in Thrissur district, Kerala, during the period between March to May 2014. These temple ponds hold significance for bathing, washing, and religious rituals in Kerala.

Tessy and Sreekumar, (2017) conducted an assessment on the seasonal and spatial distribution of freshwater diatoms in the Thrissur Kole lands. They reported 74 diatom taxa during their research. Out of the identified diatom taxa, 35 taxa are newly revealed additions to the diatom flora of Kerala and these taxa belong to 20 different genera. Initial documentation of two diatoms *(Caloneis Africana (Giffen) Stidolph* and *Luticola nivalis (Ehrenberg) D. G. Mann* from the South Western shore of India (Cochin backwaters) was first reported by Joseph and Francis, (2019). Over the course of a year, monthly surface water samples were gathered from twelve stations across the ecosystem. Physicochemical parameters were analyzed, and permanent slides of diatoms were made up by following standard procedures. The paper provides detailed depiction of global distribution information and accompanying photographs of these newfound species. This discovery contributes to the already diverse diatom flora of the Cochin backwaters, enhancing our understanding of their ecological significance in this region. Seena *et al*., (2019) on assesses the existing biological and ecological situation of phytoplankton diversity in 3 tributaries of Bharathapuzha river and the rivers Chittur, Kalpathy, Kannadi Rivers. During the study period from 2018-2019 eight one species were observed. Forty species comes under the Bacillarophyceae Family. Tessy, (2019) documented 112 taxa coming under 21 genera based on the methodical evaluation of freshwater phytoplankton in the perennial ponds of Thrissur, Kerala. Anjali *et al*., (2020) reported 9 diatom species coming under 4 genera based on the study of diversity of freshwater algal communities from Cheruchakkichola, Mangad, Kerala. Cheruchakkichola is an evergreen forest undergoing degradation. The study aims to document the correlation between the phytoplankton population and various physicochemical factors. Sampling was conducted at 5 different locations. Achankunju and Panikkar, (2022) studied variation in the distribution and composition of diatom species of Pathanamthitta district of Kerala and reported 90 taxa of diatom belonging to 29 genera. The study found that *Navicula* and *Pinnularia* were the most prevalent genera, each with a high number of species. Additionally, the presence of diatoms like *Cyclotella meneghiniana* and *Mastogloia smithii* in certain water bodies suggests a significant level of pollution in those areas. During their study a large number of taxa reported in post monsoon and low number of taxa reported in pre monsoon season. Devikrishna *et al*., (2023) conducted an assessment on fresh water algal diversity of Peechi Dam in Thrissur, identifying approximately nine species. Praseetha *et al*., (2024) documented ten diatom species from Tanikkudam River, Thrissur.

2.2. Diatoms in mangrove ecosystem: Diversity and Taxonomy

The mangrove environment is a special place where the most of flora, animals, and microscopic creatures like phytoplankton can be found and have the capacity to tolerate salt conditions. Among phytoplankton diatom serve as important members for maintaining aquatic food web. They inhabit on the stem, roots of mangroves. Mangroves together with this micro-species forms an ecosystem. Mangroves are home to a diverse range of plant species that belong to different taxonomic groupings but are all connected by their adaptability to a shared ecological environment. Species like *Avicenia* and *Rhizophora* are well-known. Mangrove ecosystems are one of the prolific in the world. Many taxonomic studies have progressed over time, each putting forward to identify the different taxa of species that live in the intertidal zones of coastal estuaries.

A study organised by Maples, (1983) on diatom communities that dwelling on pneumatophores of black mangrove, *Avicennia germinans*, revealed a total of 109 species encompassing 27 genera in samples collected from five different sites of mangroves. The predominant species included *Nitzschia brittonii Hagelstein, Nitzschia frustulum (Kutz.) Grun., Navicula diserta Hust., Denticula subtilis Grun., and Amphora tenuissima Hust. The* phytoplankton abundance in the Pitchavaram mangroves was notably high. A total of 82 species of diatoms were enlisted by Kannan and Vasantha, (1992). A total of 21 genera were recorded in a study by Sarpedonti and Sasekumar, (1996) based on a two-month primary survey performed in five mangrove zones largely occupied by *Avicennia* or a mix of *Avicennia* and *Rhizophora* species. *Nitzschia* and *Navicula* were the most common genus among these. Furthermore, these diatoms are a crucial source of nourishment for deposit feeders. Beltrones and Castrejón, (1999) investigates the pelagic diatom accumulations from the mangrove forest of mexico enlisted 230 diatom species encompasses 48 genera, which comprises,109 newly recorded species to for the Baja California. Durin their study period species majorly reported from *Navicula, Nitzchia, and Amphora, Achnanthes and Diploneis.* Another study conducted by Zong and Hassan, (2004) recorded 71 diatom taxa based on the analysis of sediment samples of mangrove tidal flats in Peninsular Malaysia.

Sylvestre *et al*., (2004) enlisted 178 diatom species from the 85 samples studied in the mangrove swamps of the Kaw Estuary (French Guiana). The study also demonstrates that marine planktonic species like *Coscinodiscus centralis, Cyclotella stylorum, and Thalassionema nitzschioides* transported by oceanic waters were the main dominant species in the fluid mudflat. They also identified that *Gyrosigma, Nitzschia and Navicula* species were dominant due to their capacity of high motility in mangrove mudflat and also maintain the vegetation. A study conducted by Changping *et al*., (2005) the focus was on investigating the biomass, species composition, and diversity of littoral diatom assemblages in mud-flat soils or sediments of *Kandelia candel* vegetation. They enlisted a total of 103 taxa in which, 84 taxa were Discerned in the mud-flat with vegetation, while 74 taxa were noticed in the mud-flat without vegetation. According to Siqueiros *et al*., (2005) investigation of samples of epiphytic diatom aggregations recognized on red mangrove *Rhizophora mangle* prop roots of Mexico, a total of 171 diatom species were identified, which comprises 16 newly recorded species. Horton *et al*., (2007) have discovered 95 different diatom taxa from 31 different samples taken from the mangrove settings in Indonesia's Ambeua and Mantigola. They also discovered that the amount of duration and frequency of intertidal exposure play a crucial part in governing the relative diatom abundance in Indonesian mangroves. In a study conducted by Hendrarto and Nitisuparjo, (2011) enlisted the presence of 86 different species of benthic diatoms within three different mangrove forests located in Central Java. Rejil and Joseph, (2013) conducted research on microalgal variation in mangrove ecosystem and documented 57 diatom species. According to a study by Prabavathy and Pillai, (2017) on the diatoms that residing in the sedimentary layers of the Manakudy Estuary, recorded 128 species of diatoms representing 50 genera. Of these species, 21 were common, and 74 species belongs to pennate diatoms that predominated over 54 species of centric diatom obtained from the four regions.

Another investigation organized by Samanta and Bhadury, (2018) embarked on a pioneering exploration of diatom assemblages within the Sundarbans mangroves region, employing both light microscopy and rbcL gene sequencing coupled with phylogenetic analysis. Their findings revealed a total of 15 diatom species, comprising 11 centric forms and 4 pennate forms, as elucidated through light microscopy. Furthermore, our rbcL phylogenetic analysis unveiled the presence of 3 major clades of diatoms. Interestingly, seven of the fifteen diatom species that have been found were discovered for the initial time within the Sundarbans mangrove waters. Fulmali *et al*., (2019) delves into the arrangement of diatoms in Pulicat Lagoon's mangrove ecosystem a total 32 genera of diatoms were documented. They also observed that in this ecology, pennate diatoms are more common than centric forms.

Another study by Saifullah *et al*., (2019) documented 62 species of diatoms from tropical mangrove regions. Jeslin *et al*., (2021) recorded 81% of the microphytobenthic community from Kollam, Kannur and Kochi mangrove ecosystem. In this Pennate diatom, constituting 93% of the entire population of diatom, were the dominant group.

Nihal *et al*., (2022) enlisted 15 diatom species from mangrove ecosystem of Edakochi. Koshy *et al*., (2022) conducted a research study examining the epibiotic community present on pneumatophores and artificial substrates within a mangrove ecosystem. Their findings revealed a diverse array of diatoms, with representatives from 21 different genera. Notably, common genera were observed on both the substrates such as *Cocconeis, Pleurosigma, Navicula, Nitzschia, Gyrosigma, Biddulphia, Cymbella, and Melosira*. However, certain genera such as *Coscinodiscus, Cyclotella, Campylodiscus, Bacillaria, Diploneis, Licmophora, Striatella, and Amphora* were exclusively limited to pneumatophores, while others species like *Cyclostephanus, Puncticulata, Pinnularia, Lindavia, and Encyonopsis* were confined only to the artificial substratum.

3. MATERIALS AND METHODS

3.1. Study area

Kerala, nested in the South West of India, boasts nearly 600km of stunning Arabian Sea coastline along the tropical Malabar Coast. Kerala State lies at the southwestern edge of peninsular India, stretching from around 8°18' to 12°48' north latitudes, and 74°52' to 77°22' east longitudes. The current study was undertaken in a selected mangrove area within Thrissur district. The mangroves in Thrissur provides majorly shoreline stabilization protection etc. Mangroves and diatoms share a fascinating relationship within coastal ecosystems. Diatoms have the ability to survive in extreme conditions in mangrove habitats, where they play crucial roles in nutrient cycling and primary productivity.

3.1.1. Sample stations

Samples were gathered from various locations in Thrissur. Samples are collected from 3 sites.

Site 1: Kandassanakadavu Vadanampally, the distinctiveness of Kandassanakadavu, Vadanampally, is the occurence of mangrove species belongs to ***Rhizophora mucronata***. The area extends from approximately 10.47109°E to 76.094347°N.

Site 2: Kadappuram, Mattummal, stretches from around 10.549086°N to 76.029815°E. The region forms a distinct ecological feature with ***Avicennia sps*** that harbours along the shoreline of coast.

Site 3: located at Kanoli near Karekadavu Bridge in Orumanayur, Thrissur between 10.553796°N to 76.030306°E. The uniqueness Orumanayur, Thrissur, is the occurence of multiple mangrove species majorly ***Avicenia sps*** lies along the streamline of coast.

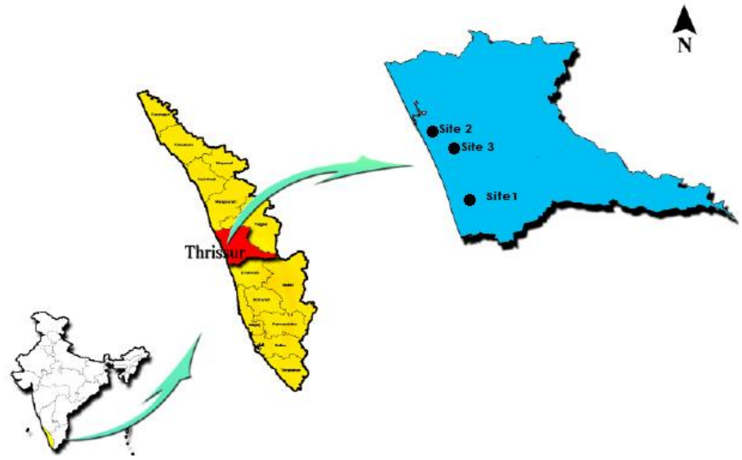


Fig 1. Study area

3.2 Collection

Diatoms can appear as a delicate golden-brown layer on surfaces, which can become more prominent under certain conditions or seasons. They thrive on solid surfaces, moist sediments, and plant stems, and can also be found suspended in water or attached to man-made objects like paper or plastic. Diatom attached surface forms a slimy or mucilaginous nature. The field collection equipment includes large and small sample bottles, a scalpel, a pH meter, a thermometer, labels, and plastic cups, plastic Pasteur-pipettes. As part of the study, samples are collected from attached substrates on mangroves, as well as from the roots of mangroves, pebbles, and other relevant sources, pH and temperature are recorded at the time of sample collection using a pH meter and a thermometer, respectively. Samples are collected from above 3 locations. Samples from the three locations are collected in tarson bottles, while pebbles or substrata attached samples are collected using a small scalpel and placed in small container for preservation and analysis. The bottles are appropriately labeled to indicate the three collection sites. The collected samples are transported to the Department of Forest Botany at KFRI Peechi Laboratory for further processing, including clearing, identification, and taxonomic studies. The collected water samples were left to settle overnight after adding a few drops of 98% ethyl alcohol as a preservative.

3.3. Sample preparation

The equipment includes beakers, gloves, reagents such as concentrated HNO3 (nitric acid), a hot plate, a fume hood, a measuring cylinder, a watch glass, and labels. Concentrated diatom samples were cleared by hot HNO3 method (Taylor *et al.*, 2005). About 1:2

concentrated HNO3 added to the samples in the beaker, adjusting the amount based on the volume of the sample taken. Then place the beaker on a hot plate inside fume hood. Heat the sample at 80°C for 30-45 minutes and time depends on the amount of organic matter present in it. Centrifuge the sample remove the supernatant and permanent slide is prepared by Naphrax mounting medium (Taylor *et al.*, 2005) The sample is now prepared and ready for observation under the microscope.

3.4. Observation

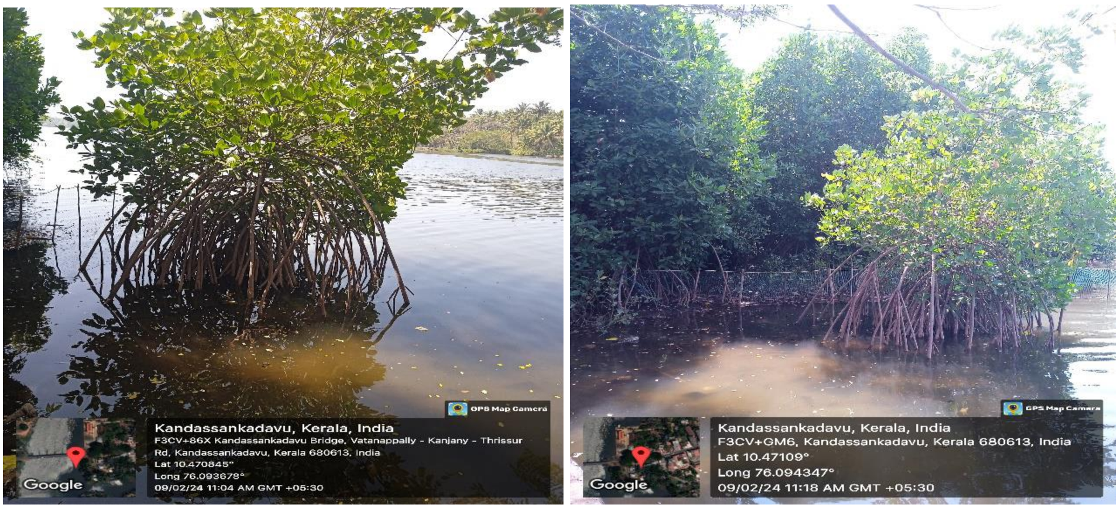
The prepared diatom samples are viewed under camera attached Research microscope and digital photographs are taken by Leica DM 2000 V4.11.0 application suite. The measurements and photomicrographs were obtained using a Leica DMC 2900 digital camera and LAS (Leica Application Suite) for capturing and analysing images. Measurements of diatom samples are also recorded, typically including parameters such as stria density, valve length, valve breadth, and so on. Specimens can be examined under 4x, 10x, 20x, 40x, 100x. It should be ensured that high-quality images should be captured to facilitate easy identification of the diatom samples.

3.5. Taxonomic description of diatoms

The diatom taxa are identified with the assistance of authentic scientific literatures such as Gandhi (1967), Freshwater diatoms of Maharashtra by Sarode and Kamat (1984), Common diatoms of peninsular India by Karthick *et al.,* (2013), A systemic account of some South Indian diatoms by Venkataraman (1939). An illustrated guide to some common diatom species from South Africa by Taylor *et al.,* (2007), Diatoms from the Hida Mountain Range in the Japan Alps by Hirano, (1972), Algal flora of Kerala by John and Francis (2013), Marine benthic microalgae of India by Joseph and Saramma (2011). Additionally, other online journals and reputable websites such as Diatoms of North America and Algae Base were referenced for taxonomic identification.

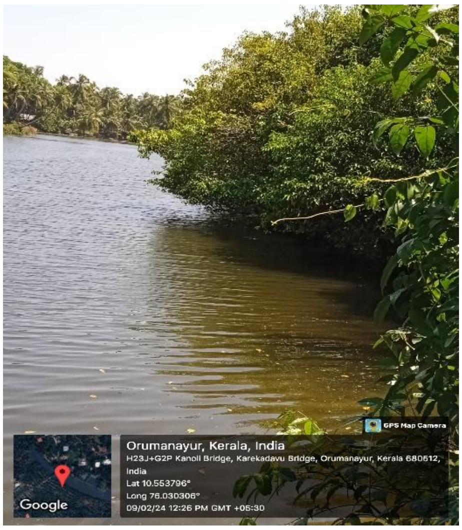
3.6. Classification of Diatoms

The identified diatom taxa are systemized based on the classification proposed by Cox, (2015). Nowadays Cox classification is widely accepted and commonly used for diatom classification.



Site 1: Kandassanakadavu

Site 2: Kadappuram



Site 3: Orumanayur

Fig.2. Collection of samples

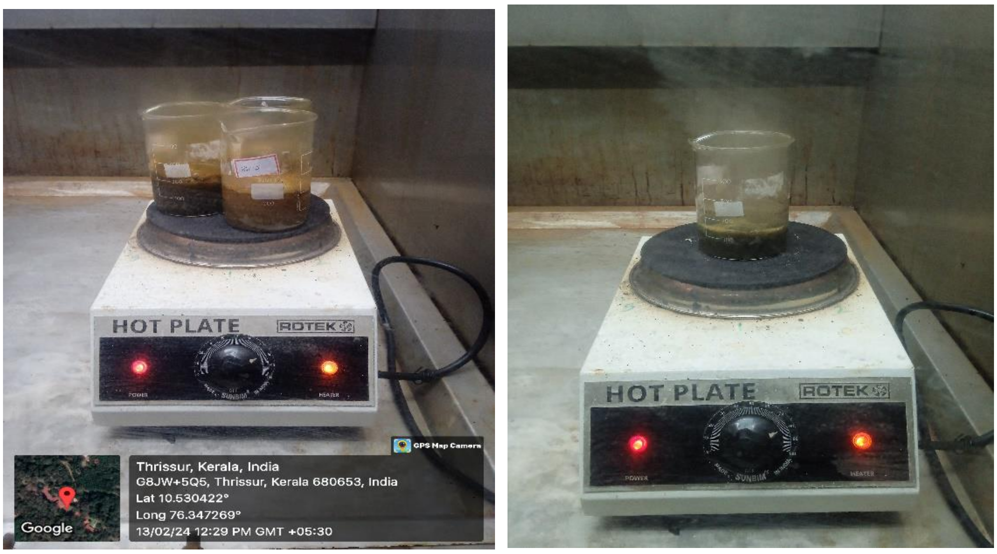


Fig 3. Hot plate Method

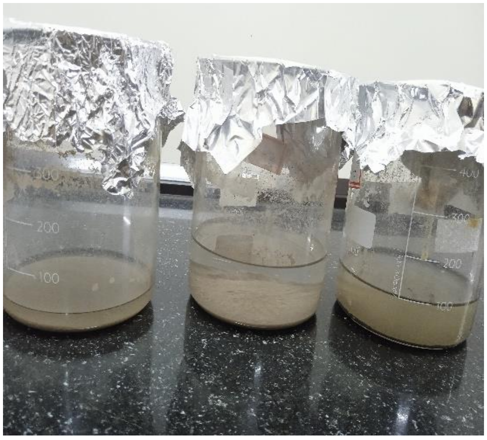


Fig. 4. Sample ready for analysis

4. RESULTS

Taxonomic description of diatoms

The taxonomic characterization of diatoms is organized according to their classification.

Class : Coscinidophyceae

Subclass : Melosirophycedae

Order : Melosirales

Family : Aulacoseiraceae

1**. *Aulacoseira granulata*** (Ehrenberg) Simonsen (Pl.1, fig. a)

Taylor *et al*., 2007, Pl. 2

Valve diameter: 38.646 µm, valve mantle depth: 9.420 µm, striae density: 13/10 µm. The frustules are connected end to end by elongated linking spines, forming long filaments. Smaller spines may also be present around the margin of the valve. Valves are predominantly observed in girdle view, with coarse areolae. Areolae on the valve face are randomly distributed, although in many specimens they are concentrated or predominantly found along the margin. An elongated linking spine is also present in the filament of terminal cell.

Family : Hyalodiscaceae

2**. *Podosira montagnei*** Kützing (Pl.1, fig. b)

Joseph and Saramma 2011, Pl. 1. Fig. 4

Valve diameter: 21.424 µm. Cells are frequently united in short chains exhibiting globular or short cylindrical in shape. The valves are characterised by deeply convex and hemispherical in shape, girdle constructed from numerous intercalary bands. On the valve face, fine areolae are present, that are arranged on the oblique lines on the deeper convex surface, and in irregular fascicules with a sub radial arrangement on upper surface.

Subclass : Coscinodiscophycidae

Order : Coscinodiscales

Family : Coscinodiscaceae

3. ***Stellarima microtrias*** (Ehrenberg) G.R.Hasle & P.A.Sims (Pl.1, fig. c)

Hasle *et al.*, 1996, Pl. 19

Valve diameter: 46.363 µm, Striae density: 13/10 µm. The cells are discoid, with valves that are more or less convex depending on their diameter. Areolae are arranged in radial rows, larger in size without marginal processes. Numerous small chloroplasts, irregularly shaped, are also present.

Class : Mediophyceae

Subclass : Thalassiosirophycidae

Order : Thalassiosirales

Family : Stephanodiscaceae

4. *Cyclotella bifacialis* Jurilj (Pl.1, fig. d)

Karthick *et al.*, 2013, Pl. 4

Valve diameter: 33.875 µm, striae density: 8-9/10 µm. The frustules exhibit a drum-shaped structure with tangential undulations and a flat valve face. Marginal striae are strongly radial, tapering towards the centre. Fascicles are not distinctly visible under low magnification, but they are separated by interfascicular costae, each terminating in a spine.

Family : Thalassiosiraceae

5.***Thalassiosira oestrupii var. venrickiae*** G.A.Fryxell & Hasle (Pl.1, fig. e)

Kandari *et al.*, 2009, Pg no. 42, Pl. 2, Fig. G-L

Valve diameter: 32.637 µm. Cells can exist singly or in chain formations, with valves that are either slightly convex or entirely flat. Areolae are arranged eccentrically, slightly large towards the centre.

6. ***Thalassiosira weissflogii*** (Grunow) G.A.Fryxell & Hasle (Pl.1, fig. f)

Taylor *et al*., 2007, Pl. 7

Valve diameter: 28.511µm. It is characterised by several valve fultoportulae (2-15) located in the central area. A ring of fultoportulae present at the junction of valve face and mantle. The Areolae are fine and structural details are not discernible under light microscope. A solitary noticeable rimoportula is also present on the edge of the valve.

Order : Eupodiscales

Family : Eupodiscaceae

7. ***Pleurosira laevis*** (Ehrenberg) Compère (Pl.1, fig. g)

Karthick *et al*., 2013, Pl. 6

Valve diameter: 128.714 µm. Valves range from circular to elliptical in shape. The valve face is slightly hemispherical. Two ocelli are visible, positioned opposite each other, consisting of fine rows of porelli. Radiate striae visible. The ocelli vary in size, with one probably larger than other. Two to three rimoportulae are evident, each surrounded by a small, translucent area. Areolae are arranged in short radial rows at the valve edge and irregularly distributed in central region. Spinules are present across valve face and along its peripheral margin sides.

Class :Fragilariophyceae

Order : Fragilariales

Family :Fragilariaceae

8. ***Fragilaria crotonensis*** Kitton (Pl.1, fig. i)

Karthick *et al*., 2013, Pl. 15

Valve length: 48.039 µm, width: 3.979 µm, striae density: 14/10 µm. The frustules form filamentous colonies, with opposing valves attached centrally within the cells. Valves are linear-lanceolate, swollen at the centre, and exhibit nearly capitate, rounded apices. The central sternum is narrow at the ends, gradually widening towards the centre. "Ghost" striae are observed alongside parallel striae in the central region.

9. ***Fragilaria biceps*** (Kützing) Lange-Bertalot (Pl.1, fig. m)

Syn. ***Synedra ulna*** var. biceps (Kutzing) Kirchner in Cohn

Taylor *et al*., 2007, Pl. 13

Valve length: 207.843 µm, width: 10.666 µm, striae density: 9/10 µm. Valves exhibit linear shapes with rounded, sub-capitate, or capitate tips. Their central region appears small, hyaline, and lacks distinct definition. Striae consist of a solitary line of clearly visible puncta. When viewed from the side, they appear rectangular.

Class :Bacillariophycidae

Subclass :Eunotiophycidae

Order : Eunotiales

Family : Eunotiaceae

10. ***Eunotia camelus*** Ehrenberg (Pl.1, fig. h)

John and Francis 2013, Pg no. 194

Valve length: 79.569 µm, width: 12 µm, striae density: 15/10 µm. The valves exhibit a distinctive arc shape, with a convex dorsal side featuring four equally spaced rounded humps, while the ventral side is concave. The ends are sharply narrowed on the dorsal side, forming rounded sub capitate protrusions. Small terminal nodules and a discernible raphe are present at the apices of the ventral margin. Additionally, the striae are characterized by coarse lineate.

Order : Achnanthales

Family :Achnanthidiaceae

11.***Achnanthidium exiguum*** (Grunow) Czarnecki (Pl.1, fig. k)

Taylor *et al*., 2007, Pl.26

Valve length: 18.719 µm, width: 10.913 µm, striae density: 20/10 µm. It may vary from elliptical to linear- elliptical. A specialised butterfly shaped central area present on the raphe wall.

Subclass : Bacillariophycidae

Order :Mastogloiales

Family :Mastogloiaceae

12. ***Mastogloia exigua*** f. brevirostris Venkat (Pl.1, fig. j)

Sarode and Kamat 1984, Pl. 6, fig. 130

Valve length: 26.219 µm, width: 10.827 µm, striae density: 15/10 µm. It is characterised by broad, elliptical, with broadly rounded ends. The raphe is straight with slightly bent terminal fissures. axial area narrow and central area nearly square. Five loculi are present in which bigger are arranged in the middle portion and smaller ones at the end region. Two longitudinal septal bands abruptly curve inward and outward before converging near the ends. The striae are radial and subtly punctuated.

Order : Cymbellales

Family : Anomoenoidaceae

13. ***Anomoeoneis sphaerophora*** (Ehrenberg) Pfitzer (Pl.1, fig.l)

Taylor *et al*., 2007, Pl.63

Valve length: 71.460 µm, width: 22.284 µm, striae density: 15/10 µm. Valves have sub-rostrate to capitate apices and range in shape from elliptic to elliptic-lanceolate. A single row of areolae surrounds the small axial space on all sides. Areolae vary in lateral spacing, with the exception of the area at the valve edge. The middle portion is lyrate and asymmetric, reaching the valve edge on one side and being extensively rounded on the other. There are faint ghost striae in the centre. The raphe is straight and lateral. The tips of the proximal raphe are twisted to one side and slightly swollen. Fissures in the distal raphe are severely deflected in the same direction. Striae are radiating, with apices where they either become parallel or gradually converge. It is characterised by the presence of large lateral hyaline area. Areolae is transapically elongated.

Family : Gomphonemataceae

14. ***Gomphonema insigne*** W. Gregory (Pl.2, fig. a)

Taylor *et al*., 2007, Pl. 121

Valve length: 49.789 µm, width: 10.450 µm, striae density: 10/10 µm. Valves are lanceolate with strong heteropolarity. The head pole is broadly rounded, contrasting with the sharply rounded foot pole. Moderately broad and linear axial area is observed. A small, rounded central area is formed due to the shortening of central striae. The raphe is lateral, featuring small, rounded proximal endings, and comma-shaped distal endings. Striae are parallel to radiate near the poles, exhibiting variable density.

15. ***Gomphonema parvulum*** (Kützing) Kützing (Pl.2, fig. b)

Taylor *et al*., 2007, Pl. 122

Valve length 15.076 µm, width 6.480 µm, striae density 14/10 µm. The valves display a subtly heteropolar club-like shape, varying from lanceolate to elliptical to oval. When observed from above, they appear weakly tapered to rectangular, with slightly extended and gently capitate apices. A narrow and linear axial area is present, accompanied by a small central area resulting from the shortening of the central striae. Stigmata are closely situated along the longer central striae. The raphe is faintly lateral, while the striae run parallel to weakly radial patterns, displaying faint punctation.

16. ***Gomphonema sps.*** (Pl.2, fig. c)

Santos *et al*., 2012, fig. h-j

Valve length: 54.141 µm, width: 7.898 µm, striae density: 12/10 µm. Biraphid diatom, characterised by swollen middle region. Apices strongly protracted and elongated. Striae size become shorter towards the tips.

Family : Cymbellaceae

17.***Cymbella turgidula*** Grunow (Pl.2, fig. d)

Taylor *et al*., 2007, Pl. 106

Valve length: 36.159 µm, width: 11.902 µm, striae density: 12/10 µm. The valves are dorsiventral, with a strongly arched dorsal margin and a weakly convex ventral margin. Apices are short and blunt, ranging from sub-rostrate to rostrate-truncate, with weak protraction observed in larger specimens. The axial area is narrow, while the central area is small and rounded, typically more developed on the dorsal side and occasionally absent in smaller specimens. The raphe is weakly lateral, with rounded proximal endings.

18. ***Encyonema hustedtii*** Krammer (Pl.2, fig. e)

Karthick *et al*., 2013, Pl. 99

Valve length: 47.756 µm, width: 10.656 µm, striae density: 11/10 µm. Valves are dorsiventral and semi-elliptic, featuring a strongly convex dorsal side and a gently convex ventral side, with a pronounced bulge at the middle region. Ends are rounded yet somewhat acute. The axial area is notably displaced anteriorly. The central area is indistinct, exhibiting a slight widening towards the dorsal region. The raphe is moderately wide, displaying a straight to slightly curved trajectory, with branching occurring primarily in its central segment. Striae are punctate, showing broader spacing towards the middle and becoming coarser towards the ends.

Order :Naviculales
Family :Pinnulariaceae

19. ***Caloneis africana*** (Giffen) Stidolph (Pl.2, fig. f)

Witkowski *et al*., 2000, Pg no. 152, Fig. 1,2

Valve length: 110.425 µm, width: 33.832 µm, striae density: 14/10 µm. The valves are elliptic, featuring broadly rounded or produced obtusely rounded apices. The raphe is straight, with external central endings expanded, and distant apical endings sickle-shaped and curved on one side. The axial area at the apices is narrow, broadening towards the middle. The central area is weakly separated, typically large and circular. Transapical striae radiate throughout the valve.

20. ***Pinnularia subcapitata*** W. Gregory (Pl.2, fig. h)

Taylor *et al*., 2007, Pl. 88

Valve length: 33.521 µm, width: 8.832 µm, striae density: 14/10 µm. Valves linear with parallel, weakly curved concave or convex margins. Apices are rounded, protracted, or capitate type. Proximal raphe terminations bent, closely positioned terminal fissures semi-circular. The stria is moderately spaced, conspicuous and short. Axial region is linear, slightly broadened. Central zone wide and rounded or extending into a fascia.

21. ***Pinnularia acrosphaeria*** W. Smith (Pl.2, fig. l)

Karthick *et al.*, 2013, Pl. 74

Valve length: 51.172 µm, width: 9.221 µm, striae density: 13/10 µm. Valve outlines are linear, with straight margins that exhibit slight convexity, particularly swollen at the middle region. Ends are broadly rounded, occasionally resembling a capitate shape. The axial area is broad and linear, slightly expanding near the central area. Terminal fissures are notably large, exhibiting a sickle-shaped form that varies among different varieties. Striae are predominantly parallel to weakly radiate, running parallel or slightly converging towards the ends. Both the axial and central regions consist a feature of distinct irregular surface texture.

Family :Diplonidaceae

22.***Diploneis smithii*** (Brébisson) Cleve (Pl.2, fig. i)

Taylor *et al*., 2007, Pl. 41

Valve length: 33.857 µm, width: 20.122 µm, striae density: 12/10 µm. The valves are linear-elliptical with broadly rounded apices, while median ribs (longitudinal canals) gently taper from the centre towards the ends. A relatively small central area forms an irregular, rounded to rectangular hyaline region. Longitudinal canals intersect with striae, which are distinctly doubly-punctate and radiate. Foraminal perforations are clearly visible.

23.***Diploneis puella*** (Schumann) Cleve (Pl.2, fig. k)

Taylor *et al*., 2007, Pl.41

Valve length: 22.257µm, width: 13.960 µm, striae density: 13/10 µm. The valves exhibit an almost oval shape, with a narrow, linear axial area containing a small, slightly rectangular central region, measuring 1.0-1.5 µm in width. A narrow and linear longitudinal canal is present. The raphe appears straight, with slightly expanded central ends. Striae are robust and slightly radiate. Areolae may not be easily distinguishable under light microscopy, but become apparent with critical illumination, appearing biseriate. Perforations can visibly be seen on the foramina near the axial area.

24.***Diploneis elliptica*** (Kützing) Cleve (Pl.2, fig. j)

Taylor *et al*., 2007, Pl.40

Valve length: 48.975 µm, width: 18.795 µm, striae density: 11/10 µm. The valves exhibit an elliptical shape, characterized by convex margins and rounded apices. A narrow-lanceolate axial area is discernible, slightly widening from the apices towards the central region. Notably, the central area is prominent and circular in form. Longitudinal canals flank both the axial and central areas, widest near the central region and tapering towards the apices. The raphe is straight with expanded proximal ends, while terminal raphe fissures deflect unilaterally, ceasing short of the valve periphery. Striae are primarily radiate at the mid-valve, intensifying in radiance towards the apices. These striae consist of intricate, round to rectangular areolae, arranged in a uniseriate pattern. Perforations in the foramina not visible in light microscopy.

Family : Naviculaceae

25. ***Gyrosigma rautenbachiae*** Cholnoky (Pl.2, fig. g)

Taylor *et al*., 2007, Pl.34

Valve length: 130.146 µm, width: 23.897 µm, striae density: 15/10 µm. The central area exhibits a distinct structural composition. Externally, the proximal raphe endings curve in opposing directions, dividing one or two longitudinal striae. Internally, this central region features two prominent, thickened margins that are raised above the surrounding surface. Longitudinal and transverse striation can be seen.

26.***Gyrosigma attenuatum*** (Kützing) Rabenh (Pl.3, fig. a)

Taylor *et al*., 2007, Pl. 33

Valve length 260.725 µm, width 32.518 µm, striae density 12/10 µm. The valves are narrowly lanceolate and moderately sigmoid in shape. The central area is small, longitudinally elliptical, and occasionally irregular. The raphe runs straight for at least two-thirds of its length and is centrally positioned on the valve. Toward the apices, the raphe adopts a sigmoid curve. The proximal raphe ends diverge to opposite sides of the valve near where the axial area widens to form the central area. The axial area is narrow, broadening into a triangular shape at each end of the valve. The distal raphe ends also diverge in opposite directions. Longitudinal striae run parallel to the axial area, including within the central area where it widens. These longitudinal striae exhibit greater coarseness compared to the transverse striae. Oblique orientation in the central area.

27.***Gyrosigma acuminatum*** (Kützing) Rabenhorst (Pl.3, fig. b)

Taylor *et al*., 2007, Pl. 35

Valve length: 77.858 µm, width: 11.464 µm, striae density: 18/10 µm. The valve exhibits a moderately sigmoid shape, ranging from slender to somewhat more broadly lanceolate with fairly obtuse or subacute ends. The raphe sternum displays minimal double curvature, nearly straight for half its length, mostly median except slightly eccentric near the ends, with a raphe angle ranging from +3 to +8 degrees. Central raphe fissures show a "crook-shaped" pattern, oppositely deflected to either the convexity or concavity of their raphe sternum (dimorphic deflection type). The central area is oval and not rotated. Terminal areas feature unilaterally dilated funnels positioned semi -laterally. A crescent of minute apical micro foramina encircles the apex in the hyaline terminal area, barely visible under light microscopy. Longitudinal striae, notably closer together at the valve margin (observed via SEM), with transverse striae being almost equally fine or very slightly coarser.

28. ***Navicula rostellata*** Kützing (Pl.3, fig. i)

Taylor *et al*., 2007, Pl.68

Valve length: 40.895 µm, width: 11.644 µm, striae density: 11/10 µm. The valves are lanceolate to slightly linear lanceolate with protruding rostrate apices. The axial area is narrow, central area is moderately large and rounded, featuring a centrally placed nodule that is symmetrically thickened on one side. The striae are radial towards the centre, transitioning to convergent near the poles. Raphe straight, filiform, with proximal raphe ends become dilated slightly and bent towards any one side.

29.***Navicula jogensis*** H.P. Gandhi (Pl.3, fig. d)

Gandhi 1959, Pg.no. 142, Pl.15, Fig. 112-115

Valve length: 50.958 µm, width: 23.740 µm, striae density: 15/10 µm. The valves are broad, broadly elliptical rhomboid with or without slightly constricted, broad, truncately rounded ends.Raphe is thin and straight with distinct central pores, and terminal fissures that are short but sharp towards the extremity. Axial Area characterised by narrow, linear or sublinear. The Central Area is large, rounded, or transversely elliptical, without punctae or stigma.

30. ***Navicula erifuga*** Lange-Bertalot (Pl.3, fig. e)

Karthick *et al*., 2013, Pl. 68

Valve length: 32.818 µm, width: 5.653 µm, striae density: 14/10 µm. The valves are lanceolate-elliptic to lanceolate-linear with typically acute apices, though occasionally obtuse. The raphe exhibits filiform branches, with the outer branch curved towards the proximal end. Terminal raphe fissures are hooked towards the secondary side. Central area appears narrow and asymmetrically rectangular on the side where pores are deflected, and elliptical on the opposite side. Central area is "bow-tie" shaped on the primary side and crescent-shaped at the secondary side. Striae are weakly radiate, becoming convergent near the poles. Lineolae are visibly seen under light microscopy.

31.***Navicula metareichardtiana*** Lange-Bert. and Kusber (Pl.3, fig. h)

Kusber *et al*., 2019.

Valve length 15.592 µm, width 7.096 µm, striae density 14/10 µm. The valves exhibit a lanceolate shape with elongated, slightly tapering ends. The axial area appears narrow and linear, while the central area is diminutive. Striae are arranged in a radiate pattern towards the center, becoming convergent towards the apices, typically numbering 14-16 per 10 µm. Areolae are approximately 32-36 in 10 µm, presenting a challenge to discern under light microscopy due to their faint appearance. Notably, the striae exhibit a distinctive curvature at the midpoint of the valve. Additionally, shorter striae intermittently alternate with longer ones around the central area.

32. ***Navicula cryptotenella*** Lange-Bertalot (Pl.3, fig. i)

Taylor *et al*., 2007, Pl. 75

Valve length: 25.994 µm, width: 5.982 µm, striae density: 14/10 µm. The valves range from narrow to broadly lanceolate, with acutely rounded apices. The raphe is filiform to weakly lateral, and the axial area appears narrow and linear. A small central area is present, characterized by an irregular border. Striae are radiate and slightly curved at the valve center, transitioning to convergent towards the poles.

33. ***Navicula germainii*** J.H.Wallace (Pl.3, fig. f)

Karthick *et al*., 2013, Pl.65

Valve length: 32.11 µm, width: 7.555 µm, striae density: 13/10 µm. The valves are lanceolate with slightly extended, sharply rounded tips. The raphe is thread-like, with proximal ends strongly curved. The central area varies from small to moderately large, either elliptical or transversely expanded and rectangular. The central nodule thickening is asymmetrical. Striae are faintly radiate, transitioning to weakly convergent near the apical region.

34. ***Navicula brasiliensis*** Grunow (Pl.3, fig. g)

Boyer 1927. Pg no. 404

Valve length: 58.417 µm, width: 28.375 µm, striae density: 11/10 µm. The valves are elliptic-lanceolate, typically with slightly rostrate ends. The axial area is narrow or indistinct, while the central area is small and usually transverse. Striae radiate towards the ends, appearing punctuate, with puncta closer near the margin and arranged in longitudinal rows.

Family : Plagiotropidaceae

35. ***Plagiotropis lepidoptera*** (W. Gregory) (Pl.3, fig. j)

Joseph and Saramma 2011, Pg no. 40, Pl. 4, Fig. 2

Valve length: 97.729 µm, width: 22.080 µm. The frustules are weakly siliceous and elongated, taking on a more or less rectangular shape with strong constriction in the middle. Valves are linear-oblong or lanceolate with acute ends, featuring an indistinct small central area and a distinct wing projecting above the central nodule. The central nodule itself is small, with the terminal nodule rounded. Only one valve exhibits a unilateral keel, protruding above the median line, often observed in a tilted position rather than in a central orientation. The frustules are hyaline without costae, concave at the area of the central nodule. The girdle is rectangular, with finely punctuate transverse striations.

Family :Stauroneidaceae

36. ***Craticula ambigua*** (Ehrenberg) D.G. Mann (Pl.3, fig. k)

Syn. ***Navicula ambigua*** ehrenberg

Taylor *et al*., 2007, Pl. 47

Valve length: 45.546 µm, width: 14.071 µm, striae density: 18/10 µm. The valves exhibit a lanceolate shape, characterized by elongated rostrate ends. The axial area appears narrow and linear, while the central area shows minimal enlargement around its midpoint. A filiform raphe traverses the valve, with slightly expanded proximal raphe ends. Striae are faintly radiate, converging towards the extremities. There may be a subtle discrepancy in stria density between opposing sides of the valve. Notably, as the size range decreases within this taxon, stria density tends to intensify. Apices are characterised by protracted rostrate to weakly sub-capitate apices.

Family : Pleurosigmataceae

37. ***Pleurosigma salinarum*** (Grunow) Grunow (Pl.3, fig. c)

Taylor *et al*., 2007, Pl. 37

Valve length: 126.068 µm, width: 17.384 µm. The valves exhibit a subtle Sigmoid-shaped curvature, varying from lanceolate to linear-lanceolate in shape. Their apices are characterized by a blunt and rounded appearance. In the central region, a slender and distinctly S-shaped area is observed, often with a small elliptical structure at its core. The raphe displays a thread-like appearance, following a Sigmoid-shaped trajectory, with the external proximal ends positioned in close proximity to each other. Striae are faintly punctate in nature. Diagonal striae are discernible, appearing finer compared to the transverse striae.

Order :Thalassiophysales

Family :Catenulaceae

38. ***Amphora copulate*** (Kütz.) Schoeman and Archibald (Pl.4, fig. a)

Karthick *et al*., 2013, Pl. 87

Valve length: 38.058 µm, width: 20.928 µm, striae density: 13/10 µm. The valves display a semi-lanceolate to semi-elliptical shape, featuring a smoothly arched dorsal margin and a concave ventral margin. Valve ends are narrowly rounded. The axial area appears narrow. The raphe, arched and located towards the ventral margin, exhibits dorsally deflected proximal and distal ends. Distinct and round to elliptical dorsal fascia are present, typically "closed" to the axial area and dorsal margin by a row of short striae. Ventral fascia, typically longer in the apical axis than dorsal fascia, extend to the ventral margin. Weakly radiate dorsal striae in the central area become more radiate at the apices and are interrupted by intercostal ribs. A thickened, hyaline bar often appears on the dorsal margin, separating the valve face and mantle. Ventral striae are uninterrupted, radiate in the middle, converge towards the apices, and consist of a single areola.

39. ***Amphora coffeaeformis*** (C.Agardh) Kützing (Pl.4, fig. d & e)

Taylor *et al*., 2007, Pl. 99

Valve length: 46.108 µm, width: 10.623 µm, striae density: 14/10 µm. The valves are narrow with half-lanceolate shape, featuring a convex dorsal margin and a weakly concave ventral margin. The apices are narrow, protracted, and capitate. The raphe is slightly arcuate, positioned very close to the ventral margin, with proximal raphe endings slightly deflected to the dorsal side. Ventral striae are very short, while dorsal striae are initially parallel in the middle and become radiate. Puncta are not visible under light microscopy.

Order :Bacillariales

Family : Bacillariaceae

40. ***Bacillaria paradoxa*** J.F. Gmelin (Pl.4, fig. c)

Karthick *et al*., 2013, Pl. 109

Valve length: 59.251 µm, width: 7.8 µm, striae density: 22/10 µm. The valves exhibit a linear to linear-lanceolate shape, characterized by narrow rostrate or capitate apices. The keel is centrally positioned or nearly so, upheld by irregularly spaced fibulae. Rectangular and irregular puncta adorn the keel. Distinct, parallel striae run perpendicular to the keel. Frustules are arranged in lengthy chains, interconnected, and move via a gliding action along their valve.

41. ***Nitzschia recta*** Hantzsch ex Rabenh (Pl.4, fig. f)

Taylor *et al*., 2007, Pl. 145

Valve length: 129.437 µm, width: 9.925 µm, fibulae density: 8-9/10 µm. The valves are linear, ranging from linear-lanceolate to lanceolate in shape. The poles are slender and cuneate, while the apices are somewhat prolonged, with a slight capitate or acutely rounded appearance. The raphe is positioned marginally. Fibulae are narrow, elongated, and irregularly distributed. Striae are not distinguishable under low magnification but sometimes visible in large specimens. A conopeum is visible sometimes in LM.

42.***Nitzshia obtusa*** var. kurzii Rabenhorst (Pl.4, fig. g)

Taylor *et al*., 2007, Pl. 146

Valve length: 84.047 µm, width: 8.388 µm, fibulae density: 8/10 µm. The valves exhibit a linear-sigmoid shape, with poles that are cuneate in appearance and apices that are short and broadly rounded. Margins are distinctly constricted in the central region. The raphe is positioned marginally, while fibulae appear broad, irregularly spaced, and occasionally fused. The central area is discernible as it interrupts the fibulae in the central region. Punctate striae are only faintly visible under low magnification.

43. ***Nitzchia sigma*** (kutzing) W. Smith (Pl.4, fig. b)

Taylor *et al*., 2007, Pl. 149

Valve length: 96.878 µm, width: 8.757 µm µm, fibulae density: 8/10 µm. The valves exhibit a sigmoid shape, ranging from linear to linear-lanceolate. The poles are somewhat elongated, with cuneate apices. The raphe is positioned marginally and is upheld by slender fibulae that remain continuous across the central region. Transapical striae display irregular punctation, forming irregular longitudinal striae. Keel is somewhat strongly excentric pattern.

44**.** ***Tryblionella apiculata*** W. Gregory (Pl.5, fig.f)

Taylor *et al*., 2007, Pl. 138

Valve length: 46.257 µm, width: 6.611 µm, striae density: 17/10 µm; Taxa characterised by the presence of raphe on both sides of the valve face. These diatoms are characterised by undulate valve face adorned with transapical ridges. The valves are linear in shape, weakly concave in the middle portion and protracted narrow rostrate apices. The striae exhibit interruptions, typically by a single, somewhat broad longitudinal sternum, while fibulae are short and stout, often interrupted in the middle region, striation is peculiar, it is easy to see not only transverse but also oblique striae. The raphe is eccentric, while a central nodule may be present, it is not always easily visible.

45. ***Tryblionella hungarica*** (Grunow) Frenguelli (Pl.4, fig. h)

Taylor *et al*., Pl.139.

Valve length: 61.802 µm, width: 8.454 µm. The valves exhibit a linear shape with a subtle concavity at the center. The apices are slightly extended and have a blunt, rounded appearance. The raphe is positioned off-center, featuring 8-11 fibulae per 10 µm. Striae display a costate pattern rather than distinct punctation. Additionally, there is a longitudinal fold running the length of the valve. Fibulae are discontinuous in the middle region. Striae are interrupted by longitudinal internal sternum.

Order :Rhopalodiales

Family :Rhopalodiaceae

46.***Rhopalodia gibberula*** (Ehrenberg) O.Müller (Pl.4, fig. i)

Taylor *et al*., 2007, Pl.133

Valve length: 34.855 µm, width: 7.617 µm, fibulae density: 3/10 µm. Valves are dorsiventral in shape characterised by dorsal margin strongly convex with a slight indention in the centre and ventral margin is almost straight and slightly curved, with narrow round tips. Raphe branches follow the shape of the dorsal margin and it is supported by fibulae.

Order :Surirellales

Family :Surirellaceae

47.***Cymatopleura solea*** (Brébisson) W.Smith (Pl.5, fig. a)

Taylor *et al*., 2007, Pl.173

Valve length: 71.009 µm, width: 11.243 µm, fibulae density: 6-7/10 µm. The valves range from narrow to broadly linear, with margins that vary from weakly to strongly panduriform, rarely parallel. The apices are slightly cuneate and broadly rounded. The valve face exhibits strong longitudinal undulations, typically with four to six waves per valve, which are most clearly visible girdle view. Long forms may also display warts ornamenting the valve face.

48.***Cymatopleura solea var. apiculata (W.Smith)*** Ralfs (Pl.5, fig. b)

Taylor *et al*., 2007, Pl. 174

Valve length 55.418 µm, width 14.704 µm, fibulae density 9/10 µm. The valves of this variety are smaller compared to the nominate variety, yet they exhibit significantly more pronounced longitudinal undulations on the valve face.

49.***Campylodiscus clypeus*** (Ehrenberg) Ehrenberg ex Kützing (Pl.5, fig. c)

Taylor *et al*., 2007, Pl. 178

Valve diameter: 126.279 µm. The valves exhibit a saddle-shaped morphology, with fibulae interrupted by a continuous hyaline ring (sternum), creating a roughly rectangular area in the centre of the valve.

50. ***Campylodiscus*** sps (Pl.5, fig. d)

Karthick *et al*., 2007.

Valve diameter: 26.210 µm. The frustules can be either isopolar or heteropolar, with the raphe positioned along the entire valve margin. The raphe is situated on the canal, which may protrude above the valve surface. The valve is saddle-shaped in appearance.

51.***Surirella ovalis*** Brébisson (Pl.5, fig. e)

Taylor *et al*., 2007, Pl. 175

Valve length: 75.909 µm, width: 42.679 µm. Valves exhibit pronounced heteropolarity in larger specimens, transitioning to isopolarity in smaller ones. They appear cuneate in girdle view and rhombic-lanceolate to broad-lanceolate in valve view, with rounded apices. The valves display concentric undulations, noticeable in light microscopy as certain areas come into focus while others blur. The striae are interrupted by a distinct longitudinal line where the fibulae terminate.

SI. No	species	Site 1	Site 2	Site 3	General environment				
					Brackish forms	Fresh water forms	Marine forms	Both fresh and marine forms	All
1.	***Aulacoseira granulata*** (Ehrenberg) Simonsen	**+**	-	-		✓			
2.	***Podosira montagnei*** Kützing	-	+	-			✓		
3.	***Stellarima microtrias*** (Ehrenberg) G.R.Hasle & P.A.Sims	+	-	+			✓		
4.	***Cyclotella bifacialis*** Jurilj	-	+	+	✓				
5.	***Thalassiosira oestrupii var. venrickiae*** G.A. Fryxell & Hasle	+	-	-			✓		
6.	***Thalassiosira weissflogii*** (Grunow) G.A. Fryxell & Hasle	-	+	-					✓
7.	***Pleurosira laevis*** (Ehrenberg) Compère	-	-	+	✓				
8.	***Fragilaria crotonensis*** Kitton	+	-	-		✓			
9.	***Fragilaria biceps*** (Kützing) Lange-Bertalot	+	-	-		✓			
10.	***Eunotia camelus*** Ehrenberg	-	-	+		✓			
11.	***Achnanthidium exiguum*** (Grunow) Czarnecki	+	-	-		✓			
12.	*Mastogloia exigua* f. brevirostris Venkat	-	-	+					✓
13.	***Anomoeoneis sphaerophora*** (Ehrenberg) Pfitzer	-	-	+	✓				

14.	***Gomphonema insigne*** W. Gregory	-	-	+		✓			
15.	***Gomphonema parvulum*** (Kützing) Kützing	+	-	-		✓			
16	***Gomphonema sps***	-	-	+		✓			
17.	***Cymbella turgidula*** Grunow	-	+	-		✓			
18.	***Encyonema hustedtii*** Krammer	-	-	+		✓			
19.	***Caloneis africana*** (Giffen) Stidolph	-	+	+			✓		
20.	***Pinnularia subcapitata*** W. Gregory	+	-	-		✓			
21.	***Pinnularia acrosphaeria*** W.Smith	+	-	-		✓			
22.	***Diploneis smithii (Brébisson)*** Cleve	-	+	+					✓
23.	***Diploneis puella*** (Schumann) Cleve	-	+	+		✓			
24.	***Diploneis elliptica*** (Kützing) Cleve	-	+	-		✓			
25.	***Gyrosigma rautenbachiae*** Cholnoky	-	+	-		✓			
26.	***Gyrosigma attenuatum*** (Kützing) Rabenh	+	+	+		✓			
27.	***Gyrosigma acuminatum*** (Kützing) Rabenhorst	+	+	+		✓			
28.	***Navicula rostellata*** Kützing	-	+	-		✓			
29.	***Navicula jogensis*** H.P.Gandhi	-	+	+		✓			

30.	***Navicula erifuga*** Lange-Bertalot	+	-	-		✓			
31.	***Navicula metareichardtiana*** Lange-Bert. and Kusber	-	-	+		✓			
32.	***Navicula cryptotenella*** Lange-Bertalot	-	+	-		✓			
33.	***Navicula germainii*** J.H.Wallace	-	+	+		✓			
34.	***Navicula brasiliensis*** Grunow	+	-	-		✓			
35.	***Plagiotropis lepidoptera*** (W.Gregory)	-	+	-					✓
36.	***Craticula ambigua*** (Ehrenberg) D.G. Mann	+	-	-		✓			
37.	***Pleurosigma salinarum*** (Grunow) Grunow	-	+	+				✓	
38.	***Amphora copulate*** (Kütz.) Schoeman and Archibald	-	+	+					
39.	***Amphora coffeaeformis*** (C.Agardh) Kützing	+	+	+	✓	✓			
40.	***Bacillaria paradoxa*** J.F.Gmelin	+	+	+		✓			
41.	***Nitzschia recta Hantzsch*** ex Rabenh	-	+	-	✓				
42.	***Nitzshia obtusa*** var. kurzii Rabenhorst	-	+	-	✓				
43.	***Nitzchia sigma*** (kutzing) W Smith	-	+	+	✓				
44.	***Tryblionella apiculata*** W.Gregory	-	-	+	✓				
45.	***Tryblionella hungarica*** (Grunow) Frenguelli	-	-	+	✓				

46.	***Rhopalodia gibberula*** (Ehrenberg) O. Müller	-	+	+		✓			
47.	***Cymatopleura solea*** (Brébisson) W. Smith	-	-	+		✓			
48.	***Cymatopleura solea*** *var. apiculata (W.Smith)* Ralfs	-	-	+		✓			
49.	***Campylodiscus clypeus*** (Ehrenberg) Ehrenberg ex Kützing	-	-	+				✓	
50.	***Campylodiscus*** sps	-	-	+				✓	
51.	***Surirella ovalis*** Brébisson	+	-	-		✓			

Distribution of species in the selected study area.

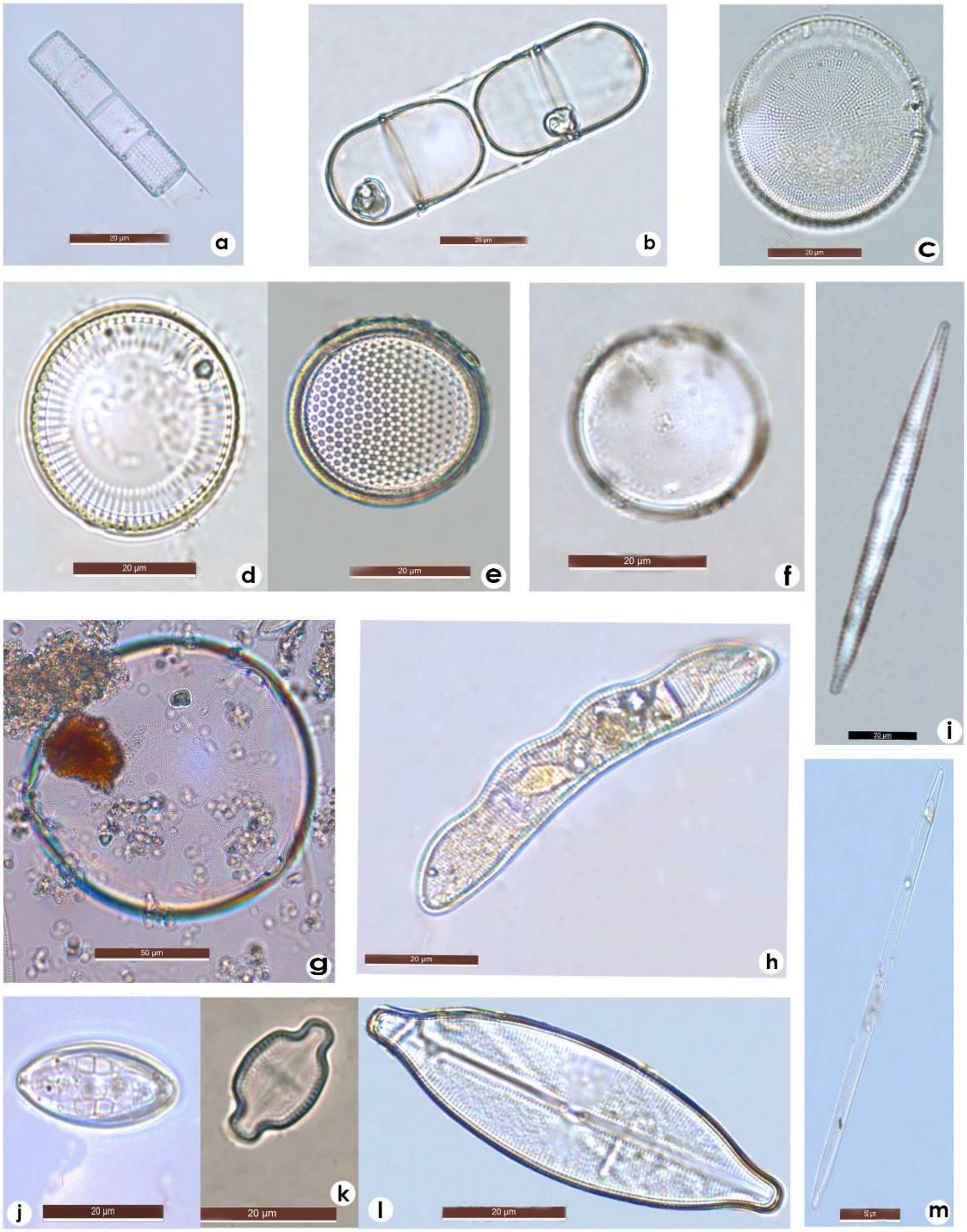


Plate 1.a.***Aulacoseira granulata*** (Ehrenberg) Simonsen b. ***Podosira montagnei*** Kützing c. ***Stellarima microtrias*** (Ehrenberg) G.R.Hasle & P.A.Sims d. ***Cyclotella bifacialis*** Jurilj e. ***Thalassiosira oestrupii*** var. ***venrickiae*** G.A.Fryxell & Hasle f. ***Thalassiosira weissflogii*** (Grunow) G.A.Fryxell & Hasle g. ***Pleurosira laevis*** (Ehrenberg) Compère h. ***Eunotia camelus*** Ehrenberg i. Fragilaria crotoneis Kitton j. ***Mastogloia exigua*** f. brevirostris Venkat k. ***Achnanthidium exiguum*** (Grunow) Czarnecki l. ***Anomoeoneis sphaerophora*** (Ehrenberg) Pfitzer m. ***Fragilaria biceps*** (Kützing) Lange-Bertalot.

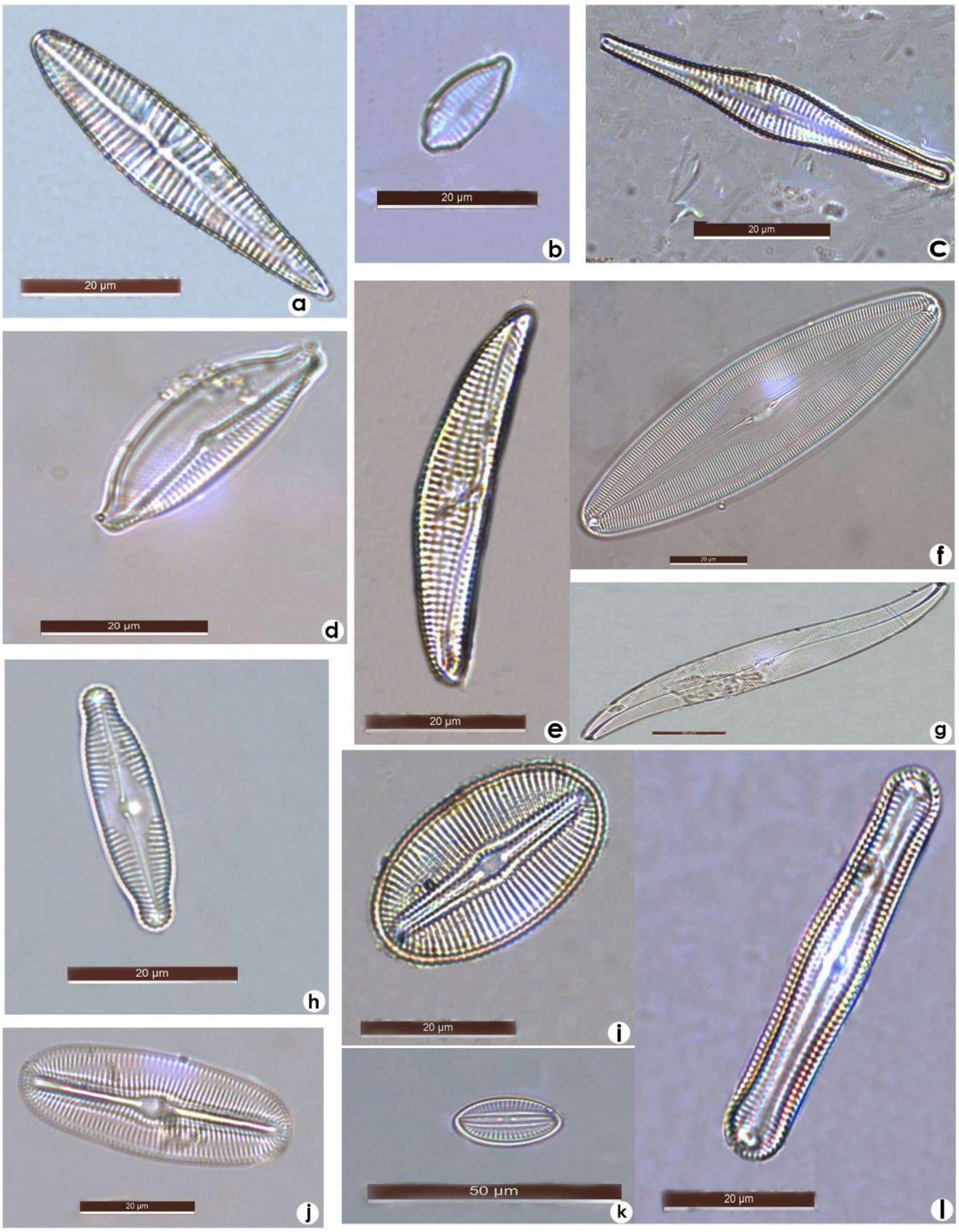


Plate 2.a. ***Gomphonema insigne*** Gregory b. ***Gomphonema parvulum*** (Kützing) Kützing c. ***Gomphonema*** sps. d. ***Cymbella turgidula*** Grunow e. ***Encyonema hustedtii*** Krammer f. ***Caloneis africana*** (Giffen) Stidolph g. ***Gyrosigma rautenbachiae*** Cholnoky h. ***Pinnularia subcapitata*** W. Gregory i. ***Diploneis smithii*** (Brébisson) Cleve j. ***Diploneis elliptica*** (Kützing) Cleve k. ***Diploneis puella*** (Schumann) Cleve l. .***Pinnularia acrosphaeria*** W.Smith

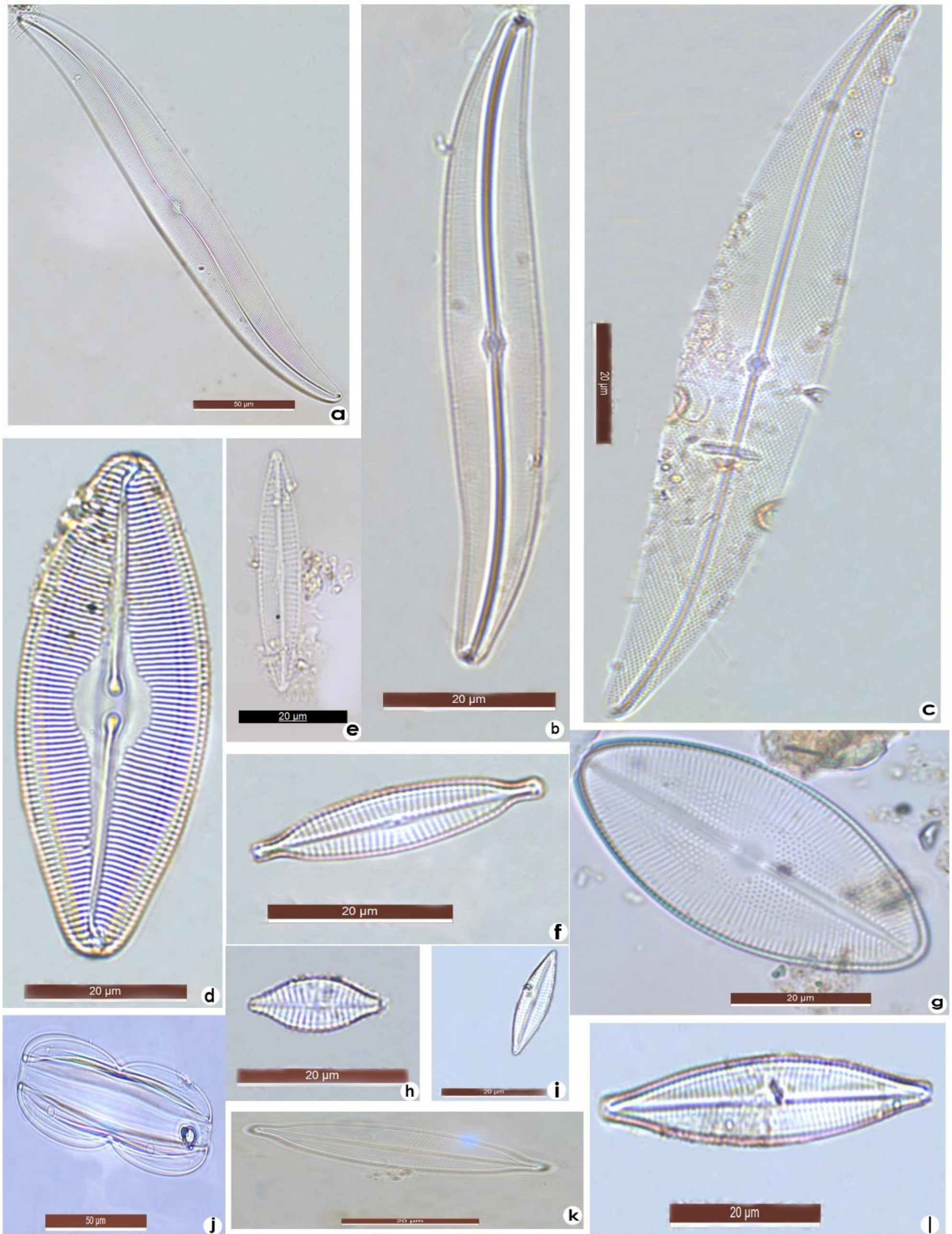


Plate 3.a. ***Gyrosigma attenuatum*** (Kützing) Rabenh b. ***Gyrosigma acuminatum*** (Kützing) Rabenhorst c. ***Pleurosigma salinarum*** (Grunow) Grunow d. ***Navicula jogensis*** H.P.Gandhi e. ***Navicula erifuga*** Lange-Bertalot f. ***Navicula germainii*** J.H.Wallace g. ***Navicula brasiliensis*** Grunow h. ***Navicula metareichardtiana*** Lange-Bert. and Kusber I. ***Navicula cryptotenella*** Lange-Bertalot j. ***Plagiotropis lepidoptera*** (W.Gregory) Kuntze k. ***Craticula ambigua*** (Ehrenberg) D.G.Mann l. ***Navicula rostellata*** Kützing.

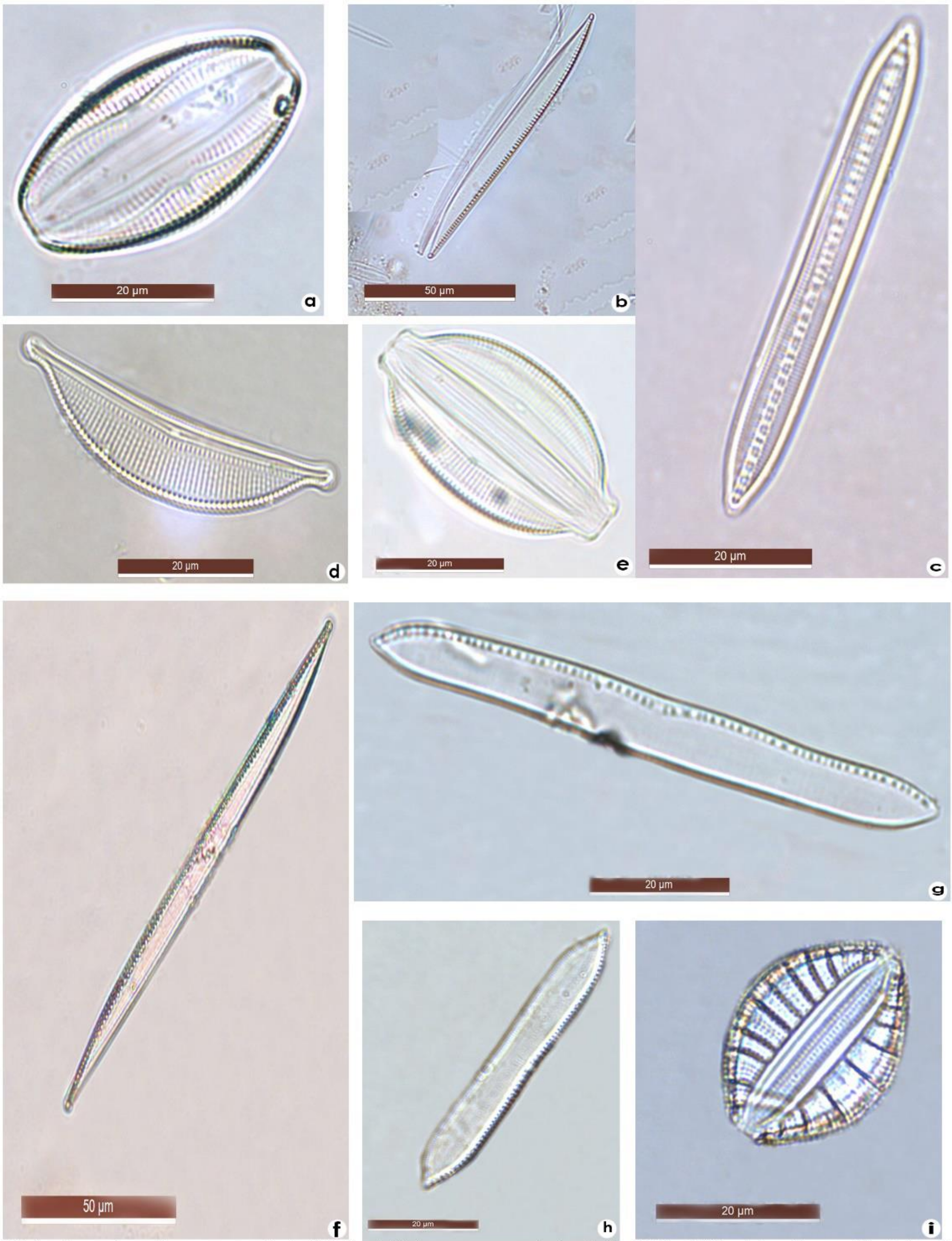


Plate 4.a. ***Amphora copulate*** (Kütz.) Schoeman and Archibald b. ***Nitzshia sigma*** (kutzing) W Smith c. ***Bacillaria paradoxa*** J.F.Gmelin d & e. ***Amphora coffeaeformis*** (C.Agardh) Kützing f. ***Nitzschia recta*** Hantzsch ex Raben g. ***Nitzshia obtusa*** var. ***kurzii*** Rabenhorst h. ***Tryblionella hungarica*** (Grunow) Frenguelli i. ***Rhopalodia gibberula*** (Ehrenberg) O.Müller.

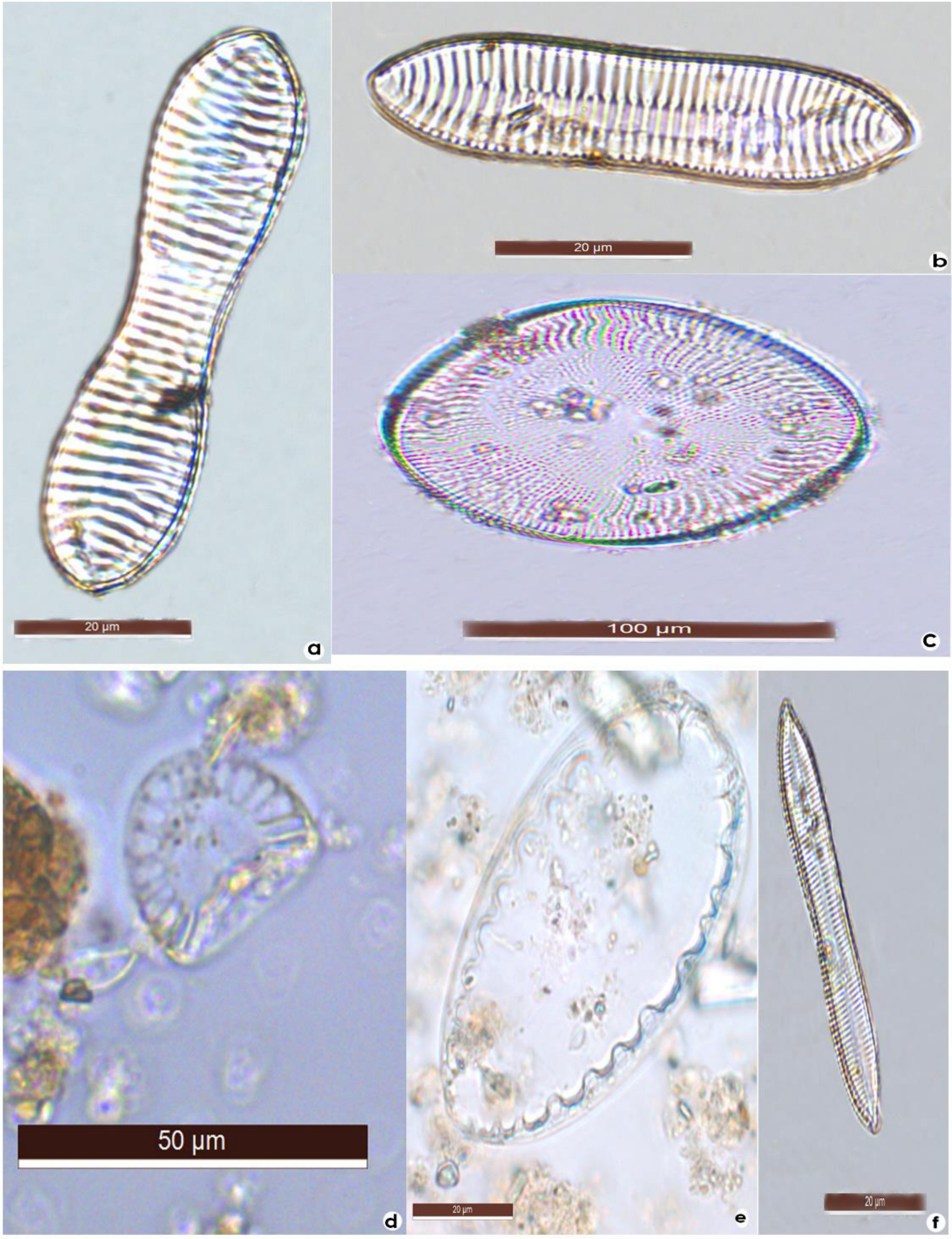


Plate 5.a. ***Cymatopleura solea*** (Brébisson) W.Smith b. ***Cymatopleura solea*** var. ***apiculata*** (W.Smith) Ralfs c. ***Campylodiscus clypeus*** (Ehrenberg) Ehrenberg ex Kützing d. ***Campylodiscus*** sps. e. ***Surirella ovalis*** Brébisson. f.***Tryblionella apiculata*** W.Gregory.

5. DISCUSSION

The mangrove ecosystem is recognized as a dynamic and exceptionally productive environment characterized by abundant biodiversity. Rahaman *et al*., (2014) observed that Mangrove estuaries function as avital freshwater interfaces between rivers and seas enduring strong tidal current fluctuations, shifting water depth, salinity, and rising sediment concentrations. The mangrove ecosystem also provides an ideal habitat for various floral and faunal species. Rajkumar *et al*., (2012) identified that diatoms, a prominent group of phytoplankton in littoral habitat are essential indicators of aquatic ecosystem because they reproduce quickly and react promptly to environmental changes, and also providing an early alert to pollutions. In estuaries and shallow coastal locations, diatoms are acknowledged as the primary component of this benthic microalgal ecosystem (Mclusky, 1989). Diatoms are remarkable group of organisms which can produce 20-25% of oxygen. As major part of phytoplanktoms, diatoms serve as important primary producer of aquatic food chain. Not only diatoms a varied group of cyanobacteria can also flourish in such sedimentary environments. The association between mangrove and cyanobacteria are documented in a research study conducted by Ram, (2021).

The current study centered on exploring the diversity of diatoms in mangrove ecosystem. The samples were collected from three different mangrove flourishing locations of Thrissur. During a two-month study about 51 species of diatoms were identified. In this 60.78% (31) diatoms belong to Freshwater taxa, 17.64% (9) diatoms were brackish water taxa, 7.84% (4) diatoms belong to marine forms and 4 of them can be seen in brackish, fresh water and marine forms, 5.88% (3) diatoms belong to both marine and freshwater. As the mangrove ecosystem is a brackish water habitats mostly freshwater diatom species can also thrive in that habitat. Similar observations were identified in a study conducted by Joseph (2019) in which the highest taxa belong to freshwater. Brackish water is a blend of freshwater from rivers and stream and seawater from oceans, resulting from a salinity level falls between fresh water and sea water. This intermediate salinity range supports the adaptation of various diatom species from freshwater and marine habitats.

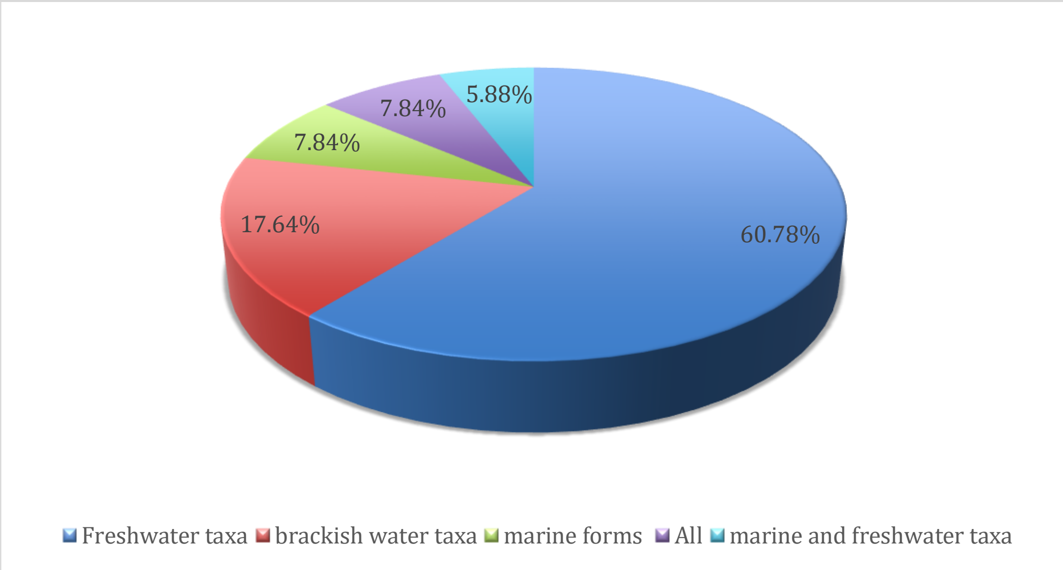


Fig. 5. Distribution of diatom taxa

During the study period, certain genera were found to be more prevalent compared to others, particularly when comparing the order centrales and pennales. In order centrales only 7 species were reported and the remaining 44 species were coming under order pennales. In pennales naviculaceae were the dominant family followed by six species from Bacillariaceae, five species from Surirellaceae, three species reported from Diplonidaceae, pinnulariaceae, and Gomphonemataceae, two species from Cymbellaceae, Catenulaceae, Fragilariaceae one species reported from Rhopalodiaceae, Pleurosigmataceae, Stauroneidaceae, Plagiotropidaceae, Anomoenoidaceae, Mastogloiaceae, Achnanthidiaceae, Eunotiaceae.

Another observation identified in current study, that is the dominant species belongs to following families naviculaceae which encompasses 10 species contains 7 species of *Navicula* and 3 species of *Gyrosigma* were reported, followed by the family bacillariaceae with 6 species in which 3 of the belongs to *Nitzschia* and 2 *Tryblionella* species and 1 *Bacillaria* species. Similar results were also documented by Sylvestre *et al.*, (2004) from Kaw estuary. During the study, contemporary diatom assemblages were analysed in 85 surface sediment samples obtained from Kaw estuary and nearby mangrove swamps. Samples collected from fluid mudflats to mangrove swamps densely covered with vegetations. Their study dominated with species *Nitzschia, Navicula and Gyrosigma* species. According to Admiraal, (1984) documented that *Gyrosigma* and *Nitzschia* are noticeable for their high motility rate within sediments and are well optimized to fluid sediment conditions.

Sylvestre *et al*., (2004) documented that *Gyrosigma* and *Nitzschia* are good indicators of fluid mud phase. They also identified that navicular species are typically found in well-established areas dominated by mangrove trees. These genera are commonly encountered in coastal waters worldwide by (Hendey 1964; Simonsen, 1974; Hoek *et al*., 1995; Tomas, 1997). The physico-chemical parameters such as pH, temperature etc are important for diatom growth. The study carried out during February and pH is observed between 8-9. Site 1 shows 9 pH and site 2 records 8.1 and site 3 pH 8.9. Fluctuations in ph can be viewed in 3 sites but pH is observed as alkaline along 3 sites. The variation in pH can be cited as Site 1>site 3>site 2. Similar observations were identified by Patil, (2020) and their study observed that the pH is almost alkaline and highest ph is observed during summer season that ranges between 8.3-8.9. and highest ph which may reach upto 9 observed during the month January and February. Another study conducted by also shows that pH is almost alkaline.

Temperature is also important for diatom growth. As my study is during the summer season so the temperature is also high. The highest temperature was reported from site 3 is of about 37.1 degrees Celsius. Lowest temperature reported at site 1 is 33.9. site 2 shows 35.1 degree Celsius. Similar temperature variations also reports and it also exhibits maximum temperature on summer season by Patil, (2020).

Another observation identified during study is the occurrence of pollution tolerant species like *Navicula sps, Gomphonema sps,* and *Cyclotella sps*. These species are categorised as pollution tolerant according to palmer pollution index series. Similar results were observed by a case study conducted by Khan, (1990) on tropical River basin. Navicula and Nitzschia have been discovered in water bodies exhibiting organic pollution, as evidenced by Trivedy and Goel, (1984). Paul and Anu, (2016) documented Fifteen pollution tolerant algal species from Guruvayoor temple pond during their study period. Tapia, (2008) reported *Nitzschia sps, Gomphonema sps* as bioindicators of pollution in Mantaro river.

The present investigation also shows that *Gyrosigma attenuatum, Gyrosigma accuminatum, Bacillaria paradoxa, Amphora caffeaformis,* etc were identified to be present in all 3 sites. Diatoms represent the most prevalent group of phytoplankton within aquatic ecosystems. Their relevance in shoreline waters stems from their remarkable sensitivity to fluctuations in salinity, temperature, nutrient levels, and various environmental variables. Due to their cell walls primarily consisting of hydrated silica diatoms exhibit excellent preservation qualities within sediment layers. So, the present study om diatoms of mangrove ecosystem provide a baseline data for pollution management studies etc.

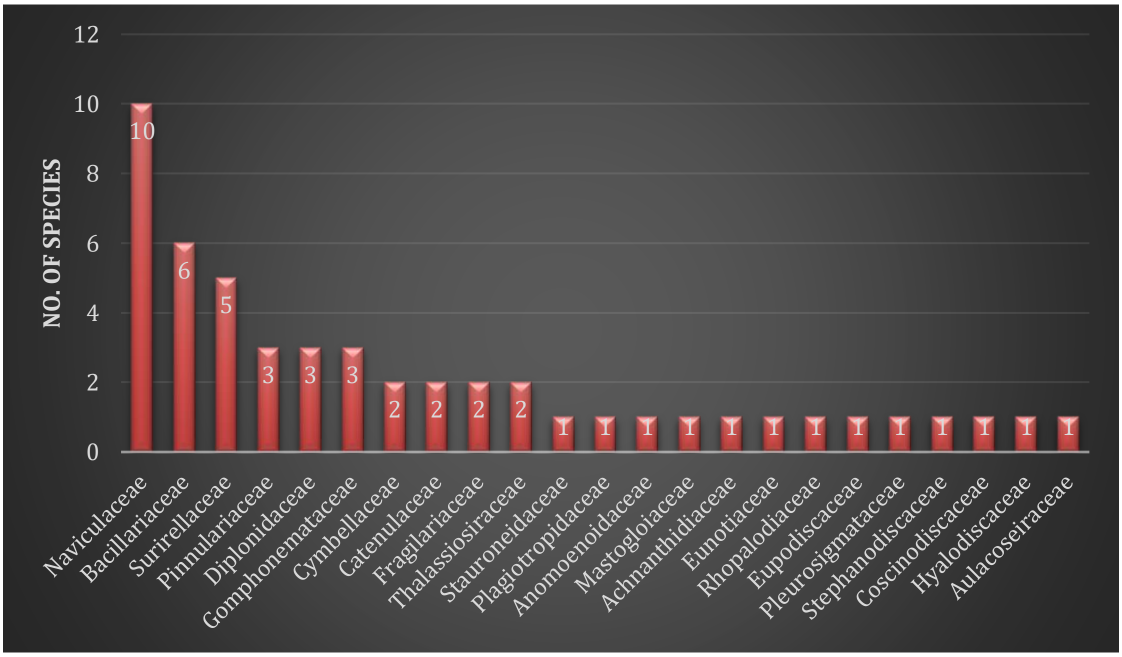


Fig.6. showing the dominant family in the study area

6. CONCLUSION

As primary producers, Diatoms are highly significant group within the realms of diversity, ecology, and various industries, with notable application in field of medicine, agriculture, ecosystem stability, environmental maintenance, for checking water quality, industries etc. Their distinctive silicious cell wall renders them not only unique but also fascinating subjects for study. Exploring diatom diversity from unexplored regions providing better information about distribution and also diatom diversity in mangrove ecosystem. The study represents an identification and taxonomic study of diatom, about 51 diatom taxa under to 30 genera belonging to 23 families were reported. Diatom taxa encompasses both centrales and pennales types. The abundance of pennales were high than centrales. Naviculaceae being the dominant with three *Gyrosigma sps* and eight *Navicula sps* followed by Bacillariaceae, surirellaceae etc. During my study the genus *cymatopleura* and its variety are identified. According to Palmer pollution index studies, *Navicula* and *Nitzschia* were prominent as pollution indicators were reported as dominant during study period. This reveal that the study area is prone to organic pollution. The mudflats within the mangrove ecosystem provide an ideal habitat for diatom species, particularly *Gyrosigma sps* and *Nitzschia sps*.

An insight into diatom diversity is crucial for their role in ecology and also in field of medicine. The study also delivers that due to their silica walls diatoms can thrive in saline conditions of mangrove ecosystems. This study helps to elucidate the diatom assemblages of mangrove ecosystem and also provide a primary information about the pollution management and protection of the mangrove habitat from pollution. The study also delivers the significance of diatoms in the mangrove ecosystem.

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