CHAPTER 2

LITERATURE REVIEW

The coastal ecosystems harbour wealth of species and genetic diversity, store and cycle nutrients, filter pollutants and help to protect shorelines from erosion and storms. This region is of very high biological productivity and thus an important component of the global life system. The coastal zone of the world is under increasing stress due to development of industries, trade and commerce, tourism and resultant human population growth and migration, and deteriorating water quality. Since, last few years, scientists worldwide are more concerned about the health of estuarine ecosystem, because of the loss of varied floral and faunal diversity it harbors. Evaluation of hydro-geochemical properties and biotic components will help to understand the unique characteristics of an estuary and mangrove environment and help to implement management strategies (Borja et al., 2010).

2.1. Physico-chemical properties of water

2.1.1. International status

Several workers all over the world have investigated physico-chemical parameters of various marine water ecosystems. The hydrochemistry and plankton dynamics of the Ologe lagoon, Nigeria was investigated by Onuoha et al. (2011). Moskovchenko et al. (2009) worked out the stream water chemistry, including pH, temperature, salinity, DO, nitrate, phosphate, sulphate, chloride and ammonia of Vatinsky Egan River catchment, West Siberia. They studied spatial and seasonal variations of the water quality and assessed the anthropogenic chemical inputs into the river system. Their study revealed high concentration of chloride and total petroleum hydrocarbon in the aquatic system. The similar work on changes in the tropical estuarine system of Imo river, Nigeria was carried out by Akoma (2008). Akpan (1993,
1994) processed the seasonal variability of the phytoplankton biomass in relation to physico-chemical changes in the Cross River Estuary, Nigeria. They studied the seasonal variations in temperature, pH, conductivity, alkalinity, DO, salinity, nitrate, silicate and phosphate and their influence on phytoplankton. **Wen et al. (2008)** carried out comprehensive bimonthly field surveys of subtropical mountain river system, the Danshuei tributary, Taiwan from September 2000 to June 2002 and studied the seasonal dynamics and the inter-annual variability of dissolved inorganic nitrogen (DIN; nitrate, nitrite and ammonium) and dissolved inorganic phosphorus (DIP). **Alvin et al. (2008)** investigated the seasonal and spatial dynamics of nutrients and phytoplankton biomass at Victoria harbor in Hong Kong waters and emphasized that chemically enhanced primary sewage treatment enhanced the water quality as indicated by a significant decrease in NH$_4$ and PO$_4$ and an increase in the bottom DO.

**Pannard et al. (2008)** investigated physical and chemical conditions of two coastal zones and also recorded the short-term changes in phytoplankton community structure. **Bouillon & Dehairs (2007)** explored the distribution, sources and processing of particulate and dissolved organic carbon and inorganic carbon in the estuarine mixing zone of Tana river in Northern Kenya. Pains taking work was carried out by **Radach & Patsch (2007)** for twenty three years from 1977 to 2000. They extensively studied the nutrient inputs from fresh riverine water by determining riverine freshwater, nitrogen and phosphorus loading into the North Sea from Belgium in Netherlands and Germany. Nutrients play a major role in changing the trophic structure of aquatic environment. The role of nitrate, phosphate, light availability, DO and water residence time in determining the distribution of phytoplankton along estuaries of England and Wales was assessed by **Painting et al. (2007)**. The influence of surface run-off water in contributing nutrients like sodium, potassium, silicate and carbon into river water was studied at lower reaches of Wu Jiang river in China by **Zhu et al. (2005)**.
Huang et al. (2003) analyzed the status and characteristics of nutrients and eutrophication through a 24-h time series and synchronization of vertical profiles of NO$_3$-N, NO$_2$-N, NH$_3$-N, PO$_4$-P, Chlorophyll-$a$, total solids, salinity, temperature and other chemical parameters at different stations in Pearl river estuary in China. The interaction between the Atchafalaya river and the Atchafalaya delta estuarine complex was examined by estimating suspended sediments, inorganic nutrients (NO$_3$, NH$_4$ and PO$_4$), Chlorophyll-$a$ and salinity by Lane et al. (2002). Magni et al. (2002) worked out the physical and chemical variability of the water column at subtidal station of an estuary in the Seto Inland Sea, Japan, during a spring tide (tidal range ca. 2 m) in May 1995. Physical, chemical and biological characteristics of Danish estuaries were evaluated by Conley et al. (2000) to understand the functioning of these estuaries as filters and transformers of nutrients. Eyre & McKee (2002) explored carbon, nitrogen and phosphorus budget in a shallow subtropical coastal embayment of Moreton Bay in Australia. Comparative studies on changes in physico-chemical parameters like phosphate, ammonium, nitrate and silicate along the salinity gradient of three temperate estuaries of Scotland in United Kingdom and three tropical estuaries of Queensland in Australia were carried out by Eyre & Balls (1999).

Spatial and temporal variations in nutrients and their importance to estuarine primary producers have been extensively studied by Cowan & Boynton (1996). Akpan & Offem (1993) provided data on the seasonal variations in temperature, salinity, dissolved oxygen, biochemical oxygen demand, ammonium, nitrite, nitrate, phosphate, silicate, pH and Secchi disc transparency. They stated that main influencing factor is the seasonal variation of rainfall, but biological cycles may also play a significant role on chemical variables. Mississippi estuary in U.S was examined for evidence of pollutant impact upon the coastal environment by Lytle & Lytle (1990). Several investigators have reported that nitrogen is the limiting nutrient to
primary productivity in marine and estuarine systems (Ryther & Dunstan, 1971; Nixon & Pilson, 1983).

2.1.2. National status

In India, during last four decades considerable work has been carried out on estuarine ecosystems. Seasonal variation in physico-chemical parameters like nitrate, phosphate, silicate and DO of Vellar river estuary was carried out by Palpandi (2011) to study the distribution of biotic components in relations to the change in physico-chemical parameters. Diurnal variation of physico-chemical properties and primary productivity of phytoplankton in Bheema River were carried out by Vasanthkumar & Vijaykumar (2011). The monitoring of water quality of Narmada River was carried out for one year by Sharma et al. (2011). The seasonal variation in physicochemical properties and distribution of diatom species was studied at estuaries of Dakshina Kannada and Udupi Districts for a period of one year by Shruthi et al. (2011). A study has been carried out on the physico-chemical status of Muthupettai mangrove, South east coast of India by Srilatha et al. (2012). An investigation of hydrographical parameters, nutrients, total coliforms and total heterotrophic bacteria populations was carried out in water and sediment samples of Mullipallam Creek in Muthupettai mangroves by Ashokkumar et al. (2011). Seasonal variations in physico-chemical parameters of Vellar River, Vellar Estuary and Portonovo Coastal Waters, Southeast coast of India were worked out by Prabhahar et al. (2011). Mohamed et al. (2011) examined the levels of varying physico-chemical parameters such as temperature, salinity, pH, alkalinity, dissolved oxygen, biological oxygen demand and chemical oxygen demand of five different environs along the Thondi coastal waters, southeast coast of India. The temporal and spatial distribution of salinity, DO, BOD, turbidity, pH, hardness and dissolved nutrients of surface water collected from different points of Dhamra estuary were measured by Muduli & Panda (2010).
A study was carried out to determine the physico-chemical characteristics and heavy metals in water and sediments in Uppanar Estuary, Nagapattinam, Southeast coast of India by Sankar et al. (2010). An exploration was also carried out to examine the variations of physico-chemical properties in Kalpakkam coastal waters, east coast of India, during southwest to northeast monsoon transition period by Satpathy et al. (2010). To trace the influence of modernization activity on Devi estuary (Orissa coast) and to understand the quality of the Devi estuarine water reaching the coastal region, studies on physico-chemical parameters (temperature, pH, salinity, dissolved oxygen), including dissolved nutrients (PO$_4$-P, NO$_3$-N, NO$_2$-N, SiO$_4$-Si) were carried out in the water in Devi estuary by Pradhan et al. (2009). Hulyal & Kaliwal (2009) investigated physico-chemical factors in relation with dynamics of phytoplankton of the Almatti reservoir of Bijapur District.

Physico-chemical studies were carried out in Uppanar estuary for a period of two years by Nedumaran & Perumal (2009). Ayoade et al. (2009) also studied the physical, chemical and biological parameters of rivers Bhagirathi and Bhilangana in Garhwal region of Himachal Pradesh. A number of studies have been carried out on hydro-chemistry in different estuaries of peninsular India. A detailed study on spatial and temporal variation of depth, temperature, salinity, currents, flushing time and classification of Krishna river estuary was carried out by Kumari & Rao (2009). Distribution and chemistry of major inorganic forms of nutrients along with physico-chemical parameters were investigated for surface sediments and overlying waters of the Ashtamudi and Vembanad Lakes in the southwest coast of India by Sujatha et al. (2009). A study pertaining to the seasonal variation in physico-chemical properties like phosphate, nitrate and silicate of the coastal waters was carried out at Kalpakkam coast by Satpathy et al. (2009). Seasonal and spatial variations in water quality parameters, such as nutrients (NH$_4^+$-N, NO$_2^-$-N, NO$_3^-$-N, PO$_4^{3-}$-P, total nitrogen and total phosphorus), Secchi disc depth, salinity, dissolved oxygen, Chlorophyll a,
primary productivity and phytoplankton standing stock, were studied in Chilika Lagoon by Panigrahi et al. (2009). Physico-chemical parameters such as rainfall, temperature, salinity, pH, dissolved oxygen and nutrients like nitrate, nitrite, inorganic phosphate and reactive silicate in Uppanar estuary, southeast coast of India were investigated by Soundarapandian et al. (2009). A study was attempted on the physico-chemical variability of two different environs along Parangipettai and Cuddalore coastal and estuarine waters of Bay of Bengal by Sundaramanickam et al. (2008).

Statistical evaluation of hydrobiological parameters of Narmada River water at Hoshangabad City, India was carried out by Shraddha et al. (2008). An investigation was undertaken by Sharma et al. (2008) to study the effect of domestic sewage and effluent from security paper mill on physico-chemical parameters like temperature, pH, DO, nitrate, phosphate, silicate and ecology of river Narmada at Hoshangabad and results revealed the positive effect of effluent on nitrate, phosphate and phytoplankton composition. Physico-chemical parameters such as temperature, salinity, pH, dissolved oxygen and nutrients like nitrate, nitrite, inorganic phosphate and reactive silicate were studied in Pichavaram mangroves, southeast coast of India, for a period of two years by Prabu et al. (2008). A study on the fresh water influence on nutrient stoichiometry in Cochin backwaters, a tropical estuary was carried out by Martin et al. (2008) and they analyzed the changes associated with transformation of micro tidal estuary from freshwater dominated to tide dominated system. The nutrient and dissolved metal concentration in Bhitarkanika mangrove system, Orissa, east coast of India was examined by Rita & Ramanathan (2008). Nutrient dynamics in the sediments of a tropical estuarine mangrove ecosystem of Pichavaram was investigated by Prasad & Ramanathan (2008). Seasonal and tidal dynamics of dissolved nutrients (NH$_4$-N, NO$_3$-N, NO$_2$-N, and PO$_4$-P), Chlorophyll a, and primary production were studied in Pichavaram mangroves, Southeast coast of India by Senthilkumar et al. (2008). Rajkumar et al. (2008) measured dissolved N$_2$O, CH$_4$, O$_2$, NH$_4^+$,
NO$_3^-$, NO$_2^-$ and N$_2$O and CH$_4$ emissions along the polluted Adyar estuary of Chennai, Tamil Nadu. Anilakumary *et al.* (2007) carried out water quality study of Adimalathura estuary in Kochi, Kerala exposed to pollution from the domestic wastes and coconut husk retting. Their results revealed the deleterious effects of waste disposal on the water quality and marked increase in the concentration level of nutrients and a decrease in dissolved oxygen. Physico-chemical characteristics of the Hooghly estuary during winter, summer and post-monsoon seasons have been studied by Sadhuram *et al.* (2005).

Water quality assessment of Gauthami-Gothavari estuarine ecosystem was carried by Tripathy *et al.* (2005) to understand the present status of water quality and the impact of external inputs during southwest monsoon in the study areas. Physico-chemical events in the coastal waters of Cochin and their relationships with each other revealed that these do not occur independently but are found linked with each other (Iyer *et al.*, 2003). Qasim (2003) reviewed the studies on estuaries of India, which included Sabarmati, Mahi, Narmada, Tapi, Mindola, Purna, Par, Ambika, Auranga, Kolak, Damanganga, Ulhas, Mahim, Savitri, Kundalika, Vashisti, Ashatmudi and Ennore estuaries and Cochin Backwaters. Physico-chemical characteristics in relation to pollution and phytoplankton production potential of brackish water were carried out in Sundarbans of India by Saha *et al.* (2001). Physicochemical characteristics in relation to pollution and phytoplankton production potential of brackish water were carried out in Sundarbans of India by Shyamalendu *et al.* (2001). Hydro-chemical and geochemical features of water and sediment nutrients of Ashtamudi estuary, Kerala was explored by Nair *et al.* (1993). Seasonal pattern of temperature, salinity, pH, dissolved oxygen, phosphate, nitrate and silicate profiles of the Mahanadi estuary were examined by Upadhyay (1988). A comprehensive survey of the pre-pollution status of Godavari estuary was undertaken by Sastry & Chandramohan (1990). Amba river estuary was studied to evaluate its physical characteristics.
with a point of application to locate a suitable release point of industrial effluent by **Dinesh Kumar et al. (1991)**. Mangroves have been ecologically well-studied by many authors: along the Sundarbans by **Naskar & Guha Bakshy (1989)**, the Andaman–Nicobar Islands (**Singh et al., 1986, 1987; Ellis, 1987; Dagar, 1987; Rao & Chakrabarti, 1987**), the Mahanadi delta by **Banerjee (1987)**, the Krishna estuary by **Prasad (1992)**, the Cauvery delta by **Kathiresan (2000)** and the Mumbai (Bombay) coasts by **Ghosh et al. (1994)**.

### 2.1.3. Regional status

About 16 large, medium and small rivers flow westward direction in southern part of Gujarat state which are open into the Arabian Sea. Most of the rivers end into shallow, wide estuaries named after the rivers as listed: (1) Sabarmati (2) Mahi (3) Dhadhar (4) Narmada (5) Kim (6) Tapi (7) Mindhola (8) Purna (9) Ambika (10) Kaveri (11) Karera (12) Auranga (13) Par (14) Kolak (15) Damanganga and (16) Varoli. Multivariate statistics and principal component analysis were used to study water characteristics of Kandla creek by **Shirodkar et al. (2010)** which indicated significant increase in nutrients from anthropogenic additions. They also concluded that increase in turbidity, total suspended solids (TSS) and salinity may be attributed to natural effects. A study was carried out to determine the physicochemical characteristics of water and sediment and the textural aspects of sediments in western mangroves of Kutch-Gujarat, west coast of India, for a period of two years during 1999-2000 by **Saravanakumar et al. (2008a)**. Flushing characteristics and pollution assessment of Purna estuary were worked out by **Zingde et al. (1987)**. **Zingde et al. (1986)** also carried out environmental studies of the Ambika and associated river estuaries.

An assessment of spatial and temporal fluctuations in water quality of a permanent estuarine system of Tapi was carried out by **Nirmal Kumar et al. (2009)**. **Nirmal Kumar et al. (2012)** have also worked out physico-chemical characteristics of the coastal water of Narmada estuary, Gujarat and gave
statistical evaluation of its seasonal changes. A study on the water quality of river Damanganga was carried out by Zingde et al. (1980). Zingde et al. (1981) also studied the base line water quality parameters of the river Narmada and its estuarine region.

2.2. Physico-chemical properties of sediment

2.2.1. International status

Estuarine sediment contamination is an important ecological issue since many years. The use of sediment bioassays in combination with chemical analysis to determine its impact on the ecosystem has been practiced since long. The chemical composition and vertical distribution of phosphorus in poorly oxygenated sediments extending from open Baltic Sea to inner bay was worked out by Lukkari et al. (2009) using sequential extraction to examine the potential for release of sediment phosphorus. The investigation of how toxic compounds are mobilized during dredging operations in the channel of the Port of Santos, Brazil was conducted to assess changes in the bioavailability and toxicity of these contaminations by Torres et al. (2009). Phosphorus dynamics and its bioavailability in sediments in relation to Alexandrium bloom occurrences were investigated in macro tidal estuary of Penze in France by Loyer et al. (2008). Pereira et al. (2008) emphasized the potential sources of metals; the links among metal levels in water, sediments, and invertebrates; and the contrasting effects on metal speciation and bioavailability in a coastal lagoon in Brazil. The sediments of Tagus estuarine beaches, Portugal were characterized by Freire et al. (2007) in order to understand their origin and to contribute to a better knowledge of sediment budget. Characterization of nutrient, organic carbon, sediment loads and concentration from the Mississippi River into the Northern Gulf of Mexico was studied by Turner et al. (2007).
Stedmon et al. (2006) assessed the inputs of dissolved carbon, nitrogen, and phosphorus for an estuary and its catchment of Horsens in Denmark. They observed that seasonal patterns in the concentrations of dissolved organic matter in the freshwater supply to the estuary differed depending on the soil and drainage characteristics of the area. Ouyang et al. (2006) reported temporal and spatial distributions of sediment total organic carbon (TOC) and its relationships to sediment contaminants in the Cedar and Ortega rivers, USA, using three-dimensional Kriging analysis which revealed a negative correlation between TOC and polycyclic aromatic hydrocarbons (PAHs) or polychlorinated biphenyls (PCBs). The factors influencing the biogeo-chemistry of sedimentary carbon and phosphorus in the Sacramento-San Joaquin Delta in California were worked out by Nilsen & Delaney (2005). They characterized the organic carbon and phosphorus geo-chemistry in surface sediments of delta. Biochemical characteristics like temperature, salinity, dissolved organic carbon (DOC), total dissolved nitrogen, dissolved macronutrients ($\text{NO}_3^+$, $\text{NO}_2$, $\text{PO}_4$, $\text{Si(OH)}_4$), Chlorophyll-$a$, pigment composition, total suspended matter (TSM), particulate organic carbon (POC), and particulate nitrogen (PN) were evaluated in lower Mississippi River, USA by Dagg et al. (2005). A study of ecological conditions associated with bottom sediments in the Neuse estuary at Pamlico Sound, U.S.A. was undertaken by Balthis et al. (2002). Wolfe et al. (1996) explored the sediment toxicity, its distribution and correlation with chemical contamination in the Hudson-Raritan Estuary in New York.

An evaluation of benthic exchange of nutrients and regeneration in Galveston Bay, Texas was carried out by Warnken et al. (2000). Their study showed that the fluxes of ammonium and phosphate were directed from the sediments into the overlying waters, the fluxes of silicate and chloride changed in both magnitude and direction in response to changing Trinity River flow conditions. The role of coarse material (sand fraction) in the distribution of metals in polluted marine sediments was investigated in the
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2.2.2. National status

Suspended sediment dynamics on a seasonal scale in the Mandovi and Zuari estuaries, central west coast of India was carried out by Rao et al. (2011). Concentrations of Hg, total organic carbon (TOC), Al, Fe and Mn were determined in sediment of the Amba estuary in Mumbai harbour by Ram et al. (2009). In order to gain insight into the formation dynamics of mud banks off of the Kerala coast of India, extensive surveying of the near shore bathymetry along with sediment characterization was undertaken by Narayana et al. (2008) and the textural and geotechnical properties of the surface sediments were determined during pre-monsoon, monsoon and post-monsoon periods. Krupadam et al. (2003) reported the enhanced metal concentration in the sediment with marked enrichment in organic carbon, total nitrogen, and humic acid in Godavari estuary. Rajasegar et al. (2002) emphasized effect of nutrient rich water from the shrimp farms on sediment composition, organic carbon, total phosphorus and total nitrogen content of sediments in Vellar estuary. Study on the sediment characteristics of the Poonthura river estuary in Kerala was made by Anilakumary (2001) in relation to pollution.

Geochemical study of bottom sediments of the Periyar and Muvattupuzha rivers, Cochin estuary and the adjoining near shore continental shelf was carried out to understand the distribution and enrichment pattern, sources, possible factors responsible for the enrichment and depletion of elements and environmental contamination of the systems by Paul (2001). Sediment organic carbon, total nitrogen, total phosphorous and hydrography of the overlying waters of the estuarine region in Mandovi estuary have been studied by Nasnolkar et al. (1996) and they reported a significant linear variation among carbon, nutrients and sediment
characteristics with clay and silt. A study on the sediments of Hoogly estuary was undertaken by Ghosh & Choudhury (1989) where the focus was laid on distribution of organic carbon, total nitrogen, available nitrogen, total phosphorus and available phosphorus in relation to the texture of the sediment. The lowest content of all the elements was observed in sandy sediments but as the texture got finer element content enhanced.

2.2.3. Regional status

Source and dispersal of suspended sediment in macrotidal Gulf of Kutch was investigated by Ramaswamy et al. (2007) and they found that Perennial high suspended sediment concentration in the Gulf was due to re-suspension of sediments by strong tidal currents, shallow bathymetry and presence of fine-grained sediments on the sea floor. The composition of mineral fractions of the Narmada and Tapi estuarine particles, mainly suspended matter and bottom sediments was carried out by Baskaran et al. (1984). Particulate matter from Mahi estuary was studied for organic carbon, organic nitrogen and Chlorophyll-a by Bhosle et al. (1985).

2.3. Biotic Components

The analysis of biotic components of an estuarine ecosystem provides a clear view to determine the quality of that ecosystem. Community structure, biomass and relative abundance of functional groups and indicator species have also been developed and used as environmental indicators (Deeley & Paling, 1999). Autotrophic protists (periphyton, phytoplankton) appear to be useful for describing nutrient enrichment, salinity and pH profiles. Zooplankton appears to be limited as environmental indicators, but may be useful as elements of biotic indices across trophic groups. Benthic macro-invertebrates have been successfully used to describe the nature and magnitude of organic enrichment of estuaries.
2.3.1. Phytoplankton

2.3.1.1. International status

Rochelle et al. (2011) investigated the factors controlling phytoplankton distribution and phytoplankton-bacterial coupling in the Bach Dang Estuary of Northern Vietnam. Annual data on composition, abundances, species richness and diversity of the phytoplankton surface community and some physical-chemical parameters variations were discussed in the tropical reservoir Valle de Bravo, Mexico by Gaytan-Herrera et al. (2011). Phytoplankton succession in relation to some physicochemical characters of some water bodies at Jeddah Coast in Saudi Arabia was studied by Hussein et al. (2010). Seasonal variation of zooplankton biomass was carried out at two selected sites on Greater Zab River in Iraq by Luay (2010). Esmaeili et al. (2010) investigated the distribution and fluctuations of phytoplankton and selected physico-chemical factors in relation to Artemia distribution in Urmia Lake in Iran. Studies on zooplankton in five stations through the Chabahar Bay in Gulf of Oman was carried out by Neda et al. (2010). Their results showed that seasonal variation of Chlorophyll-a concentration associated phosphate concentration was a major factor controlling abundance of copepod after a time lag. Abundance of copepod was significantly higher during the premonsoon as compared to other seasons.

The variation in phytoplankton community as a response to improving water quality was studied in the severely polluted Golden Horn Estuary in Turkey by Seyfettin et al. (2009). Felicity & Alex (2007) investigated spatial and temporal variation in macroalgae epiphytic on pneumatophores of the Grey Mangrove, Avicennia marina in the Clyde River of Australia. Diversity and abundance of marine plankton and benthos at selected locations in the Gulf of Mannar and Palk Bay in Sri Lanka was analysed by Jayasiri & Priyadarshani (2007).
Putland & Iverson (2007) evaluated the seasonal pattern of phytoplankton biomass (Chlorophyll and particulate organic carbon) and the salinity related pattern of phytoplankton biomass and size composition in Apalachicola Bay, Florida and reported that phytoplankton biomass was the highest during summer and the lowest during winter. Lehman (2007) found out the relative contribution of riverine and freshwater phytoplankton using measurement of primary productivity, respiration and phytoplankton species composition along the San Joaquin estuary in San Francisco. Emmanuel & Onyema (2007) investigated the physico-chemical characteristics, phytoplankton, zooplankton, finfish and shell fish components of an estuarine creek in south-western Nigeria. Their results showed notable seasonal variation in composition and abundance of biotic components. The relationships between phytoplankton productivity, nutrient distributions and freshwater flow were examined at Escambia bay in USA by Murrell et al. (2007). Greenwood (2007) pointed out that organisms tend to inhabit predictable portions of estuaries along salinity gradients between the ocean inlets and the freshwater tributaries. Wilk-Wozniak & Zurek (2006) analysed the general relationships of phytoplankton with chemical and zooplankton in the meromictic Piaseczno reservoir of Southern Poland. Glibert et al. (2006) assessed the factors potentially limiting both biomass and production in Moreton Bay in Queensland through stoichiometric comparisons of nitrogen, phosphorus, silicon and carbon concentrations. Bonilla et al. (2005) investigated the relationship of phytoplankton bio-volume, structure and species life strategies with major abiotic factors in a subtropical choked coastal lagoon, Atlantic Ocean.

A study on the distribution pattern, biomass estimates and diversity of Izmit Bay in Turkey was explored by Aktan et al. (2005) in which qualitative and quantitative characteristics of phytoplankton community structure and the environmental factors that affected its distribution were evaluated. The distribution of phytoplankton taxa and biomass was recorded by Calliari et
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al. (2005) to assess their association to environmental variables in the Rio-de-la-Plata estuary of South America. Their results suggested an overriding importance of salinity-light gradients in modulating biomass levels and species distribution in the Rio-de-la-Plata. Ringuet & Mackenzie (2005) studied the nutrient and phytoplankton dynamics during normal flow and storm runoff conditions at southern Kaneohe bay in Hawaii. They found that nutrient loading via runoff generally led to an increase of the phytoplankton biomass and gross primary productivity. Ferreira et al. (2005) assessed the effect of flushing rate, salinity tolerance, light, nutrients and grazing on phytoplankton distribution on some of the European estuaries. Distributions of dissolved nutrients and Chlorophyll a were investigated in the Matang Mangrove Estuary, Malaysia by Katsuhisa & Poh-Sze (2000). They found that variations in the phytoplankton biomass and nutrients probably reflected the greater nutrient availability in the spring tide due to outwelling from the mangrove swamp and creek.

2.3.1.2. Indian status

The diversity of phytoplankton in relation to physico-chemical parameters in two perennial ponds of Kulasekharam area, Kanyakumari district, Tamil Nadu was worked out by Mary (2011). An investigation was made on the influence of physico-chemical parameters on zooplankton composition of Ayyampatinam coastal region situated in southeast coast of India by Santhosh & Perumal (2011). A study was carried out on the dynamic relationship of water physico-chemical characteristics with phytoplankton at the Dhamra river estuary of Bay Of Bengal, India by Palleyi et al. (2011). Rajagopal et al. (2010) investigated the diversity of phytoplankton in relation to physico-chemical parameters of two perennial ponds of Sattur area, Tamil Nadu.
Assessment of phytoplankton community and nutrient dynamics of shallow coastal station at Bay of Bengal was studied by Choudhury & Pal (2010).

An investigation was carried out on hydrography, composition and community structure of phytoplankton and zooplankton including Chlorophyll-a content and primary productivity at the Kaduviyar estuary, Southeast coast of India by Perumal et al. (2009). Seasonal variations of phytoplankton and Chlorophyll-a along with its environmental variations including nutrients were carried out in Mahanadi estuary by Subrat et al. (2009). Monitoring and surveillance of algal blooms along the southwest coast of India, both from the coastal and estuarine were made by Sanilkumar et al. (2009). Harnstrom et al., 2009 investigated the relationship phytoplankton with several environmental variables at a coastal area near Mangalore. Similar type of work was carried out by Naik et al. (2009) in Mahanadi estuary in east coast of India to understand the effect of chemical factors, especially salinity and nutrient composition on phytoplankton.

Biswas et al. (2007) studied the inter-annual variations of phytoplankton abundance and community organization over a two-decade period along with the ancillary parameters at the land ocean boundary associated with the Sundarban estuarine ecosystem, along the north-east coast of the Bay of Bengal. Their study revealed that phytoplankton bio-volume showed seasonality, with the highest levels during post-monsoon periods and the lowest levels during the monsoon period. Shalapyonok et al. (2001) investigated the abundance, size distribution and carbon biomass of autotrophic phytoplankton in the Arabian Sea during summer, south-west and north-east monsoon seasons and found that the phytoplankton community structure was strongly linked to water-mass characteristics. Planktonic diatoms of the Zuari estuary, Goa were investigated by Redekar & Wagh (2000). Phytoplankton pigment, cell count and species diversity were
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studied at five locations in Dharamtar Creek, Bombay by Tiwari & Nair (1998) and recorded a total of 58 genera of phytoplankton comprising 46 diatoms, 6 dinoflagellates and 6 other algae.

2.3.1.3. Regional status

The diversity of phytoplankton and zooplankton of Narmada river in Gujarat was studied by Sharma & Mankodi (2011). They observed that the Bacillariophyceae was the most dominant group of phytoplankton studied among the different sites. Vachhrajani & Mankodi (2008) studied the plankton diversity of coastal area-Gopnath in Gulf of Khambhat and reported 38 phytoplankton and 25 zooplankton species from the area. Estimation of plankton species diversity of Sabarmati river as an index of environmental changes was carried out by Shaji & Patel (1991) and their study revealed that the values of index for all the sites were indicative of moderate to heavy pollution of the river. Distribution of phytoplankton in Auranga, Ambika, Purna and Mindola estuaries was studied by Desai et al. (1984). A detailed evaluation of phytoplankton, zooplankton and benthic community structure was carried out in all major ten estuaries of southern Gujarat by Qasim (2003).

2.3.2. Zooplankton

2.3.2.1. International status

Mialet et al. (2011) investigated the response of the crustacean zooplankton community in improving water quality in the Scheldt estuary, Belgium. They found that Cyclopoids populations strongly decreased in freshwater while Cladocerans did not change their abundance. Responses of estuarine bacterioplankton, phytoplankton and zooplankton with dissolved organic carbon and inorganic nutrient additions were worked out in Hunter estuary of Australia by Hitchcock et al. (2010) and their results suggested that the heterotrophic community was limited by DOC at studied sites and across
seasons. **Silva et al. (2009)** inspected the influence of environmental variables on the spatial and temporal composition of the most abundant zooplankton groups (cladocera and rotifera) in a tropical inverse estuary of Northeast Brazil. **Reaugh et al. (2007)** examined the changes in plankton community structure and function in response to variable freshwater flow in two tributaries of the Chesapeake Bay in United States. Effects of mesoscale physical processes on thin zooplankton layers at four sites along the west coast of United States were carried out by **Cheriton et al. (2007)**.

### 2.3.2.2. Indian status

**Annalakshmi & Amsath (2012)** investigated the composition, abundance, frequency of occurrence and diversity of net zooplankton species inhabiting in river Cauvery and its tributaries Arasalar at Kumbakonam, Tamil Nadu. The spatial, temporal and tidal dynamics of zooplankton communities of Kodaikkari coastal waters were investigated by **Damotharan et al. (2010a)** to study the role of physico-chemical parameters in determining zooplankton distribution. Mysids from a tropical estuary (Cochin backwater) in India were studied based on samples collected over a period of one year by **Abraham & Saramma (2010)** and they observed that *Mesopodopsis orientalis*, *Mesopodopsis zeylanica*, *Rhopalophthalmus indicus* and *Kochimysis pillaii*, were the most dominant species during the monsoon period. Their study also revealed that environmental parameters, salinity and Chlorophyll-\(a\), had much influence on the population density of Mysids.

**Devi et al. (2010)** evaluated the seasonal variation and trophic ecology of micro-zooplankton in the south-eastern Arabian Sea and found that micro-zooplankton community during the spring inter-monsoon was numerically dominated by ciliates while heterotrophic dinoflagellate was the dominant one during the monsoon periods. The distribution of seventeen groups of zooplankton in Cochin backwaters was carried out by **Varghese & Krishnan (2009)** and their study revealed the dominance of copepods and rotifers at the
selected stations. Seasonal abundance and the relationship of micro zooplankton with higher trophic levels were studied in the tropical estuarine and mangrove waters, Parangipet tai by Godhantaraman (2002).

2.3.2.3. Regional status

A study on population dynamics and seasonal abundance of zooplankton community in Narmada river was carried out by Sharma et al. (2010) and they found that Rotifera was the most dominant group among Protozoa, Cladocera and Copepoda which were reported from the estuary. The zooplankton was assessed quantitatively and qualitatively with regard to their abundance in creek waters at three sites along the western mangrove of Kutch, west coast of India by Saravanakumar et al. (2008b) and they reported a total of 69 species of which Copepods formed the dominant group. Desai et al. (1983) made the comparative account on zooplankton in polluted and unpolluted estuaries such as Kolak, Par, Damanganga and Auranga of Gujarat.

2.3.3. Benthic fauna

2.3.3.1. International status

Tomiyama et al. (2008) reported spatial intertidal distribution of bivalves and Polychaetes in relation to environmental conditions in the Natori estuary, Japan. Molluscs and Polychaetae distribution in the mud flats along the Dese estuary of Italy was analysed by Maggiore & Keppel (2007) to evaluate the taxonomic biodiversity and zonation pattern of soft macrobenthos in an area of lagoon. Monthly variation in community composition of Oligochaetes and environmental characteristics in two South Carolina Tidal Creeks were assessed by Gillett et al. (2007). Their study provided an insight note into the ecology of the Oligochaetes and their potential effects on other biota. Salgado et al. (2007) studied the distribution
patterns of the macro zoobenthos assemblage in the salt marshes of Tejo estuary in Portugal. A study was conducted in the Capibaribe river estuary in Brazil by Paranagua et al. (2005) to assess the Cladocerans community. Their study revealed that Cladocerans played an important role in the food webs of the plankton community. Macrobenthic communities from estuaries throughout the northern Gulf of Mexico were studied to assess the influence of sediment contaminants and natural environmental factors on macrobenthic community by Brown et al. (2000). Sagasti et al. (2000) characterized the abundance and species composition of sessile and mobile epifaunal assemblages in the York river, of the Chesapeake Bay in United States. Steimle & Ward (1989) assessed the benthic macro fauna of the Raritan estuary in New York. The cumulative effects of urbanization on the benthic fauna of two urban and three rural estuaries near Townsville, Queensland were studied by Inglis & Kross (2000).

2.3.3.2. National status

Temporal variability of macrofaunal community from Mormugao Bay, Zuari estuary, on the west coast of India was examined by Sivadas et al. (2011). Kundu et al. (2010) studied the diversity and seasonal variations of macro-benthic fauna and associated environmental factors influencing the benthic community in the inshore waters of southern Indian coast, Parangipetty. Impact of changing ecological conditions on Polychaeta assemblages along the extremely polluted Thane creek on the west-coast of India was studied by Quadros et al. (2009). The community structure of polychaete fauna of Godavari estuary was explored by Rao et al. (2009). Anilakumary (2008) studied community structure of meiobenthic nematodes in Poonthura estuary of southwest coast of India. Impacts of physical disturbance on the community structure of estuarine benthic meiofauna of Vellar estuary in southeast coast of India wa evaluated by Mani et al. (2008). The marine zone of Vellar estuary was explored for temporal changes in
community structure of benthos using advanced statistical tools by Murugesan et al. (2007).

Effect of thermal effluent discharge on benthic fauna of Tuticorin Bay of Tamil Nadu was examined by Kailasam & Sivakami (2004). Harkantra & Rodrigues (2004) investigated species diversity, biomass and population density of soft bottom macro fauna in relation to environmental influences of Mandovi and Zuari estuaries of India. Sunilkumar (2002) extended study on biomass distribution, horizontal zonation, relative dominance and vertical distribution of Polychaetes in littoral sediment of Cochin estuarine mangrove. A review on the biodiversity of soil dwelling organisms in Indian mangroves was carried out by Kumar (2000). Community structure of meiobenthos from tropical Zuari estuary of India was assessed by Ansari & Parulekar (1998) and they found that free living Nematodes were the most dominant group which occurred prominently during pre-monsoon season.

2.3.3.3. Regional status

Sub-tidal micro and meio-benthic community structure of Gulf of Kutch was investigated during pre-monsoon season by Ingole & Goltekar (2004). Plankton and benthos of the Narmada estuary, Dahej creek and Bukki creek were investigated by Gajbhiye et al. (1981) and their study revealed that the physico-chemical parameters had a significant influence on distribution of organisms.

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