Chapter 7
Diatoms: A Potential for Assessing River Health

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Abstract Diatoms are autotrophic, photosynthetic, and eukaryotic microalgae belonging to phylum Ochrophyta. The main function of diatoms is to convert dissolved carbon dioxide to oxygen in water. In aquatic ecosystems, diatoms are primary producers. Presence of diatoms in rivers is very common and of equal importance. River health assessment is assessing the health and quality of river. Diatoms add up to nutritional status, can be used as biomarkers, and are usually dominating at higher altitudes and in upwelling regions. For long time, physical and chemical monitoring is being done for river assessments. River ecosystems are prone to threat by human activities causing moderations in sedimentation delivery, flowing patterns, and even biodiversity loss. Diatoms, being a good bioindicator for quality of water and land use, can be used as a potential to assess the health of a river. Diatoms respond with change in nutrient availability, concentration of ions, and organic loading.

Keywords Diatoms · River health assessment · Water · Quality · Bioindicator

7.1 Introduction

Single-celled and photosynthesizing algae having siliceous skeleton are diatoms. They are present in fresh waters, marine waters, soil, and places that have adequate moisture content. Diatoms reproduce by cell division. Diatoms are not motile; their mobility occurs by the secretion of mucilaginous material with raphe (a slit like

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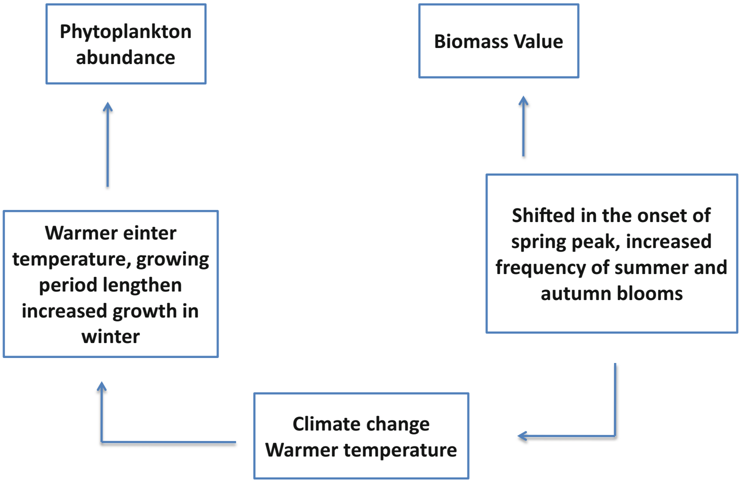

Fig. 7.1 Impact of environmental stressors on rivers

groove/channel). Diatoms are autotrophic and hence restricted to only 200 m down water depths called photic zone. Their cell is composed of transparent, opaline silica. Diatoms contain chlorophyll a and chlorophyll c content which are light-absorbing molecules. These molecules gather energy through the sun and by the process of photosynthesis turns into chemical energy. They can remove atmospheric carbon dioxide through carbon fixation. Long-chain fatty acids are produced by diatoms, and they are a crucial energy source for food web (zooplanktons to insects to fish to whales). Diatoms can be used as a bioindicator to know the health of aquatic systems such as rivers. Different species of diatoms have different tolerant ranges for environmental stressors like concentration of nutrient, suspended sediment, elevation, flow regime, and human interferences (Fig. 7.1). Hence, their presence aids in monitoring and assessing water's biotic conditions. Communities of diatoms demand specific environmental conditions and counter quickly to environmental change which employs them as cost-effective to assess the health of rivers (aquatic ecosystems) and human impacts. (Dalu and Froneman 2016). Fishes and macroinvertebrates have longer generation times as compared to diatoms. Quick response to change in environmental conditions by diatoms offers EWS (early warning systems) for increased pollution and restored habitat success. Their study is an important aspect for assessing and monitoring programs globally. Habitat history of surface water body can be identified by undisturbed core sediments from aquatic ecosystems (Amoros and Van Urk 1989; Cremer et al. 2004; Gell et al. 2005). Previous aquatic conditions may be assessed using diatoms on fishes and macrophytes (Venkatachalapathy and Karthikeyan 2015; Rosati et al. 2003; Yallop et al. 2009). Diatom's study can also help in inferring environmental changes in water bodies including marine, estuaries, and brackish water; however, in freshwater rivers and lakes, interpretations and techniques are highly challenging.

7.2 Health of Aquatic Ecosystems and Rivers

Two general methods for environmental conditions assessment in streams and rivers using diatoms are diatom index and IBI (index of biotic integrity) (Stevenson et al. 1999). Rimet et al. in 2012 observed that, in Europe, Australia, and America, development of many biotic indexes took place before 1999 (Rimet 2012). Some of diatom indexes were developed in Asia (Xue et al. 2019) In America, Europe, and Asia, the development and application of benthic diatom index of biotic integrity (BD-IBI) in ecosystem health assessment already took place (Ruaro and Gubiani 2013; Zalack et al. 2010). However, in China, BD-IBI is applied and shown good results in monitoring and assessing ecosystem health for the past few years (Tang et al. 2006; Tan et al. 2015).

Aquatic pollution not only includes organic and nutrient pollution but also metals and pesticides (Fig. 7.2). Policies are concerned with pollution and its environmental impact. Very few published papers established diatoms, hydrocarbons, and pesticides relationship (Schmitt-Jansen and Altenburger 2005; Debenest et al. 2008, 2009; Morin et al. 2009; Rimet et al. 2004; Rimet 2012). Ethiopian streams had shown advantage of diatoms in water courses that were severely affected. The stream showed presence of diatoms and no macroinvertebrates (Rimet 2012). Diatoms,

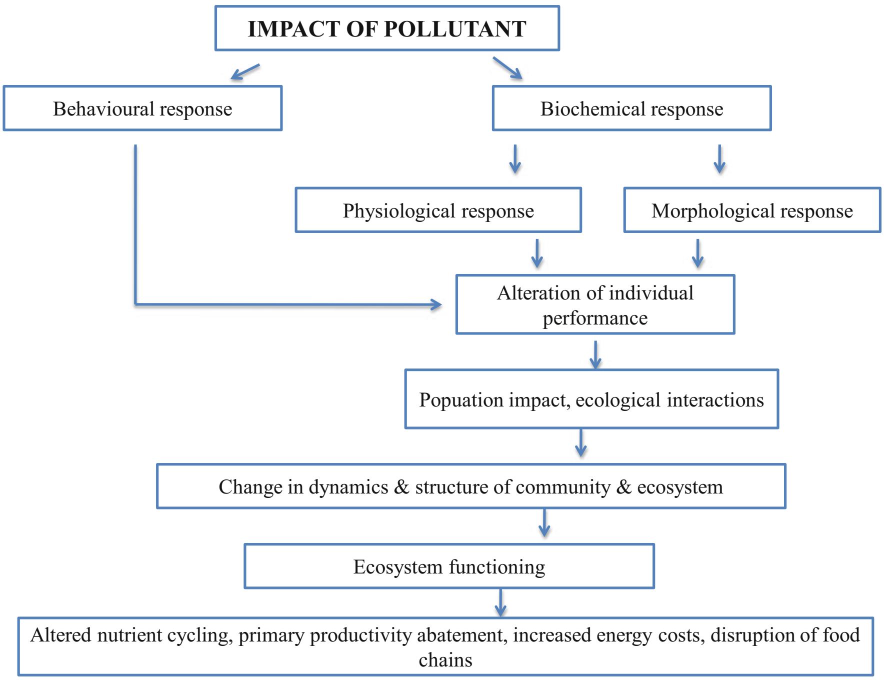

Fig. 7.2 Impact of pollutants on aquatic ecosystem

fishes, macroinvertebrates, and macrophytes were four bioindicators compared in one study (Hering et al. 2006).

Benthic algae, fishes, and macroinvertebrates have unique importance in riverine ecosystems' health conditions and are convenient for biological indices' sampling, identification, and calculations, and therefore they are commonly used in health assessments (Chessman and Royal 2004; Kennard et al. 2006; Qu et al. 2016).

With increased metal concentration in water and decreased measured biomass, chlorophyll a and cell density are observed (Hill et al. 2000; Ivorra et al. 2000; Gold et al. 2002; Morin et al. 2007; Raunio and Soininen 2007; de la Pena and Barreiro 2009). Some studies based on measuring mat thickness showed that the exposure of *Navicula pelliculosa* to Cd contamination prevents mat formations and reduced biomass (Irving et al. 2009; Rimet 2012). Freshwater organism and its biodiversity are sustained by rivers and streams as they are valuable ecosystem (Qu et al. 2016; Arthington et al. 2006).

Several decades ago, initial development of biological indices took place, and since then they are used in river health assessments (Norris and Hawkins 2000).

In the past, many approaches used single kind of aquatic organism for river health assessment on the basis of budget limitations and expert opinions (Barbour 1999; Boulton 1999). However, recent advancements and understanding of the relationships among three different aspects, viz., biological, physical, and chemical, lead to more detailed assessment and application of broad range of aquatic organism and ecosystem processes (Flinders et al. 2008; Wei et al. 2009; Bunn et al. 2010; Bae et al. 2011, 2014).

7.3 Diatoms in River Health Assessment

Two hundred 50 million years ago, during the Triassic period, diatoms arose suggested by molecular clock-based estimates (Sorhannus 2007), and the earliest well-preserved fossils of diatoms came from 190 million years ago, the early Jurassic period (Sims et al. 2006). Primarily, only cyanobacteria and green algae (slightly larger than bacteria) constituted phytoplankton before the arrival of diatoms (Armbrust 2009). The emergence of dinoflagellates and coccolithophorids (larger eukaryotic phytoplankton and diatoms) shifted the global organic cycling which initiated the decline in concentration of atmospheric carbon dioxide and increased oxygen concentrations (Fig. 7.3) (Katz et al. 2005).

The cell wall of diatoms is made with hydrated glass (SiO2.nH2O) essentially (Drum and Gordon 2003). The biogenic silicon cycling is controlled by diatoms in world's ocean such that each silicon atom entering the ocean incorporates into diatom cell wall (Strzepek and Harrison 2004) before getting buried on the sea floor (Treguer et al. 1995). Dead diatom's cell wall accumulates on the sea floor depending upon conditions as immense silica deposits up to 1400 meter thick. This was found on eastern Antarctic peninsula's island named Seymour (Sims et al.

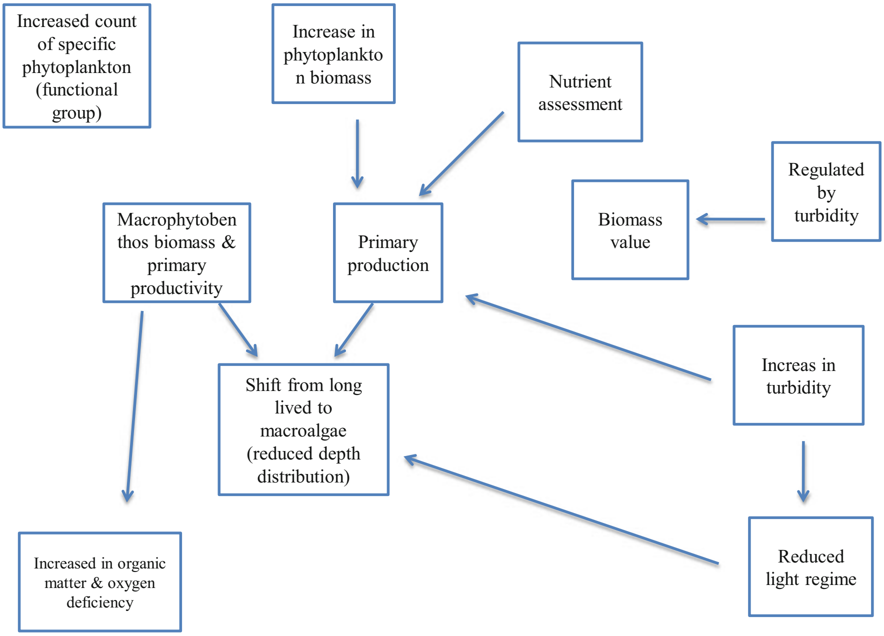

Fig. 7.3 Algae/diatoms as bioindicator

2006). Diatomaceous earth has numerous uses such as flea powder, insulations, and ingredients for toothpastes (Armbrust 2009).

7.4 Water Quality and River Health Assessment

Use of multi-metric bioindicators was recommended by freshwater scientists and European Water Framework Directive (Karr 1981) based on reference condition approach (Bailey et al. 1998) for assessing river ecological conditions and accounting natural heterogeneity of communities (Marzin et al. 2014).

Rivers have various functions to offer human beings, but human activities impact river's health which leads to poor conditions of rivers (Wang et al. 2019). The river suffered degradation through human influence directly and indirectly. Process and structure of natural aquatic ecosystem is adversely affected by channel modifications, flow regulations, and water pollution all throughout the world (Maddock 1999). River health concept was first introduced by USEPA in 1972 Clean Water Act which requires to maintain physical, chemical, and biological integrity of river (Wang et al. 2019).

The impact of ecological effects of water on aquatic biodiversity is direct, and therefore it is used as health indicator (Fryirs 2003). A powerful indicator named zooplankton is present in between fish (top-down regulators) and phytoplankton (bottom-up factors) in a food web and provides information on cost-effective and key measuring indicators for river to be of well ecological status (Hulyal and Kaliwal 2008; Jeppesen et al. 2011). The primary producer in a water body is single-celled phytoplankton which is sensitive to water environment change. They are important for monitoring water bodies biologically (Cardinale et al. 2002; Wang et al. 2019).

7.5 Bioindicators for River Health Assessment

Three types of indicators were recognized by Cairns and McCormick (1992), which are early warning indicators signifying impending health decline, compliance indicator signifying acceptable limit's deviation, and diagnostic indicators identifying deviation causes. The range of these above indicators is from different aspects of the physical and chemical habitat (Maddock 1999; Maher et al. 1999) to biological features of the inhabitants. Focuses of biological aspects are broad taxonomic group like water birds (Kingsford 1999), macroinvertebrates (Kay et al. 1999; Marchant et al. 1999), and diatoms. Various living organisms like algae, macroinvertebrates, fish, etc. are present in aquatic ecosystem habitats (Fig. 7.4) which are capable to tell

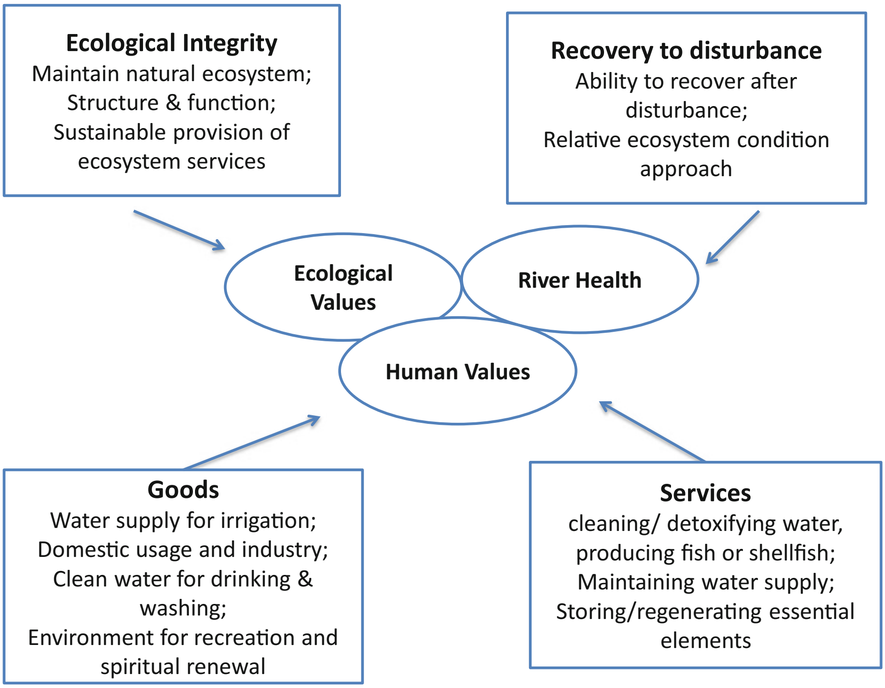

Fig. 7.4 River habitat

continuous and integrative characteristics of water quality. This is why they are considered as worthy bioindicators (Singh and Saxena 2018).

Nutrient levels in water are indicated by diatoms. Excess in these nutrient levels is one of the greatest threats in US streams. Higher nutrient levels increase algae productivity resulting in blooms. These blooms can reduce dissolved oxygen which eventually kills the fishes.

Population dynamics of aquatic ecosystem is directly affected with change in natural environmental conditions such as flow rate, dissolved oxygen, water temperature, and food resources. These population change, human activities, and pollution increase characteristic biological communities with differing ecosystems. Agricultural fertilizer runoff and sewage pollution causes eutrophication feeding plants and algae leading to their overgrowth.

Expert panel recommended DELPHI forecasting method as best way for selecting variables for water quality indices (Pinto and Maheshwari 2011). In Kenya, South Africa, Zimbabwe, and Zambia, implementation of diatoms-based biomonitoring programs were a success. In South Africa, this approach was also incorporated in the National River Health Program (Dallas et al. 2010) which now is the part of National Aquatic Ecosystem Health Monitoring Program. In South Africa, methodology standardization led the foundation for diatom sample's collection and analysis (Taylor et al. 2007). The program is anticipated to give alike results in African countries like Kenya, Zimbabwe, and Zambia, and these countries are in standardizing diatom methodology process; these protocols should take endemic diatom taxa into considerations (Dalu and Froneman 2016).

7.6 Future Perspectives and Conclusion

It is necessary to know how ocean ecology and biochemistry is affected by diatoms. Genomic sequencing of representative diatoms and its analysis can identify how these organisms can help in interpreting river health assessments. Next generation eco-genomic sensors monitor the sentinel species presence, its expression, and give the information about physiochemical properties that are biologically relevant. Monitoring genes that encode iron storage molecule ferritin continuously can provide information for biological availability of iron in surface waters and iron's presence in water (Sedwick et al. 2007). Concluding that diatoms use in biomonitoring has value in going relevant information to common problems about ecological conditions. This can be used for both short- and long-term biomonitoring for health and functioning of aquatic ecosystem.

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