Biodiversity is a compressive term for expression of nature's variety and represents the richness and variety of flora and fauna and forms the basis of our quality of life, food, security, health and recreation. Unfortunately due to a variety of reasons like being industrialization, urbanization and excessive exploitation of natural resources, the biodiversity is under tremendous pressure with many plant and animal species already lost and many on the way to extinction. Like other ecosystems lake in urban environment are facing problem of environmental degradation mainly due to pollution from untreated domestic sewage and industrial effluents (Kodarkar, et al., 1995).

In an aquatic ecosystem physicochemical environment has profound influence on its biotic components. It controls biodiversity, biomass and spatial distribution of biotic communities in time and space. The physical and chemical parameters exert their influence on both individually and collectively and their interaction produces abiotic environment which ultimately condition the origin, development and finally succession of biotic communities. Further, biotic communities, in turn, continuously alter abiotic environment thus a constant interaction between the abiotic and biotic components goes on a dynamic ecosystem. Each ecosystem has its characteristics abiotic and biotic factors and their thorough understanding is essential for its effective management. The physical and chemical conditions of water body are largely governed by the basic hydrologic balance of inputs (i.e. precipitation, groundwater inflow, ocean over-wash) and outputs (i.e. evaporation, groundwater seepage), as well as basin morphometry, surrounding geology, biologic activity and climate. Differences in these conditions lead to changes in salinity, pH, DO and other parameters. The physico-chemical pollution of water brings about changes in water with regard to its color, odour, density, turbidity, acidity, alkalinity, pH, dissolved oxygen, hardness, carbon dioxide, chlorides, sulphates, etc. Biological pollution is caused by the excretory products of worm-blooded animals and also brought about by viruses, diatoms like protozoa, rotifers, crustaceans, and plant toxins (Malathi, 1999).
The present study is aimed to investigate some of the important physical and chemical parameters such as Temperature, pH, Dissolved oxygen, Alkalinity, CO₂, B.O.D., Hardness, Chlorides, etc., along with primary productivity, heavy metal analysis of different lotic and lentic water bodies where species abundance is more.

Temperature is a very important physical parameter, because it influences the biota in a water body by affecting activities such as behavior, reproduction and metabolism. It is necessary to study temperature variations in water body and in animals eco-physiological and toxicological aspects because, water density and oxygen content are temperature related and hence temperature indirectly affects osmoregulation and respiration of the animal (Patil, 1993). Temperature is one of the most important abiotic parameters that regulate the self purification capacity of rivers, lakes, and reservoirs and measurement of water temperature is of vital importance in the fields of limnology and oceanography. Increase in the environmental temperature increase the rate of degradation of organic matter leading to future build up of carbon dioxide in water. In the lakes, dams and rivers the water temperature is maximum in summer and minimum in winter (Khatavakar, 2004). In the present study, the temperature showed rising trend from winter to summer in lotic and lentic water bodies. The minimum temperature was observed in winter and the maximum being observed in summer but in Kheina river, Khultabad pond, Andhari dam and Yesgaon dam it was minimum in monsoon. In summer, the temperature was high may be because of low water level, low velocity, clear atmosphere and greater solar radiation. Minimum temperature in monsoon and winter season can be explained on the basis of frequent clouds, high percentage of humidity, high current velocity and high water levels. Water temperature is low during winter season and thereafter steadily increased till May month. Similar observations were reported by, Borse and Bhave (2000), Shaikh and Yeragi (2004). A significant correlation between ambient temperature and water temperature in Kailana lake (Jakher and Rawat, 2003). This agreement also supported by Kato (1941), Ganpati (1962) and Verma (1967). Pawar and
Mane (2006) observed that the effect of atmospheric temperature was amply reflected in the water temperature changes in Sadatpur lake. Higher surface water temperature was observed in May is in the agreement with the works of Kumar (1984), Ramesh (1989), and Meitei et al. (2004). William (1987) stated that temperature is the determining factor in the seasonal distribution of organisms. The relationship can be deduced between chemical conditions and plankton population at any specific time. Salaskar and Yeragi (1997) stated that the air temperature between 29.8\(^0\)C to 31.8\(^0\)C, minimum in winter and maximum in summer. However the water temperature ranged between 28.7\(^0\)C to 31.2\(^0\)C which showed a close correlation between atmospheric and water temperature. Similar observations were reported by number of workers (Munawar, 1974; Swarnalatha, 1994; Chandrasekhar, 1997). The temperature was higher in summer at the sampling site of Pravara river, Sukhana river and Kham river may be due to mixing of domestic sewage and washing activities, vehicles cleaning etc. This is in conformity with the observations of Vyas (1968) and Anitha (2002) in Mir-Alam lake. Gahtori et al. (1981) pointed out that in sewage fed ecosystem maximum water temperature noted during summer (29.6\(^0\)C) and continued till mid rains (28.8\(^0\)C), while minimum water temperature (10\(^0\)C) was observed during winter. Malathi (1999) reported that rise in temperature accelerates the rate of chemical reactions, reduces the solubility of gases amplifies taste and odor metabolic rate which was higher in summer and relatively lower in monsoon and winter. Water temperature followed a common pattern, it was higher in summer and relatively lower in monsoon and winter. Similar pattern is reported by a number of workers (Patil,1993; Malathi,1999; Patwardhi,2002; Zadpide; 2002; Meitei et al. 2004). Narasimharao and Jaya (2001) observed that rise in temperature can be resulted in high rate of evaporation which may cause decline in water level during summer. Kamath, et al. (2006) stated that temperature plays an important role which influences on the periodicity and abundance of phytoplankton. The ambient temperature in surface water is of vital importance as it determines the degree of dissociation of dissolved salts in water system and controls to some extent
the rate of oxidation of organic matter. Temperature affects chemical toxicity or complex because temperature also may be lethal toxicant, which may alter thermal limits in unpredictable ways and influence on the survival of animals (Akarte, 1985; Muley, 1985). It has been observed that the temperature was raised in summer at Tisgaon lake, Daultabad pond, Nandrabad pond and Sukhna dam. Rise in temperature may be due to saturation levels of solids like domestic sewage and municipal wastes and gases in water. Similar observation was reported by Thirumala et. al. (2006) in Ayyanakere lake. The rising of water temperature particularly in summer can be attributed to overall increasing trend in atmospheric temperature in addition to exothermic chemical processes due to mixing of domestic sewage and the human activities prevail all along the lake observed by Auti (2002). Deshmukh and Ambhore (2006) showed that the temperature was higher during May and lower during December the DO was inversely proportional i.e. higher during December and lower during May. Singh et. al. (1998) studied water quality from Rapti river at Gorakhpur recorded water temperature at site – A 21.2 to 30.5°C, at site – B 22.2-20.5°C and at site – C 5.5 to 31.2°C. Deshmukh et. al. (1964) observed that the water temperature from Ambazari lake ranged from 18 to 32°C depending upon the seasons, solar radiations and other climatic conditions. Fluctuation in surface water temperature was noted by Lohar and Patel (1998). The temperature is known to play a prime role in the productivity of water by influencing the abundance of primary producers on which the primary consumers depends for food source. It affects not only the metabolic activities of plankton but also their proliferation (Shukla et. al., 1991).

pH is one of the most important abiotic factors that serves as an index for pollution. The factors like photosynthesis, exposure to air, disposal of industrial waste and domestic sewage affect pH (Saxena, 1987). The range of pH was between 7.1 to 9.0 at Karpara reservoir (at station A,B,C) (Dhere and Gaikwad , 2006). The range of pH of majority of lakes and reservoirs in between 6 to 9 reported by Moor (1950), Ganpati (1960) and Wetzel (1983). pH was also reported to play an important role in formation of
algal bloom (Blum, 1956). It has been observed that the pH was high in summer at Godavari river, Sukhna river, Harsul lake, Daultabad pond, Khultabad pond, and Tembhapuri dam while it was low in monsoon at Girja river, Gautala lake, Kagzipura lake, Ambadi dam, Tembhapuri dam and Sukhna dam may be due to environmental factors such as temperature, salinity and pressure. Similar observations were reported by Shiakh and Yeragi (2004) Malathi (1999), Patil (1993), Saokar (1994), Nagwanshi (1997) and Sawane (2006). The pH of water has a marked effect upon the toxicity of substances commonly present in water body. Specially on chemicals that ionize under the influence of pH. The hydrogen ion normally associated with high photosynthetic activity in water (Patil, 1993). pH dropped during monsoon in subsequent days due to heavy rains, rainwater rapidly incorporated into the water body. Similar results were obtained by Jawale and Kumawat (2002). Sadhuram et al. (2005) studied pH between 8.05 - 8.18, 8.12 - 8.28 and 7.87 - 8.09 during winter, summer and post-monsoon seasons, respectively in Haldia channel of Hooghly estuary, India. The pH of the lake water ranged 7.2 to 7.8 is alkaline in nature hence favorable for the growth of the fishes (Lendhe and Yeragi, 2004). In the present study, the pH was maximum in monsoon at Khelna river, Salim Ali lake, Tisgaon lake, Andhari dam, Jaikwadi dam, and Yesgaon dam while it was minimum in winter at Godavari river, Tisgaon lake, Harsul lake, Daultabad pond, Khultabad pond, and Jaikwadi dam. In rainy season, the alkaline earth carbonates from runoff soil and clay enter into the water body along with rain water. The large quantity of water in flooded water dilutes the pollutants causes slight depletion of pH in rainy season at sampling station. These observations were tally with those of Mohanta and Patra (2000) in river Panchananda. pH exhibited considerable variations in rainy seasons which were due to continuous water movement and inflow which brought the levels of carbon dioxide and carbonates in the water (Anitha, 2002). Timms (1973) reported that inflow of water caused fluctuations of pH in the coastal lakes of East Gippsland. Dwivedi and Pandey (2002) suggested that high pH and alkalinity are associated with high photosynthetic activity besides favoring
saturation of the dissolved oxygen. It is significant to note that the pH of clear water remains neutral throughout. The pH concentration was increased in winter at Pravara river, Girja river, Kham river, Mahismal lake, Gautala lake, Kagzipura lake, Nandrabad pond, Ambadi dam and Sukhna dam while it was decreased in summer at Pravara river, Kham river, Mahismal lake, Salim Ali lake, Nandrabad pond, Andhari dam and Yesgaon dam. The pH was high in winter may be due to richness of salts in water during winter. The reduced rate of photosynthetic activities reduces the assimilation of CO₂ and bicarbonates which is ultimately responsible for increase in pH. These findings were supported by Sawane et al. (2006) in Irai river. Koshy and Nayar (1999) in Pumba river also recorded similar findings. pH values was some what higher in winter presumably due to higher photosynthetic activity (Huchinson et al., 1967; Roy, 1955). There was sudden fall of pH as the flood water entered the lake in the early rainy season (Mishra and Yadav, 1989). It has been observed that the pH concentration was found lower in summer may be due to reduced level of water. The increased photosynthetic activities and intense sunlight causes the assimilation of bicarbonates by phytoplankton’s, which lower the pH of water to some extent. These findings are noted by Phophali et al. (1990) in Patra river. Generally, slightly alkaline conditions are favorable for growth of algal species in lotic systems (Welch, 1952; Blum, 1956). pH affects species diversity and distribution in an ecosystem. The factors like photosynthesis, exposure to air, disposal of industrial waste and domestic sewage affect pH (Saxena, 1987). Palanivel and Rajaguru (1999) stated that the high amount of TSS and pH was mainly due to the discharge of industrial and domestic wastes into the river. Singh (1988) reported that the pH was alkaline in tanks ranged from 7.2 to 8.2. From the above study, it is found that all water bodies maintain alkaline pH except in Kham river and Harsul lake where it was slightly acidic. On the otherhand, it was neutral in Yesgaon dam. Generally pH of water is influenced by geology, catchment area and buffering capacity of water. Chandrasekhar (1997) observed alkaline pH in Sarrornagar lake water due to high quantum of sewage. Similar observations
were noted by Malathi, (1999); Pathak, (1999) and Mohd Ilyas (2001). In urban centers, pH of water is also highly influenced by nature of pollution in the form of sewage and industrial effluents (Kodarkar, 1995).

Dissolved oxygen is one of the most important abiotic factors influencing life in an aquatic ecosystem. Its depletion perhaps is the most critical manifestation of pollution and effects of low level of dissolved oxygen. The dissolved oxygen level in natural water depends on physical, chemical and biological activities of the water body. Concentration of dissolved oxygen decreases with increase in temperature. A healthy stream or lake should have adequate dissolved oxygen. The oxygen rich water, bacteria and protozoan and microorganisms multiply rapidly and then become food for advanced aquatic animals. The presence of dissolved oxygen is essential to maintain variety of forms of biological life in water. Non-polluted surface waters naturally saturated with dissolved oxygen. Lower dissolved oxygen in summer may be due to high temperature and low solubility of oxygen in water can subsequently affecting the BOD (Singh et al., 1998). Shastri et al. (1999) observed a strong correlation between pH and dissolved oxygen. It has been noted that the dissolved oxygen was high in summer at Khelna river and Jaikwadi dam. There was a positive correlation between temperature, sunlight and soluble gases like dissolved oxygen. Similar observations are reported by Krishna Murthy (1966). The dissolved oxygen values ranged from 2.03 to 2.41 mg/l. in summer is probably accounted for the rise in temperature due to the maximum addition of domestic sewage discharge into the pond (Patwari, 2002). Low values of the dissolved oxygen in monsoon at Nandrabad pond, Jaikwadi dam and at Ambadi dam might be attributed to the activity of domestic sewage causing anoxic conditions due to the decay of organic matter. These findings are in accordance with Patil (1993) and Auti (2002). Sewage loading pattern and pollution from detergents and domestic waste has a very complex and unpredictable influences on dissolved oxygen. In general, the monsoon pattern and the total turnover of water profoundly influences dynamics of dissolved oxygen gases like oxygen and carbon dioxide. Dissolved oxygen showed a
significant inverse relationship with temperature. Dissolved oxygen remained comparatively high during winter viz. Dec, Jan. and Feb. and low during July to October (Datta et al., 2001) Desale and Mehadi, (2005) stated that the solubility of oxygen decreased with increase in temperature. Sabata and Nayar (1995) reported that the dissolved oxygen showed a negative correlation between dissolved oxygen and temperature. Low temperature favored the dissolution of dissolved oxygen (Khabade et al., 2002). Muley and Patil (2006) found that the dissolved oxygen varies from 0.41 to 7.105 mg/l. At station C and D the dissolved oxygen values were less, especially during February to May. It is associated with heavy organic matter at downstream. The highest values were observed at station A and B during November and December respectively. Dissolved oxygen was also high in monsoon due to progressive lowering of turbidity resulting in resumption of photosynthetic activity in Godavari river, Pravara river, Sukhna river, Tisgaon lake, Gautala lake, Tembhapuri dam and Yesgaon dam. Similar findings were noted by Anitha (2002), Patwari (2002) and Auti (2002). The dissolved oxygen in water body is dependent on the green plants in it. The amount of oxygen that these phytoplankton as well as rooted vascular plants can provide depends on the density of the photosynthetic plants as well as intensity and duration of light. Oxygen from a water body is removed by respiration by the biota and also by decomposition of organic matter (Chakrabarathy et al., 1959; David and Roy, 1966). Busulu et al. (1967) observed that the photosynthetic activity responsible for supplying oxygen remains restricted to the zone up to which light can penetrate, respiration and decomposition which are responsible for oxygen deficiency in the water. During winter, dissolved oxygen was low at Pravara river, Khelna river Sukhna river, Gautala lake and Tembhapuri dam due to high turbidity, low aeration rate and low photosynthetic activity might have decreased the amount of dissolved oxygen, comparatively during monsoon. Relatively lower values of dissolved oxygen and anaerobic situation in this zone resulted into very low biotic diversity and biomass (Reddy, 1991). Anwar and Siddiqui (1988) pointed out that the monthly variation of dissolved oxygen of
the river varied from 4.2ppm to 8.6ppm round the year. The distribution of macro invertebrate fauna appears to be related to dissolve oxygen of the water. Ellis (1937) pointed out that the minimum dissolved oxygen content in water for maintaining fish life in healthy conditions is 5.0 mg/lit at 20°C. The present study indicated that the dissolved oxygen was raised in winter at Harsul lake, Nandrabad pond, Daultabad pond and Ambadi dam. In winter, the dissolved oxygen is sufficiently present in these water bodies because of decrease in temperature of land surface (Auti, 2002). With the progress of winter, DO increase to its highest value which may be due to circulation by cooling and draw down of DO in water (Hannan, 1979). Relatively higher oxygen concentrations in winter and post-monsoon seasons showed the flow of freshwater wherein oxygen solubility is greater. It is apparent from the data that oxygen concentration was controlled by hydrographical parameters (temperature and salinity) in association with physical and biological processes in the estuarine environment (Sadhuram, et al., 2005). Ekundayo (1977) and Imevbore (1983) reported that the contamination of water with faces, increases the BOD because it contains mainly organic matter making oxygen less available to desirable organisms. Lower dissolved oxygen in summer at Tisgaon and Harsul lake was probably due to two reasons, in summer due to high temperature, rate of oxidation of organic matter in water increased and oxygen was consumed in the process, secondly at higher temperature the water had a lesser oxygen holding capacity and surplus oxygen was lost to the atmosphere (Rutner, 1963; Reid, 1966; Saha and Pandit, 1986). The DO content of water was low in summer because of its enhanced utilization by microorganisms in the decomposition of organic matter (Sangu and Sharma, 1987). Anitha (2002) observed that during summer low values of dissolved oxygen and increased values of phytoplankton in some cases may be due to the decrease of photosynthetic activity. Such an observation depicting the direct relationship between phytoplankton and dissolved oxygen content has also observed by Albaster and Lloyd (1982). In the present study, results showed the inverse relationship between temperature and dissolved oxygen at Girija river,
Mahismal lake, Kagzipura lake, Salim Ali lake, Daulatabad pond, Andhari dam and Yesgaon dam. Yeole and Patil (2005) showed inverse relationship with water temperature. Mishra and Tripati (2001) and Dev and Mishra (1978) found an inverse relationship between DO and water temperature Michael (1964), Bohra et. al. (1978) and Saxena and Bhaskaran (1981) observed a direct relationship between the two. Seasonally during October - February rise in DO is related to low temperature and which the demand for oxygen decreases and the ability of water to hold oxygen increased (Macan, 1963; Goldman and Horn, 1983; Verma and Shukla, 1967; Singhal et. al. 1986). The dissolved oxygen indicates low values at Kham river, Khultabad pond and Sukhna dam which may be due to sever domestic and municipal waste released into the water bodies. The lowering Do as a result of pollution is one of the key factors in the distribution of biota (Jampani, 1985).

Water is said to be alkaline when the concentration of the hydroxyl ions exceeds that of hydrogen ions. Chemically pure water is neutral having equal amount of hydrogen and hydroxyl ions. Alkalinity is the acid neutralizing capacity of water which depends on the strength of carbonates in a sample and it determines the availability of free carbon-dioxide which is essential for photosynthesis and thus is directly related to productivity. In general, alkaline water increases productivity and supports the diversity of aquatic life. The carbonate values were in uniform range in both the years reported by Oomachan and Belsare (1986), Ghosh and Geron (1989) and Malapath (1999). Das (1978) stated that high alkalinity indicates pollution. The alkalinity is harmful for irrigation which leads to the soil damage and crop yield and imparts bitter taste to the water. The pH, free carbon dioxide and alkalinity in water body are interrelated. In the present observation, the alkalinity was high in summer at Godavari river, Pravara river, Kham river, Tisgaon lake, Nandradab pond, Tembapuri dam, Sukhna dam and Yesgaon dam which indicated the pollution of river by sewage (Upadhyay and Rana, 1991) and Chakrabarty et. al. (1959). Adebisi (1981) showed that alkalinity value was inversely related to the water level. Kaushik et. al. (1990) observed that the pond water was found to be less polluted comparatively.
due to dilution of water, in winter it was moderately polluted while in summer it was grossly polluted. However, when total alkalinity was high and varied from 220 to 360 mg/l, such high alkalinity indicated pollution (Das, 1978; Patil et al, 1983). The alkalinity was low in monsoon at Pravara river, Girija river, Khelna river, Mahismai lake, Nandrabad pond, Daultabad pond, Sukhna dam and Yesgaon dam may be due to dilution with rain water. The total alkalinity values showed to be higher in summer and low in monsoon periods, which supported by Saha and Pandit (1986), Auti (2002), Sultana and Sharif (2004). Decrease in alkalinity during rainy months was obliviously due to dilution (Mishra and Yadav, 1989). Rupavathi and Radhakrishanan (1983) studied quarry pools and observed a decreased alkalinity during rainy season. However, such typical seasonal change was not recorded in total alkalinity (Pejavar, et al, 2004). The alkalinity showed higher values during monsoon at Sukhna river, Salim Ali lake, Harsul lake, Gautala lake, Kagzipura lake and Andhari dam while it was minimum in winter at Godavari river, Kham river, Tisgaon lake, Kagzipura lake and Tembhapuri dam. The amount of bicarbonate was more during rainy season than winter and summer, because of the inflow of mineral salts along with water by rivers. These findings are in accordance with Choudhary et al(1979), Malathi (1999), Auti (2002) and Pejavar et al. (2004). The variation of alkalinity might be due dissolved salts, dilution of surface water due to rain and change in rate of decomposition of waste material (Hedge and Bharti, 1985). Alkalinity ranged from 60 mg/l to 180 mg/l. low in summer and monsoon and high in post monsoon and winter (Pawar and Mane, 2006). The alkalinity showed higher values during summer and lower values during winter season reported by Sakher and Joshi (2003). Wetzel (2001) reported that during the photosynthesis, carbon dioxide and calcium carbonate is precipitated by algae and macrophytes. Alkalinity and hardness are closely related to each other. With high alkalinity, hardness and chlorides are found to be more productive and support rich flora and fauna in summer. Moyle (1946) reported similar phenomena. The water was alkaline with pH between 8.5 to 9.5, which do not supported the growth of aquatic ecosystem (Robert and
Williams 1940; Das, 1978). However present study revealed that the alkalinity was high in winter at Girija river, Khelna reiver, Mahismal lake, Daulatabad pond, Khultabad pond, Jaikwadi dam and Ambadi dam. On the otherhand, it was low in summer at Sukhna river, Salim Ali lake, Harsul lake, Gautala lake, Khultabad pond, Andhari dam, Jaikwadi dam and Ambadi dam. The alkalinity of water which is high may be due to the carbonates and bicarbonates (Nayak et. al., 1982). This observation was further supported by Brion Moss (1973), Wetzel (1983) and Auti (2002). The maximum alkalinity of pond water may be due to the accumulation of carbonate salts form the surrounding and removal of carbon dioxide due to excessive photosynthesis (Patwari, 2002). The increase in total alkalinity during winter is due to high concentration of nutrients in water, and decreased during monsoon due to dilution with rain water (Goel et. al., 1980). Ghosh and George (1989) observed that in an ecosystem with pH range of 7.0 to 9.0, alkalinity concentration remain high. The reflected high alkalinity in winter and sharp declined in monsoon (Pahwa and Mehrotra, 1966; Auti, 2002). The alkalinity was ranged 172.53 to 3.7 mg/l. at all the sampling stations. The alkalinity was higher at Pravara river and it was lower at Gautala lake. Highly productive water body has alkalinity over 100 mg/l.(Jhingran, 1982). Moyle (1946) and Srinivasan (1964) have suggested that a water body with alkalinity values > 40mg/l. is nutritionally rich. Bazmi and Ahmed (2006) observed that the alkalinity values ranged between 90–120mg/l. the values were slightly higher in summer may be due to increased rate of organic decomposition, during which CO₂ is liberated, which reacts with water to from HCO₃ thereby increasing the total alkalinity in summer of Rajokhar wetland.

Carbon dioxide is dissolved in water from atmospheric air, percolation from soil, respiratory activity and the process of decomposition. Free carbon dioxide is used for photosynthetic activity. In an aquatic ecosystem, sources of carbon dioxide are community respiration and decomposition while it is consumed in the photosynthesis depending on the pH and other biological conditions. Carbon dioxide is found any one of the three forms, free carbon...
dioxide, carbonic acid and bicarbonates. Carbon dioxide plays an important role in organisms and plants. Carbon is essential in the photosynthesis, plants absorbs carbon and synthesize into their food and release oxygen, which is essential for all animal kingdom. Generally, in all natural waters carbon dioxide is a common factor, its concentration differs on the basis of pH, temperature and other environmental parameters. Dhanapakiam et. al. (1999) showed the high carbon dioxide in the river Cauvery which was due to decomposition of organic matter within the water. On the basis of data collected from the study carried out, it is observed that the increased level of CO₂ was recorded during summer at sampling stations Sukhna river, Harsul lake, Gautala lake, Kagzipura lake and Khultabad pond while it was decreased during monsoon at Girija river, Sukhna river, Salim Ali lake, Harsul lake, Khultabad pond and Yesgaon dam. Increase in concentration of pollutants in water due to less flow of water in summer is responsible for maximum values of CO₂. In addition to this, the increased microbial activities resulted into the formation of CO₂. Increase in turbidity of water due to incoming pollutants is like industrial effluents and domestic wastes are responsible to lower the photosynthetic activities in water, which intern lower the assimilation of CO₂ by phytoplanktons. These findings were observed with those of Sawane et. al. (2006) in Irai river at Chandrapur and Haniffa et. al. (1993) in Tabarparsi river at Tirunelveli. Free CO₂ was recorded at Salim Ali lake throughout the study period, the high CO₂ value was observed in monsoon (11.5mg/l.) followed by winter (11mg/l.) and summer (9mg/l.) observed by Auti (2002). Shrivastava (1990) detected higher values of CO₂ during summer. The Free CO₂ was totally absent at Godavari river, Khelna river, Kham river, Tisgaon lake, Nandrabad pond, Andhari dam, Jaikwadi dam and Tembhapuri dam while it was minimum in winter at Gautala lake and Kagzipura lake. The absence of Free CO₂ can be due to its complete utilization in photosynthetic activity (Shreenivas, 1965, Malathi, 1999) or it was being invited by presence of appreciable amount of carbonates in water (Brion Mass, 1973). Free CO₂ was observed to nil, almost 50% samples of lake indicating its enhanced uptake by phytoplankton (Pejavar et. al., 2004).
Free CO₂ values ranged between 1.76 to 4.84mg/l. maximum was observed in month of May and minimum in the month of December reported by Lendhe & Yeragi (2004). Shastri et al. (1999) observed that the free carbon dioxide was absent from January to June, however, from July it was recorded and reached at highest value in November. Organically enriched water showed free carbon dioxide in morning sample accumulated due to community respiration. Water is generally carbon dioxide free during day time due to accelerated photosynthesis (Sahu et al. 1995). The higher concentration of CO₂ in winter season at Girija river, Salim Ali lake, Daultabad pond, Sukhna dam and Yesgaon dam. Free CO₂ was high in winter due to higher organic load which may be due to incorporation of fertilizers, organic manures, industrial effluents and domestic wastes which are responsible to lower the photosynthetic activities in water body. Similar observations were reported by Tamulkar and Ambore (2006) in Alisagar dam water. The high carbon dioxide level indicated the higher organic load due to organic manure and fertilizers incorporated into the pond (Pandey and Tripathi, 1988). The comparatively lower values of CO₂ during summer at Daultabad pond, Ambadi dam and Sukhana dam might be due to no significant source of pollution. Similar observations were noted by Sawane et al. (2006) and Chakrabarthy et al. (1959). Kulkarni et al. (1995) recorded high carbon dioxide in winter followed by monsoon and summer due to process of decomposition. Free carbon dioxide was generally low except during winter reported by Shina (1988). In the present study, it is found that there was an inverse relationship between Free CO₂ and dissolved oxygen at Mahismal lake and Ambadi dam. Khatavakar et al. (2004) found inverse relationship between dissolved oxygen and CO₂ during the study. The results were supported by a number of workers like Deshmukh (1964), Prakash (1982) and Lohar and Patel (1998). Several authors have showed direct relationship of free CO₂ with temperature and pH, while on inverse correlation with oxygen (Vyas, 1968; Selot, 1977; Salodia, 1996; Sahu et al., 1995; Shastri et al., 1999).
Chloride as chloride anions (Cl\(^-\)) are major anions in water and wastewater. The chloride concentration is higher in organic waste and its higher level in natural water is definite indication of pollution from domestic sewage. The ecological significance of chloride lies in its potential to regulate salinity of water and exert consequent osmotic stress on biotic communities. The increase in chloride concentration in lake with the discharge of municipal, industrial waste was also reported by Kant and Raina (1990). A number of stagnant water bodies polluted by domestic sewage and industrial effluents studied by Goel et al. (1980), Chandraashekhar and Kodarkar (1994), Kodarkar and Chandrasekhar (1995), Senthil et al. (2001), Lendhe and Yeragi (2004), Thirumala et al. (2006). In the present study, the higher values of chloride were encountered in summer at Pravara river, Sukhna river, Mahismal lake, Kajzipura lake. Generally sewage contributes to the salinity of water in urban wetlands and chloride was higher in summer due to the evaporation water losses. Similar observations were reported by Malathi (1999), Patwari (2002), Auti (2002) and Zadpide (2002). Highest values observed in summer period may be due to low level of water, richness of organic pollution, human and animal activities. Presence of chlorides above the usual background concentration in water source is also used as an indicator of pollution by domestic sewage (NEERI, 1979). Further lower values of chloride were encountered in monsoon at Pravara river, Khelna river, Sukhna river, Mahismal lake, Harsul lake, and Nandrabad pond which can be attributed to dilution effect from renewal of water mass from summer stagnation in monsoon. The rise of chloride in summer was obtained due to rise in temperature and evapotranspiration occurs, this could be explained by the fact that the presence of chloride salts may interfere with other nutrients, which are being utilized in the process of photosynthesis while in monsoon the chlorides were recorded minimum because of heavy rain, dilution of chloride occurs (Anitha, 2002). The higher range observed in summer season denote the effect of higher temperature and rapid reduction of water mass (Patil, 1993; Malathi, 1999; Pejavar, 2004). Goel et al. (1980) showed that the concentration of chloride increases with the degree of
eutrophication. The presence of chloride indicates the availability of organic matter, presumably of animal origin and increase the amount of ammonical nitrogen and organic matter. The sources of chlorides are the solvent power of water which dissolves chloride from the soil. A water body, having high chloride concentration, affects the metallic pipes and agricultural plants (Pulle and Khan, 2001). The maximum concentration was recorded in summer due to the evaporation of water and winter available water of post monsoon observed high chloride (Singh, 1985). The chloride content was high during monsoon at Girja river, Gautala lake, Andhari dam, Jaikwadi dam and Yesgaon dam which indicated organic pollution from domestic sewage. Similar observation reported by Patil (1993), Chandrashekhar and Kodarkar, (1994). High chloride content of the water (120 to 98mg/l.) indicates organic pollution of animal origin which confirms the findings with Thresh et. al. (1994). Besides the high chloride content indicates high organic pollution (Todd, 1970; Cole, 1975; Patil, 1983). High chlorides indicated pollution particularly from domestic sewage (Haniffa, 1994). Lohar and Patel (1998) studied the chloride range between 90 to 312 mg/l. and 89 to 269 mg/l. at Tapi and Aner river. Singh (1988) pointed out that chloride value varied from 3.2 ppm in January to 48.5ppm in September in north tank and between 24.6ppm in November to 56.3ppm in October in south tank. Both tanks showed higher chloride values during monsoon. In winter, again low range of chloride recorded at Kagzipura lake and Yesgaon dam which may be due to the high sedimentation rate in relatively stable environmental conditions. Similar observations were reported by Auti (2002) and Patwari (2002). The chloride values fluctuated between 190–365mg/l. showed positive correlation with total hardness. These values also showed positive correlation with phytoplankton (Verma and Shukla, 1970). The present study, however revealed that the chloride content was high in winter at Godavari river, Khelna river, Kham river, Salim Ali lake, Tisgaon lake, Harsul lake, Nandrabad pond, Daultabad pond, Khultabad pond and Ambadi dam which may be due to anthropogenic activities in addition with the progression of atrophy and edging of the water body. Similar findings were
observed by Patwari (2002), Anitha (2002) and Zadpide (2002). The rising concentration depends upon dumping of effluents of municipal as well as industrial sources and human activities. Similar observations were reported by Mohan (1980) and Kulkarni (1995). Sinha (1986) reported high concentrations of chlorides are the indicators of large amount of organic matter in the water due to eutrophication. The chloride content of water was minimum during summer at Godavari river, Girija river, Kham river, Salim Ali lake, Tisgaon lake, Gautala lake, Daultabad pond, Khultabad pond Andhari dam, Jaikwadi dam and Ambadi dam. Lower values were encountered in summer, which can be attributed to absence of sewage load. It is noteworthy that in absence of any sewage or organic load, the chloride range is comparable with other urban lakes of Thane (Pejavar et al., 2002). Pawar and Mane (2006) observed chloride low in summer and monsoon and higher in post monsoon and winter. Chloride values were comparatively low which might be due to the absence of pollution from animal or human origin and also likely to be due to continuous availability of water in lake. Puckridge, et al. (2000) found a rise of chloride due to increase in temperature. Chloride is present in soil in minimum amount but if the quantity is increased then it is due to septic tank effluents, animal waste etc. The quantity of chloride is within the limit that is 14 – 44mg/l. and 19 – 22mg/l. in river respectively (Pahwa and Mehrotra, 1966). (Verma and Dalela (1975) pointed out that presence of high amount of chloride influences the amount of dissolved oxygen, which may adversely affect the number of aquatic organisms. It has been noted that the chloride concentration was high at Sukhna dam and Tembhapuri dam. The high amount of chloride are found in inland saline lakes, indicates pollution from domestic and municipal sewage and industrial effluents. Though chloride level as high as 250mg/l. is safe for human consumption, a level above this imparts a salty taste to the potable water. Other number of workers have estimated chloride in lake water polluted by domestic sewage (Halser, 1947; Zafar, 1974; Khan et al., 1985; Mohan, 1980; Ambasht , 1981; Barica, 1981; Jaya devi , 1985; Kodarkar et al., 1991; Chandrashekhar and Kodarkar, 1994; Swaranlatha, 1994).
Hardness often employed as an indicator of water quality depends on the concentration of carbonate and bicarbonate salts of calcium and magnesium or sulphate, chloride or other anions of mineral acid. Hardness is due to concentration of alkaline earth metals. Ca and Mg ions are the principal cations imparting hardness, it prevents lather forming. Ca$^{++}$ and Mg$^{++}$ are the most abundant elements in natural surface and ground water and exists mainly as carbonates, bicarbonates and carbon dioxide constituted major source of inorganic carbon to producers in an aquatic ecosystem. They also act as buffers regulating the pH of the medium. The bicarbonate alkalinity is considered more important which influences the density of bottom fauna (Needham and Usinger, 1956). Nirmal (1989) observed a positive relation between total hardness and alkalinity and anions. The ecological significance of major cations i.e. calcium and magnesium in the biotic dynamics of aquatic fauna and flora is well-established fact. Hardly a group of fresh water animal exists in which the distribution of some species has not been related to calcium concentration in the environment (Macan, 1961). In the present study, it is found that the higher amount of hardness during summer at all lotic water bodies except in Sukhna river, it was high in monsoon and low in summer. The variation of this parameter is likely due to both temperature influences as well as trophic status of the water body during summer season and additional effect of human activities. These findings were supported by Patwari (2002) and Auti (2002). Mehti et al. (2004) reported maximum hardness during post monsoon and minimum during monsoon may be due to sewage and low water level. Similar results were observed by Khoshy and Nayar (1999). Mishra and Tripathi (2001) reported high value of hardness, 295mg/l. in Ganga river. Higher values of hardness can be attributed low water level and high rate of evaporation (Mussaddiq and Fokmure, 2002). Similar observation was recorded by Ajmal and Raziuddin (1985) in Kalinandi, India. Mohanta and Patra (2000) stated that addition of sewage, detergents and large scale human use might be the cause of elevation of hardness. Muley and Patil (2006) observed that the relatively higher values of hardness was
recorded in February and lower July. Total hardness of Kharbhav lake ranged between 260 mg/l. to 870 mg/l. Maximum in the month of April and minimum in the month of November. It was very high may be due to presence of carbonates and bicarbonates (Lendhe and Yeragi, 2004). The low hardness levels generally indicated dilution effect of rain water in monsoon at Godavari river, Khelna river, Girija river, Kham river, Mahismal lake, Salim Ali lake, Tisgaon lake, Harsul lake, Guatala lake, Kagzipura lake, Daulatabad pond, Khultabad pond, Andhari dam, Sukhna dam. Izonfuo et. al. (2001) observed that the lower values of these parameters suggested that the runoff water only contributes to dilution of the parameters in the rainy season. The values of total hardness was 48.75mg/l. during summer, 37.75mg/l. in winter and 34.5mg/l. during rainy season observed by Hiware and Jadhav (2001). The range in both the lakes was high as compared to range of 8mg/l. to 76mg/l. observed at Quarry pools in Guntur (Rupavathi and Radhakrishnan, 1983). Magnesium is essential for flora for chlorophyll biosynthesis and enzymatic transformations, particularly the phosphorylation, in algae, fungi and bacteria (Wetzel, 1975). Maximum hardness was observed in monsoon at Sukhna river. On the otherhand, it was minimum in winter at Pravara river, Nandrabad pond and Jaikwadi dam. Decrease of toxicity with increased in hardness may caused the reaction of these cations with bicarbonates. The relations between carbonates, bicarbonates and carbon dioxide have been reported in the polluted zones by number of workers (Nirmal kumari, 1989; Adwant, 1981). Sawyer and McCarty (1966) suggested that classified water in to four classes on the basis of hardness; soft with hardness of 75 mg/lit, moderately hard with hardness ranging between 75 to 150 mg/lit, hard with 150 to 300 mg/lit. Hardness in different zones of Kukatpally nala increased in down streams (Reddy, 1991). The total hardness was maximum in winter at Salim Ali lake, Tisgaon lake, Andhari dam, Ambadi dam, Tembhapuri dam and Yesgaon dam while it was minimum in summer at Sukhna river, Ambadi dam, Tembhapuri dam and Yesgaon dam. It might be due to enrichment of carbonate and bicarbonates. Similar observations were reported by several researchers (Wetzel, 1975;
Patil, 1993; Narashimha Rao and Jaya, 2001; Lendhe and Yeragi, 2004). Total hardness is due to concentration of calcium and magnesium ions expressed in terms of calcium carbonates (Senthil Kumar et al., 2001). It is evident that hardness of the water is mainly due to calcium ions. Hardness showed a negative relationship (not-significant) with pH (Bahura, 2001). Senger et al. (1985) observed that the total hardness of water varied from 221.0 to 828.0 mg/l in up stream and 230.0 to 919.0 mg/l in down stream. Nirmal Kumari (1989) observed a positive relation between total hardness and alkalinity and anions, same result has been observed by Shreenivas (1965). Maximum hardness was noted down in summer in lentic water bodies at Mahismal lake, Harsul lake, Gautala lake, Kagzipura lake, Nandrabad pond, Daulatabad pond, Khultabad pond, Jaiwadi dam and Sukhna dam which may be due to discharge of sewage and lowering of water column and minimum during monsoon because of dilution of sewage and proper sink for human activities. Chandrashekhara et al. (1997) reported range of total hardness between 380 – 824mg andl. in Saroornagar lake. According to Datta, et al. (1985) 15mg/l. or more of total hardness is congenial for fishery growth while fish mortality occurred at 5mg/l. 15-250mg/l. of total hardness facilitates good production. Zafar (1966) pointed that pH of water is dependant upon the relative quantities of calcium, carbonates and bicarbonates. According to Reid (1966) the pH values between 7 to 9, bicarbonates are of great significant. It is well known that the increasing hardness decreases the toxicity of cations of aquatic fauna as well. Available data indicates that toxicity is linear function of hardness. In majority of natural water, the most abundant ion is bicarbonate (Child’s, 1971).

Biological oxygen demand is used to infer the general quality of the water and its degree of pollution by biodegradable organic matter. BOD is an important parameters that indicates the magnitude of water pollution by oxidizable organic matter. The main sources of organic pollution include untreated domestic sewage, agricultural runoff, containing residual fertilizers and certain industrial effluents. The components of oxidizable matter include
carbonaceous organic matter, nitrogenous compounds and chemically reducing compounds. In natural course the organic matter on oxidation enters into biogeochemical cycles. However, when an aquatic ecosystem receives excessive organic pollution load due to low availability of dissolved oxygen, net biological oxygen demand generates. BOD thus can be defined as the quantity of dissolved oxygen in mg/lit required under test condition (aerobic bacteria) for the organic matter for test sample (Patil, 1993). In present study, the BOD was quite high in summer at Sukhna river, Jaikwadi dam and Ambadi dam while it was minimum in monsoon at Pravara river, Girija river, Tisgaon lake, Gautala lake Kagzipura lake, Andhari dam, Jaikwadi dam and Ambadi dam. BOD was quite high in summer though the impact of pollution was found to be localized, yet it creates the stress on environment for biotic communities. The lower BOD values which is been slashed down in monsoon indicating the retaining capacity of lake water to recover from pollutational stress of organic substances. Similar observations were reported by Patwari (2002) and Zadpile (2002). A high value of BOD in summer was also reported by Kulkarni et al. (1995) in Sadatpur reservoir. According to Sharma and Agrawal (1999) the high values of BOD in the summer season may be due to the high pollution load and reduced water flow, while lower values in monsoon and winter may be due to dilution of water. Ragunathan et al. (2000) stated that the BOD values indicates organic enrichment and showed decay of plant and animal matter in the river and lake must be contributing to recorded values. BOD affects the benthic diversity observed by Bilgrami and Siddiqui (1983). Dhanpakiam et al (1999) showed the highest BOD during the summer months which may be attributed to the maximum biological activity at elevated temperature. BOD gives an idea of the quantity of biodegradable organic substances to aerobic in water which is subjected to aerobic decomposition of microorganisms. It provides a direct measurement of state of pollution (Prashanthti and Jeevanrao, 1999). Voznaya (1981) found that the high population of microorganisms in Russian reservoirs during the month of May and July. The BOD was high in monsoon at Godavari river, Khelna river, Mahismal lake,
Salim Ali lake, Nandrabad pond, Daultabad pond, Khultabad pond, and Sukhna dam may be due to high pollution load and receiving of waste water discharges directly from municipal and industrial area. Lower values of BOD in winter at Khelna river, Sukhna river and Mahismal lake which indicated that the water body have got the self purification capacity to dilute the organic load because of sufficient oxygen content and do not receive directly the waste water discharges from municipal and industrial sources. Similar observation were reported by Patil (1993) and Auti (2002). Shinde et al. (1997) observed high dissolved oxygen and low BOD values at all the stations indicated well aerated nature of water with low organic pollution load. BOD represents the quantity of oxygen required by bacteria and other microorganism during biochemical degradation. BOD ranged from 2.2 - 8.0mg/l and 1.0 -3.6mg/l. in Kali river respectively (Singh et al., 1998). BOD more than 35mg/l. are not considered good quality for fish culture reported by Pande and Sharma (1999). There was a sharp decline in BOD in December at several water bodies which may be due to low temperature, which slows down the microbial activity (Bhatt, 1999). BOD values were high in winter at Pravara river, Girija river, Kham river, Tisgaon lake, Harsul lake, Gautala lake, Kagzipura lake, Khultabad pond, Andhari dam, Tembhapuri dam and Yesgaon dam while it were low in summer at Godavari river, Kham river, Salim Ali lake, Harsul lake, Nandrabad pond, Daultabad pond, Khultabad pond, Tembhapuri dam, Sukhna dam and Yesgaon dam. The peak values of BOD were due to high concentration of dissolved and suspended solids in water (Jameel, 1998). BOD is an important parameter that indicates the water pollution by oxidizable organic matter and the oxygen used to oxidize inorganic material such as sulphides and ferrous ions. Low value of BOD comparatively in winter season may be due to lesser quantity of total solids, dissolved solids, suspended solids in water as well as to the quantitative number of microbial population (Anitha, 2002). Ekundayo (1977) and Imevbore (1983) reported that the contamination of water with faces increases the BOD because it contains mainly organic matter making oxygen less available to desirable organisms. Rao and Jain (1985) and
Abbasi et al. (1996) noticed an inverse correlation between BOD and DO in the polluted ponds and streams. High BOD values during summer induce the high growth of bacteria (Pyatkin and Krivoshein, 1980). It has been observed that the BOD increased than DO at Kham river and Tembhapuri dam which may be due to enrichment of organic load and the city sewage introduced into river from local areas. Muley and Patil (2006) observed that the increasing trend of BOD and decreasing trend of DO towards downstream, clearly indicated increasing load of pollution towards downstream of river.

Primary productivity is the rate at which sun's radiant energy is stored by photosynthetic activities of producer's organisms in the form of organic substance which can be used as food material. It forms the basis of whole metabolic cycle in natural aquatic system. The gross primary productivity in an ecosystem is a rate of transformation of radiant energy into chemical energy or the organic matter used up during the process of respiration. The net productivity is determined by the rate of community respiration (Pulle and Khan, 2001). Sumitra (1971) studied seasonal variation in primary productivity in the tropical ponds. She established a direct correlation between productivity and alkalinity values. Hussainy (1967) worked on limnology, primary production of tropical lakes near Nagpur, found fluctuation in chlorophyll, pH and dissolved oxygen and were interrelated. Nair (1975) reported very little variation in the primary production in lake water in a single year. Takahashi (1970) carried out studies in the filed of primary productivity of coastal Meromictic Lake in Hukkaido. Marine primary production contributes to 10-50 % of global photosynthetic production. Carbon fixation by phytoplankton helps to maintain steady state of atmospheric CO$_2$. Changes in ocean circulation results in increased primary productivity in low nutrient open ocean waters. Magnitude of marine primary productivity ranges from 20-55 Gt. of carbon/ year (Val Smith et. al, 1983; Platt, 1988). Ocean primary productivity, defined as the sum of all photosynthetic rates within an ecosystem or the rate of carbon fixation as a direct result of photosynthesis in mg C/m$^2$/day, plays an essential role in the global carbon cycle. Marine photosynthetic organisms, composed almost entirely of single-celled
phytoplankton, comprises less than 1% of the total global plant biomass but at the same time accounts for 40% of the total global carbon fixation (Falkowski et al., 1998). Connel (1963) observed that the primary productivity and fish harvest in small desert impoundments discussed on the relation between the total fish harvest and gross photosynthesis. Later Gilmartin (1964) reported that 90% of the year’s primary production was attributed by the nanoplankton in his study in British Coumbian Fjord. Fortes (1973) studied on chlorophyll in pond waters, observed a direct relationship between the concentration of chlorophyll and primary productivity.

Several workers carried out exhaustive studies on primary productivity in freshwater bodies Srinivasan (1963, 1970), Datta et al. (1984), Qasim (1969), Nair (1975), Rajyalakshami and Premswarup (1975), Ganpati and Pathak (1978), Khan and Zutshi (1979), Jhingran and Pathak (1988), Pulle and Khan (2001), Salaskar and Yeragi (2004). Val Smith (2007) stated that the eutrophication is a serious environmental and economic problem in aquatic ecosystems worldwide. It has recently been recommended that measurements of primary productivity, being a sensitive and accurate indicator of eutrophication, should be mandatory when monitoring and assessing the ecological status of waters. The units of primary productivity chosen for eutrophication assessment will be very important because not all measures of primary productivity vary monotonically (or even straightforwardly) with changes in aquatic fertility. Volumetric expressions of primary productivity (rates of carbon fixation per unit volume of water) may proved to be the most sensitive and most reliable measures to use when evaluating the eutrophication status of aquatic ecosystems.

In the present study, it is found that the gross and net primary productivity was higher in summer and lower in monsoon from maximum lotic and lentic water bodies. The high rate of productivity during summer was probably due to increase in temperature and high transparency rate. Such parameters speed up the photosynthetic activity and phytoplankton. Similar observations have been made by Pulle and Khan (2001) in Isapur dam, Arvind Kumar (1996) for the two fresh water bodies in Santal, India and
Shreenivas (1966) in three tropical ponds. Khan and Siddiqui (1971) noted high gross primary productivity from March to May in pond Moat. Kannan and Job (1980) observed high primary production in April- July in Sathiar reservoir of Powai lake. Temperature plays an important role in regulating the primary productivity in freshwater bodies. Vijayaraghvan (1971) and Datta et al. (1984) have reported significantly a positive relationship between temperature and primary production. The primary productivity values were low during monsoon period may attributed to the poor light conditions due to the cloudy sky and also due to the rain water. Similar observation reported by Pulle and Khan (2001). Hutchinson (1975c), considered transparency as an index of primary productivity. According to Sankaranarayanan and Reddy (1968a) during monsoon, the nutrients are brought up to the surface water layer. Increased vertical stability of the water particularly in the post monsoon periods keeps the nutrient levels low in correlation of periphyton production with biomass standing crop, hydrographic parameters and nutrients had no consistent correlation between primary production values and hydrographic parameters. Increase in plant biomass over period plus losses during that time were the primary production. It has been used as potential index of productivity for many ecosystems of the world (Wetzel, 2001). Prasad and Nair (1963) reported very little variation in the primary production in tropical waters in a single year. Vijayaraghavan (1971) found the maximum values of the primary production 10 times greater than the minimum values in Othakadi pond, 4 times in Teppakulum tank and about 5 times in Yannamalai pond.

In the present study, it is found that the primary production was high during monsoon at Kham river, Mahismal lake, Harsul lake, Khultabad pond and Sukhna dam may be due to dilution effect of water. The high water flow, many resources that are open to water bodies and high transparency, less turbidity and good water column because of there exists good quality. The productivity of any aquatic environments depends on many hydrobiological features. The important factor is the availability of inorganic nutrient content for the phytoplankton, which in turn, determines the level of animal
population (Reddy and Reddy, 2004). Shreekumar (1997) reported the highest value of 296.6mg/c/m³/hr in September whereas the lowest 29.75mg/c/m³/hr. was reported during July. The rate of production was highest during monsoon and lowest in post monsoon. Gillmartin (1964) stated that a smaller population under favourable conditions might have a high rate primary production, whereas a large population under favourable conditions may have low rate of primary production. The trend of variation in primary production shows that, the production was high in monsoon and did not find any direct relationship between the other parameters and primary production. The trends of gross production indicated peak of phytoplankton abundance coinciding with monsoon as observed by Srinavasan (1970). Subbamma (1993) stressed that the floral and faunal population was high in summer and should be attributed to prolonged day length and high intensity of light. Low primary production coincided with high water level, increased turbidity as observed by Srinivasan (1964) in an identical situation. Goldman and Roger (1980) observed that the temperature clearly played an important role in influencing the outcome of competition among phytoplankton species in enriched cultures. Bohra and Bhargav (1977) found the high annual average primary production of 26.169 mg/c/m³/day in Padam Sagar and 24.3 mg/c/m³/day in Rani Sagar lake near Jodhpur. The gross primary production of Mitbhav estuary was higher than those of the other estuaries of Konkan (Patwardhan, 1990). Nair (1975) reported that the average primary production rate of 1.2g/c/m³/day. The gross primary productivity was low during winter at Khelna river, Kham river, Harsul lake, Kagzipura lake, Daulatabad pond, Jaikwadi dam and Yesgaon dam while net primary productivity was low during winter at Pravara river, Girija river, Sukhna river, Kham river, Mahismal lake, Kagzipura lake and Jaikwadi dam may be due to significant changes in environmental factors such as transparency, reduced light penetration, low ambient nutrients and phytoplankton density. Primary factors affecting primary productivity in the Whidbey Central Basin at Washington are sunlight, stratification, and residence time. Runoff is lowest in late summer and peaks in the winter and
spring (Strickland, 1969). Increased sunlight caused by long days, clear skies, and a high sun rays coincides with stratification at the surface, making May to July the peak growing season in the Central Basin (Radhakrishna et al., 1978). Pant (1992) showed that gross primary production varied inversely with tidal height. Retting of coconut husk is one of the major problems of pollution in the estuaries (Kayals) of Kerala. It discussed the salient features associated with the variation in gross and net primary productivity values in the Kadinamkulam Kayal based on fortnightly data from two selected stations. The gross primary productivity value in the surface water ranged from 0.06 to 0.29 gm/C/m³/day at station- I and from 0.06 to 1.49 gm/C/m³/day at station- II (Azis, 1994). Joshi et al. (1995) found the productivity values were increased from late winter, reach it peak in summer and declined there after. The values were directly proportional to transparency, temperature, sunshine and phytoplankton density. Population of phytoplankton and the quantity of respiration were increased, whereas gross primary production and net primary production were decreased towards Kanpur (downstream) from Haridwar (upstream). The water quality was degraded towards the downstream due to increase of oxygen demand in pollutants or photosynthesis inhibitory pollutants in the river water from Garmukteswar to Kanpur (Sahu et al., 1995). Attempt to measure the primary productivity in terms of phytoplankton standing crop have been made by Edmondson and Edmondson (1946), Wrieght (1959), Prasad and Nair (1963) and Weber (1963). They observed a positive relation between phytoplankton population and productivity. However Sumitra (1971) reported that there is no strict correlation between chlorophyll content and productivity values.

In the present study, it is observed that the gross primary productivity was high in winter at Tisgaon lake, Gautala lake and Khultabad pond while net primary productivity was high in winter at Salim Ali lake, Tisgaon lake, Gautala lake, Daultabad pond, Andhari dam and Yesgaon dam may be due to different ecosystems, have different physico-chemical and biotic environment. The variations in the amount of productivity greatly differ from
lake to lake within the same lake, depending on changing environmental conditions (Salaskar and Yeragi, 2004). The gross primary production of Achara creek was not uniform throughout the year but varied from month to month and place to place (Yeragi and Yeragi, 2003). Saran and Adoni (1985) observed high values during late winter. Marry Ester (1983) found that the gross production varied between 1.36gm/c/m$^3$/day and 7.46gm/c/m$^3$/day in Banjara while in Nadimi they fell in the range of 0.76gm/c/m$^3$/day and 10.58gm/c/m$^3$/day. She found the average primary production of 5.22gm/c/m$^3$/day in Banjara and 4.32gm/c/m$^3$/day in Nadimi. The photosynthesis that forms the basis of ecosystem functioning since it makes the chemical energy and organic matter available to the entire biological community. The chlorophyll bearing organisms utilize solar energy and convert it into chemical energy in the form of carbohydrate molecules by taking carbon dioxide and water from the environment (Mishra and Saksena, 1992). In comparison to work done on the productivity of stagnant waters very little information is available on free flowing waters (Rajyalakshmi and Premswarup 1975, Ramarao et al. 1979, Anand 1982, Saha et al. 1985, Jhingran and Pathak 1988, Shukla et al. 1989). Factors such as water level, meteorological factors like light intensity, photoperiod, rainfall, wind velocity, etc., and hydrological cycle (inflow and outflow) have great influence on the rate of primary production in estuarine and flowing waters (Gupta 1982, Verma and Datta Munshi, 1989). It has been observed that the gross primary productivity found low were during summer at Mahismal lake, Kagzipura lake and Jaikwadi dam while the net primary productivity low were during summer at Harsul lake, Khultabad pond and Sukhna dam, is because of the correlation between gross production and retention time by freshwater discharges. Similar findings were made by Anand (1982). Annual primary productivity over the photic zone was significantly lower than that of the Main Basin of Puget, primarily because of reduced light penetration caused by the silt load in the Kadinamkulam estuary (Azis, 1994). Ahmed et al. (2005) observed that the plankton density has decreased over time due to the problem of anthropogenic environmental distortion that is continuously
affecting the river Meghna. With rapid urbanization in the recent decade this river receives a huge quantum of industrial and domestic effluents of multiple natures. Such industrial pollutant load, metal toxicity and nutrient-gradient play a significant role on the nature of the ecosystem and stressing the biota therein as well. In the winter months, value of water flow reduces and proportionate concentration of pollutant becomes higher which affect the concentration of plankton in the ecosystem and the primary production as well. Subbamma (1993) found that the gross production values ranged from 385.50 to 1980.75 mg/c/m³/hrs and the net production values ranged from 62.00 mg/c/m³/hrs to 390.25 mg/c/m³/hrs. Ganapati and Pathak (1978) found that the gross production in Sayaji Sarovar, Baroda varied between 0.422 gm/c/m³/day and 7.46 gm/c/m³/day in 1963 and between 0.45 mg/c/m³/day and 1.57 mg/c/m³/day in 1964. The gross primary production at the surface of the Vellar estuary estimated by Venugopalan (1969) reported very high values of primary production 251.20 mg/c/m³/hr. in Mandavi and Zuari estuary values incorporated. Quasim (1979) observed that the based on oxygen technique primary productivity were 135 to 550 mg/c/m³/day and 150 -580 mg/c/m³/day. Hepher (1964) observed that the primary productivity directly correlates with solar radiation and same kind of direct relation was observed in the present study.

Aquatic ecosystems are under constant pressure of anthropogenic pollutants originating from various point and non-point sources as a result of rapid population growth, increased urbanization, increased industrial activities, extensions of irrigation and agricultural practices, exploration and exploitation of natural resources as well as the lack of environmental regulations. It is very rare for aquatic ecosystems to receive single pollutants such as, heavy metals. Heavy metals represent one of the most widespread and serious agents of environmental pollution (Pruski & Dixon, 2002). Low metal concentrations are present in natural aquatic ecosystems, but can be introduced by various anthropogenic activities and can be readily transported from one system to another (Elder & Collins, 1991; Biney et al., 1994; Hamilton & Hoffman, 2003). The release of pollutants into aquatic systems is
subjected to various factors, such as emission patterns and the physico-chemical properties of the environment, which will alter the distribution and concentration of pollutants (van der Oost et al., 2003). The most important difficulty in defining exposure in aquatic systems is that total metal concentrations in solution and sediments, are not the concentrations available to the organisms. Factors influencing metal bioavailability and toxicity to organisms include geo-chemical factors, anthropogenic and physico-chemical factors that make the spatial and temporal distribution of metals complex as well as the interactive effects of multiple pollutants (Luoma & Carter, 1991). Furthermore, various pollutants, such as metals, present in an aquatic environment will interact with and alter the bioavailability of each other and thereby, the biological effects on aquatic organisms (Cossu et al., 2000). Therefore, the relationship between increased environmental metal concentrations and biological responses can be negatively correlated (Martin et al., 1984; de Lafontaine et al., 2000). Metals are non-biodegradable, but can be altered into more toxic forms or complexed to more stable and less toxic compounds. Thus, metals can be readily bioaccumulated, which can lead to latent toxic responses in organisms (Elder & Collins, 1991). The occurrence of heavy metals in aquatic ecosystems in excess of natural background load has become a problem of increasing concern. Heavy metals in the water may accumulate to acutely toxic levels without visible signs. This may occur naturally from normal geological phenomenon such as ore formation, weathering of rocks and leaching or due to increased population, urbanization, industrial activities and agricultural resources. The aquatic environment is frequently the ultimate recipient of heavy metal pollution reported by Khan et al. (2006). Heavy metals are largely found in dispersed rock formations. Industrialization and urbanization have increased the anthropogenic contribution of heavy metal in the biosphere. Presence of high toxic metal ions in natural water is a subject of serious concern, when such water resources are used for drinking purposes by human and living organisms (Sultana and Sharief, 2005). Metal availability in aquatic organisms is
influenced by many external factors such as season, pH, hardness of water, concentration and composition of particulate matter (Phillips, 1977; Luoma & Bryan, 1979). It is very difficult to compare concentrations of heavy metals in sediment from the assessed locations because of the different character of the sediment. It is noticed that sediment in Ataturk Dam had high and very fine silt and organic matter content in it, while in the other two places the sediment comprised sand. In general, metal concentrations in sediment increased with the decrease of the particle size and increase of organic matter content (Karadede and Unlu, 2000). Zinc created a serious environmental problem in Norway in the 1990’s (Dons & Beck, 1993). Many zinc compounds are soluble in water and it is accumulated in organisms. It is an essential element to all organisms, and for humans a daily intake of 9 mg zinc is needed for normal body functions (Anonym, 1997). The human body can regulate uptake of zinc and overdoses can cause diarrhoea and vomiting. For organisms in water, high doses of zinc can be acute poisonous or give chronic effects (Dons & Beck, 1993). Blue mussels can regulate zinc uptake, and is not counted as a reliable indicator species for zinc contamination (Lobel et. al., 1982; Julshamn, 1981a). It has also revealed that Zn could be toxic to some aquatic organisms such as fish (Alabaster and Lloyd, 1982). Certain metals such as Cu and Co are classified as essential to life due to their involvement in certain physiological processes. Elevated levels of zinc have been found to be toxic (Spear, 1981).

In the present study, the zinc content was observed in water samples at different lotic and lentic water bodies. The zinc content was high in monsoon at Tisgaon lake, Nandrabad pond, Harsul lake as well as Jaikwadi dam. On the otherhand, at Godavari river and Jaikwadi dam it was high in winter. The zinc content was low in summer at Harsul lake, Nandrabad pond as well as Jaikwadi dam. On the otherhand, at Godavari river and Tisgaon lake it was low in monsoon and winter. The zinc content was high in monsoon and winter may be due to the natural and anthropogenic activities, agricultural runoff, domestic activities, wastewater discharges, effluent discharges and another non-point sources opened into water bodies. These
agreements were according to Dons & Beck (1993), Fernandes et al. (1994), Filipovic (2002), Shrivastava et al. (2003). The sources of zinc are metallurgic industry, pyrite mines, galvanic industry, incineration plants and anti corrosive products, paints, plastic and rubber, anthropogenic activity, wastewater discharges, effluent discharges and another non-point sources. (Nichols, 1991). Zinc, copper, chromium and other metals like Iron, and Manganese etc. are essential in human diet. They play significant roles in metabolic processes. Natural and anthropogenic activities result in gaseous emissions and wastewater discharges into air, water and land. When the substances in the emissions and effluent discharges in the environment are in very minute amounts or in low concentrations, are not toxic to plants and animals and have short residence time in the environment, they are described as "contaminants" (Odite, 1999). Metal like Zn, Cr, Fe, Mn, Mo, N, Cr and Co are called micronutrient and are toxic when taken in excess of requirement (Blaylock and Hung, 2000). The concentration of in Trace elements (Mn, Ni, Zn, Cr, Co, Pb, Cd, Fe, Hg etc.) in lake Skadar water has been (0.02-4.6 mg/l) determined (Filipovic, 2002). Barman and Lal (1994) observed that the zinc, copper, cadmium and lead contents in the soil much higher than background level. Water and sediments have been recognized as sources of heavy meals in aquatic system and have been shown to cause degradation in the quality of waters.

It has been noted that the zinc content were high in summer in sediment at Godavari river, Harsul lake, Nandrabad pond as well as Jaikwadi dam while at Tisgaon lake it was high in monsoon. The zinc content was low in summer at Tisgaon lake while at Jaikwadi dam it was low in monsoon. On the otherhand, at Godavari river, Harsul lake as well as in Nandrabad pond it was low in winter. Enrichment of zinc in the sediment might be the result of the input of domestic sewage (Facetti et al., 1998). Schiffer (1989) found that median zinc levels decreased from 75 mg/L at a storm water inlet to 20 mg/L at a distance of 30.5 m from the inlet. Therefore, the magnitude of the disturbance associated with transportation systems is partially dependent on the size (particularly the width with respect to the
roadway) of the water body. Obviously small, stagnant ponds and narrow, slow moving streams flowing parallel to major transportation routes were stressed more than swift river flowing under a highway bridge. The accumulation of metals in the sediment is mainly a result of biogenous and lithogenous formations (Forstner & Wittman, 1979). The precipitation of lead, copper, iron, chromium and zinc might be the result of alkaline pH in the form of insoluble hydroxides, oxides and carbonates. Metals such as chromium, copper and nickel have interacted with organic matter in the aqueous phase and settled, resulting in a high concentration of these metals in the sediment, such a situation also observed by Pande and Sharma (1999). Zinc and copper are used in fertilizers for deficiency of soils while Zn, Cu, and Cd are constituted of some fungicides. In addition, Cd and Zn occur as contaminants of phosphoric fertilizers (Langard and Norseth, 1979). Copper, Zn and Co from the essential group of metals required for some metabolic activities in organisms. Toxicological effects of large amounts of Co include vasodilation, flushing and cardiomyopathy in humans and animals observed by Teo and Chen (2001). Copper, iron, manganese, nickel, zinc and lead increased during the second year of the study in both the sewage inlet drain and the lake water. The concentrations of chromium, nickel, zinc and lead were beyond the limits set for aquatic life by the United States Environmental Protection Agency (USEPA) (1976). Mobilization of zinc and lead is also affected by higher concentrations of manganese in the sediment (Fernandes et al., 1994). Chromium, lead and zinc in the sediment were categorized as 'non-pollution', nickel was categorized as 'moderate pollution' and copper was categorized as 'heavy pollution', as per the criteria for sediment concentration of metals established by the USEPA (Nichlos et al., 1991). Chromium toxicity to aquatic biota is significantly influenced by abiotic variables such as hardness, temperature, pH, and salinity of water and biological factors such as species, life stage, and potential differences in sensitivities of local populations (Ecological Analysts, 1981). The maximum permissible limit of chromium, copper and arsenic in drinking water is 0.05mg/l, (Awashthi, 2000). In general, elevated levels of Cr in biological or
other samples have been positively correlated with increased industrial and other uses of the element—especially uses associated with plating and foundry applications, chemical manufacturing, and corrosion inhibition (Taylor and Parr, 1978). McElroy et al. (1975) reported that the millions of tons of fertilizers and pesticides are applied to croplands every year, cultivated soils can become enriched with toxic metals associated with these applications although the concentrations may vary between specific formulations, many of these fertilizers contain Chromium, Copper, Iron, Manganese, Nickel and Zinc and selected pesticides use heavy metals such as mercury as an integrate component. During the late spring and early summer, after fertilizers and pesticides have been applied, the runoff from rain flushes these contaminants into the water systems. The atmospheric fallout is also a one of the source of metal contamination to aquatic environments.

From the observations it is found that the chromium content was high in summer at Harsul lake and Godavari river while at Nandrabad pond it was high in monsoon. On the otherhand, at Tisgaon lake and Jaikwadi dam it was high in winter. The chromium content was low in summer at Tisgaon lake while at Jaikwadi dam it was low in monsoon. On the otherhand, at Godavari river, Harsul lake and Nandrabad pond it was low in winter. Seasonal variations of chromium concentrations may be due to the waste discharges into the water bodies from the variety of sources in different seasons. Similar observations were reported by Khan et al. (2006) in Godavari river, Pande and Sharma (1999), Guhathakurta and Kaviraj (2000), Mayer and Schick (1981), James and Bartlett (1983b), Pfeiffer et al. (1980), Jenkins (1980) and Eisler (1981). Athar and Vohara (1995) observed that the concentrations of chromium and copper are lower than the reported values of these metals in most of river of Indian sub-continent, but these were higher than the world average value. The concentrations of metals could not be correlated to every sampling station due to entering pollutants from diverse non point sources and mixing of water bodies. Natural mobilization of Cr by weathering processes is estimated at 32
thousand tons/year, the amounts of Cr added to the environment as a result of anthropogenic activities are far greater. New York City alone contributes about 440 tons of Cr annually to the environment (Steven et al., 1976). Major atmospheric emissions of Cr are from the chromium alloy and metal producing industries; lesser amounts come from coal combustion, municipal incinerators, cement production, and cooling towers (Towill et al., 1978). Atmospheric emissions contribute 4 to 6 times more Cr to aquatic ecosystems than do liquid wastes (Ecological Analysts, 1981). In aquatic environments, the major sources of chromium are the electroplating and metal finishing industries and publicly owned treatment plants relatively minor sources (other than localized contamination) are iron and steel foundries, inorganic chemical plants, tanneries, textile manufacturing, and runoff from urban and residential areas (Towill et al., 1978; Ecological Analysts, 1981). Chromium in phosphates used as fertilizers may be an important source of Cr in soil, water, and some foods (Langard and Norseth, 1979).

It has been observed that the chromium content was high in summer in sediment at Godavari river, Tisgaon lake and Harsul lake while at Nandrabad pond and Jaikwadi dam it was high in monsoon. The chromium content was low in summer at Jaikwadi dam while at Godavari river, Tisgaon lake and Harsul lake it was low in monsoon but at Nandrabad pond it was low in winter. Chromium concentration was increased may be due to source of urban and residential area, phosphate used fertilizers, waste discharges and industrial effluents. These findings were observed by several authors Towill et al. (1978), Ecological Analysts (1981), James and Bartlett (1983a) and Steven et al. (1976). Most of the Cr+6 found in nature is a result of domestic and industrial emissions (Steven et al., 1976). Trivalent Cr tends to form stable complexes with negatively charged inorganic or organic compounds, and thus is unlikely to be found un-complexed in aqueous solution if anionic or particulate compounds (such as decaying plant or animal tissues, or silt or clay particles) are present (Steven et al., 1976; Pfeiffer et al., 1980; Ecological Analysts, 1981). Precipitated Cr+3
hydroxides remain in the sediments under aerobic conditions under low pH and anoxic conditions, however, Cr+3 hydroxides may solubilize and remain as ionic Cr+3 unless oxidized to Cr+6 through mixing and aeration (Ecological Analysts, 1981). Among estuarine sediments, Cr content tends to be highest in those of small grain size and high organic and iron content; concentrations in European estuaries ranged from 3.9 mg/kg in intertidal sands to 162.0 mg/kg in anaerobic muds (Rehm et. al., 1984). Adsorption of Cr by sediments is salinity-dependent; adsorption is greatest at salinities of 0.1 to 1.0 % (Mayer and Schick, 1981). Colloidal iron strongly scavenges Cr+3 from river water; flocculation of the colloids when they are mixed with seawater, coupled with lack of removal of the colloids to the sediments by gravitational settling or scavenging by suspended sediments, promotes the flux of Cr+3 through the estuary to the open ocean (Mayer et. al., 1981). The solubility and potential bioavailability of waste Cr added to soils through sewage sludge, animal manures, and industrial wastewater are modified by soil pH and organic complexing substances (James and Bartlett, 1983a, 1983b). Sediment accumulated more heavy metals than the water in this study as have been observed by Bower (1979), Fabris et. al. (1994), Lau et. al. (1996, 1998), Besada et. al. (2002) and Chindah et. al. (2003). Sediment is the major depository of metals in some cases, holding more than 99 percent of total amount of a metal present in the aquatic system (Odiele, 1999). The observed low concentrations of Cr, Cd and Pb in his work are consistent with the findings of Obire et. al. (2003) worked on this creek but contrary to the reports of Chindah et. al. (2004) observed higher values of Cd and Pb in this aquatic body. This observation is also different from the findings of Lau et al. (1998) in the sediment of Sarawak Kanan, Malaysia. In natural waters, only very small amounts of the dissolved metals, such as Cu, Pb or Zn, are present as free (aquo) metal ions, since most of the metal is absorbed to colloidal particles or combined in complexes (Florence et. al., 1992). The copper content in the freshwater was estimated and studied by several workers, Mule and Patil (2000), Bhosale and Patil (2001), Mazher and Dawood (2005). Obasohan et. al. (2006) reported that value of copper
of Ogba river is in the range of 0.002 to 0.041 mg/l. at different stations. This level of copper in Ogba river is below the permissible limit. According to Lester (1983) the solid waste or sewage sludge is commonly disposed in landfills or solid as fertilizers. Heavy metals can be released through leaching of sewage sludge in landfills. Sewage sludge also contains plant and nutrients and compares favorably to other fertilizers in crop production. Soil cultivation accounts for at least 90 percent of the soil erosion in the more humid areas of United States, and its concentration increase with the amount of sediment introduced into the streams and rivers. Metal containing particulates that are washed from the atmosphere by rain and snow are deposited in drainage basins and find their way into lakes and rivers. As of 1973, the total nationwide airborne particulate emissions were distributed basically among three sources, 51 percent from industrial processes, 29 percent from fossil–fuel combustion and 20 percent from miscellaneous burning particles (Magee et al., 1973).

In the present investigation, the copper content was high in summer at Godavari river, Harsul lake and Nandrapad pond while at Jaikwadi dam it was high in monsoon but at Tisgaon lake it was high in winter. The copper content was low in summer at Tisgaon lake while in Godavari river and Nandrapad pond it was low in monsoon, on the otherhand, at Harsul lake and Jaikwadi dam it was low in winter. The high content of copper in summer and winter may be due to its dissolution in the water body which comes mostly from industrial and municipal wastewaters. In monsoon, the concentration of dissolved copper generally increased in the down-flow direction, especially near urban centers. Some tributaries carry greater concentrations of copper than the main stream, but their influences on main stream concentration seem to be minimal. There are several sources of copper contamination into the environment, mainly by anthropogenic activities, like domestic wastewater, industrial effluents, pesticides, and so on (Rashed, 2001). Further, more findings were reported by Yin Xu (1993), Lanjun, Lǔ (1994), Bozhi Li (1996), Qiuling Ouyang (1997), Sasalone and Buchberger (1997) and Ramamoorthy and Rust (2006). According to Wen
et. al. (2001) adsorption and desorption plays an important role in the transformation process and in the concentrations of trace and heavy metals in natural waters. Copper concentrations in sediments are highly affected by the physical and chemical conditions of the water column. In this context, Wen et. al. (2001) studied the adsorption and desorption behavior of copper on polluted sediments from the Le-An river (China) and concluded that the adsorption behavior of the polluted samples is dependent on pH and polluted ion concentration in the water column.

It has been observed that the copper content was high in summer in sediment at Godavari river and Tisgaon lake while at Nandrabad pond it was high in monsoon while at Jaikwadi dam it was high in winter. The copper content was low in summer at Jaikwadi dam while in Godavari river, Tisgaon lake and Harsul lake it was low in monsoon but at Nandrabad pond it was low in winter. Also, it is important to observe that the spatial-temporal distribution variation was pronounced in copper concentrations in the sediment. The higher concentrations were detected during summer and winter sampling, in which it retained than in monsoon sampling, as diffused pollution sources have to be considered to explain this concentration increased during the summer and winter months, like agriculturist activities and cattle breeding in small properties around the study area. Similar observation reported by Davi Gasparini et. al. (2007), Becker et al. (2001) and Onyari et al. (2003). DWAF (1992) investigated the temporal variability of trace metals transported in the river, the concentration correlated with the amounts of solids discharged, and suggested that abundance of decaying organic matter may result to give high concentrations of metal binding particulates. The maximum copper concentration obtained by Cardwell et. al. (2002) in the sediment of a natural wetland in Southeast Queensland, Australia, was 49.6 mg kg⁻¹, which is higher than copper concentrations obtained in the wetland in Ribeira to Iguape Basin. Levels of Cu in river water ranged from trace to 0.387 ± 0.002 mg/l while that in sediment ranged from 0.082 ± 0.007 to 0.496 ± 0.004 mg/kg (OR Awofolu et. al., 2005). The range obtained was lower than the set value, hence adverse effects from
domestic use are not expected as far as this parameter and the results obtained are concerned. At neutral or alkaline pH, typical concentration of Cu in surface water is 0.003 mg/l (DWAF, 1996a). Cu and Pb form very stable complexes with dissolved organic matter, and only a very small fraction of these metals exists as free hydrated metal ions, when soil pH is not strongly acidic (Aualiitia and Pickering, 1986; Sauve et al., 1998). The metal levels in soil were higher than those in the river water and vegetables with the exception of Ni. Plants are known to take up and accumulate trace metals from contaminated soils (Singh and Narwal, 1984; Bojakowska and Kochany, 1985; Pulford and Watson, 2003; Madejon et al., 2003). The study revealed that Shahpura lake is contaminated with heavy metals. Although the metals are accumulated in the food chain, the observed concentrations are safe for human consumption, and bioconcentration requires the uptake of metals mainly from water (Forstner & Prosi, 1978; Manson, 1996). According to Jernelov (1969) equilibrium exists between sediment and water with a concentration of 90-99% mercury located in the sediment while the rest was being associated with water apart from natural changes occurring in the dissolved heavy metal content in water as a result of bioaccumulation (Becker et al., 2001). According to Kamman et al. (2005) environmental mercury contamination is an issue of global importance. In the past two decades, the concentration of mercury has been determined in numerous environmental matrices, including air, water, sediment, and biota. As sediments serve as the ultimate repository for much of the particulate matter that moves through watersheds, sediments are a well studied environmental matrix. Mercury concentrations in the river and the wetland sediments were pretty high.

In the present study, the mercury content was high in summer at Godavari river, Tisgaon lake, Harsul lake as well as Jaikwadi dam. On the otherhand, at Nandrabad pond it was high in monsoon. The mercury content was low in summer at Nandrabad pond while at Godavari river, Tisgaon and Harsul lake it was low in monsoon but at Jaikwadi dam it was low in winter. The high mercury values recorded in summer and monsoon
season from both the samples, the metal concentrations are generally
greater during periods when the river flow is low, during droughts and late in
winter, because the decrease in water volume decreases dilution effects and
the decrease in suspended sediment concentrations decreases metal
scavenging processes. Conversely, the increases in river flow during the
rainy months either dilute heavy metal concentrations through increased
scavenging processes resulting from higher suspended sediment
concentrations. In monsoon, the metal level increased may discharge waste
water from water bodies, agricultural runoff, mining activities and industrial
manufacturing activities caused increase in heavy metal concentrations near
by urban areas. Concentration of mercury correlated with the amount of solid
discharged and decaying organic matter into water system due to low level
of mercury observed in winter. Human activities prevail in the vicinity of pond
and domestic animals always graze and wander around pond. The passage
through natural influx also exists for the domestic discharge, sewage water
into the pond, which is arriving from the village might have contributed
mercury in the water and sediments. The water body receives much water in
monsoon due to heavy rainfall and gets flooded. However, in summer the
level of water considerably decreases. From monsoon (July) to winter
(March) much vegetation exists in the water body which likely to contribute
much of the pollution problems in the Kagzipura swamp (Patil, 1993). Similar
observations were reported by Patil (1993), Patil and Mane (1998), Hall et
suggested that the wetlands may be a major source of methyl-mercury
(MeHg) environment, the concentrations of mercury in the wetland sediment
is extremely preoccupying, since the synthesis of methylmercury may
happen and the toxicity of this compound is extremely high. Mehrotra and
Sedlak (2005) observed that the MeHg poses a significant risk to humans
and wildlife due to its neurotoxicity and tendency to accumulate in aquatic
food chains. Kamman et al. (2005) observed that the mercury
concentrations in sediments of different ecosystems and obtained the
highest total mercury concentrations in lakes and reservoirs, ecosystems
with a lower water velocity, when compared to rivers. In waters of higher salinity there is an increased tendency for soluble phase partitioning of metals in chloride complexes (Bourg, 1988).

It has been observed that the mercury content was higher in summer in sediment at Godavari river and Nandrabad pond while at Tisgaon lake, Harsul lake and Jaikwadi dam it was high in monsoon. The mercury content in sediment was low in summer at Tisgaon lake and Harsul lake while at Godavari river and Nandrabad pond it was low in monsoon but at Jaikwadi dam it was low in winter. It is observed that the direct inputs such as sewer discharges and surface runoff, rather than inputs from the upstream freshwater sections, are the major source of mercury to these sediments. Machado et al. (2002) and Marins et al. (2004) showed the increase of mercury concentration in the sediment than water of Iguape river, which is the main river of the basin indicates the metal transportation from other tributaries to Iguape River basin. Mascarenhas et al. (2004) studied Acre River, in Acre state, Brazil, obtained 0.2 mg kg⁻¹ as the highest mercury concentration in sediment. The average metal concentrations in the lower core sections are among the highest reported for estuarine sediments of the United Kingdom, and for Cd and Hg these are approximately double the higher range of values reported by Bryan and Langston (1992) for industrialized areas. The studies of cadmium contamination in major aquatic systems over the past 20 to 30 years have conclusively demonstrated that cadmium levels in these water bodies have decreased significantly since the 1960s and 1970s (Elgersma et al., 1992; Mukunoki and Fujimoto, 1996) for example, studies on the Rhine river Basin indicated that the point source cadmium discharges to the Rhine river decreased from 130 to 11mt per year over 14 – year time span, a reduction of over 90% (Elgersma et al., 1992). It accumulates mainly in the kidney and liver and high concentrations have been found to Cd to chronic kidney dysfunction. It induces cell injury and death by interfering with calcium (Ca) regulation in biological systems. It is found to be toxic to fish and other aquatic organisms (Woodworth and Pascoe, 1982). The use of cadmium containing fertilizers and sewage sludge
is most often quoted as the primary reason for the increase in the cadmium content of soils over last 20-30 years in Europe (Mukunoki and Fujimoto, 1996). Apart from natural sources, other probable sources of this metal in surface water include leaching from Ni-Cd based batteries, runoff from agricultural soils where phosphate fertilizers are used and other metal wastes (Hutton et al., 1987).

In the present study, the high cadmium values were recorded in summer at Godavari river and Tisgaon lake while at Nandrabad pond it was high in monsoon, on the otherhand, at Harsul lake and Jaikwadi dam it was high in winter. The cadmium value was low in monsoon at Godavari river, Harsul lake, and Jaikwadi dam while at Tisgaon lake and Nandrabad pond it was low in winter. A decrease in pH increases cadmium availability and solubility of cadmium is influenced by pH. Similar results were obtained by Van der Sloot et al. (1991), Fatoki and Awofolu (2003). Cd occurs naturally in the environment, in insignificant amounts but its release in the recent past is steadily increasing due to human activities causing pollution of soil and aquatic systems. The occurrence of Cd in considerably toxic amounts was reported by earlier workers in various aquatic ecosystems (Arno Kaschl et al., 2002; Audrys et al., 2004; Chrastny et al., 2006; Kiran et al., 2006). Cadmium is a natural, usually minor constituent of surface and ground water. It may exist in water as the hydrated ion, as inorganic complexes such as carbonates, hydroxides, chlorides or sulphates or as organic complexes with humic acids (OECD, 1994). The high-concentration range of 0.01 to 0.26 mg/l Cd has been reported in the Gomti River (Gaur et al., 2004). The river water flow rate as at the period of sampling could be regarded as normal. The higher level of Cd obtained in water samples relative to the amount in sediment might be due to contribution from other sources such as agricultural runoff where fertilizers are used in addition to possible release of sediment bound-metal. A higher Cd concentration ranged between 0.008 ± 0.003 and 0.017 ± 0.002 mg/l in Tyume River has been previously reported (Fatoki and Awofolu, 2003).
It has been noted that the cadmium content was high in summer in sediment at Tisgaon lake while at Godavari river, Harsul lake and Jaikwadi dam it was high in monsoon but at Nandrabad pond it was high in winter. The cadmium content in sediment were low in summer at Nandrabad pond while at Godavari river, Tisgaon lake, Harsul lake and Jaikwadi dam it was low in winter may be due to dumping of the wastes, domestic wastes, human activities and agricultural runoff from nearby villages, rivers, lakes, ponds and dams containing excess cadmium may contaminate surrounding land, either through irrigation for agricultural purposes or dumping of dredged sediments after flooding. Similar results were obtained by Fakoti (1993), Patil (1993), Patwari (2002), Zadpide (2002) and Kiran et al. (2006). Cadmium may enter aquatic systems through weathering and erosion of soils and bedrock, atmospheric deposition, direct discharge from industrial operations, leakage from landfills and contaminated sites and the dispersive use of sludge and fertilizers in agriculture. Much of the cadmium entering freshwaters from industrial sources may be rapidly adsorbed by particulate matter and thus sediment may be a significant sink for cadmium emitted to the aquatic environment (WHO, 1992). Perusal of literature shows that sediments in lakes and streams range from 0.2 to 0.9 ppm in contrast to the levels of Cd generally less than 0.1 ppm cited for freshwaters (Fakoti and Mathabatha, 2001). Partinoning of cadmium between the adsorbed in sediment state and dissolved in water state is therefore an important factor, whether cadmium emitted to waters is or is not available to enter the food chain and affect human health. Cadmium is one of the non-essential heavy metals, known for its non-corrosive nature and widely used in paints, dyes, cement and phosphate fertilizers (Jarrup, 2003). Cadmium in soils is derived from both natural and anthropogenic sources. Natural sources include underlying bedrock or transported parent material such as glacial and alluvium. Anthropogenic input of cadmium to soils occurred by aerial deposition and sewage sludge, manure and phosphate fertilizer application. Cadmium is much less mobile in soils than in air and water. The major factors governing cadmium speciation, adsorption and distribution in soils
are pH, soluble organic matter content hydrous metal oxides content, clay content and type, presence of organic and inorganic ligands and competition from other metal ions (OECD, 1994). Cadmium is one of the most toxic elements with reported carcinogenic effects in humans (Goering et al., 1994). Cadmium has been implicated in endocrine disrupting activities, which could pose serious health problems. Apart from the health implication, the metal (Cd), together with other elements, e.g. Zn form a toxic "soup" that often acts synergistically. Sources of Cd include wastes from Cd-based batteries, incinerators and runoff from agricultural soils where phosphate fertilizers are used since Cd is a common impurity in phosphate fertilizers (Zadpide, 2002). Idodo - Umesh (2002) reported that the pollutant level of the aquatic ecosystem by determining the concentration of metal Pb, Cd, Cr and Hg present in the water and sediment, plankton and fish samples, which may have the potential human risk. Most heavy metals released into the environment enter aquatic phase as a result of direct input, atmospheric deposition and erosion due to rain (Veena et al., 1997). Panichayapichet et al. (2007) stated that soil disturbance from land-use activities including tillage and traffic increased leaching of trace metal from soils, agricultural activities, surface runoff, land encroachments in the upper and middle part of the watershed which have high potential of Pb must be strictly controlled in order to reduce the Pb contamination from non-point sources. The presence of toxic metals such as Pb and Cd in the environment has been a source of worry to environmentalists, government agencies and health practitioners. This is mainly due to their health implications since they are non-essential metals of no benefit to humans (Tyler, 1981; Borgmann, 1983). OR Awofolu (2005) detected elevated levels of Cd and Pb in the river, which may be directly detrimental to the health of the aquatic ecosystem and indirectly to man since the river water is used to irrigate a nearby farmland. The high levels of lead found in the Orleans' sediments are likely due to past use of lead in paint and gasoline, or to leakage from industrial sites in and around New Orleans (Solomon et al., 2006).
In the present study, it is found that the lead content was observed in the water samples at different lotic and lentic water bodies. The lead content was high in summer at Tisgaon lake, Nandrabad pond and Jaikwadi dam. On the other hand, at Godavari river and Harsul lake it was high in monsoon. The lead content was low in summer at Godavari river while at Nandrabad pond it was low in monsoon but at Tisgaon lake, Harsul lake and Jaikwadi dam it was low in winter. The increase in lead content may be due to the water acidity, known to influence the solubility, availability and toxicity of Pb in the aquatic ecosystems. The levels of Pb obtained in sediment were higher than those in the river water hence the sediment may be influential factor on the level of Pb in river water with other enhancing factors such as the current flow and pH since water acidity is known to influence the solubility and availability of metals (OR Awofolu et. al., 2005; Nriagu, 1979; Vries et. al., 2005). Kremling & Streu (2000) observed a significant decrease in the Cd, Cu, Ni, Zn and Pb concentrations in the surface waters of the Baltic. This negative temporal trend pattern is clearly marked for Cd and Pb because of their reduced use in industry and agriculture (Cd) and the restrictions on leaded petrol (Pb) in recent decades. Thomas and Eggleton (2004) observed that the dissolved oxygen played an important role in lead and copper concentrations in sediment. The inverse correlations reached -0.9 for these metals. A higher concentration range of 0.24 to 1.11 mg/l of Pb in Gomati River has been reported by Gaur et al. (2004).

In the present investigation, the concentration of lead was increased in summer in sediment at Godavari river, Tisgaon lake, Harsul lake, Nandrabad pond and Jaikwadi dam. The content of lead is low in monsoon at Godavari river and Tisgaon lake while at Harsul lake, Nandrabad pond and Jaikwadi dam it was low in winter. The concentration of lead have also increased by excess release of free metal ions into the water bodies from kitchen utensils and solubility of old paintwork from buildings during acidic wet deposition, village area, local atmospheric pollution, such as metabolic wastes, corrosion of household plumbing system and agricultural runoff. Different point and non-point sources have been identified the heavy metals
which are released in water bodies. The discharge of Pb in Labu river system has mainly originated from Pb containing domestic wastewater such as from metabolic wastes, corrosion of household plumbing systems, local scale open burning, surface runoff of pesticides in agricultural estates and wet deposition (Laws, 1981; Wait, 1984). Concentration of cd and Pb in Labu river system have also increased by excess release of free metal ions into water bodies from kitchen utensils and solubility of old paintworks (Lim et al., 2003). Khan et al., (2006) reported that the river systems are contaminated with heavy metals, the wide spread contamination of aquatic ecosystem with heavy metals is the increasing concern to environmental scientists. Tomazelli (2003) studied Piracicaba River (São Paulo state, Brazil) and obtained higher lead concentrations in the sediment of this river. The concentrations ranged between 80.0 mg kg⁻¹ and 233.0 mg kg⁻¹ Pb. Excess of heavy metals are often introduced into aquatic ecosystems as by products of industrial process and acid mine drainage residues. Recently, the significance of air borne non-ferrous metals and their accumulation in plants and soils has received increasing attention (Bower, 1979). Stone and rock crushing, iron and steel industries, grain handling operations and cement production emit the greatest percentage of the particulates. Coal used extensively for power generation often contains significant concentrations of metals such as Vanadium, Copper, Nickel, Chromium, Zinc, Lanthanium, Tin and Mercury (Magee, et al., 1973).

Heavy metals have also been subjected to seasonal trend analysis. However, the variations in heavy metal concentrations were found high. In fact it is very difficult to conclude a marked seasonal trend in case of heavy metals at each of the sampling locations. However, a general feature of the seasonal profile showed that the concentrations were highest during the summer followed by winter. The concentrations of heavy metals during monsoon season were found lowest. The reasons for high variability of the metal concentrations as discussed earlier are the effect of variable source inputs during the course of water bodies. Lower concentrations during monsoon are effectively due to the effect of runoffs as well as dilution and
dispersion since the water bodies are open throughout the study area. It could be concluded that in most of the cases, the concentrations are directly dependent upon direct discharges of these metals from the surrounding urban areas and seasonal variations have limited effect on the same.

Weather the concentrations of heavy metals in lotic and lentic water bodies in Aurangabad district have increased or decreased in recent years is difficult to determine. Although most of the heavy metals in the rivers are associated with sediments, water and concentrate into organisms. Even for the dissolved metals, comparisons are difficult to draw between earlier and more recent data because analytical laboratory techniques have become markedly more sensitive in the last decade and field-sampling techniques have not been adequately standardized. In view of the importance of fish or any other organisms (like food) to diet of man, it is necessary that biological monitoring of the water should be done regularly.

Heavy metals enter the aquatic environment naturally through weathering of the earth crust. In addition to geological weathering, human activities have also introduced large quantities of metals to localized area of the sea, in some cases upsetting the natural steady state balance (Forstner and Wittmann, 1983). Nicolau et al. (2006) reported that the rivers are a dominant pathway for metals transport and that the existence of heavy metals in aquatic environments has led to serious concerns about their influence on plant and animal life. Clean Water Act (2002) stated that metals are either necessary in low concentrations to the human beings (trace metals) or extremely toxic for them in any concentration (heavy metals). High concentrations may cause many diseases and injuries to the human health. Besides, they tend to bioaccumulate in upper levels of the food chain. Bioaccumulation means an increase in the concentration of a chemical compound in a biological organism over time, compared to the chemical's concentration in the environment. According to WRI (2006) humans are exposed to metals through inhalation of air pollutants, consumption of contaminated drinking water and food and exposure to contaminated soils or industrial waste. Food sources, such as vegetables, grains, fruits, fish and
shellfish may become contaminated by accumulating metals from surrounding soil and water. Davydova (2005) observed that the metals can exert detrimental effects not only on human health but on the whole environment. Sediments are important sources contamination in aquatic systems (Gaur et al., 2004). Many marine ecosystems are contaminated by different pollutants, and especially metals, as a result of human activities. Bivalves, mussels and oysters can accumulate high concentrations of heavy metals and serve as bioindicators of metal contamination in the aquatic environment (Langston et al., 1998).

Over the past several decades, the increasing use of metals in industry has lead to serious environmental pollution through effluents (Goldberg et al., 1978; Phillips, 1980; Seriano et al., 1995). Under certain environmental conditions, heavy metals may accumulate to a toxic concentration (Güven et al., 1999), and cause ecological damage (Harms, 1975; Jeffries and Freestone, 1984; Freedman, 1989).

Aquatic systems are very sensitive to heavy metal pollutants and the gradual increase in the levels of such metals in aquatic environment, mainly due to anthropogenic sources, became a problem of primary concern. This is due to their persistence as they are not usually eliminated either by biodegradation or by chemical means, in contrast to most organic pollutants. Moreover, the decay of organic materials in aquatic systems together with detritus formed by natural weathering processes provides a rich source of nutrients in both the bottom sediments and overlying water body. Microorganisms, microflora and algae are capable of incorporating and accumulating metal species into their living cells from various supply sources. Consequently, small fish become enriched with the accumulated substances. Predatory fish again, display higher levels than their prey. Eventually man, consuming the fish, inevitably suffers from the results of an enrichment taken place at each trophic level, where less is extracted than ingested (Forstner and Wittmann, 1983).

Bivalve molluscs have gained considerable attention in the view of metal accumulation since; these animals occupy the lower level of the food
chain and are filter feeders. These animals cannot migrate from one place to another far a distance, like prawns, lobsters or fishes (Philips, 1977). Bivalves molluscs are known to occupy several habitats from shallow to deep waters in freshwater or marine environments the heavy metal concentrations in sediments, particulates and detritus are many times higher than those in living organisms. Patil and Mane (2001) showed the differences in the trace metals in winter and summer, arising predominantly from dilution by fixed carbon resulting from the higher biological productivity. Trace metal can exist in a variety of chemical forms in natural waters including free ions, inorganic complexes, organic complexes and metal absorbed on or incorporated into particulate matter (Panda and Sahu, 2002). Dallinger and Rainbow (1993) studied that some species of invertebrate's animals are known to be efficient accumulators of trace elements. Generally, metal accumulations by such organisms are based on efficient detoxification mechanisms, such as intracellular compartmentalization, or metal inactivation by binding to metallothionens. Galtsoff (1964) found that the increase in metal concentration between sampling period were related to the loss of oyster body weight, metals are preferentially partitioned in the gills and mantle. Some also be incorporated into glycogen and lipid compartment, some times resulting the reaction of metal body burden due to spawning. Molluscs are known to accumulate metal ions from the environment to a very high level relative to the concentrations in water (Nambisan et al., 1970). Freshwater mussels are also used to evaluate the distribution and availability of trace metals, their radioisotopes and organic pollutants (Doherty et al., 1993; Oertel, 1998; Ravera, 2001). Hassett-Sipple et al. (1997) stated that mercury uptake involves a number of mechanisms, both passive and active (energy dependent), and the importance of each is highly dependent on the particular organism and on the specific tissue membrane. Thus, the toxicity of mercury to aquatic organisms is widely recognized. Mercury is most toxic among all the heavy metals, has complex behavior in the environment, and may persist for decades following abatement of the source. Mercury’s environmental persistence is due in part to its high affinity for particulates.
and organic matter. Even if mercury concentrations in sediment and water decrease over time, concentrations in organisms may not decrease due to the slow rate of elimination of the highly bioavailable methyl mercury form. The physical properties, bioavailability and toxicity of mercury are governed by speciation into both organic and inorganic forms. Elemental mercury, bivalent inorganic mercury and mono methyl mercury are the three most important forms of mercury occurring in natural aquatic environments (Battelle, 1987).

Substantial enrichment of heavy metals in bivalve molluscs from India have been reported by many workers since these molluscs form useful tools in monitoring of heavy metal pollution (Lakshmanan and Nambisan, 1989; Mane, 1990; Patil, 1993; Patil and Mane, 1998; Patwari, 2002; Zadpide, 2002).

It has been observed that the mercury content in summer, compared to monsoon increased significantly in mantle, hepatopancreas, and gill but decreased significantly in adductor muscles and foot in *L. marginalis* while the content increased significantly in mantle, hepatopancreas, gonad, and adductor muscles but decreased significantly in gills and foot in *L. corrianus*. The content increased significantly from all the body parts but in gills decreased significantly in *L. caeruleus*. In summer, compared to winter the content increased significantly in mantle, hepatopancreas and gills but decreased significantly in adductor muscles followed by foot, gills and gonad in *L. marginalis*, while, the content increased significantly in gills, mantle and hepatopancreas but decreased significantly in adductor muscles, foot and non-significantly in gonad in *L. corrianus*. On the otherhand, the content increased significantly in gonad and mantle but decreased significantly in adductor muscles, foot, and non-significantly in hepatopancreas and gills in *L. caeruleus*. In monsoon, compared to winter the mercury content was decreased significantly from all the body parts from all the species but in gills increased significantly in *L. marginalis* and it increased non-significantly in *L. caeruleus*. In monsoon, compared to summer the mercury content increased significantly in adductor muscles, foot and non-significantly in gonad but
decreased significantly in mantle, hepatopancreas and gills in *L. marginalis* while the content increased significantly in gills and non-significantly in foot but decreased significantly in mantle, hepatopancreas, gonad and non-significantly in adductor muscles in *L. corianus*. On the other hand, the content decreased significantly in hepatopancreas followed by gonad, mantle, adductor muscles, and foot it decreased non-significantly but in gills it increased significantly in *L. caeruleus*. In winter, compared to summer the mercury content increased significantly from adductor muscles, foot, gonad but decreased significantly in gills, mantle and hepatopancreas in *L. marginalis*. while the content increased significantly in adductor muscles, foot and non-significantly in gonad but decreased significantly in gills, mantle and hepatopancreas in *L. corianus*. On the otherhand the content increased significantly in adductor muscles followed by foot, and non-significantly in hepatopancreas and gills but decreased significantly in gonad and mantle in *L. caeruleus*.

In the present study, it is observed that the mercury content was higher during summer in mantle, gills and hepatopancreas whereas during winter the content was higher in gonad, adductor muscles and foot in *L. marginalis*. The species revealed comparatively more sensitivity to mercury in summer. Mercury content was higher in summer may be due to change in the physiological status of the animal in coordination with the changing environmental parameters. The rise in temperature, low oxygen content and low food availability in the water body in summer are mainly accounting for the physiological demand to the survival of the species. Similar findings were observed by Patil (1993), Patil and Mane (1998), and Patwari (2002). Addition of mercury stress increased the demand and there by probably the animal becomes sensitive to the mercury stress (Patil et al., 1994; Patil and Mane, 1998). Many parameters may affect the mercury accumulation, such as specimen size, sexual maturity, sensitivity to season, feeding habits, trophic position, water quality, and environmental contamination Unlu et al., 1994). Acute toxicity of mercury compounds for various species are summarized, the concentration of inorganic mercury inducing acute toxicity
was observed to range over almost three orders of magnitude from 0.1μg/l to more than 200μg/l when results from tests with different species were compared (Eisler, 1987). Elemental mercury in aquatic environments has a high vapor pressure, a low solubility in water and an octanol-water partition coefficient (K_{ow} = 4.15). Total mercury concentrations may also vary seasonally due to physical factors such as winter storms and mercury contaminated in sediments (Gill and Bruland, 1990). The accumulation of mercury from water occurs via the gill membranes. Gills take up aqueous methylmercury more readily than inorganic mercury (Boudou et al., 1991). Methyl mercury is eventually transferred from the gills to muscle and other tissues where it is retained for longer period of time (Julisamn, 1982). *Mytilus edulis* mussel takes up mercury and is a suitable indicator species for mercury contamination (Fabris et al., 1994). Deshmukh (1995) studied the effect of heavy metals like, CuSO_{4}, HgCl_{2} and CdCl_{2} on the freshwater bivalve Parreysia corrugata. HgCl_{2} was more toxic followed by CuSO_{4} and CdCl_{2}. Patil (1998) observed the toxicity of heavy metals like CuSO_{4}, HgCl_{2} and ZnSO_{4} to the freshwater bivalve Lamellidens corianus and found that HgCl_{2} was more toxic as compared to CuSO_{4} and ZnSO_{4}. Mercury is accumulated in kidneys of fish and mammals and organic mercury in brains. Overdoses of mercury can cause damage in kidneys and central nervous system (Aune, 1998). Kumaruguru et al. (1979) observed that oysters exposed to solution of mercuric chloride became translucent with mucus coagulated over the gills, probably due to chemical action between the metal ions and mucus secreted by the gills. Dissolved mercury taken up from the water by bivalve mollusks is accumulated initially by the gills then distributed to other organs. (Cunnigham and Trip 1975 ; Roesijadi et al., 1981). According to Azevedo (2003) mercury’s physical and chemical properties make it easy to be introduced in the human organism and absorbed by the humans, considering that Jacupiranguinha River and the wetland are used as sources of fish by the local population. Moreover, up-to date researches have been showing that about 60-95% of total mercury was found in fish and
invertebrates (muscular tissue) (WHO, 1990; Akagi et al., 1996; Burger and Gochfeld, 2005).

In the present investigation, it is found that the mercury content was higher during summer in mantle and hepatopancreas whereas during monsoon the content was higher in gills and during winter the content was higher in gonad, foot and adductor muscles in *L. corrianus*, while, the content was higher during summer in gonad and mantle whereas during monsoon the content was higher in gill and during winter the content was higher in hepatopancreas, adductor muscles and foot in *I. caeruleus*. The mercury content was higher in summer than monsoon and winter in *L. corrianus* and *I. caeruleus*. It has been observed that the rate of uptake of mercury in freshwater bivalve increased with increasing mercury concentration in water. Similar results were obtained by Patil (1993), Patil and Mane (1998), Patwari (2002). Krishnakumar et al. (1990) found that accumulation of mercury in the green mussel, *Perna viridis* was maximum in gill followed by vicesra, mantle and foot. The authors also found that with the lapse of time in mercury water, mercury loss from gill and mantle was faster from viscera and muscle. Ayyadurai and Krishnaswamy (1989) suggested that in summer the mercury absorbed by humic acid in the sediment will be released into water phase. In spite of this release, mercury concentration in sediment does not decrease because of its high retentive power (98%) as reported by Thanabalasingam and Pickering (1985). Patil (1993) and Kulkarni (1993) studied the effect of heavy metals like mercury and cadmium on the freshwater bivalve *L. marginalis*. Patil (1993) studied the failure in the rhymetic shell valves closing, occurrence of diapedesis, failure to respond the external stimulant and permanent wide opening of the shell valves in the mussels exposed to the different test concentrations of mercury given an insight into the disfunction of the nervous system. In phytoplankton, algae and microorganisms, mercury uptake is primarily a passive process that occurs by adsorption to the cell surface either through interaction with functional groups in the cell wall or through sorptive properties associated with the extra-cellular matrices (Darnell et al., 1986; Gadd, 1988). Bryan
(1980) studied with the form of metal ions in water stressed the importance of soluble and particulate organic and inorganic form of metals while dealing with the factors influencing physiology of organisms. The main emphasis was given to the temperature, pH, dissolved oxygen, light and salinity with regard to the condition of organisms, stage in the life history (eggs, larva etc.), changes in life cycle (e.g. Moulting, reproduction) age and size, sex, starvation, activity, additional protection (e.g. shell) and adaptation to metals have been considered. On the other hand, altered behaviors of an organism during the toxicity of metals are also to be considered. Mehrotra and Sedlak (2005) studied a natural wetland system around San Francisco Bay, USA, obtained 1.0 mg/kg-1 as the highest mercury concentration in the sediment. Comparing mercury concentrations in the sediment of the river and of the wetland, the former presented the highest concentrations, reaching 0.8 mg kg-1, which is a different pattern, compared to the other trace metals quantificated in research. Water is an important exposure pathway for mercury uptake by lower organisms and thus into the food web (Francesconi and Lenanton, 1992). Uptake in phytoplankton and aquatic plants has been correlated with the concentration of mercury in the water (Windom et. al., 1991; Lenka et. al., 1990). Phytoplankton, invertebrates, fish (including eggs and larvae), and mammals take up inorganic and organic mercury from the water column. (Christensen et. al., 1977; Penetreath, 1976a, 1976b). Dissolved mercury concentrations in water are typically very low; the major increase in mercury concentrations occurs between water and phytoplankton of about a factor of 10-5 to 10-6 (Mason and Sullivan, 1997). Uptake methyl mercuric chloride in water by different tissues of brook trout was found to be directly related to the water concentration of the mercury (Christensen et. al., 1977). Cetesb (2005) established 0.5 mg kg-1 as an acceptable mercury concentration in freshwater sediments. Cadmium is a natural constituent of rock phosphates and deposits from some regions of the world contain markedly elevated levels of the metal. The manufacture of phosphate fertilizer resulted in a redistribution of the cadmium in the rock phosphate between the phosphoric acid product and the gypsum waste (Cheggour et.
al., 1999). Concern about effects of cadmium on organisms and environment has led to increasing focus on reduction of spillage of this element into environment. The main sources of cadmium are mining and processing of zinc, galvanizing and paint industry and products like Ni/Cd batteries and offer anodes (Dons & Beck, 1993). The main sources into water are offer anodes used in ships and offshore industry, mining, sewage and long distance transport by ships (Huse, 1999). Harland et al. (2000) found that the metal content in the soil depend on organic matter and particle size content. Ruiz and Saiz- Salinas (2000) studied variations in the concentration of trace metals in sediment and bivalves from the Bilbao estuary, the reduced river flow raised the metal –binding capacity of sediments, and restrictions in the water supply increased the corrosion of sewers and their leaching of some elements. The concentration of trace metals in bivalve (Cd reached 100 and 458 ppm dry wt, respectively, for whole tissues and digestive gland ) mirrored the sediment contamination dynamics, but at a slower pace.

However, present study revealed that the cadmium content increased significantly from mantle followed by hepatopancreas, foot, gills and non-significantly in gonad but in adductor muscles it decreased significantly in L. marginalis in summer, compared to monsoon while the content increased significantly from all the body parts of L. corianus and I. caeruleus, but in hepatopancreas it increased non-significantly in L. corianus in summer, compared to monsoon. In summer, compared to winter the cadmium content increased significantly in gills and non-significantly in mantle but decreased significantly in adductor muscles, foot, and non-significantly in gonad and hepatopancreas in L. marginalis. While, the content increased significantly from all the body parts of L. corianus and I. ceruleaus but from gills it decreased non-significantly in I. caeruleus. In monsoon, compared to winter the cadmium content decreased significantly from all the body parts but from gills it decreased non-significantly in L. marginalis. On the otherhand, the content increased significantly from all the body parts in L. corianus while the content increased significantly in foot and non-significantly in adductor
muscles but decreased significantly in mantle followed by gonad, gills, and hepatopanreas it decreased non-significantly in I. caeruleus. In winter, compared to summer the cadmium content increased significantly in adductor muscles, foot, gonad and non–significantly in hepatopanreas but decreased significantly in gills and non-significantly in mantle in L. marginalis while, the content decreased significantly from all the body parts in L. corrianus. The content decreased significantly from all the body parts but in gills it increased non-significantly in I. caeruleus. In winter, compared to monsoon the cadmium content increased significantly from all the body parts but in gills it increased non-significantly in L. marginalis. The content decreased significantly from all the body parts in L. corrianus while the content increased significantly in mantle, gonad, gills and hepatopanreas it increased non-significantly but decreased significantly in foot and adductor muscles non-significantly in I. caeruleus. The cadmium content was higher during summer in mantle, gills whereas during winter it was higher in adductor muscles, foot and gonad in L. marginalis. On the otherhand, the content was higher during summer in gonad, mantle, hepatopanreas, foot and adductor muscles whereas during winter the content was higher in gills in I. caeruleus.

In the present study, the cadmium content was higher during summer and winter in L. marginalis and I. caeruleus. The high values of cadmium content in summer and winter may be due to the unfavorable environment. Due to gametogenic storage in summer there was high energy demand for maintenance for the normal physiological activities (Kulkarni et al., 1993). The difference in susceptibility of the Lamellidens marginalis to cadmium is mainly accounted for the lentic environment in Kabzipura swamp because it has been reported that the bivalve species living in lentic environment are comparatively more adapted to the resistance capacity to polluting substances than those living in lotic environment (Mane, 1990). Nair and Nair (1986) while studying seasonality of trace metals in Crossostrea madaeensis from Cochin backwaters in India found seasonality in the distribution of cadmium, copper, iron, manganese, zinc and mercury and
found that heavy metal load in the tissue was possible due to variation in the ambient water temperature. Some species of invertebrate animals are known to be efficient accumulators of trace elements. Generally metal accumulation and detoxification mechanisms such as intracellular compartmentation and metal concentrations in the animal body reflect quantitatively or semi quantitatively environmental pollution levels. In reality, many factors, such as the animal’s weight and age, can disturb such quantitative relationship. These factors have therefore to be accumulation indicators for metal pollution. Apart from accumulation many invertebrates exposed to elevated metal concentration respond to this stress. The concentrations of cadmium between 0.08 mg/kg and 0.2 mg/kg fresh weight are within the normal range found in blue mussels (Julshamn & Duinker, 2002). Noel (1975) found that large portion of cadmium in the gill is bound to particulate fraction. In addition, a cytosolic cadmium in the gill is associated with high molecular protein and kindly in the particulate Cd fraction in smaller fraction is mainly bound to MT - like proteins. The hypothetical view of an energy dependent elimination of metals has been shown by Zadpide (2002) Cd accumulation–elimination study on *M. edulis* that an effective elimination of cadmium depends on enhanced metabolic processes under conditions of the fuel to body supply (Tran, et al., 2001). Phillips (1976a) found that cadmium uptake was increased and lead uptake was decreased in *Mytilus edulis* near to fresh water inputs of trace metals. During spring, snow melting and heavy rains increase freshwater runoff from land.

It has been noted that the cadmium content was higher during summer in hepatopancreas, foot, gonad, gills, mantle and adductor muscles in *L. corrianeus*. The content was increased in summer and decreased in both other seasons. Thus, the depuration in cadmium in the external environment, high concentration was compared to high depuration rate from different body parts. Similar observation was made by Zadpide (2002) in *L. marginalis* from Kagzipura lake. Elder ad Collins (1991) observed the bioaccumulation of metals in biota is a function of both uptake and depuration. Uptake in molluscs may be through either of two vectors-ingestion of food, other metal
containing substances or through direct adsorption of dissolved constituents. Bioaccumulation and acute and chronic toxicity are highly dependent on metal speciation. Mainly, because of this influence of metal speciation, toxicity and bioaccumulation do not have a consistent relation to each other. Sensitivity to toxic effects of a metal is likely to be considerably greater in juvenile or larval stages than adults. A second factor contributing to the rise in oyster metal concentrations up river is the salinity gradient. Oysters take up Ag, Cd, and Cu from solution more rapidly at lower salinities (Abbe and Sanders, 1990; Amiard-Triquet et al., 1991). Another potential source of variation in the metal concentrations of oysters is from diet. Modeling of accumulation of number of metals by C. virginica and Mytilus edulis from both water and suspended particles suggested that the majority of these elements, including Cd and Cu, food is the predominant pathway (Thomann et al., 1995). Cadmium is found in marine waters mostly in the dissolved form (Balls, 1985). It accumulates in fish and mammals, has long biological half life and is acute poisonous for organisms in water and mammals. The values of Cd accumulation obtained in the gills and digestive gland of mussels in the present study are in agreement with those described by Serra et al. (1995) in the bivalve Scapharca inaequivalvis, 7 or 21 days of exposure. Blue mussels accumulate cadmium effectively (Phillips, 1976a; Julshamn, 1981a; Julshamn & Grahl-Nielsen, 1996). The water solubility and the uptake of cadmium by blue mussels increase with decreasing salinity, and higher cadmium concentrations have been found in blue mussels growing in the brackish water (Phillips, 1976b; 1977). Lead pollution is extremely common in aquatic ecosystems, since there are many sources of contamination by this metal, as it was already observed by many authors (Lima et al., 2001; Silva, 2002; López-Flores et al., 2003). According to EPA (2006) lead has a wide variety of uses due to its properties of high density, softness, low melting point, resistance to corrosion, and ability to stop gamma and x-rays. Lead is commonly used in storage batteries for automobiles and industry; electrical and electronic equipment; machine bearings; cable coverings; and in pipes, traps, solder, and sheets for building
construction. Besada et al. (2002) proved that the anthropogenic emissions in Spanish North-Atlantic coast of this metal are due to the consumption of leaded gasoline, as well as to the low or nonexistent treatment of urban and industrial sewage. There is often little accumulation of lead in marine and freshwater species. Consequently lead is not a threat to fisheries resources except at extreme pollution (Clark, 1989). Moore and Rammoorthy (1981) reported that there is generally no correlation between residues and feeding habits. Furthermore, they explained the low level of Pb in fish muscle to the relatively low rate of its binding to SH groups, beside the low solubility of lead salts that restricts movement across cell membranes. The concentration of Pb in muscle on the present fish species was below the recommended level given by the I.S.B. for human consumption (Hadjmohammadi, 1988).

It is observed that the lead content increased significantly in foot, gonad, mantle and non-significantly in hepatopancreas but decreased significantly in gills and non-significantly in adductor muscles in L. marginalis in summer, compared to monsoon while the content increased significantly in foot and non-significantly in mantle and gonad but decreased significantly in gills, adductor mussels and hepatopancreas in L. corrianus compared to monsoon. On the otherhand, the content increased significantly from all the body parts in L. caeruleus compared to monsoon. In summer compared to winter, the lead content increased significantly from all the body parts in L. marginalis while the content increased significantly from all the body parts except in gills where it decreased non-significantly in L. corrianus. The content increased significantly in gonad followed by foot, adductor muscles and hepatopancreas but decreased non-significantly in gills and mantle in L. caeruleus. In monsoon compared to winter, the lead content increased significantly from all the body parts in L. marginalis and L. corrianus. On the otherhand, the content decreased significantly in gills followed by hepatopancreas, mantle, and non-significantly in foot and adductor muscles but in gonad it increased non-significantly in L. caeruleus. In monsoon compared to summer, the lead content increased significantly in gills and non–significantly in adductor muscles but decreased significantly in
foot, gonad, mantle, and non-significantly in hepatopancreas in *L. marginalis* while the content increased significantly in gills, adductor mussels and hepatopancreas but decreased significantly in foot and non-significantly in mantle and gonad in *L. corrianus*. On the other hand, the content decreased significantly from all the body parts in *L. caeruleus*. In winter compared to summer, the lead content decreased significantly from all the body parts in *L. marginalis* and *L. corrianus* except in gills where it increased non-significantly. On the other hand, the content increased non-significantly in gills and mantle but decreased significantly in gonad, foot, adductor muscles and hepatopancreas in *L. caeruleus*. In winter, compared to monsoon the lead content decreased significantly from all the body parts in *L. marginalis* and *L. corrianus*. The content increased significantly in gills followed by hepatopancreas, mantle, and non-significantly in foot and adductor muscles but decreased non-significantly in gonad in *L. caeruleus*.

In the present study, the lead content was higher during summer in foot, mantle, gonad, hepatopancreas whereas during monsoon the content was higher in gills and adductor muscles in *L. marginalis* while the content was higher during summer in foot, mantle and gonad whereas during monsoon the content was higher in gill, hepatopancreas and adductor muscles in *L. corrianus*. The lead content was higher during summer and monsoon. In summer, the prevailing high temperature and demand to utilize more oxygen and food for metabolic activity. The lead concentrations within a certain trophic levels fluctuate considerably according to different dietary habits observed in monsoon reported by Plaskett and Potter (1979). In addition to organisms which feed on strongly contaminated material should be examined in order to determine how such material affects the overall metal concentration in the organism. This is particularly important for organisms which live in or feed on sediments (Oertel, 1998). Contaminants concentrations in the tissues of bivalves more accurately reflect the magnitude of environmental contamination. Monitoring programs and research for metals in the environmental samples have become widely established because of concerns over accumulation and toxic effects,
particularly in aquatic organisms and to humans consuming these organisms (Rainbow, 2002). Factors known to influence metal concentrations and accumulation in these organisms includes metal bioavailability, season of sampling, hydrodynamics of the environment, size, sex, changes in tissue composition, and reproductive cycle (Szefer et al., 2004). Seasonal variations have been related to a great extent to seasonal changes in flesh weight during the development of gonadic tissues (Rainbow, 2002; Szefer et al., 2004). One of the main reasons for the lack of correlation between element concentration in the water and in the tissues of the organism is the tendency to consider the total element concentration in the water instead of the element forms available to the mussel (Ravera, 2004; Maruo & Orians, 2006). Generally, the ionic form of an element is the most readily available, though there are exceptions (e.g., Hg, Pb). The particulate form may also be important for filter feeding animals like mussels. The relative proportion of the various element forms varies in relation to the element as well as to environmental conditions (Ravera, 2001). Maanan (2007) showed that the levels of Cd and Pb in the mussels collected from coastal waters (9.92, and 10.75 mg kg⁻¹, respectively) were lower than Baltic Sea coastal waters (33 and 13.4, respectively); whereas the levels of Hg (0.7) and Cu (17.04) were found to be higher than those obtained from Spanish Atlantic coast (0.11–0.61 and 5.33–7.2, respectively). Lead is used in building materials and mechanical industry as well as in batteries, cables, pigments and gasoline. Use of lead in gasoline and other fossil fuels has reduced dramatically in Norway from 225 tons to 4.9 tons (Huse, 1999). Lead exists in water mostly in particulate form (Balls, 1985).

In the present study, the lead content was higher during summer in foot, gonad, adductor muscles and hepatopancreas whereas during winter the content was higher in mantle and gills in I. caeruleus. The lead concentration was high during summer and winter, may be due to the seasonal changes in trace metal such as lead concentrations have been related to the factors such as food supply associated with an increase of productivity resulting from higher temperatures and longer days during
summer or seasonal metal content in the water body. These findings are dealt by Paezosuna and Marmoleja –Rivas (1990). Blue mussels take up lead from the water and food particles in similar rates and reflect environmental pollution effectively (Schulz- Baldes et. al., 1983; Phillips, 1976a; Julshamn, 1981a). E.P.A. (2006) has set the upper limit of lead concentration in mussels to 1.5 mg/kg fresh weight, when used for human consumption. Babukutty & Chacko (1992) observed higher lead, manganese and cobalt concentrations in the shells of the estuarine bivalve Villottoria cyprinoides V. cochinensis. Specifically, *M. balthica* has been used as an indicator of metal contamination for mercury, lead, silver and arsenic in several estuaries (Bordin et. al., 1992). Because the bivalves are in intimate contact with the sediments and feed mainly on the surficial sediments (they will occasionally filter-feed on suspended sediments) (Harvey & Luoma, 1985) their tissue concentrations tend to be indicative of bioavailable metals in the sediment. The acceptable lead levels for river sediments according to Cetesb (2005), up to 72.0 mg kg⁻¹. The sediment of the wetland in Ribeira to Iguape Basin represented higher concentrations than those obtained by Aksoy et. al. (2005) studied Sultan Marsh, a natural wetland in Turkey. The highest concentration in the Turkish wetland sediment was 7.9 mg kg⁻¹. The major sources of lead in the environment of significance to living organisms arise from lead mining and the refining and smelting of lead and other metals. Aquatic sediments are composed of several different geochemical phases that can act as potential sinks for metals entering an estuarine system. These phases include clay, silt, sand, organic material, oxides of iron, manganese, aluminium and silica, carbonates and sulphide complexes (Shea, 1988). Metal availability probably fluctuated with salinity in these lagoons during the seasonal cycle, probably caused the higher metal burden and concentration in the wet season (such as for Fe and Zn). Higher wet season levels of Fe and Zn might as well be due to 'import' as most roofing in Ghana are made of galvanized iron sheets. Lower wet season levels for Cd and Hg could be attributed to lost through spawning or washed-out of the lagoons during the rainy period. Many metals are also found in agricultural
products. Those present in fertilizers include Cd, Cu, Cr, Ni, Mn, Mo and Zn. Eventually, many of these metals may accumulate in soils and become exposed to run-offs during the rainy season (Phillips, 1977; Cossa and Rondeau, 1985). In nature, seasonal fluctuations in trace metal concentrations of animal tissues caused changes in metal body burden are superimposed upon a background of variation driven by changes in tissue weight. Any single change in metal concentration may reflect either one or the simultaneous influence of both variables. The effects of weight-driven changes on trace metal concentrations are found to be significant (Phillips, 1976, Simpson, 1979).

It has been observed that the zinc content increased significantly from all the body parts but in foot it decreased significantly in L. marginalis in summer compared to monsoon while the content increased significantly in gonad followed by gills, mantle, hepatopancreas and non-significantly in foot but in adductor mussels it decreased non-significantly in L. corrianus in summer compared to monsoon, while the zinc content increased significantly in gonad, gills, mantle and hepatopancreas but decreased significantly in adductor muscles and foot in I. caeruleus in summer compared to monsoon. In summer compared to winter, the zinc content increased significantly in hepatopancreas gonad, and adductor muscles and gills but decreased significantly in foot and mantle in L. marginalis while the content increased significantly in gills, gonad, hepatopancreas and mantle but decreased significantly in adductor mussels and foot in L. corrianus. On the other hand, the content increased significantly in mantle, gills and gonad and non-significantly in hepatopancreas but it decreased significantly in adductor muscles and foot in I. caeruleus. In monsoon compared to winter, the zinc content decreased significantly from all the body parts and non-significantly in adductor muscles in L. marginalis while the content increased significantly in gills and adductor mussels but decreased significantly in foot followed by mantle, gonad, and hepatopancreas in L. corrianus while, the content increased significantly in mantle, gills, foot and adductor muscles but decreased significantly in gonad
and hepatopancreas in *L. caeruleus*. In monsoon compared to summer, the zinc content decreased significantly from all the body parts but in foot it increased significantly in *L. marginalis*. The content decreased significantly in gonad followed by gills, mantle, hepatopancreas and non-significantly in foot but in adductor mussels it increased significantly in *L. corrianus* while the content increased significantly in foot and adductor muscles but decreased significantly in gonad, gills, mantle and hepatopancreas in *L. caeruleus*. In winter compared to summer, the zinc content increased significantly in foot and mantle but decreased significantly in hepatopancreas and gonad and adductor muscles and non-significantly in gills in *L. marginalis* while the content increased significantly in adductor mussels and foot but decreased significantly in gills, gonad, hepatopancreas and mantle in *L. corrianus*. On the otherhand, the content increased significantly in adductor muscles and foot but decreased significantly in mantle, gills and gonad and non-significantly in hepatopancreas in *L. caeruleus*. In winter compared to monsoon, the zinc content increased from all the body parts but in adductor muscles it increased non-significantly in *L. marginalis* while the content increased significantly in foot, mantle, gonad and hepatopancreas but the content significantly decreased in gills and adductor mussels in *L. corrianus*. The content decreased from all the body parts but in hepatopancreas it was increased non-significantly.

The present study indicated that the zinc content was higher during summer in hepatopancreas, gills, gonad and adductor muscles whereas during winter the content was higher in mantle and foot in *L. marginalis*. The zinc content increased in muscle tissues may be due to biological variables such as size, sex, or changes in tissue composition and reproductive cycle as well as environmental factors like, water temperature, pH, salinity and season of sampling. Biological variables such as size, sex or changes in tissue composition and reproductive cycle as well as the season of sampling and the hydrodynamics of the lagoons have to be considered (Otchere et al., 2000). Biological and geochemical factors can cause large variations in contaminant of metal levels. Similar observations have been made by
several authors (Brown & Luoma, 1995; Shindo & Otsuki, 1999; Stecko & Bendell-Young, 2000; Patwari, 2002; Zadpile, 2002). Seasonal variations have been reported to be higher in winter/dry than in summer/wet. These seasonal variations have been related to a great extent to seasonal changes in flesh weight during development of gonadic tissues (Cossa and Rondeau, 1985; Joiris et al., 1998; Othere et al., 2000, 2003). Shaffer (2006) observed the metal compared level of bivalve tissues sampled over two years period showed that Olympia oysters had higher tissue concentrations of arsenic, copper, zinc, and lead and than either Crassostrea gigas (Lofall site), or littleneck (Prototheca/Venerupis spp). Olympias had consistently lower levels of mercury. Levels of cadmium in Olympia oysters tissues relative to other bivalves varied by site. The changes in metabolic rates of bivalves with length and season as well as the variation in bioavailability of metals in the surrounding environment with time might be responsible for these variations in these molluscs (Boyden, 1974; Cossa and Rondeau, 1985). Phillips (1976) and Boyden and Phillips (1981) studied Mytilus galloprovincialis, M. edulis and Crassostrea gigas respectively and concluded that temporal variations in metal concentrations were mainly caused by changes in soft tissue weights of the bivalves according to the sexual cycle. Thus, alterations in the concentrations of metals reciprocated those of the whole soft tissue weights. Investigations of element seasonality in bivalve molluscs are important in terms of their implications for the use of these organisms as biological indicators of metal abundance. The accumulation of essential metals was low, specially for Zn observed in Macoma balthica (Bordin et al., 1994).

It has been observed that the zinc content was higher during summer in gonad, gills, mantle and hepatopancreas whereas during monsoon the content was higher in adductor muscles. During winter the content was higher in foot in L. corrianus while it was higher during summer in mantle, gills, gonad and hepatopancreas, during monsoon the content was higher in foot but during winter the content was higher in adductor muscles in L. caeruleus. The zinc content was higher during summer than monsoon and
winter. In summer the zinc content was enriched in sediment and water as a result of human activities and evaporation of water. The essential metal such as zinc have important biochemical functions in the organisms, they form either an electron donor system or function as ligands in complex enzymatic compounds. The concentrations of essential elements are generally higher in organisms than in water. If there is too great an in abundance of essential heavy metals, the metal content in the organism can be regulated by homeostatic control mechanism (Bryan and Hummerstone, 1977). The bivalves are in intimate contact with the sediments and feed mainly on the surficial sediments (they occasionally filter-feed on suspended sediments) their tissue concentrations tend to be indicative of bioavailable metals in the sediment (Harvey & Luoma, 1985). Guary & Fowler (1981) stated that muscle and mantle tissue retained "Antimony" effectively, but comparatively rapid loss from shell, byssus, viscera, and gills, analogous to the environmental influence on metal accumulation. Estuarine sediments are a major reservoir of trace metals, both of anthropogenic and natural origins (Bryan et. al., 1980, Langston, 1982). Mussels can accumulate 65-Zn and 241-Am from the dissolved state as well as from food, giving rise to somewhat different tissue distributions (Pentreath, 1973). Uptake from water is largely a result of metal adsorption to available surfaces, generally producing higher metal concentrations associated with byssal threads and the shell. Both Am and Zn are known to associate primarily with the periostracum rather than the calcite fraction of the shell (Hamilton &Clifton, 1980). A half-life of - 76d was calculated for 65- Zn in mussels contaminated at the mouth of the Columbia River and transplanted to cleaner waters off San Diego; after 1 yr, > 97 % of the 65-Zn in the soft parts was lost (Young & Folsom, 1967). Romeril (1971) and Engel & Brouwer (1984) found that Zn largely associated with metallothionein type protein in oysters. Shaffer (2006) reported that oysters had low cadmium and mercury levels than copper and zinc level. Zinc concentrations found in blue mussels varied between 15 mg/kg and 51 mg/kg fresh weight, while the normal values in the Hordaland county within the range of 17 - 22 mg/kg fresh weight (Julshamm
& Duinker, 2002). Despite the removal of the municipal wastewater discharges from the area, zinc concentrations in the Bergen centre are still high. The sediments in Michigan lake are markedly polluted by zinc (Nienke and Lee, 1982). Simkiss et. al. (1982) suggested that various types of ligands may bind metals in mussels, and these ligands may well vary among different tissues. Thus, they indicated that hydroxyl groups may be operative in the intestinal epithelium and byssal threads, metallothioneins in the gills, urates in the kidneys, and phosphates in the digestive gland. Several environmental factors have been significantly influenced mussel accumulation of metals, including temperature, salinity and dissolved organic carbon levels (Phillips, 1980). Chromium is one of the few elements of the periodic table which can affect mankind in all ways, as an important material used in technology; as a toxicant in food chains and to man, the final consumer, due to anthropogenic activity or to natural sources in the environment; and as an essential component for biological and physiological functions such as the maintenance of normal glucose tolerance (Mertz, 1969). Cr occurs in the natural environment almost exclusively in the trivalent state and its concentration in water ranged between 0.3 and 0.6 ppb (Riley & Chester, 1971). The ability of organisms to accumulate substantially in excess of ambient water levels well documented (Fukai & Broquet, 1965).

In the present investigation, in summer compared to monsoon, the chromium content increased significantly from all the body parts in L. marginalis and L. corrianus while the content increased significantly in hepatopancreas and mantle but decreased significantly in gonad followed by adductor muscles, gills and foot in L. caeruleus. In summer compared to winter, the chromium content decreased significantly in adductor muscles followed by hepatopancreas, gonad, foot, and gills decreased non-significantly but in mantle it increased significantly in L. marginalis, while, the content increased significantly from all the body parts in L. corrianus. On the otherhand, the content increased significantly in foot and non-significantly in adductor muscles but decreased significantly in gonad followed by mantle, gills and hepatopancreas in L. caeruleus. In monsoon
compared to winter, the chromium content decreased significantly from all the body parts in *L. marginalis* while the chromium content increased significantly from all the body parts in *L. corrianus*. The content increased significantly in foot, adductor muscles and non-significantly in gills but decreased significantly in gonad, hepatopancreas and mantle in *L. caeruleus*. In monsoon compared to summer, the chromium content decreased significantly from all the body parts in *L. marginalis* and *L. corrianus* while the content increased significantly in gonad followed by adductor muscles, gills, foot but decreased significantly in hepatopancreas and mantle in *L. caeruleus*. In winter compared to summer, the chromium content increased significantly in adductor muscles followed by hepatopancreas, gonad, foot and gills it non-significantly, but in mantle wherein it decreased significantly in *L. marginalis* while the content decreased significantly from all the body parts in *L. corrianus*. The content increased significantly in gonad, mantle, gills and hepatopancreas but decreased significantly in foot and adductor muscles and non-significantly in *L. caeruleus*. In winter compared to monsoon, the chromium content increased significantly from all the body parts in *L. marginalis* while the content decreased from all the body parts in *L. corrianus*. On the otherhand, the chromium content increased significantly in gonad, hepatopancreas and mantle but decreased significantly in foot and adductor muscles and but in gills non-significantly in *L. caeruleus*.

It has been noted that the chromium content was higher during summer in mantle whereas during winter the content was higher in hepatopancreas, adductor muscles, foot, gills and gonad in *L. marginalis*. The metal concentration in *L. marginalis* depends greatly on the body weight and hence the reproductive stage of the individual. Two factors known to modify Cr accumulations in molluscs are the weight of the organism and the salinity of the medium. Concentrations of Cr in clams were reported to decrease with increasing body weight (Eisler et al., 1978) and increasing salinity (Olson and Harrel, 1973). Accumulation of Cr by oysters (*Crassostrea gigas*) was independent of sediment, Cr levels and dependent on organism size—suggesting some homeostatic regulation of this metal
(Ayling, 1974). Clams, oysters, and mussels accumulate Cr from the medium or from contaminated sediments at comparatively low concentrations. For example, oysters subjected to 5.0 ppb of Cr+6 for 12 weeks contained 3.1 mg Cr/kg dry weight in soft parts and retained 52% of the accumulated Cr after they were transferred to Cr-free seawater for 28 weeks (Zaroogian and Johnson, 1983). At high environmental concentrations of Cr+6 (i.e., 2.0 ppm in water) and at alkaline pH, concentrations in rainbow trout tissues were greatest in gill, liver, kidney, and digestive tract; after transfer of the fish to Cr-free media, residues tended to remain high in kidney and liver; concentration in gill tissues tended to be greater at pH 7.8 than at pH 6.5 (Van der and Putte et. al., 1981a). Capuzzo and Sasner (1977) demonstrated that Cr in New Hampshire sediments (contaminated with Cr+3 from tannery wastes) was bioavailable to clams by diffusion from seawater, and that both diffusion and particulate uptake were important pathways for mussels. Accumulation was observed at sediment Cr concentrations as low as 150 ppm. Kaolinite sediments containing up to 1,200 ppm of Cr+3 produced the most pronounced adverse effects on filtration rates and ciliary activity of bivalve molluscs, leading the authors to conclude that Cr that has accumulated in areas affected by industrial wastes might have serious consequences to filter feeding bivalves. Chromium concentrations were high in digestive gland in muscles. Cr uptake and loss by the bivalves Crassostrea virginica and M. edulis were studied to determine their potential as an indicator of Cr pollution (Zaroogian & Johnson, 1983). Van der and Part (1982) studied with perfused gills showed that the transfer of Cr was directly coupled with the transfer of oxygen from the external solution to the internal perfusion medium and that this transfer was significantly more rapid at pH 6.5 than at alkaline pH. Several workers reported cytopathological changes induced by Cr in the gills of aquatic species. In the freshwater fish Barbus coachonius, Cr-exposed gills showed edema, collapse of pillar cells and desquamation of the respiratory epithelium, with consequent reduction of O2 uptake by the gill lamellae (Gill & Pant, 1987). Edible tissues of
commercially important North American molluscs contained 0.1 to 0.6 mg Cr/kg fresh weight (Hall et al., 1978).

In the present investigation it is found that the chromium content was higher during summer in mantle, gill gonad, adductor muscles foot and hepatopancreas in L. campanus. The heavy metal load in the tissue was possible due to variation in the ambient water temperature. Similar results were observed by Kulkarni (1987). The available data are of particular interest concerning filter feeding bivalves which are well known for their ability to reflect environmental levels of trace metal contaminants in aquatic ecosystems. It is established that the mussel Mytilus edulis can concentrate metals (Bryan, 1980). Metal concentrations in mussel tissue showed seasonal cycles, with minima in winter. This is in agreement with the results of Mubiana et al. (2005). Metal bioaccumulation showed bioavailability which highly depends on seasonal, meteorological, oceanographic characteristics and anthropogenic inputs (industrial, urban, and agricultural (Rainbow et al., 2000; Casas and Bacher, 2006). Most toxicity tests so far conducted involve continuous exposure of test animals to a constant concentration of the test substance, and obviously this does not necessarily simulate a natural pollution situation. Many pollutants occur in fluctuating concentrations, and others as single episodic events in which the pattern of exposure to toxic substances and its consequences may be different from those provided by conventional tests (Pascoe and Edwards, 1989). Hellmann (1970) stated that the chromium, cobalt, nickel, copper, zinc, mercury and lead have become sediment enriched chiefly as a result of man’s activities. Seasonal influences on the metal concentrations in the mussels. In fact, this influence the combined result of the biological cycle and the seasonal variations of the physical environment may be considered (Bryan, 1973; Metcalfe-Smith, 1994). The chromium content was higher during monsoon in foot, adductor muscles and gills whereas during winter the content was higher in gonad, hepatopancreas and mantle in L. caeruleus. Observed decreased value of metal concentrations in the tissues during a period of high phytoplankton density and an increased when the
phytoplankton density was low. Other several studies reported that phytoplankton and metal concentration in different water bodies (Lenka et al., 1990). Bryan (1973) observed an increase of metal levels in the tissues of marine bivalves during low phytoplankton density, and a decrease when the phytoplankton density was high. The rapid reproduction of the phytoplankton caused a decrease of the metal concentrations in the water and a low concentration of metals in the algal cells due to biological dilution. As a result the bivalves feed on phytoplankton poor in metals so that the metal concentrations in their tissues were low. In contrast, the low density of phytoplankton richer in metals was the cause of the high concentrations of metals in the bivalve tissues. Metal adsorption into the particles, metal sedimentation is accelerated and concentrations in the water decreases. On the otherhand, if a lower concentration of ionic metals in the water is available, mussels take up a greater amount of metals with the particles ingested as a food. In addition, a fairly important influence on metal concentrations in the water is constituted by iron and manganese co-precipitating with other metals in the presence of oxygen (Markich & Jeffree 1994). Chipman & Schommers (1968) observed that the mussels take up elements from the water and with food, and a fraction of these is accumulated in the soft tissues. A part of the metabolized elements is transferred from the mantle to the shell. A certain amount of the elements present in the shell is adsorbed from the water onto the periostracum, which is colonized by a film of bacteria, algae, protozoa and other small organisms. Copper is essential in respiration from many organisms and other enzymatic functions. It is stored in liver and bone marrow in humans. In contrast, some dissolved copper salts are hazardous for many algae, bacteria and fungi, as well as fish and plankton. An overdose in humans can cause liver damage, low blood pressure, coma or even death (Dons & Beck, 1993; Blomseth & Hartmann-Pedersen, 1995). Phillips (1976a,) considered using Mytilius edulis as a monitor for several metals, the uptake of copper by the mussel was erratic and unpredictable.
It is observed that the copper content increased significantly in mantle and non-significantly in adductor muscles but decreased significantly in gills and non-significantly in hepatopancreas, foot and gonad of *L. marginalis* in summer compared to monsoon while the content decreased significantly from all the body parts of *L. corrianus* in summer compared to monsoon. The content increased significantly in mantle, foot and non-significantly in gills but decreased significantly in gonad, adductor muscles and hepatopancreas in *I. caeruleus* in summer compared to monsoon. In summer compared to winter, the content increased significantly from all the body parts in *L. marginalis* whereas the content decreased significantly from all the body parts in *L. corrianus*, while, the content increased significantly in foot and mantle but decreased significantly in hepatopancreas, gills, gonad and adductor muscles in *I. caeruleus*. In monsoon compared to winter, the copper content increased significantly from all the body parts in *L. marginalis* while the content increased significantly in adductor muscles followed by gonad, gills, hepatopancreas and mantle but decreased non-significantly in foot of *L. corrianus* while the content increased significantly in foot, adductor muscles and gonad but the content decreased in significantly in, gills mantle and hepatopancreas of *I. caeruleus*. In monsoon compared to summer, the copper content increased significantly in gills and non-significantly in hepatopancreas, foot, and gonad. On the other hand, the content decreased significantly in mantle and non-significantly in adductor muscles in *L. marginalis* while it increased significantly from all the body parts in *L. corrianus*. The content decreased significantly in mantle, foot, gonad, hepatopancreas and gills it was non-significantly but in adductor muscles it increased significantly in *I. caeruleus*. In winter compared to summer, the copper content decreased significantly from all the body parts of *L. marginalis* while the content increased significantly from all the body parts of *L. corrianus*. The content increased significantly in hepatopancreas, gills, gonad and adductor muscles but decreased significantly in foot and mantle in *I. caeruleus*. In winter compared to monsoon, the copper content decreased significantly from all the body parts in *L. marginalis* while the
content decreased from all the body parts except in foot, it increased significantly in *L. corrianus*. On the other hand, the content increased significantly in gills, mantle and hepatopancreas but decreased significantly in foot, adductor muscles and gonad in *L. caeruleus*.

In the present study, the copper content was higher during summer in mantle and adductor muscles whereas during monsoon the content was high in foot, gonad, gills and hepatopancreas in *L. marginalis*. As the body weight decreased, the concentration upwards retained in newly acquired metals (Zaroogian et al., 1983). These results were reported by Eisler et al. (1978) and Olson and Harrel (1973). Blue mussels accumulate copper in the body although the species can regulate the uptake (Phillips, 1976a; Davenport, 1977; Davenport & Manley, 1978; Julshamn, 1981a). Copper concentrations in blue mussels ranged from 0.8 to 4.1 mg/kg fresh weight. Normal values of copper in blue mussels in the Hordaland county are 0.5-2.0 mg/kg fresh weight (Julshamn & Duinker, 2002). The acceptable levels for copper in river sediments are according to Ceteb (2005), up to 60.0 mg kg⁻¹. Young et al. (1979) reported extremely high concentrations up to 127 mg/kg dry weight, of copper in blue mussels in the harbor area in Southern California. There is also a large dry-dock in Puddefjorden. On a dry-dock, old paint is removed from ships by sandblasting. Spillage from sandblasting operations and leakage from removed paint particles has previously been recognized as a direct source of copper to water (Degerman & Rosenberg, 1981; Sekse & Kvingedal, 1992). In general, studies on heavy metals can be important in two main aspects. First, from the public health point of view, where the attention has been drawn to the necessity of measuring the accumulation of heavy metals, particularly the metals which pose serious health hazards to humans (e.g. Cd, Pb, Hg). Secondly, from the aquatic environment the main problem has been to prevent biological deterioration and to identify the sources which threaten ecological equilibrium. In this regard, the more abundant metals such as copper, zinc and manganese may sometimes represent greater hazard than lead, mercury and cadmium (Kinne, 1984). The copper content was higher during summer in mantle, adductor muscles,
gills, hepatopancreas and gonad whereas during winter the content was higher in foot in L. corianus. It is observed that the increased metal concentrations may be due to the environmental factors as well as water in which they live. These findings were observed by Patil (1993) and Mansour et al. (2005). Davi Gasparini (2007) observed that the spatial-temporal distribution variation was pronounced in copper concentrations in the river sediment. The higher concentrations were detected during January, in which it rained more than in October sampling. Diffused pollution sources have to be considered to explain the concentration increase during the rainy month, like agriculturist activities and cattle breeding in small properties around the study area. Meiggs (1980) found that both mussels and sediments were significantly contaminated by copper and zinc in the vicinity of a dry dock. Contaminated food probably represents a more important source of copper than water and thus burdens in fish cannot be consistently related to ambient pollution levels in water (Moore and Ramamoorthy, 1981). Viarengo et al. (1990) showed the relationship between copper exposure and changes in lipid peroxidation in the mussel Mytilus galloprovincialis. Lipid peroxidation and resulting damages are modulated by antioxidant systems (superoxide dismutase, catalase, glutathione peroxidases, glutathione). Contaminated food probably represents a more important source of copper than water and thus burdens in fish can not be consistently related to ambient pollution levels in water (Moore and Ramamoorthy, 1984). Despite the existence of a number of detoxifying and storage systems for Cu, it is the most toxic metal after mercury and silver, to a wide spectrum of marine life, hence its value in antifouling preparations (Clark, 1989). The higher level of copper recorded for Siganus rivulatus relative to that in Sargus sargus is due to the food habit where the first is herbivorous and the second feeds mainly on crustaceans, molluscs beside small fishes. The same results were previously recorded by Pourang (1995) in two fish species (Carassius auratus and Esox lucius) collected from Anzali wetland water in Northern Iran.
From the above study, it is observed that the copper content was higher during summer in foot and mantle whereas during monsoon the content was higher in adductor muscles and gonad. During winter the content was higher in gills and hepatopancreas in *L. caeruleus*. The increased metal level may be due to high metabolic rates and uptake rate increased from monsoon to summer. Similar observations were made by (Scott, 1972). Phillips (1976) found that cadmium uptake was increased and lead uptake was decreased in *Mytilus edulis* near to fresh water inputs of trace metals. During spring, snow melting and heavy rains increase freshwater runoff from land. Increase of metals levels in tissues of some invertebrate and fish species were observed during summer months that was related to the increased metabolism due to high temperature (Uysal and Tuncer, 1984; Alliot and Frenet-Piron, 1990). Metal accumulators have often been used as accumulation indicators of environmental metal pollution. Mussels can play an important role in the environments where they are very abundant (Dame et. al., 2002). One of the main reasons for the lack of correlation between element concentration in the water and in the tissues of the organism is the tendency to consider the total element concentration in the water instead of the element forms available to the mussel (Ravera, 2004; Maruo & Orians, 2006). Mussels have several characteristics which appear to indicate their use as bio-monitors for estimating the environmental pollution level and the bioavailability of various types of pollutants (Metcalf-Smith et. al., 1996; Ravera, 2001). Bivalves, including blue mussels (*Mytilus edulis*), have been found to be suitable bio-monitor species for trace metals (Goldberg, 1975; Phillips, 1976a; 1977; Brown & Luoma, 1995; Julshamn & Grahl-Nielsen, 1996; Riget et. al., 1996). Blue mussel is capable to accumulate trace metals such as cadmium, mercury and lead to a larger extent than fish and algae (Julshamn, 1981a; Julshamn & Grahl- Nielsen, 1996).

Thus, from the above study it is found that the metal concentrations determined in *Lamellidens marginalis* is found that the quantity of mercury, cadmium and lead in mantle and foot tissue is relatively high compared to
other soft tissues in summer, in monsoon it was high in mantle, adductor muscles and foot while in winter it was high in mantle and adductor muscles. On the other hand, the metals like zinc, chromium and copper accumulate to the maximum by mantle, foot and hepatopancreas tissues in summer, monsoon and winter. The mantle and foot tissue appeared to be a target organ to store more metals in summer, monsoon and winter probably due to its direct contact with water and more surface area exposed to environment. Mansour et al. (2005) reported that the ability of invertebrates to adsorb metals is largely dependent on the physical and chemical characteristics of the metal as well as the seawater in which they live. Many metals are also found in agricultural products. Those present in fertilizers include Cd, Cu, Cr, Ni, Mn, Mo and Zn. Eventually, many of these metals may accumulate in soils and become exposed to run-offs during the rainy season. The accumulation of mercury by other organ is more gradual and probably related to transport from gills to other organs, the mercury concentration of gills increases with time and is present in high concentration. The gills therefore, represent an organ, which function both as a site of uptake for mercury as an important reservoir for the total mercury body burden (Roesijadi and Fellingham, 1987). The above cited studies and several other studies indicate that the gills, rather than the internal organs are the initial site for metal toxicity during exposure to water born heavy metals (Ravera, 2004). Cd, Cu and Zn loads of the molluscs exceeded environmental concentrations, but not so for the apparently less bioavailable Pb where traffic emissions probably caused increased metal contents. High environmental metal concentrations were poorly reflected by the bioindicator species. The gastropods showed about 20-fold higher concentrations than the bivalves. This may indicated a higher Cu regulation capacity of bivalves. The suitability of the investigated molluscs species as bioindicators depends on their specific relationship to the environmental compartment. According to Gundacker (2000) and Lakashmanan and Nambisan (1989) the bivalves are well known for their ability to concentrate heavy metals in their tissue from environment. Bioaccumulation and depuration of Hg, Cu, Zn and Pb from the
muscles *prena viridis* (*Linnaeus*) from seawater and explores it as indicator organism for metal pollution. Zn, Cu, Mn and Fe were determined in the soft body parts (mantle, gill and adductor muscle) of *Crassostrea cucullata*. The concentrations of Zn were higher than other metals analyzed. Gill and mantle exhibited higher concentration of metals than the adductor muscles. Concentration of all metals enhanced in all the body parts during the monsoon months observed by Mitra *et al.* (1994).

It is found that the metal concentration determined in *Lamellidens corrianus* is found that the quantity of mercury, cadmium and lead in mantle and hepatopancreas tissue is relatively high compared to other soft tissues in summer, monsoon and winter. On the otherhand the metals like zinc, chromium and copper accumulated to be maximum by mantle, foot and gonad tissue. The mantle and foot tissue observed to be a target organ to stored more metals in summer, monsoon and winter. The low nutrition status of the muscles due to increased uptake of food and water increased concentration of metals in the soft tissues in these seasons. Klaric *et al.* (2004) observed in winter and spring the concentration increase in the soft tissues, due at least partly to the low nutrition status of mussels in these seasons.

Many investigators have observed seasonal variations of heavy metal load in water, sediment and animal body. Gokhale (1994) reported enhanced level of heavy metals in gastropods *Dostia voloccia* and *Cerithidiopsilla degadiaviensis*. Bhosale and Matondkar (1987) found variations in trace metals in two populations of green muscles. Kraak *et al.* (1993) suggested that every increase in dissolved Cd concentration in water resulted in a significant increase in its concentration in muscles. The same was observed by Graney *et al.* (1983) and Timmermans (1993). Consequently, if Cd were available in the environment, muscles would probably accumulate it. A strong linear relation between Cd accumulation was found in zebra muscles (Castilho *et al.*, 1984). Klaric *et al.* (2004) established that, although Cd occurs in the aquatic environment in only trace concentrations, most aquatic organisms, especially mollusks and
crustaceans can accumulate it rapidly. Cadmium and lead are non-essential elements that accumulate in tissues of living organisms, causing toxicity problems to local biota and to man (Förstner and Wittmann, 1983). Huanxin et. al. (2000) stated that the environment affected by contaminants, both oyster tissues and shells have an opportunity to adsorb heavy metals from suspended particles. These suspended particles may be either as contaminated sediment or sediment controlled by the behavior of heavy metals themselves, and the physical and chemical conditions of the environment. Therefore, there are no clear relationships between concentrations of heavy metals in the giant clamshell and those in sediment.

In the present study, the metal concentration determined in *Indonaia caeruleus* is found that the quantity of mercury, cadmium and lead in gonad, foot and gill tissue is relatively high compared to other soft tissues in summer, monsoon and winter. The gonad tissue appeared to be a target organ to store more mercury, cadmium and lead in summer, monsoon and winter. On the otherhand the heavy metals like zinc, chromium and copper accumulated to be maximum by foot and adductor muscles. From the observations foot and gonad tissue is stored more metals compared to other soft tissues in summer probably due to the mechanism of uptake / accumulation which are interdependent on the metabolic rates and tissue absorption sites within the body. Similar observation was reported by Scott, (1972). Hebling, (1976) stated that the other physiological parameters have to be taken into consideration, such as the reproductive cycle, stress caused by manipulation and adaptation to another environment, which is impossible to control which might affect the intake of Cd and Pb by the muscles. The changes in the physiology may result in changes in rate of intake, storage and excretion of metals by organisms, resulting in changes in concentrations (Naimo et. al., 1992). Patil and Mane (1998) observed that the environmental parameters like temperature, pH, total alkalinity were high while the oxygen content was comparatively low in summer than monsoon and winter on the habitat of *L. corriarius* from the Godavari river at Kaigaon showed that the muscles face a drastic situation of above environmental
parameters and probably low food availability in summer may be due to gonad development is arrested for a short period of a couple of months, from the second fortnight of April to the first fortnight of June. Bivalves, in particular, exhibit growth and reproductive cycles that result in seasonal changes in the metabolism of the animals, which may affect the rate of absorption and/or excretion of some metals (Kraak et al., 1993; Naimo et al., 1992). Radhakrishnaiah (1988) while studying the effect of cadmium on freshwater bivalves Lamellidens marginalis showed that the cadmium gains entry largely through the gills, the first physiological function to be affected is oxygen consumption. He showed that the drastic suppression in the rates of oxygen consumption and ciliary activity of these muscles. With the increase in exposure period in lethal concentrations may be due to considerable damage to gill tissue and the formation of mucus layer over it. This may cause decreased flow of water on the gill surface leading to the reduced intake of oxygen. Biological variables such as size, sex or changes in tissue composition and reproductive cycle as well as the season of sampling and the hydrodynamics of the lagoons have to be considered. Seasonal variations have been reported to be higher in winter/dry than in summer/wet. These seasonal variations have been related to a great extent to seasonal changes in flesh weight during development of gonadic tissues (Cossa and Rondeau, 1985; Joiris et al., 1998; Otchere et al., 2000, 2003). Bivalves can concentrate pollutants in their tissue at concentrations greater than the ambient seawater (Szefer et al., 2004). The metal concentration in bivalve tissue could be based on sediment concentration (Thomann et al., 1995; Chang and Wang, 2000; Kwon and Lee, 2001).

Seasonal biochemical changes were observed in different tissues of Lamellidens Corianus. The study was done by analyzing the protein, glycogen, lipid, cholesterol and ascorbic acid contents from different body parts like mantle, gill hepatopancreas, gonad, foot and adductor muscles (both anterior and posterior muscles combined). The content expressed in terms of mg g⁻¹ body parts, on dry weight basis in summer, monsoon and winter. The studies on biochemical changes enable to define the dose
response relationship, threshold limit value and reversible and irreversible nature of pollutant effect. In addition, to the biochemical indices of toxicity derived after a relatively short exposure time may useful in predicting the appropriate threshold concentration of chronic effects (Christensen et al., 1977). Jadhav (1993) determined the physiological status and biochemical composition of freshwater bivalve *Corbicula striatella* while lipid content was not significantly different, protein and carbohydrate levels were significantly lower in infested versus non-infested mussels. Energy metabolism in bivalve molluscs dealing with relationship among different body tissue and their energy requirements and metabolic transformations of reserves have been dealt by Gabbot (1975, 1976), Sastry (1979), Muley (1985) and Patil (1993). Glycogen is utilized as energy by marine bivalves prior to and during the reproductive cycle, while proteins and lipids are conserved. After spawning, proteins and lipids are utilized as energy, while glycogen reserves are recovered (Gabbot 1976, Kreeger and Langdon, 1993, Berthelin et al. 2000a). The mechanism of this phenomenon has been the subject to numerous investigations (Friberg et al., 1979; Prabhakar Rao, 1989). Many of the observed toxic effects are though to be the result of secondary deficiencies in essential trace elements like Zinc, Manganese, iron, etc. Cadmium are induced deficiency of these elements has been demonstrated by several workers (Ashby et al., 1980; Anke et al., 1997) Similar effects on the essential elements and deleterious effect due to cadmium was reported by Patil (1993), Kulkarni (1993), Patil and Mane (1998). The gain in the body weight has been correlated with food supply in surrounding water for gonad development and building of reserves. It has been shown that when the food supply is limited in environment, the reserves are utilized, while studying the biochemical reserves of mantle, foot and adductor muscles (organs playing an important role in opening and closing the shell valves) of fresh water bivalve *Lamellidens corianus*. The bivalves exposed to several environmental factors may reflect adaptive metabolic mechanisms due to the challenges of the challenging environment including the pollutants (Patil, 1994). Intra cellular and extra cellular proteins have the capacity to
bind foreign compounds and reduce the concentrations of these compounds at the active sites of enzymes involved in their metabolism. This capacity to bind foreign compounds results from the presence of proteins of hydrophobic region that bind lipid soluble (non–water soluble) compounds and hydrophilic regions that contain polar side chain of amino acids capable of forming hydrogen and electrostatic bonds with polar groups in water soluble foreign compounds (Noel, 1975). As expected, the % protein in the gonad tissues reached a maximum in December and a minimum in June, correlated with the water temperature. The values (30–65%) were similar to those found in the digestive gland of oysters from France (Berthelin et al., 2000a). Venkatraman and Chari (1951) observed that the protein value coincided with spawning season in Ostrea maclurasensis and in Meretrix casta. Patil (1993) also measured glycogen, protein, and lipid content in captive and wild freshwater mussels. Although they reported no significant differences in glycogen and lipid levels, there were lower protein levels in captive mussels compared with those taken directly from the natural environment. These studies provided evidence that biochemical content of freshwater mussels, including protein and lipid, can be adversely affected by environmental stress and zebra mussel infestation. These results differ from those of previous studies in which glycogen, protein, or lipid levels declined in captive, nutritionally stressed, or zebra mussel-infested mussels (Noel, 1975; Patil, 1993; Patterson et al., 1997; Gatenby, 2000; Newton et al., 2001). T. verrucosa Zebra mussel infestation, which presumably causes nutritional stress in freshwater mussels, results in catabolization of first glycogen and then protein stores in freshwater mussels (Doherty, et al., 1993). Starvation also results in a decline in glycogen and protein content as well as lipid content of mantle tissue over a time (Patterson et al., 1997) because gametes contain high levels of protein and lipid (Bayne et al., 1978), storage of these substrates in bivalves vary seasonally with the gametogenic cycle (Gabbott and Walker, 1971; Kreeger and Langdon, 1993; Berthelin et al., 2000a). Monroe and Newton (2001) stated that the protein concentration varied over time in whole bodies of A. plicata and A.
*ligamentina* collected from the Mississippi river and reported a decline in protein and lipid content of mantle tissue in nutritionally stressed mussels. Mutvei and Westermark (2001) found a decrease in glycogen, protein, and lipid levels in nutritionally stressed mussels, Patwari (2002) found no difference in glycogen, protein, or lipids in emersed mussels compared to controls.

From the present observation in summer, the protein content decreased significantly from all the body parts compared to monsoon but from adductor muscles it decreased non-significantly while the content increased significantly in hepatopancreas, gonad, mantle, and gills but decreased significantly in foot and non-significantly in adductor muscles compared to winter. In monsoon, the protein content increased significantly from all the body parts compared to both season while foot and adductor muscles it increased non-significantly compared to both season. In winter, the protein content decreased significantly in mantle, gills, hepatopancreas and gonad but increased significantly in foot and non-significantly in adductor muscles compared to summer while the content decreased significantly from all the body parts but decreased non-significantly in foot and adductor muscles compared to monsoon.

The protein content was higher during monsoon in foot followed by hepatopancreas, adductor muscles, gills, mantle, and gonad compared to both season. In monsoon, the protein content was increased from all the body parts compared to summer and winter. It has been observed that the protein content was increased during monsoon may be due to all tissue build up body reserves to the maximum than in winter and summer, but in this season the metabolic energy is also utilized for maturation of the gemmates. Hence, the detoxification mechanism probably increased in this season. Similar findings were observed by Patil (1993), Patil and Mane (1998), Zadpide (2002) and Patwari (2002) in *L. corrianus* at Nandrabad pond. The digestive gland has been known as a site of nutrient storage in bivalves for several decades (Nakazima, 1956; Owen and Sandhu, 2000; Bayne et al., 1978). An inverse relationship between the size of the digestive
gland and the development of the gonad was found in some species, suggesting the transfer of nutrients from the digestive gland to the gonad (Giese, 1969; Sastry, 1971; Voigt, 1972; Vassallo, 1973). Shejul and Zambre (2003) reported that the increased in the level of protein in the ovary, while contrast results were observed in the hepatopancreas. Shingadja and Sakthivel (2006) reported that the estimation of proteins at the end of the treatment period of 48 and 96 hrs. showed significant changes (depletion) in the vital tissues like gills, hepatopancreas, gonads, mantle and foot as compared to the values of the control group of animals. The gills and hepatopancreas suffered the greatest damage followed by gonad, mantle and foot. The high concentration of total proteins in gonads of both sexes may be explained by the presence of structural proteins in gametes of both sexes, and also reserve proteins in the female oocytes. These results were similar to the descriptions by other authors, who considered proteins to be the principal component of bivalve oocytes, along with lipids (Gabbott, 1983). Nagabushnanam and Lomte (1972) reported that the protein level of most of the body components of Parryesia corrugata is very high (30–75%). They further showed that the protein levels of the gonads are quite variable and are highest when they are gravid which presumably reflected the high protein content of the maturing gametes. The energy required to carry out the gametogenic process can be covered by using directly ingested food or the previous storage of reserves in the gonad or other tissues (Ansell, 1974; Gabbott and Bayne, 1973; Barber and Blake, 1983; Pazos et al., 1997). The increase in protein levels in most of the body parts exposed to mercury is also evidenced in mollusc, L. corrianus due to increased mercury binding proteins associated with stabilization in mercury concentration for storage and detoxification of certain sub-cellular compartments (Patil, 1993; Patil and Mane, 1998; Choudhary, 1999). Detoxification impairment due to exposure of Mytilus edulis to mercury enhanced the mercury binding proteins (Roesijadi, 1981). This might result in increase in the protein content in certain tissues of the freshwater bivalves like Indonaia caeruleus (Vedpathak and Mane, 1988). Barkarti and Ahmed
(1991) indicated minimum valves opening during April to June, the spawning time, soon after which the biochemical components showed a rise in the content. The result clearly showed that decreased in tissue weight was mainly due to glycogen. A drop in protein percentage occurred in May where as in lipids a major loss occurred in April – May. Percentage of variations in glycogen content was similar to the variations in their weight due to which an inverse relationship developed between protein and glycogen. In general, glycogen is most suitable substrate for aerobic and anaerobic metabolism as an immediate source of energy and maintenance of this reserve material is an essential feature of the normal metabolism (Zadpide, 2002) The glycogen reserves of the pallium are utilized for anaerobic respiration during adverse conditions, (Deshmukh, 1995). Glycogen is the main storage house of carbohydrate in bivalves (Hummel et. al, 1989) and the primary energy reserves (Dezwaan and Zandee, 1972). Glycogen and lipid proportions in oyster tissues varied considerably seasonally and between years within the range < 2 – 12%. Where comparisons can be made the total body lipids are within the range recorded for Pacific oysters from other parts of the world (Almeida et. al., 1997 and Kang et. al., 2000). Patwari (2002) reported that glycogen content often decreases in mussels subjected to environmental stress before mortality occurs. They found that mussel-fouled L. corrianus had a 50% reduction in glycogen content compared to the un-fouled control, but survival did not differ between the groups, because, it is typically the first energy reserve to be used. Although glycogen is the main energy reserve in bivalves, proteins and lipids are important energy sources throughout the reproductive cycle, especially in nutritionally stressed individuals (Bayne, 1973, Hummel et. al., 1989). Gatenby (2000) reported that compared to controls from the Ohio River glycogen levels of captive mussels decreased 58-77% after 1 year and 87-93% after 3 years. Newton et. al. (2001) observed significantly lower glycogen levels in pond-relocated mussels than river-relocated mussels. Seasonal variations in glycogen content have been observed in previous studies of freshwater mussels. Amblesia plicata and A. ligamentina collected from the Mississippi River had their highest glycogen
levels in the spring and lowest in late fall, which was attributed to their gametogenic cycle (Monroe and Newton, 2001).

It has been observed, that the glycogen content increased significantly in hepatopancreas, and non-significantly in gonad and foot but decreased significantly in mantle and non-significantly in gills and adductor muscles in summer compared to monsoon. The content decreased significantly from all the tissues except in adductor muscles it increased significantly and non-significantly in gills in summer compared to winter. In monsoon, the glycogen content increased significantly in gills, adductor muscles and non-significantly in mantle but decreased significantly in hepatopancreas, gonad and non-significantly in foot compared to winter, while, the content increased significantly in mantle and non-significantly in gills and adductor muscles but decreased significantly in hepatopancreas and non-significantly in gonad and foot compared to summer. In winter, the glycogen content increased significantly in hepatopancreas, mantle, gonad, and non-significantly in foot but decreased significantly in adductor muscles and gills compared to summer while the content increased significantly in hepatopancreas, gonad and non-significantly increased in foot but decreased significantly in gills, adductor muscles and mantle it decreased non-significantly compared to monsoon.

The glycogen content increased during monsoon in mantle, adductor muscles and gills, whereas during winter it was increased in hepatopancreas, gonad and foot. The glycogen content increased in mantle tissue when the gonad tubules are reduced, the mantle tissue contains numerous storage cells and there is maximal glycogen metabolism and storage capacity. Similar observations were reported by Berthelin et al. (2000b). Most of the glycogen content from the depot tissue like hepatopancreas was being utilized during this winter season for the body maintenance as observed by Patil and Mane (1998). Patwari (2002) observed that the glycogen content increased in depot tissue like hepatopancreas during summer season for body maintenance after exposure to mercury. Patil (1993) observed that the hypothesis by
biochemical investigation that the conversion of glycogen into lipid within developing oocytes occur. Kulkarni (1987) found that the quantity of stored glycogen varied from one species to another according to the individuals resistance towards environmental perturbations on the same habitat. The glycogen level in Penaeus merguiensis in the gonad increased during the peak of reproductive phase observed by Pillay and Nair (1973) in Fidler crab Uca annulipes, showed that low glycogen occurred during the reproductive cycle when pre-stored glycogen is converted into lipid during vitellogenesis. There was high glycogen in the mantle tissues between April and August, before increase in gonad volume (Perdue & Erickson, 1984). Nagabhushnanam and Lomte (1972) reported that the freshwater mussel, Parryesia corrugata the highest glycogen correlated with the period of sexual activity. Nagabhushananam and Mane (1975) observed low level value of glycogen during the period when the clams were in the mature stage. Glycogen was at its peak in immature clams. Glycogen concentrations were higher in the other tissues and the seasonal pattern was similar to that of the digestive gland, with two annual minima and a peak in summer. As far as the gametogenic stages were concerned, there was a major decrease from the sexual rest to the mature stage (Susana Darriba, 2005). Traditionally, the physiological and nutritional conditions of bivalve molluscs have been monitored by evaluating tissue of glycogen content (Gabbott and Walker, 1971; Willis et al., 1976). The deposition and utilization of not only glycogen but also lipid by the bivalve molluscs may be influenced by a number of factors, seasonal variations in tissue glycogen and lipid contents are important in the reproductive cycle, are well documented (Galtsoff, 1964; Swift et al., 1990). Ruiz et al. (1992) reported in Crassostrea gigas found that glycogen accumulation was followed by a period of gametogenesis. Lipid biosynthesis during vitellogenesis was associated with glycogen breakdown. High variation in carbohydrate levels during storage and gametogenic development suggests the carbohydrates are the main respiratory substrate. In contrast, proteins and lipids are important for supporting energetic costs during winter when the available food is scare as
indicated by low chloride level. Susana Darriba (2005) stated that the gametogenesis is a process that requires energy. In females, there is a demand for lipids, especially triacylglycerols, evidenced by the numerous lipid droplets in the yolk and the low quantities of glycogen. In spermatogenesis, there is a demand for energy required by the multiplication of cells and a need for structural lipids for the membranes. Swami et. al. (1983) suggested that the flux of carbon through the Kerb’s cycle can be controlled by the relative channeling of glucose 6-phosphate through pentose phosphate pathway and generated acetyl co-enzyme A into the pathway of lipid biosynthesis. The two metabolic pathways are complimentary to each other as one provides NADPH required for lipogenesis over the other. Many workers studied the lipid alteration in different animals after exposure to toxicants (Kulkarni, 1993; Jadhav, 1993; Deshmukh, 1995).

It has been observed that the lipid content increased significantly in mantle, gonad and non-significantly in adductor muscles but decreased significantly in hepatopancreas, foot and non-significantly decreased in gills in summer, compared to monsoon while, the content decreased significantly from all the tissue in summer, compared to winter. In monsoon, compared to winter the lipid content decreased significantly from all the tissues but in hepatopancreas it increased non-significantly. The content increased significantly in hepatopancreas and foot and non-significantly in gills but decreased significantly in mantle, gonad and in adductor muscles it decreased non-significantly compared to summer. In winter, compared to summer the lipid content increased significantly from all the tissues while as compared to monsoon the content increased significantly from all the tissues except in hepatopancreas wherein it decreased non-significantly.

The lipid content increased during monsoon in hepatopancreas whereas during winter it was increased in gonad, gills, foot, mantle and adductor muscles. The lipid content increased in hepatopancreas and gonad tissue as it is depot a tissue and also transformation of glycogen into lipid probably due to its diminished transport from the tissue like hepatopancreas to other organs, similar results were observed by Patil (1993), Patwari (2002).
and Zadpide (2002). Hiswankar et al. (1988) found that elevation in the lipid content in most of the body parts of *L. marginalis* is due to mercury stress. The authors further found that the protein synthesis from most of the tissue of *L. marginalis* due to mercury occurred since mercury might have bound plasma protein and intracellular proteins. The rapid increase of mercury binding proteins was associated with stabilization in mercury concentration of certain sub cellular compartments. The increase in the lipid content which occurred almost in most of the tissues in different seasons is probably related to the anoxic endogenous oxidation process providing extra high energy for survival. Similar observation was reported by Patwari (2002) in *L. Corrianus* at Nandrabad pond. Adiyodi and Adiyodi (1971a) suggested a possibility of mobilization of hepatopancreatic phospholipid and unsaturated fatty acids according to the vitelogenesis need in *paratelphusa hydrodromous*, Decline of lipid content in hepatopancreas and increase in the lipid content in the gonad during reproductive phase of reproductive cycle in *Penaeus merguiensis* is in agreement with the findings of Mathur (1994) in freshwater crab, *Barytelphusa guerini*. Shejule and Zambre (2003) observed that the increased in lipid values in the ovary during peak period of gonad activity, where decline in the lipid level of hepatopancreas. Okumus and Stirling (1998) showed that the change from lipid to glycogen storage in *Mytilus edulis* juveniles was a time related event and was not associated with the onset of sexual maturity. Accumulation of carbohydrate reserves in several bivalve species occurred prior to the onset of gametogenesis. Warren (1973) reported that the decreased in the level of lipid content of hepatopancreas during reproductive cycle in pink shrimp *Pandalus montagus*. Voogt (1983) stated that lipids in bivalves is multifunctional and in different species, one or some of the functions during the maturation of gametes, drastic environmental conditions, starvation, pollution stress etc. can be more noticeable. Such a role of lipid in body maintenance metabolism during mercury stress on *Lamellidens marginalis* was reported by Patil (1993). Many researchers studied the lipid alternation in different animals (Kulkarni, 1993; Jadhav, 1993; Deshmukh, 1995;
Choudhari, 1999; Jeffrey et al., 2003). It is pertinent to mention that the bivalve have the capacity to rely upon protein and lipid reserves at the time of energy demand (Zs-Nagy, 1977). Storage of lipids in the digestive gland and glycogen in the adductor muscle, during periods when food availability exceeds the metabolic demand, and which are subsequently utilized in energy-requiring processes including gametogenesis, has been described in several different scallops (Lubet et al., 1987b; Román et al., 1996, Pazos et al., 1997). However, in E. arcuatus the foot also appears to act as a storage site for glycogen, with a high quantity of reserves, because of its size. Okumus and Stirling (1998) and Gabbott (1975) have discussed the transition from a lipid-protein based energy metabolism in Ostrea edulis larvae to a carbohydrate-protein based energy metabolism in the sessile juvenile and adult stages. They reasoned that the lipid was a preferred energy reserve for planktonic existence; the disadvantages of increased specific gravity were offset by the ability to respire carbohydrate anaerobically in the sessile adult. Ren, et al. (2003) observed that the biochemical composition (% glycogen, lipid, protein) of separated gonad and somatic tissues were variable seasonally and annually. Gametogenesis (oocyte diameter) was associated with increased gonad protein and glycogen and a decrease in lipid concentrations. Khan et al. (2001) observed that the increased lipid level may be due to inhibition of lipase activity and lipid synthesis due to enhanced cadmium toxicity. Increase in the lipid content is attributed to the inhibition of enzymes activity of lipid metabolism after heavy metal treatment. (Bhagyalakshmi, 1981; Gangashettiwar, 1986; Jaiswal, 1986). McClintock & Pearse (1987) observed that the pattern of biochemical composition in the Echinoidea, was independent of species and geographical location. Protein appears to be the main component in animals belonging to this class, whereas lipid and glycogen levels are always lower. Somasunderam et al., (1978) considered that the concentration of AA depend upon the physiological state of the fishes. Rise in temperature increases metabolism in bivalve is well known (Mann, 1979; Mane and Tailkhedkar, 1976). Patwari (2002) reported that the
acute stress of mercury in summer caused significant increase in the AA content from foot and adductor muscles and decreased from mantle, gill, hepatopancreas and gonad. This decrease is possibly related to the increased demand of energy by all the body parts during toxic stress and also fatigue retardation. Similar decrease in the AA content from brain, gut and shift to muscles and other parts of *Channa gaucha* during acute physiological conditions were recorded by Ali et al. (1983).

It has been observed that in summer, compared to monsoon the ascorbic acid content decreased from all the tissues while the content increased significantly from all the tissues but increased non-significantly in foot compared to winter. In monsoon compared to winter and summer the ascorbic acid content increased significantly from all the tissues. In winter, compared to summer and monsoon the ascorbic acid content decreased significantly from all the body parts and except in foot wherein it decreased non-significantly.

In the present study, the ascorbic acid content was increased during monsoon in hepatopancreas followed by gills, mantle, adductor muscles, gonad and foot compared to both seasons. The increased level of ascorbic acid in the hepatopancreas possibly induced mixed function oxidase system and played a role of biotransformation of toxic substances to nontoxic ones. Similar observations were made by Kachole et al. (1977). The decrease in ascorbic acid content can be accounted to the increased demand of resistance by these tissues during the behavioral activities like valve opening and extension of the organs. Kulkarni et al. (1988) reported in *Indonaia caeruleus* and found that the ascorbic acid content at normal temperature in combination with pH resulted in the increase in ascorbic acid content from mantle and foot and from gonad in low pH. From hepatopancreas it was combined effect of pH and temperature. Increased the ascorbic acid content from gonad exposed to low pH and from hepatopancreas in both low as well as high pH it was decreased. The increased in the ascorbic acid content due to active conversion of ascorbigen to free AA accomplished by increased rate of utilization. Similar observation was made by Chinoy and Sitalakshami
(1977) and showed that increase in ascorbic acid content due to active conversion of ascorbigen to free AA accompanied by increased rate of utilization in steriodogenesis and also in secretory mechanism of reproductive body parts of the slug, *Laevicaulis alte*. Earlier, it has been reported that in control group, *L. marginalis* showed high content of ascorbic acid in summer than in monsoon and winter at Kagzipura swamp (Zadpide, 2002). Ascorbic acid (AA) stimulates the growth of neoplastic tissues (Bickwell and Prescott, 1953). AA a water soluble vitamin and is required for collagen and hard body parts formation in wound healing and haemorrhage and vertebral injuries (Mallete *et al.*, 1968). Ginter (1972) attributed the reduction of cholesterol by AA. On the otherhand, Spittle (1989) observed that AA enhances the activity of protein and lipase and is essential for proper metabolism of fat. The concentration of free amino acids in the tissues and extra cellular fluid compartment of molluscs was shown to vary with diet, season, temperature, reproduction and developmental stage and also environmental stresses related to desiccation, anerobiosis, osmotic pressure, pollution and parasitism (Bishop *et al.*, 1983). Barber and Blake (1985), Kreeger and Langdon (1993) suggested that mussels can be nutritionally limited by available energy or protein, depending on their dietary availability. However, O : N ratios do not distinguish whether substrates being catabolized are derived from the diet or from reserves in the tissues, and rates of catabolism must be compared to overall energy or protein balances to ascertain the contribution to tissue production. Protein and energy are paramount nutritional components for aquatic suspension-feeder. In general, dietary carbohydrates (and lipids) are catabolized to meet the energy demand of the animals, whereas dietary protein is required primarily for tissue biosynthesis. To study the adaptive mechanisms with which suspension-feeder balance their energy and protein requirements from natural diets (Langdon and Newell, 1990; Urabe, 1993), Patil and Mane (1998) observed that the cholesterol contents in almost all the tissues of *L. marginalis* was decreased significantly possibly due to the synthesis of anti-inflammatory and anti-allergic compounds. The demand of cholesterol
biosynthesis was more in mantle and hepatopancreas. Patil (1993) observed that comparatively almost all the tissue fairly stored high level of cholesterol content in winter than monsoon and summer, it may be possibly related to the increased synthesis of it as well as probably derived from the phytoplankton existing in the Kagzipura swamp. Comparatively, the cholesterol content decreased from gonad tissue in monsoon and winter compared to summer possibly due to the synthesis of sex steroids.

It has been observed that in summer compared to monsoon, the cholesterol content increased significantly in hepatopancreas and foot but decreased significantly in gills, mantle, gonad and non significantly in adductor muscles while the content increased significantly from all the tissues compared to winter. In monsoon compared to winter, the cholesterol content increased significantly from all the tissue while the content increased significantly in gills, mantle, gonad and non-significantly in adductor muscles but decreased significantly in hepatopancreas and foot. In winter compared to summer and monsoon the cholesterol content decreased significantly from all the body parts.

The cholesterol content was increased during summer in hepatopancreas and foot whereas during monsoon it was increased in gonad, gills, adductor muscles and mantle. In L. coriarius it is observed that hepatopancreas and gonad are the sties of major cholesterol synthesis due to the changed ecological factors. The rise in temperature and pH probably due to activated steriodogenesis in gonad and hepatopancreas. Major cholesterol synthesis found in hepatopancreas and gonad due to the ecological factors like water salinity with plenty of phytoplankton availability as a food of bivalve mollusc. Similar results were obtained by Swami et al. (1983) in L. marginalis exposed to pesticide toxicity. Rao et al. (1987) observed that the Indonaia caeruleus from lotic environment showed hepatopancreas and gonad as the sites of major cholesterol synthesis due to the changed ecological parameters. In Indonaia caeruleus changed ecological parameters probably activated the steriodogenesis oriented towards the formation of corticosteroidism since stress conditions elevate the
corticosteroids in the blood of animals. There is a possibility of the tissue metabolism in synthesizing anti-inflammatory and anti-allergic cortisone derivatives from the cholesterol and other precursors (Rao, 1987). Cholesterol is about 1/3rd of total sterols present in many species of bivalves (Johan and Kim, 1976; Patil, 1993). The freshwater bivalve, *Indonaiia caeruleus* exposed to normal water temperature and also at pH 5.35 and 10.6 at 34°C with a control of normal pH 7.5 at 34oC showed that cholesterol content from mantle hepatopancreas, gonad and foot was changed by these ecological factors (Rao et al., 1987). Susana Darriba et al. (2005) observed that the storage of reserves in *E. arcuratus* took place during summer when the upwelling phenomenon occurred, leading to phytoplankton blooms and consequently high food availability. This process produced surplus of ingested nutrients, which were accumulated as reserve lipids in the digestive gland and as glycogen in the anterior adductor muscle and the foot. Berthelin et al. (2000a) measured the biochemical composition of different tissues including the adductor muscles, gonad/mantle and digestive gland. It is concluded that proteins from muscle tissue contributed little to the reproductive tissue which forms from glycogen and lipids stored in the digestive gland, mantle, and gonad. Seasonal variation in total lipids in the gonad was less evident; the main lipidic component was triacylglycerol (around 10% of the dry weight), whereas total cholesterol accounted for less than 1%. The gut does not seem to act as a storage tissue in *P. lividus* and seasonal variation in biochemical components may be a consequence of fluctuations in the availability of food. Susana Darriba et al. (2005) suggested that mobilization of nutrients from other tissues was necessary to provide energy for gametogenesis, molecules for multiple cell divisions, and reserves for gametes, especially oocytes. Biochemical changes within New Zealand oyster tissues were associated with the reproductive cycle as described from the histological examinations and the weight relationships (Mann, 1979; Kang et al., 2000). Suspension-feeding animals are important agents in the regulation of biogeochemical nutrient cycles and recycling of
nutrients for primary producers, e.g. bivalve molluscs (Officer et al., 1982; Dame et al., 1989; Asmus and Asmus, 1991).

In the present study, it has been observed that from all the body parts like mantle, adductor muscles hepatopancreas and gonad stored more glycogen in monsoon and winter season as well as the protein and lipid content also increased in all the body parts in monsoon season. Thus the body "build-up" of these metabolites occurred in monsoon at the time of favorable environment. Subsequently, with the arrival of the winter season, the food availability comparatively declined and it has been stated that these freshwater bivalves in this season undergo retarded growth and utilized most body reserves for maintenance metabolism (Muley, 1985). Khan et al. (2001) found that the increased protein level is probably due to high rate of zinc binding to protein which was more pronounced at higher concentration. The glycogen content was stored in muscle tissue (anterior adductor muscle and foot), as well as in the digestive gland. When the availability of food was high in summer, glycogen was stored, but it was mobilized when gamete development started in autumn. These glycogen reserves may allow the synthesis of lipids in the gametes, as reported by several authors (Waldock and Holland, 1979; Beninger and Lucas, 1984; Lubet, 1996), in addition to maintaining the energy requirements of gametogenesis. Mohan and Kalyani (1989) studied the variation in biochemical of the body tissue such as digestive gland, foot, gonad and posterior adductor muscles. Protein level increased from January till a peak level attained during June and thereafter decreased to minimum indicating the maturation and spawning activity of the gonads except in foot, the carbohydrate level were higher in all other body parts. The carbohydrate level decreased in the gonad during monsoon and increased during the near reproductive period. Lower level of lipid in the gonad in April and June indicating an intermittent spawning which increased gradually in July with intensive feeding resulting in storage of fat before spawning. Seasonal variation in total lipids was less evident than for the other biochemical components. Total lipid levels in the gonad of P. lividus were similar to those of other echinoids, whereas the levels in the gut
were between two and three times lower (Fenaux et al., 1975; Serrazanetti et al., 1995). Penney et al. (2001) showed that neutral lipid was the major energy reserve of larvae and young spat of *Mytilus* species. In a subsequent review, Okumus and Stirling (1998) suggested that, due to its abundance and ease of mobilization, lipid is probably the major energy reserve in many aquatic invertebrates.

It has been observed that the AA plays an important role in steriodogenesis. It is likely that this also played an important role in maturation of the gametes particularly in monsoon and winter. The presence of steroid hormones and the ability of the synthesis of sex steroids have been dealt by Rao (1987). Zadpide (2002) observed that the ascorbic acid content played an important role in steriodogenesis. Patil et al. (1994) showed induction of mixed function oxidase system wherein ascorbic acid is known to play an important role in biotransformation of toxic cadmium to the non-toxic one. Patil (1993) observed the AA content was high in gill tissue compared with other tissues. It is increased level is probably related to the increased resistance to the critical environment faced by the animals during the particle sorting and respiration processes. Meyer and Meyer (1971) stated that since the biosynthesis of fatty acids and steroids requires large portion of the cells energy would evidentially be considerable selective advantage to the organisms to abandon these pathways. Seasonal changes in 17-β-hydroxysteroids dehydrogenase activity in the bivalve *Crassostrea gigas* has been studied histochemically; activity increased as maturation of gonad took place and then declined after spawning (Mori et al., 1986). It has been observed that the cholesterol increased may be due to the phytoplankton availability as a food in bivalve molluscs and ecological factors. Stoilov et al. (1984) observed that the depth and season of collection of bivalves *M. galloprovincialis, cardium edule* and *Tapes ruguts* considerably influenced the steriol compositions including cholesterol, probably due to the changes in phytoplankton composition. Cholesterol has been shown to be synthesized in gastropods and bivalves (Tishima and Patterson, 1981). The report of Yasuda (1971) stated that in freshwater
muscles higher concentration of steroids exist than snails. Patwari (2002) reported that the cholesterol content decreased from gonad tissue in monsoon than the winter and summer possibly due to the synthesis of sex steroids.