

Eco-biology of marine diatoms
with emphasis on the influence
of physico-chemical parameters



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Dedicated to my parents

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Statement

As required under the University ordinance 0.19.8 (vi), I state that the present thesis entitled “Eco-biology of marine diatoms with emphasis on the influence of physico-chemical parameters” is my original contribution and the same has not been submitted on any previous occasion. To the best of my knowledge the present study is the first comprehensive work of its kind from the area mentioned.

The literature related to the problem investigated has been cited. Due acknowledgements have been made wherever facilities and suggestions have been availed of.

Smita S. Mitbavkar

Certificate

This is to certify that the thesis entitled “Eco-biology of marine diatoms with emphasis on the influence of physico-chemical parameters”, submitted by Ms. Smita S. Mitbavkar for the award of the degree of Doctor of Philosophy in Marine Science is based on her original studies carried out by her under my supervision. The thesis or any part thereof has not been previously submitted for any other degree or diploma in any Universities or Institutions.

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Chapter 1
General Introduction

General Introduction

Diatoms (Greek – cut in two) belonging to the class Bacillariophyceae of the phylum Bacillariophyta are eukaryotic, autotrophic microorganisms with a cosmopolitan distribution. They are either solitary or colonial (occurring in chains). Size of individual diatom ranges from $\sim 2 \mu$ to 2 mm, but some chains can be several millimeters in length. Diatoms are ubiquitous phytoplankton widespread in both marine and freshwater, plankton and sediments. The most distinctive feature of this unicellular organism is its extracellular coat or frustule, which comprises of two overlapping valves, composed of silica (SiO_2) fitting into each other just like a soapbox. The upper half is known as the epitheca and the lower half as hypotheca. Each theca is further divided into two parts – the main surface and its incurved margins termed valve and connecting bands respectively. The two connecting bands represent incurved sides of the lid and the main body whereas the valve relates to the top or bottom of the box. When fitted together, the connecting band of epitheca overlaps that of hypotheca and the two bands remain united in the overlapping region called girdle, by a cementing organic substance present between them. Accordingly, a cell can be seen from two different aspects, the valve view and the girdle view. Most diatoms appear rectangular in girdle view whereas in valve view their shape is variable. The line connecting the middle of the two valves constitutes the perivalvar axis and the place along which the cell divides (at right angles to perivalvar axis) is called the valvar plane. The frustule is usually sculptured into patterns of spines, pores, channels, and / or ribs, which are distinctive to individual species. The ornamentations are confined to the valve position of the silica wall. The vast structural diversity of the frustule leads to a remarkable number of morphologically distinctive varieties of diatoms and forms a base for their identification. Depending on the shape

and symmetry, two types of diatoms are recognized: the pennate and centric forms. Pennate diatoms have elongated or “boat-shaped” valves with a bilateral symmetry. They are mostly benthic, but few planktonic genera may be abundant in the plankton. Centric diatoms have a radial symmetry and are much more common in the plankton. Along the length of its frustule, pennate diatoms have a long slit known as the raphe, which helps in their motility and attachment to substrata. Reproduction is usually by means of vegetative cell division i.e., binary fission (two new individuals formed within the parent frustule). Repeated cell division results in diminution of cell size. In order to regain the maximal size, the vegetative cell division is interrupted by sexual reproduction through auxospore formation.

Diatoms constitute the major part of the phytoplankton of the sea; they also exist as sessile communities or attached to debris, sand grains and mud. Their importance lies in the fact that they are primary producers and serve as a vital link in the aquatic food webs, either directly or indirectly and are thought to be responsible for up to 25% of the world’s net primary productivity (Jeffrey and Hallegraeff 1990). To the fishing industry they are of paramount importance as at some stage of their life cycle, all fish, mollusks, bivalves and crustaceans are diatom feeders.

The term microphytobenthos refers to the microscopic, photosynthetic, eukaryotic organisms living in intertidal areas. This includes cyanobacteria and diatoms. Generally, diatoms are the major representatives of this community (Meadows and Anderson 1968; Round 1979b). Over the last few decades, there has been increased interest regarding the benthic diatoms that inhabit shallow coastal areas and their functional importance in benthic communities. They contribute significantly to the total primary production of the estuarine and other shallow water ecosystems. These diatoms are consequently an important carbon source for benthic heterotrophs and can

significantly affect the exchange of oxygen and nutrients across the sediment-water interface (Risgaard-Petersen et al. 1994).

Benthic epipellic diatoms are the most important group of primary producers in intertidal sand and mudflats (Meadows and Anderson 1968; Sullivan 1975; Round 1979a, b; Taasen and Hoisaeter 1981; McClatchier et al. 1982; Admiraal 1984). They are known to produce copious amounts of extracellular polymeric substances (EPS) mainly consisting of carbohydrates (Hoagland et al. 1993). By doing so, diatoms form a biofilm that serves to produce their own microenvironment, which protects them from the rapidly changing conditions in intertidal sediments (Decho 1994). The excretion of EPS plays a role in the movement of epipellic benthic diatoms (Edgar and Pickett Heaps 1983) and allows the organisms to adhere to sediment surfaces (Wang et al. 1997). The presence of biofilms helps in stabilization of the sediment against resuspension (Kornman and de Deckere 1998; Paterson 1989). Through the excretion of EPS, diatoms are responsible for a considerable input of high quality organic carbon into the sediment that may be utilized as a food source of heterotrophic consumers (King 1986; Van Duyl et al. 1999).

Intertidal sandflats are dynamic environments, where the tidally generated water movement and the associated processes of deposition and resuspension of sediment affect the composition and distribution of diatoms. In addition, hydrodynamic processes carry planktonic diatoms present in the ambient water to the intertidal sediment. In many studies, diatoms were only investigated in the top few centimeters of the sediment (Riznyk et al. 1978; Colijn and Dijkema 1981; Varela and Penas 1985; Lukatelich and McComb 1986). However, the presence of diatoms at a depth of 20 cm has also been reported (Steele and Baird 1968; Colijn and Dijkema 1981; de Jonge and Colijn 1994), based on chlorophyll *a* estimations.

Many free living diatom cells in intertidal sediments have diel rhythms of vertical migration, moving to the surface when the sediment is exposed at low tide and descending before it is flooded (Palmer and Round 1965; Round 1979a, b). This may serve to avoid transport due to resuspension by advancing tides (Faure-Fremeit 1951; Ganapati et al. 1959; Heckman 1985) and escape predation (Connor and Edgar 1982). Consequently, migration can have important consequences for measurements of both diatom abundance and photosynthesis (Pinckney and Zingmark 1993). However, these migrating cells are likely to dominate biomass and productivity in intertidal sediments. Several researchers have reported large differences in benthic diatom productivity in exposed vs. immersed sediment and have attributed these differences to vertical migration below the sediment photic zone during immersion (Pomeroy 1959; Darley et al. 1976; Holmes and Mahall 1982).

Much of the literature concerning vertical migration of benthic microalgae has centered on species inhabiting mud flats (Aleem 1950; Hopkins 1963; Round and Happey 1965; Round and Eaton 1966; Round and Palmer 1966; Palmer and Round 1967; Round 1978; Paterson 1986; Pinckney et al. 1994). In case of the sand flat community, diatom migration has been recorded by Meadows and Anderson (1968), Harper (1969), Riznyk and Phinney (1972), Round (1979a, b), Joint et al. (1982), and Kingston (1999).

The upper surface sediment layers are, in fact, characterized by strong physico-chemical gradients and the sediment perturbation caused by water movements may resuspend the benthic cells in the water column. When resuspended into the water column by wind mixing (Lukatelic and McComb 1986; Pejrup 1986; Demers et al. 1987) or tidal currents (Baillie and Welsh 1980; Shaffer and Sullivan 1988), benthic diatoms may be an important source of food for both micro and macroheterotrophs

(Roman and Tenore 1978; Wainright 1990; de Jonge and Van Beusekom 1992). The microphytobenthic diatoms are also an important source of food for surface deposit feeders (Pace et al. 1979), some of which are able to switch between surface deposit feeding and suspension feeding depending on the water flow velocity (Miller et al. 1992). The presence and importance of benthic diatoms as temporary members of the phytoplankton is a well-known phenomenon (Cadee and Hegeman 1974; Baillie and Welsh 1980; Demers et al. 1987; de Jonge and Van Beusekom 1992, 1995).

Once introduced into the water column, as a basic requirement these diatoms will be in search of a substratum for attachment. As a rule, a layer of microorganisms forming a biofilm quickly covers any surface submerged in water. Zobell (1943) observed that the initial phase in the biofilm development involves the adsorption of organic compounds over the solid surfaces exposed to marine environment. These surfaces, which act as nutrient sinks, enable diverse microbial communities to develop and maintain themselves at high population diversities (Marshall 1972). Diatoms are the earliest autotrophic colonizers and constitute much of the microbial biomass accumulated on an illuminated surface (Caron and Sieburth 1981; Marzalek et al. 1979). In Indian waters, work on fouling with special reference to diatoms has been done by Daniel (1955); Mathew and Nair (1981); Kelkar (1989); Bhosle et al. (1990a, b); Pangu (1993); Prabha devi (1995a) and Redekar (1997). Such communities termed as periphytic, can serve as food for the planktonic herbivores thus playing an essential role in food web dynamics. The attached diatom community also constitutes a system rich in information for environmental monitoring which can be exploited through analysis of communities' structural characteristics (Gold et al. 2002). In such communities, where space becomes a limiting resource, close interactions among the species inevitably results in competition. Competition occurs when two species

require a resource that is in short supply, so that the availability of that resource to one species is negatively influenced by the presence of the other species (Valiela 1984).

Role of each species and their interaction with the other members will decide the fate of the climax community. In a homogenous habitat, species differ in their competitive abilities and are limited by a resource and compete for the same single resource.

According to Tilman (1982, 1999) in such a habitat at equilibrium, the best competitor among the species present would win.

An important aspect of all the above studies is the microscopic identification of individual diatom species, depending on their morphological characteristics. However, it is subject to changes depending on the environmental and culture conditions. In the recent years, identification is being made simpler through molecular approaches. In this regard, immunofluorescence technique through the use of antibodies developed against the cell surface antigens of a target species is being employed extensively (Bates et al. 1993). In the dynamic marine environment, factors such as temperature and salinity also influence survival and dispersal thereby controlling phytoplankton communities.

Taking the above into consideration, this thesis presents work carried out from a tropical marine environment and covers different aspects of eco-biology of diatoms.

The study includes

- **Diatoms of the benthic community**

- **Diatoms of the fouling community**

- **Modulations in the periphytic diatom diversity**

- **Morphological changes and detection of diatoms**