**DISCUSSION**

The physico-chemical environment has profound impact on its biotic components in aquatic ecosystems. It controls diversity, biomass and spatial distribution of biotic communities with respect to time and space. The physical and chemical parameters exert their impact both individually or collectively and their interaction produces abiotic environment which ultimately supports the origin, development and finally succession of biotic communities. Further biotic communities, in turn continuously later abiotic environment, thus a constant interaction between the abiotic components goes on in a dynamic ecosystem. Each ecosystem has its characteristic abiotic features and their through understanding is essential for its effective management and conservation.

Change in the environment cause stress to the aquatic organism (Newell, 1973), change in metabolic activity and cause metabolic disarrangement in the living system. An animal does not exist apart from its environment without certain expectation. Most of the animal faces nutritional uncertainties, marked diurnal and seasonal variations which alters rates of metabolism and activity (Hoar, 1987). Successful living demands continued physiological
adjustment in relation to environmental variables. Precisely timed physiological processes must prepare the animals for diverse activities like growth, reproduction, aestivation, migration, etc.

In terms of energy conservation, the organism would be expected to make compensatory adjustments for both gain and loss of energy in such a way that gain is maximized and loss is minimized in case of a change in environmental conditions (Bayne, 1973).

Temperature is one of the most important factors having profound influence on the biotic communities and the degree of annual variations in temperature of water body has a great barrier upon the productivity. In general temperature of atmospheric air and water depend on geographical location and meteorological conditions such as rain fall, humidity, cold cover, wind velocity etc. Apart from limiting distribution, depending to tolerance limits, temperature has profound effect on the metabolic rate in almost all organisms. Relatively very few habitats offer animals with a constant environmental temperature. In response to this reality, animals at all levels in physiology have developed mechanisms to meet the normal temperature variations of their surroundings (tolerance) and to withstand the extremes for periods of varying lengths (resistance or resistance adaptation).
In tropical regions like India in general the conditions are hot-dry from March to May, hot-wet from June to September, cool-wet in October and November and cool-dry from December to January. During the hot period the day length increases, i.e. from March to September. These weather conditions can have considerable impact on the life of bivalve molluscs, especially in the areas lacking heavy rainfall. The bivalve molluscs living especially in lotic environment have to face drastic environmental changes than those in lentic conditions.

In tropical countries, one may accept a direct relationship between the duration of bright sunshine and temperature. Many studies show that sunshine hours and temperature influence the solubility of gases in water, particularly that of carbon dioxide and oxygen, possibly long hours of sunshine enable the phytoplankton and other shrub population of the water body to carry on photosynthesis for a longer duration. This helps in the utilization of carbon dioxide in water. However, high summer temperature and bright sunshine increases the rate of decay of organic matter resulting in the liberation of large quantities of CO$_2$ and nutrients. Apparently, this CO$_2$ is utilized during photosynthesis by blue green algae which are abundant in the flowing (rivers) and standing (lakes) water during summer.
As a part of genetic environment, every animal has a capacity to compensate for environmental change. It can live with in certain range of variations, whether the variable is temperature, humidity, oxygen supply or any other environmental factor. Among several physical, chemical and biological factors, temperature is regarded as one of the most important factor which influences the animal’s activity in the environment.

Temperature of water on the habitat of *Parreysia cylindrica* (on field) is fluctuated within a very small range in the successive fortnight but in the view of seasonal variability there was much difference in temperature recorded during winter season was on December and January (18.0 – 22.0°C) and during summer, on April and May (28.0 – 32.5°C). The variations in temperature in monsoon were more. In winter it was fluctuated in narrow range, whereas it was fluctuated in range i.e. between 28.0 - 32.5°C on longer day lengths from April to May during summer.

Dissolved oxygen content is one of the most important abiotic factors influencing the life in an aquatic environment. There are two main sources of dissolved oxygen in water, diffusion of oxygen from atmosphere which depends on factors like wind action, temperature and salinity, and also on transparency, turbidity, Carbon dioxide and algal biomass. At a given point of
time factors like temperature, transparency, nutrient load and biomass of autotrophs determine the level of dissolved oxygen. Normally high dissolved oxygen is found in unpolluted aquatic ecosystem, while lower levels of the same in polluted areas. Further depletion of dissolved oxygen is due to the level of anaerobia, which is the most critical manifestation of pollution.

While working on the freshwater bivalves from the water bodies in Maharashtra state a decrease in the dissolved oxygen content during summer and high dissolved oxygen during winter and monsoon were observed by Akarte (1985), Muley (1988), Vedpathak (1989), Kulkarni (1993), Nagwanshi (1997) and Pandit (2005). Godavari river at Paithan and at Kaigaon near Aurangabad, show comparatively very low values of dissolved oxygen Muley (1988) Vedpathak (1989) and Kulkarni (1993), where the values of dissolved oxygen ranged from 6.53 to 8.82 mg/l/h. The water in Girna river of Jamda, district Jalgaon is heavily innervated by humans and cattle’s, particularly at the habitat of the bivalve mollusces. It is worthy to note that the water getting polluted at the above site shows low values of oxygen which comparatively does not got polluted. Intermediate values of dissolved oxygen in monsoon could be attributed to dilution factor and turbidity that
adversely affected the algal biomass and photosynthetic replacement of oxygen. Higher values of dissolved oxygen could be due to relatively stable abiotic conditions and higher algal biomass which stimulated the rate of photosynthesis. Compared to winter, low values of CO₂ from April to June could be due to higher water temperature, high BOD and lower rate of photosynthesis due to reduced algal biomass. The rate of decomposition might be playing an important role in controlling the oxygen level. Increased temperature of summer (April, May and early June) possibly stimulated the degree of decomposition in which dissolved oxygen is invariably utilized leading to fall in its value.

pH of the water (Hydrogen potential) is an acid alkalinity range (7-14) and negative logarithmic expression of hydrogen-ion concentration; 7 being neutral, less than 7 as acidic and above 7 as basic or alkaline. Generally, slightly alkaline conditions are favorable for growth of algal species in lotic (river water systems) system (Blum 1953), While acidic conditions are detrimental, alkaline conditions support productivity and diversity. It is well known that animal life seldom occurs at pH below 4.7 and above 8.5. (Carpenter, 1928), fluctuations in pH between 4.7 and 8.5 are
explained differently by different workers, pH of water is
dependent upon the relative quantities of calcium, carbonates and
bicarbonates. The water tends to be more alkaline if it possesses
carbonates and bicarbonates of calcium and CO$_2$. Higher total of
alkalinity indicates its high tropic status as per the classification of
Philipose (1959). According to Reid (1961), on the maintenance of
ph values between 7 to 9, bicarbonates are of great significance. In
addition, the environmental pH depends upon low contents of
alkali and alkali earth ions are removed from mineral surfaces.

Under natural unpolluted lotic environment, the pH of water
on the habitats of the bivalve molluscs was shown to increase in
monsoon than summer and winter, (Akarte, 1985, Vedpathak,
1988; Kulkarni, 1993; and Dhakane, 2005). The reported values of
pH ranged from 7.7 to 9.27 in the Girna river. The pH change is
controlled by the amounts of free CO$_2$ and HCO$_3$ and is directly
related to the pH value (Kant and Raina, 1990). The authors stated
that any change in the former complex has a direct bearing on the
maximum and minimum values of pH. In addition, the heavy
rainfall by causing considerable dilution of water and increase in
the buffering effect, caused fluctuations in the pH.
According to Trivedy et. al., (1985) as soon as the productivity is increased, the pH of water also increased simultaneously. In so far as hardness (as normally measured in terms of calcium with or without Mg$^{++}$) and pH are usually interrelated in natural waters (the pH being largely determined by the bicarbonate concentration resulting from the solution of calcium). The pH is the important factor which can influence the growth of organism either directly or by altering the nutritional status of the medium (Rajratnam et al. 1987). These authors further stated that in waste water treatment or energy production applications, pH control probably is not required but for these mass culture applications that requires the maintenance of specific species, such as aquaculture or the production of chemical derivatives pH control is necessary.

The need of oxygen is always continuous throughout the life of an active animal. The production of ATP in large amounts requires continuous supply of oxygen. The rate of supply depends on anatomical and physiological characteristics of the organs of respiration and transport pigments. In addition, the actual oxygen content of the environment could be a limiting factor while other environmental variation like temperature or chlorinity may impose
extra demands for oxygen or affects the rate of exchange. Each of the atmospheric gaseous gets dissolves in water according to its partial pressure, its solubility, coefficient and the temperature. Rising temperature reduces the solubility of gases. In addition, the solubility of gases is also altered by the presence of dissolved solids.

The Freshwater molluscs, as a whole, seem to possess a greater physiological adaptability than, marine molluscs (Berg et al., 1958). It is important to know the respiratory function of these animals to understand the physiological adaptation of species, since many features of aerobic metabolism can be studied indirectly by measurement of the rate of oxygen consumption by intact animals. Seasonal variation in oxygen consumption is, therefore, a quality which must be considered in intra - and inter - specific comparison of the physiology of the animal.

The oxygen sensitivity and oxygen uptake rate of many freshwater organisms appear to reflect the habitat in which they live (Fox et al., Van Branch et al., 1950). Bayne (1976) stated that in the light of the many varied effects of environmental change on respiration rate, it is not surprising to find a regular seasonal pattern in the rate of oxygen consumption by some species. The results
obtained on oxygen consumption which declined in small and large sized animals on monsoon and winter and it accelerated in both small and large sized animals on April and May during summer season. This is likely due the low temperatures in winter and declining food availability in the external environment, whereas oxygen uptake was accelerated during monsoon and summer seasons likely due to high temperature.

The seasonal shifts in the rate of oxygen consumption when correlated with the reproduction and biochemical constituents, from different body parts of Parreysia cylindrica, Tangade (2012) showed that levels of oxygen consumption are probably balanced with the timing of utilization of body reserves and reproduction so that there is a selection of body reserves and reproduction. The low values of respiration with low values of glycogen and protein contents from the gonad, hepatopancreas and mantle of the mussel, stated that lowered metabolic rate could be due to starvation and probably shift in the emphasis from carbohydrate oriented metabolism to a lipid or protein oriented metabolism. In Mytilus edulis, Bruce (1926) found a seasonal pattern of oxygen consumption with high values in winter and spring, and low values in summer on the other hand, the same species maintained at the
constant temperature, showed high rate of oxygen consumption in the spring; declining to the minimum rate after spawning in the summer and increasing again in the autumn (Kruger, 1960).

Both the authors correlated this seasonal pattern with the cycle of gametogenesis, and storage and utilization of nutrient reserves. Bruce (1926) concluded that the increasing proportion of gonad material in the body during the late summer and autumn increased oxygen demand of the mussels. In spite of these marked seasonal changes in oxygen demand, which are at least in part, independent of the temperature Bruce (1926) estimated that in the natural populations temperature would be more important in controlling the rate of respiration than innate physiological changes. However, temperature acclimation factor was ignored by Bruce. In the present study, as stated above, the rise in temperature in summer months as well as at 32.5°C under experimental conditions resulted in the increase in the rate of oxygen consumption which is probably due to the maintaining of the body metabolism (as has been discussed by Bayne, 1976). It is also probable that increase in the rate of oxygen consumption is accounted due to the increase in the day length (as has been
suggested by Chanchal et al., 1979). However, effect of such parameters requires special attention.

Thompson and Bayne (1974) and Widdows (1978); while working on a marine mussel *Mytilus edulis* observed that the respiratory level required to maintain this mussel increases with body size and that there may be enough food available in winter to support small individuals but insufficient to prevent utilization of body reserves in large mussels. In summer, the maximum ingestion rate is greatly in excess of growth and the production of gametes in same genus.

In the present study on *Parreysia cylindrica* increase in the rate of oxygen consumption during summer from April to May till June in small sized bivalve giving maximum values. This summer period coincides with high temperature, causing ventilation rate to increase resulting in increasing amount of oxygen delivered to gills. This probably leads to increase filtration rate and resulting in maximum ingestion rate greatly exceeding the maintenance ratio to provide the excess energy for growth and the production of gametes. From April to June is the period of increasing temperature; decreasing water level and the increasing day length gradually which leads the animal bed exposed in May. Increase in
the rate of oxygen consumption during summer months is due to increase in day length and rise in temperature has been estimated by Muley (1988) and Vedpathak (1989). The increased rate of respiration in summer and decline thereafter is directly proportional to sunshine, temperature and pH content and phytoplankton density. Since bivalves are living at the primary level of the food chain in a given aquatic ecosystem, the increase in the primary productivity can not be ruled out as observed by Meena Nagwanshi (1997) and Pandit (2005) during summer season.

The results obtained in the present study on *Parreysia cylindrica* from Girna river at Jamda, district Jalgaon revealed that the rate of oxygen uptake varies with size and weight of the animals throughout the year. The rate of oxygen consumption was accelerated in small sized animals 0.7377 ± 0.01049, 0.7912 ± 0.02014 mg/l/h during summer, 0.6558 ± 0.02540, 0.6019 ± 0.0464 mg/l/h during pre-monsoon, and 0.7653 ± 0.0128; 0.6496 ± 0.04190 mg/l/h during post-monsoon and 0.6691 ± 0.02722; 0.7314 ± 0.02193. In large sized animals it was 0.4849 ± 0.0218; 0.4545 ± 0.00678 mg/l/h during summer; 0.5135 ± 0.02424; 0.5463 ± 0.02227 mg/l/h during pre-monsoon and 0.7370 ± 0.1360; 0.6277 *Parreysia cylindrica* 0.02678 mg/l/h during post-monsoon and
The weight specific rate of oxygen consumption is found in large sized animals and high rate is found in small sized animals is a general rule. Kennedy and Mihursky (1972) determined effect of temperature on the oxygen uptake of the bivalves of different sizes. It is generally accepted that in bivalves the oxygen uptake per unit time is low in smaller animals and high in bigger ones, while the weight specific oxygen uptake is high for smaller ones and low of for bigger ones. The rate of oxygen consumption during winter was 0.7314 ± 0.02722 mg/l/h in small sized animals, and 0.6234 ± 0.3125 mg/l/h in large sized animals. The rate then increased during summer 0.7912 ± 0.02014 mg/l/h in small and 0.4545 ± 0.0676 mg/l/h in large animals. The rate of oxygen uptake was also low in monsoon 0.6019 ± 0.0464 mg/l/h in small and 0.5463 ± 0.227 mg/l/h in large animals.

In these animals the rate of oxygen uptake was low in winter followed by monsoon than summer. Similarly, it was seen that in different seasons, small animals respired at higher rate in monsoon than winter, while large sized animals respired at lower rate in winter than monsoon. Amongst the major environmental factors
high temperature and low dissolved oxygen prevailing in summer might be responsible to increase the rate of oxygen consumption in small and large sized mussels for their maintenance of metabolism. During summer the total alkalinity was high. In spite the high level of dissolved oxygen and pH in winter, the existing low temperature might be responsible for the low respiratory rates in large sized mussels. The sulphates and phosphates were low at this time, probably accounting to low productivity and low food available to these mussels during winter. In the present study, the results further showed that an average respiratory rate as minimum during winter and maximum during summer season. The rate of oxygen consumption also higher in monsoon 0.7653 ± 0.0128 mg/lit/hr, than winter 0.6691 ± 0.2722 mg/lit/hr. comparatively low values of pH and hardness in terms of carbonate were observed. In addition, existence of most of cloudy days and reduction in photosynthesis during monsoon probably accounted for low dissolved oxygen compared to post-monsoon and winter; likely have an impact on oxygen uptake of the mussels. Apart from these factors day lengths, i.e. bright sunny days in different seasons of the year also might have played role in bringing about the cyclic changes in the oxygen consumption of the mussels, i.e. the increase
in rate of oxygen consumption during summer could also be due to the increase in the day length.

In the present study, it was further noticed that the increase in the rate of oxygen consumption particularly in small animals during summer could be correlated with the gametogenic activity in the gonads of the mussels. This condition probably exerted the increased demand of energy for gametes development and maturation since glycogen, protein and lipid in the gonad increased in summer than in other tissues like hepatopancreas, mantle, gill, foot and both in anterior and posterior adductor muscles.

Many authors have stated that ammonia in general is a major nitrogenous excretory product of bivalves and there occurs profound differences in loss of nitrogen between different sizes and seasons (Bishop et al., 1983). This indicates shifts in physiological capacity with changes in temperature, season and reproductive cycle that affect the nitrogen economy and the metabolic rate in somewhat disparate fashions. The O: N ratio is an index of protein utilization in energy metabolism a few investigators also demonstrated the probable role of ammonia in the settlement of larvae of different bivalves. Bayne and Scullard (1977) stated that in bivalve mollusc, the relationship between ammonia excretion
rates and body size can be variable due to a disproportionate reliance of protein catabolism for energy production by smaller individuals and the O: N ratio was shown to vary considerably with the in complex interaction with season, temperature and ratio in *Mytilus edulis*.


Bivalves are important cycles of nitrogen in coastal marine systems releasing ammonium and dissolved organic nitrogen that can be taken up directly by phytoplankton (Dame, 1996). Several recent freshwater studies have concluded that excretory products from bivalves should be an important and readily useable resource
for phytoplankton (James, 1987; Lauritsen and Mozley, 1989) and presumably the benthic algal community. Christian and Berg (2000) and Davis et al. (2000) compared seasonal nitrogen and phosphorus cycling by three unionid species in two freshwater streams. Prior studies indicated that nutrients were limiting in both systems. So any nutrients contributed by the bivalves should be useful biologically. They found that, while excretion rates varied seasonally, the direction and magnitude of these changes were species specific. In addition, Matisoff, Fisher and Matis (1985) found that unionid activities indirectly influenced nutrient cycling by enhancing the rate of nitrate release in sediments.

Nitrogen (N) and phosphorus (P) are of particular interest in stream ecosystems due to their roles as limiting nutrient for primary production (Mulholland et al. 1995). Nitrogen and Phosphorus excreted by molluscs are present in the forms of ammonium (NH$_4$ - N) and phosphate (PO$_4$ 3-P). Because unionids can reach high densities in some streams (Christain and Berg, 2000). We propose that the amount of ammonium and phosphate excreted by unionids may serve as a significant source of N and P to local primary producers.
During winter and spring, presumably due to primary reliance on carbohydrates for energy metabolism, larger individuals were more reliant on protein catabolism, resulted in higher ammonia excretion rates. Increased protein catabolism is indicated by high level of ammonia excretion and decline in O : N ratio (Bayne, 1973) and thus changes in the rates of nitrogen excretion are best understood in the context of physiological energetic and nitrogen balance, when related to overall metabolic rate by means of the O : N ratio. The O : N ratio does not alter with size i.e. the exponents for rates of oxygen consumption and ammonia excretion against body weight are similar in *Topes tapillus* (Stikle and Bayne, 1982). The author stated that the mussel is dependent on protein for energy production which is less than healthy *Mytilus edulis* from temperate waters. A positive correlation between O : N ratio and body weight was established in *Perna viridis* because of the higher exponent for oxygen consumption than ammonia excretion against dry body weight. Rise in temperature enhanced the excretion rate. According to Khalil (1994) in *Tapes decussalus* ammonia excretion rate varied with body weight, temperature and starvation. Where as ammonia excretion rate was higher for starved clams than for fed clams of all sizes and at different temperatures. O:N ratio provides an indication of the relative catabolic balance
between carbohydrates, lipids and proteins and has been used to describe the physiological state of marine mussels (Bayne and Scullard 1977, Widdows 1978, Tedengren and Kautskv 1986). In mussels, individuals with O:N ratios of greater than 50 are considered physiologically “healthy”, while individuals with ratios less than 30 are considered “stressed” and catabolysing internal protein (Bayne et al., 1985) (Thomas et al., 1993).

In all seasons Parreysia cylindrica showed an increase in the rate of ammonia excretion with increasing body weight. There is decrease in the rate of ammonia excretion with increase in body weight. No definite conclusion could be drawn regarding the body weights of these bivalves and rate of ammonia excretion because the size ranges in two groups was considerably narrow. The oxygen consumption increased with increasing biomass but the respiration rate was decreased, whereas, ammonia released never matched the rate predicted by adding sediment effluxes to oyster excretion. The O:N ratio was influenced by oyster biomass. It was observed that the excretion rate in the Parreysia cylindrica was reduced much in June than April despite the fact that the temperature of the habitat water got reduced. Low value of O:N ratio is generally indicative of a stressed condition (Bayne and
Newell, 1983). According to author Mya arenaria exhibited a significant decrease in oxygen consumption and increase in ammonia excretion during turbidity treatment compared to control one. The authors suggested that the decrease in O:N ratio in exposed clam was due to utilization of body reserves to meet nutritional demands during exposure. In Parreysia cylindrica was observed that the rate of ammonia excretion was influenced greatly on August showing significant rise in excretory rate and decreased before the onset of rainy season. The higher rate of ammonia excretion was noted during summer i.e. April - May (0.0229 ± 0.00117 mg NH₄–N/L) and during winter on December- January (0.01347 ± 0.00153 mg NH₄–N/L). This period corresponded to the high water level on the habitat, increased turbidity and decline in the water temperature. During summer, i.e. on April and May as well as June the water level decreased considerably, oxygen content was low and temperature increased which probably caused increase in the rate of ammonia excretion.

Mathew and Menon (1993) reported that in Perna indica and Donax incarnatus, O:N ratio was influenced due to stress of heavy metals like Hg, Cu and Cd. Donax incarnatus showed increase in O:N ratio at low concentration suggesting less utilization of
protein, the ammonia excretion rates increased with increasing body mass and showed a difference between withering and non withering abalones. Authors observed seasonal pattern of metabolism depending on temperature fluctuations in relation to oxygen consumption, ammonia excretion in *Dreissena polymorpha*, Navarro and Torrijos (1994), determined a seasonal fluctuations in oxygen consumption, ammonia excretion and O:N ratio in a predatory gastropod, *Concholepas concholepas*. Oxygen consumption rate increased in spring at low temperature than summer and ammonia excretion was maximum in spring and minimum in autumn. These corresponded to the gametogenic activities of the animal. The values of ratio in small and large sized animals on August (monsoon) was increased as compared to summer and winter which showed that the bivalves had more protein substrate utilization than the value of ratio on monsoon, It is possible that in July and August, a period of monsoon, the bivalves build up the body reserve and there by increased the O:N ratio.

Studies on the energy metabolism are concerned with the ways in which the major carbohydrates, lipid and protein fuels are used by an organism for an energy production. In the present study
biochemical analysis from different body parts of *Parreysia cylindrica* in different seasons was done. The glycogen, a polymer of glucose is an energy reserve of animal tissues and maintenance of glycogen reserve is a essential feature of normal organism, glycogen is perhaps the first organic constituent to be utilized under stress conditions, is found to drastically decrease during the entire exposure span. Seasonal cycle of storage and utilization of glycogen content in *Parreysia cylindrica* is closely linked to food supply and gonad development. The content increases in gill, hepatopancreas, gonad, foot and both the adductor muscles at the time of abundant food availability in monsoon. The highest accumulation of this content is seen in hepatopancreas, protein content is also build up in mantle and hepatopancreas.

Protein is an essential, organic constituent of animal tissue and it plays a significant role in cellular metabolism. All enzymes are portentous in nature and they control sub cellular functions. In the metabolism of protein, many enzymes, coenzymes, intermediate proteins and amino acids involved are studied in many animals (Sekeri et al., 1968). Protein content was highest in hepatopancreas. Lipid reserve is also found in hepatopancreas, gonad and foot, the highest being in hepatopancreas. Thus, the
depot tissues, hepatopancreas stores more organic reserves in monsoon. These reserved from different body parts decreased in winter and summer however, certain body parts stored more organic reserves in winter or summer because of the specific functions of the organs e.g. the muscular tissue like foot, anterior and posterior adductor muscles stored more proteins since a great deal of energy is required in summer for opening the valves and extending the foot. Gill tissue also showed high content of protein in summer. Mantle stored high levels of glycogen and lipid in summer.

Carbohydrates are considered to be the first organic nutrient to be deputed and degraded in stress conditions imposed on animals (Clarke, 1975). According to Koundinya and Ramamurthi (1979), the decrease in glycogen may be due to enhanced breakdown of glycogen to glucose through glycolysis.

During environmental anaerobiosis, when the whole organism is exposed to anoxic conditions caused by external, physical factors in the microhabitat, arginine phosphate, glycogen and aspartate (only molluscs) are the substrates for the metabolism. Main end products formed are lactate (Crustacea, Xiphosura, some Gastropoda and Bivalvia), alanine, succinate and the volatile fatty
acids, propionate and acetate (most Gastropoda and most Bivalvia) Gerd Gade (2005). In Parreysia cylindrica glycogen content from gill, hepatopancreas, and foot as well as lipid content from all the tissues studied showed decrease in these contents during winter compared to monsoon. This is probably due to the high energy demand during spawning in winter as well as the declining food available in this season. The gonad stored equal amount protein during all the seasons. During summer the gonad of Parreysia cylindrica undergo gametogenic activity (as revealed through histological studies). Since the gonad follicles contain lipid globules, for nourishment of the developing gametes, the content predominated in summer and monsoon, but with the ripening and the release of gametes the content decreased in counter from gonad as well as the hepatopancreas. It is interesting to note that the glycogen content from gonad tissue increased in winter. This indicates that the time of fully mature gonads and then spawning takes place this content increases.

Bivalves store energy in the form of glycogen (Hemelroad et al., 1990; Naimo et. al. 1998). Glycogen store fluctuate seasonally, typically ebbing during the periods of gametogenesis, and decrease rapidly in response to reduced food availability and
environmental stress (Williams and McMahon, 1989; Haag et al., 1993; Patterson, Parker, and Never, 1999). Examining seasonal fluctuations in the glycogen content of bivalves may provide an additional explanation for the decline in North American unionid species diversity (Strayer, 1999). If low glycogen stores coincide with period of low food availability in a stream, bivalves may have reduced to tolerance additional stresses such as competition with exotic species or reduced food availability.

Ansell et al. (1967) in Mercenaria mercenaria found little seasonal variation in the biochemical composition of the adductor muscle, mantle, gonad, and foot. In these organ carbohydrates decrease with the corresponding increase in proteins during the period of gonad proliferation. Carbohydrates from these organs are utilized at the time of gametogenesis to meet the needs of rapid proliferating gonads. Gonads contained high levels of carbohydrates than any other organs. Since there is no marked cycle in the carbohydrate content in gonads is greater than other constituents, the gonad increase has been suggested to be responsible for seasonal changes in the carbohydrate / protein ratio. Since Parreysia cylindrica is a freshwater species and inhabit along the banks of the river, the seasonal cycles in storage and
utilization of the organic reserves are dependent upon external environment in particular food availability and the body functioning. In terms of nutrient storage in order to supply energy for gametogenesis, the role of carbohydrates is predominant in bivalves. The main factor appears to be circulating glucose in glycogen synthesis and glycogen breakdown via the glycogen synthesis. In bivalves depending on environment and reproductive period the proportion of glycogen content differs from species to species. Shrinivasan (1965), Lubet (1959) observed that in *Mytilus galloprovincialis* and *Mytilus edulis* glycogen accumulated during nonbreeding period in summer and gametogenesis in these mussels is resulted in high metabolic demand and glycogen breakdown.

Ansell *et al.* (1964) observed decreased carbohydrate content with corresponding increase in protein during the period of gonad proliferation in *Mercenaria mercenaria*. Protein storage is also important. In temperate species of bivalve, like *Mytilus edulis* protein content is higher than glycogen during the winter (Zandee *et al.*, 1980). While in the tropical species like *Perna viridis* the content is at peak in middle of monsoon and again at minor peak in early winter (Nagabushnam and Mane, 1975, 1978). Even in fluctuations in lipid content are rather small compared to changes
in both protein and glycogen. Lipids appear to have important functions, not only as structural elements of biological membranes but also in metabolism. Lipids play a nutritionally and physiologically important role by providing an efficient source of energy and essential fatty acids and the metabolism and transport of lipid is of particular importance in reproduction. Great differences are known in lipid contents of bivalves, e.g. in *Donax* species lipid contents were about 4.5% of dry weight. Voogt (1983) stated that lipids in bivalves are multifunctional and that in different species one or some of the functions during maturation of gonad, drastic environmental conditions, starvation etc. are more pronounced. In spring, there was a rapid growth of the gonad coincide with an increase in glycogen, lipid and protein. In summer, the glycogen content decreased with spawning and proteins showed the highest values (Fernandez-Castro and de vido de Mattio, 1987).

According to Ruiz *et. al.* (1992), seasonal changes in the biochemical components of the oyster *Ostrea edulis* showed similar time course accumulation of lipids and carbohydrates. Where as proteins were constant, when food was abundant, energy reserves were built up. Spawning produced a decrease in
biochemical constituent’s levels and recovery coincided with the phytoplankton bloom. The stored reserves, mainly lipids, were used to overcome a state of energy imbalance in late autumn associated with low food availability. Seasonal changes in biochemical composition of *Mytilus edulis* in British water showed increase in protein and lipid and decrease in carbohydrate during winter and spring which correlated with gonad development (Byne and Thomson, 1970). Protein and lipid decreased during the spawning period which coincided with a rapid increase in the proportion of carbohydrate with the development of the gonad carbohydrate decreased and other fractions increased. In *Mytilus edulis*, from British coast, the metabolic rate was low in summer and high in winter due to the increase in energy demand for gametogenesis. As with many other bivalves, storage and release of metabolites from the whole body and different body parts of bivalves from India also correspond with the somatic growth and reproduction taking place in coordination with the existing local environment. In mussels after minor spawning, increase in the protein content was attributed to the greater percentage of female mussels formed before the major spawning period. After spawning the protein content decreased (Nagabhushanam and Mane, 1975), the average dry weight values of the content being 68.23% in
August - September and 67.17% in February. In fact in July and January the spawn developed apparently at the expenses of glycogen and as in many other bivalves there occurred corresponding increase in fact accumulated in ripe gametes. The glycogen content reached minimum in June and thereafter rises gradually to reach its peak in October - November. The high lipid content was reflected in the long spawning period of the mussels in Monora, Decrease in protein and lipid occurred during the spawning of the mussels and at the peak spawning from July to October glycogen increased. Biochemical analysis of different body parts of *Perna viridis* from Bhatye creak at Ratnagiri on the west coast of India also showed that much of the energy for gonad maturation and body maintenance, particularly in monsoon season, was dependent upon the protein content while the fat content showed little variation. This suggested that in monsoon the food levels were low and the metabolic rate remained high, however, the increased energy demand was thought mainly from protein reserve in the non-gonadal tissue. During this time vitellogenesis was taking place and the transfer of nutrients from the digestive gland to gonad formed an important aspect of biochemical mobilization for the maturation of gonad. The author attributed the maximum and minimum accumulation of glycogen content in different tissues.
to the functional significance in different seasons. During monsoon period of July onward feeding activity begins to enhance due to monsoon rains and opening of valves to maximum extent occurred. This probably resulted in the energy requirement of mantle tissue for maximum period and hence, it is likely that tissue stored more glycogen. The mobilization of glycogen from hepatopancreas to gonad was well correlated by the author with the gametes development. According to him, the gonad was mostly with mature gametes but still there were some developing gametes and the glycogen and protein contents from gonad increased. The contents from hepatopancreas also increased during this period, possibly due to matured and spawned in September the content from the gonad decreased. During May, the drastic environmental conditions resulted in the recovery of the gonad tissue. At this time different metabolites level from different tissues fluctuated. Protein content from hepatopancreas and gonad also decreased. However, with the onset of monsoon there reoccurred the close relation between food availability from external environment and nutrients supply from hepatopancreas and gonad development and spawning. Much work has been done on the biochemical composition of different body parts. Studies on the changes in biochemical energetic in relation to reproductive cycle in bivalves have been
reviewed (Bayne, 1976; Sastry, 1979; De-Zwann, 1983 Bishop et al., 1983 Voogt, 1983). A great deal of energy is to be channelized to gonad during reproduction. Assimilated food is distributed to the body tissues by the controlling mechanism of hepatopancreas. Lubet (1959) while working on *Mytilus galloprovincialis* and *Mytilus edulis* from Atlantic coast of France found that glycogen accumulated mainly during the non-reproductive period in summer. Gametogenesis in these mussels resulted in high metabolic demand and glycogen breakdown occurred. This resulted in vitellogenesis in these animals. Ansell *et al.* (1964) determine the seasonal changes in the biochemical composition of the adductor muscle, mantle, siphon, visceral mass (gonads), digestive gland and foot in *Mercenaria mercenaria*. The biochemical composition of the body components showed little seasonal variation, with the exception of the foot, mantle and siphons. In these organs carbohydrate decreased with the corresponding increase in protein during the period of gonad proliferation. Carbohydrates from these organs were apparently utilized at the time of gametogenesis to meet the needs of rapidly proliferating gonads. Voogt (1983) stated that lipid in bivalves are multifunctional, one or more of the functions during maturation of gametes, drastic environmental conditions, starvation, pollution stress etc. can be more noticeable. The lipid
content fairly remained high in the digestive gland as compared to the other body organs, perhaps because of its function as a site for lipid storage and further supply to other organs. The hepatopancreas and gonad contained higher levels of carbohydrates than any other body organs. Since there was no marked seasonal cycle in the biochemical composition of other organs and because the carbohydrate content in gonad was greater than other constituents, the authors stated that the gonadal increase could be suggested to be responsible for seasonal changes in the carbohydrate and protein ratio for the whole animal. Idlar et al. (1964) determined total lipids, unsaponifiable material provitamin-D, and sterols in monthly samples of male and female *Placopecten magelanicus*. During the pre-spawning period in the total lipid levels were low in adductor muscle. This suggested being due to active transfer of these materials to the gonadal tissue. During the restricted growth period in April and May, the lipid content of the muscle decreased but there was a compensating increase in unsaponifiable material and sterol content of total lipids. Giese et al. (1967) found that in *Tivela stutorum* the protein level was high in all the body components except the gonad. The glycogen level was high during the early stages of the gametogenesis and decreased after the gametes had developed. In comparison, the
protein level in the gonad was high when the gametes were present and decreased after their release where there was an accompanying increase in carbohydrate. The decrease in carbohydrate with the increase in protein was suggested to be due to the conversion of carbohydrate into protein during gametogenesis. The lipid remained at the same level except in the ovary where it increased slightly, probably because of high lipid levels in the eggs. Large stores of carbohydrate in the gonads of *T. stultorum* as well as in other species like *T. pedicellale* and *M. edulis* indicated that stored reserves might be utilized for gametogenesis (Giese *et al.*, 1967, Gabbot, 1973). In *Tellina tenius* body weight was minimum in February and March and increased greatly in May, corresponding to the gonad proliferation (Ansell and Trevellion, 1967). In *Tellina tenius* total carbohydrates and nitrogen increased with an increase in body weight while gonadal development was progressing rapidly. During this period carbohydrates, especially glycogen, increased in various body parts. The biochemical constituents decreased with decline in the body weight when the gonads were mature and when spawning occurred there was a high proportion of carbohydrate. This indicated that following maturity the carbohydrates present were stored reserves. The body weight declined between October to December, with a corresponding
decrease in carbohydrates but proteins and lipids remained more or less constant. Carbohydrate in the form of glycogen reserves were utilized by *Tellina tenius* during September-February to supplement the metabolic deficit caused by the limited food during this period. Protein and foot decreased from hepatopancreas throughout the year and from mantle it was increased. While glycogen content was increased in large sized animals from hepatopancreas and gonad during all seasons, it was decreased from Gill and during summer, winter season. Seasonal change in biochemical composition of *M. edulis* in British waters showed increase in protein and lipid and decrease in carbohydrate during winter and spring which correlated with gonad development (Williams, 1969; Bayne and Thompson, 1970). It was further found that in those mussels, protein and lipid decreased during the spawning period which coincided with a rapid increase in the proportion of carbohydrate. With the redevelopment of the gonads, carbohydrate decreased. The Mediterranean waters, *M. edulis* was reported to spawn repeatedly during the spring and early summer, and between each successive period the gonad was reconstituted. The lipid levels decreased rapidly after spawning and then increased again as the gametes matured. In middle of the summer during non-reproductive period, the level of triglycerides and
phospholipids remained low (Lubet and Longcamp, 1969). The relationship among growth, food concentration and temperature was determined by Kirby-Smith (1977). Changes in total weight and body weight parallel to each other throughout the year. Nutrient reserves might accumulate in gonads independent of other body organs, depending on food concentration and environmental temperature. The increase in body weight after spawning represented an accumulation of nutrient reserves in the body tissues and/or a gain in water content. Bayne and Thompson (1970) determined the biochemical composition of mantle (germinal) and non-mantle (somatic) tissues of M. edulis maintained in the laboratory under different conditions of nutritional and temperature stress. In this mussel, the mantle tissues serve both as a site of storage and gamete production. Gamete production occurred at the expense of other body reserves when the gametes were not ripe. However, after gametogenesis was completed, the animals at sublethal temperature and under nutritional stress could not maintain the gametes in a ripe condition and the gonad regressed. Animals maintained under stressful conditions initially mobilized carbohydrate reserves from the mantle to meet energy requirement. As stress continued, protein from mantle tissue and carbohydrates and proteins from non-mantle tissue were also utilized for
maintenance. Apparently there was a complex relationship between development of gametes and utilization of carbohydrate and protein reserves were utilized in the animals under stress (De Zwaan and Zandee, 1972 and Gabbott and Bayne, 1973). Starvation experiments show lipid to be the most important reserve in *Crassostrea gigas*. In *Paphia laterisulca*, however, lipid content remained constant after starvation for 12 days, glycogen content decreased and water content increased Nagabhushanam and Mane (1977). Suryanarayan and Alexender (1971) found that pallial muscle of *L. corrianus* possesses comparatively high amount of glycogen which plays functional significant role during anaerobic respiration. In *M. edulis*, the seasonal cycle of storage and utilization of glycogen reserves was closely linked to the annual reproductive cycle (De Zwaan and Zandee, 1972). From Netherland these authors reported that in the summer the mussels were spent and the metabolic energy demand was low (Widdows and Bayne, 1971, Bayne, 1973 a). Abundant food was available in planktons and there was a marked increase in glycogen content with the highest accumulation in the mantle - gonad. Protein and lipid reserves were also build up mainly in the non-mantle tissues (Gabbott and Bayne, 1973). During the autumn and winter the metabolic demand was high due to gametogenesis, and the
glycogen reserve fall to a minimum values in winter. The loss of glycogen, in female mussel was synchronous with oogenesis and vitellogenesis of the garnetogenic cycle. In *Ostrea pulechana*, weight and energy reserves decreased in winter during the beginning of the reproductive cycle and starvation period. In spring, there was a rapid growth of the gonad coincident with an increase in glycogen, lipid and protein. In summer the glycogen content decreased with spawning, and proteins showed the highest values (Fernandez Castron and De- Vido- Demattio, 1987). It is pertinent to mention that the bivalves have the capacity to rely upon the protein or lipid reserves at the time of increased energy demand (see the review of Bayne, 1976). Although in general, glycogen is the most suitable substrate for anaerobic metabolism. Some authors point to the role of lipids under these conditions (Zs-Nagy and Galli, 1977).

While studying the biochemical reserves of mantle and adductor muscles of the freshwater bivalves, Kulkarni *et al.* (1986) stated that these two organs have functional importance in the opening and closing of the shell valves and protrusion of mantle edges and they showed differences within the species regarding the quantity of stored glycogen in accordance with the species
resistance towards environmental perturbations. Muley (1988) while studying the biochemical constituents of *Lamellidens corrianus* with respect to reproductive cycle and body weight showed that total body weight decreased in monsoon, post-monsoon and winter due to release of gametes. The highest level of glycogen occurred in mantle during summer and declined to minimum during monsoon, whereas the lowest level occurred in gills in which the maximum accumulation was seen during summer and minimum during winter. The maximum and minimum glycogen content in these tissues was attributed perhaps to the functional significance. Protein contents were reported to reach to minimum during summer. During summer at the time of maturation protein and glycogen content increased in the gonad and decreased in hepatopancreas. As the gametes matured and spawned in monsoon the contents from the gonad decreased. Due to energy demand during spawning the glycogen and lipid contents from hepatopancreas also decreased. However, as soon as the development of gametes during post-monsoon started the glycogen and lipid started to increase steadily from both gonad and hepatopancreas. In *L. corrianus* from Nandrabad pond near Aurangabad Nagawanshi (1997) showed that protein, glycogen and lipid contents got elevated during maturation and partially
spawning stages of the gonad during early monsoon. In August the biochemical contents decreased significantly.

In bivalve molluscs, the males and females of gonochoristic bivalves are very similar in gross structure (anatomy) of their reproductive system usually the gonads are paired and located near or adjacent to digestive gland (hepatopancreas). Often these male and female gonads are paired structure. The male and female gonopores serve only to convey gametes to outside. The gametes are discharged into the exhalent water in the suprabranchial chamber. Separate genital and urinary apertures are seen in some filibranchs (Morton, 1973b, 1978) and most of the unionids (Bullough, 1970, Bernard, 1972 and Jones, 1979).

Inside the gonad the surrounding vesicular tissue and the accessory nutritive cells have a nutritive function for gametogenesis. In several species of *Barnea* (Duval, 1962), *Chlomys* (Reddish, 1962), *Crassostrea* (Kennedy and Battle, 1964, Loosanoff, 1965) and *Mercenaria* (Loosanoff, 1937) there is a seasonal appearance and disappearance of follicular tissue that coincides with period of spawning and follicular growth. In the present study with *Indonaia caeruleus*, it has been observed that lipid globules and nourishing cells fill up the lumen of the follicle
during gametogenic activity. There globules along with nourishing cells decrease in quality and number as the sex products become ripe, and are being released. Generally, the reproductive cycle of a population includes a series of events, namely activation, growth and gametogenesis, ripening of gametes, spawning and a resting period (Giese, 1959, Giese and Pearse, 1974, Sastry, 1966, 1975, Mane and Nagabhushnam, 1976) underlying the reproductive cycle is the gametogenic cycle within the individual of the population.

The time course of the series of events in the reproductive cycle of a population may be synchronomous, so that all individuals breed simultaneously or asynchronomous with gametogenic cycle within the individuals of the population out of phase, so that a proportion of population may breed at any time (Sastry, 1979). In population exhibiting an asynchronous breeding period, the individuals may go through successive gametogenic cycle e.g. some tropical and deep sea animal (Giese and Pearse, 1974).

*M. margarifera* showed gametogenesis throughout the year, apart from a period of rest after spawning, lasting for 4-8 weeks. The author observed presence of early developing oogonia in the female follicles. In February the gonads were in maturing stage and spawning. The number of developing oocytes and amplitude of
spawning was maximum in May than in March. During February to May the gametogenic activity in the female follicles showed variations, where as the testicular follicles were always full of sperms throughout the year. The reduced testicular follicles were found from December to June.

In the histological preparations a few male follicles contain sperm morulae and spermatocytes. At the same time female release almost all matured gamete in males sperms are released from their follicles. In female follicles both oogonia and vitellogenic oocytes are seen. On December and January the female gametes mature. In December follicles show developing gametes. In January female matured oogonia undergo lysis. However, many small oogonia proliferate from the germinal epithelium. Both the nutritive cells and lipid globules increased in numbers during this period. Many of the mature oogonia undergo lysis probably providing the nourishment to the developing ones. Since the environment becomes unfavorable. The recovery begins in both males and females in March which last up to April and recycling of gonad development takes place.

The reproductive cycle of a species is a genetically controlled response of the environment (Sastry, 1970). In the
present study it is seen that *Parreysia cylindrica* has a gametogenic phase extended from February to May. During this period the males and females produce large quantity of gametes. The development of gametes as is slow in this period. The spawning starts in June at this time only a few gametes are released. Once again the gameteogenesis is initiated in September and continues through winter till March. Gametogenic cycles may occur in populations of species are annual semi-annual, or continuous basis. The timing and duration of gametogenic cycles and the number of cycles within a year may be a characteristic of species in the populations. In populations of *Mercenaria mercenaria* and *Cyprina islandica* (Loosanoff 1937, 1953), *Mytilus edulis* (Chipperfield, 1953, Suguiura, 1959, Moore and Reish, 1969), Argopecten (Acquipectin) iradians (Sastry 1966, 1970). The gametogenic cycles occurs on an annual basis. In some tropical species gametogenesis appears to be restricted to certain months in a year, while in others it occurs continuously throughout the year. In *Donax cuneatus* from Madras coast gametogenesis takes place between September and December and it is followed by spawning until June. The gonads are inactive for a brief period between July and August (Rao, 1967).
Although fecundity in bivalves can vary depending on environmental conditions, gamete release apparently only accounted for a portion of seasonal weight loss in mussels from Lake St. Clair seasonal trends in food availability may also have contributed to weight declines in spring and summer, changes in soft tissue weight corresponded to changes in soft tissue weight corresponded to changes in chlorophyll concentrations, which were highest in April May and declined in late June. Soft tissue weights were at minimal values during the summer months when chlorophyll concentrations were at a minimum. While gain or loss of net weight is a function of temperature, food and mussel size, consistent weight loss occurred under laboratory conditions when algal concentrations were below 100 ug carbon/L regardless of size of temperature (range 8-25°C). (Walz, 1978 a). Assuming a carbon; chlorophyll ratio of 25 (Lingerman - Kosmershock 1978), weight loss should theoretically occur at chlorophyll concentrations below 4 µg/l. At the Lake St. Clair sites, chlorophyll concentrations were consistently below this value except at station 19 in early spring. Water temperatures also apparently influenced seasonal weight trends since weight loss did not occur in early spring or fall when temperatures were lower than in summer. Metabolic efficiency (assimilation efficiency, filtering activity) declines when water
temperatures rise above 20°C (Walz 1978a, Reeders and Bij De Vaate 1980, Schneider 1972). Temperatures in Lake St. Clair were above 20°C from June into September (Table No.1). Evidence that metabolic stress occurred in lake St. Clair populations of *Dressena* during summer is provided by seasonal changes in the relationship between the amount of oxygen respired and the amount of nitrogen excreted O:N ratio (Quigley *et al.*, 1993). The O:N ratio provides an indication of the relative catabolic balance between carbohydrates, lipids and proteins and has been used to describe the physiological state of marine mussels (Bayne and Scullard 1977, Widdows 1978; Tedengren and Kautsky 1986). In mussels, individuals with O:N ratios of greater than 50 are considered physiologically “healthy”; while individuals with ratios less than 30 are considered “stressed” and catabolizing internal protein (Bayne *et al.*, 1985). At station 3 in 1990, ratios declined from about 50 in the spring to a minimum of 16 in the summer (Quigley *et al.*, 1993).

The present study revealed that in *Parreysia cylindrica* the gametogenesis begins in males by early June and in females by July during monsoon season. Thus the males undergo gametogenic activity earlier than females, though both the sex products almost get mature in batches of gametes during same time or equal time in
the latter period. This period of gametogenesis coincides with the beginning of monsoon. The follicles which have undergone gametogenesis reaches the mature stage by July during monsoon. This reveals that to reach the mature stage male follicles require comparatively shorter period (i.e. from May to July), that for male follicles (i.e. from April to May). From July to August, these mature male follicles release sperms giving out partially shed, many shed and fully shed stages. On the other hand, from July to October, the mature female follicles in small sized bivalves release ova revealing partially shed, many shed and fully shed stages. A second active period of gametogenesis simultaneously occurs in males during October to November; in the follicles which attained the mature stage. These became mature by early winter (December). In female active gametogenesis also occurs in the same period which subsequently merges into the mature stage of follicles observed in December. These mature follicles release the sex products during the same month. During this period, the gametes are released and only a small set of oogonia get matured and were released from both the male and female follicles. Thus it has been observed that many gametes of both sexes mature and release during July to November, once again a few gametes undergo gametogenesis in during late winter i.e. January, in both
males and females. Thus gametes subsequently mature by April. Thus, the pace in the release of gametes in the order of many gametes becoming mature and are released during July to October followed by production and maturation of a small set of oogonia and the release of a few gametes during December and only a very few during April. The entire population then reaches the recovery condition of gonads before the commencement of gametogenesis and maturation i.e. during summer in male follicles and during monsoon (July) in female follicles. In species releasing gametes to the external environment, fertilization results from a random contact between male and female sex cells. However, co-ordination of spawning results in a synchronous release of gametes of both sexes, thereby increasing the chances for successful fertilization and the production of the large number of larvae. The advantage of timing of spawning within a brief period, when conditions are best for survival and growth and when food abundant, have been emphasized by Thorson (1950). On the Indian coast a number of species have prolonged breeding season yet it is restricted to the specific months of the year (Rao, 1952 and Sastry 1955). In other Indian bivalves, spawning takes place throughout the year, even though peak spawning is limited to certain months (Sastry, 1979).
The reproductive cycle of a species is genetically controlled response of the environment (Sastry, 1970). In species occurring in several climatic zones, the reproductive cycle may vary in relation to the local environment as a phenotypic response of a single genotype, or it could be distinctly genetic or both, (Sastry, 1970). After attaining a certain physiological states, an organism exposed to the required environmental prerequisites begins gonad growth and gametogenesis, gametogenesis and maturation of gametes are under several exogenous (e.g. temperature, lunar periodicity, depth, mechanical factors, food abundance and availability, light intensity) and endogenous (e.g. genetic, hormonal) controls (Sastry, 1970). Of all the external controls, temperature is probably the most important and maturation of gametes is caused by annual temperature, fluctuations or threshold temperature (Mackie, 1984). Sometimes it is difficult to separate the effect of temperature, latitude and depth, Loosanoff (1960) and Goltsoff (1964) gave evidence to suggest that there are different physiological races of Oysters; each with its own threshold spawning temperature at different latitudes and depth. In these instances, temperature appears to act indirectly by optimizing the physiological development of adults (Giese, 1959). The period of gonad growth and gametogenesis in a number of species has been correlated with
seasonal changes in temperature (Giese, 1959, Vernberg, 1962, Kinne, 1970, Loosanoff, 1971, Giese and Pearse, 1974). In many species, gonad growth of gametogenesis seems to occur with declining temperature in the fall or with increase in temperature in spring and summer. Reproductive timing and duration of gametogenic activity may be characteristic of a species under natural conditions.

The frequency in release of gametes in *Parreysia cylindrica*, from July to November and the gonad redevelopment can be correlated with several exogenous factors and the animal’s physiological development to give rise to mature sex products to be ready to release. During summer and early monsoon season the rate of oxygen consumption increases due to high temperature, low oxygen content of the water, lower humidity and no rainfall. This is the period (April May) of summer that the bank of Kukadi river at Yedgaon stratifies and the animals experience low nutritional stress. This time temperature might be an important factor affecting the animals. Much of the energy is diverted for the growth of the animal itself and the body reserves seen in adequate to support gonad development under such conditions. Due to this, the gonad showed recovery condition, which is extended in case of females,
even up to first few rains during monsoon (July). As soon as monsoon reaches its peak the animal receives favorable environment with plenty of food material available during June and July since the animals are likely to pass through the starvation effect, by utilizing glycogen and protein from gonad, hepatopancreas and mantle, the active gametogenesis during monsoon slow down. This results in the late maturation of gonads in August. During this period of favorable environment, active gametogenesis also continues and the rate of respiration increases.

The perusal of literature reveals an excellent account on the reproduction of marine bivalve (Sastry, 1979) and freshwater bivalve (Mackie, 1984).

A comparative study of the reproductive cycle of the cockles, Cardium glaueum and Cardium hauiniense, from Poland has been done by (Wolomwicz, 1987). The author observed no clear cut difference between the rates of gametogenesis at various depths. The author found that in winter, the development of gametes is slowed down or inhibited. In mussel, Modious capax, the gametes are released throughout the year. Intense gamete release occurs in August. During this and following months gametogenesis in these mussels reinitiates and the liberation of
gametes continues though with lower intensity in a high number of individuals.

In the present study, on *Indonaia caeruleus* particularly in small size has a gametogenic phase extended from March to May. During this period, the male and female individuals produce large quantity of gametes. The development of gametes is slow down in this period, the spawning commences during monsoon (July) in females at this time only a few gametes are released of small sized bivalves. This spawning activity reaches peak in July as the monsoon advances. Once again the gametogenesis is initiated in August during monsoon and continues through winter till April. The gametes are produced and are released simultaneously and the spawning intensity is comparatively less than August. Many of the gametes show lysis during this period. But spawning began in July giving its peak in August of monsoon and all the follicles become empty. Release of sperms was continued October. Simultaneous gamete formation, maturation and release occurred from December to January. In December lyses of few matured gametes took place. All these events continued till March. However, lipid globules and nutritive cells began to appear from January and April. Lysis of gametes and proliferation of small young ones continued till April.
From April onwards, both males and females showed larger gametogenic phase.

Thus there are two reproductive cycles, one from April to October and second from October to January. The first one is very slow and simultaneous maturation and second one is fast and frequent. Reproduction in both the marine and freshwater species is cyclic and it may be annual semi-annual or continuous. In reproductive cycle, the gonad development, spawning and fertilization and development and growth are the three major-phases. These phases functions continuously in co-ordination with seasonal environmental changes and produce characteristic patterns.

Sastry (1970) stated that the reproductive cycle of a species is a genetically controlled response to the environment and the pattern is apparently determined through the co-ordination of successive reproductive events with changes in the external environment. The author further stated that in species occurring in several climatic zones, the reproductive cycle may vary in relation to local environment as a phenotypic response of a single genotype, or it could be directly genetic or both studies carried out by several workers indicate that a reproductive response is produced through
an interaction of environment factors especially temperature, salinity, light and food and endogenous factors within an organism. After attaining a certain physiological state, an organism exposed to the required environmental pre-requisites which begins gonad growth and gametogenesis. The life cycle of an animal is usually so timed by some environmental variables that the young are produced at a period favorable for their survival (Giese, 1959). Gonad development is an energy demanding process. The mobilization of nutrients from the ingested food for the gonads is essential for gamete development. The relationship between food and gonad development has been studied in detail for only a few species (Sastry, 1966; 1968 and Bayne, 1975).

Nutrients from ingested food are distributed to various body organs for assimilation and storage. For many species it is still unclear whether gonad development depends on food ingested directly from the surrounding water, or from stored reserves or from both. The relationship among food availability in the environment storage and reproductive activity varies among species. In the present study on Parreysia cylindrica in biochemical changes that the organic reserves particularly the glycogen is stored more during monsoon at the time of plenty of food availability.
In the present study it has been observed that in monsoon when there is a plenty of food available, the maturation of gametes is accelerated and they become mature during monsoon till winter. Perusal of literature reveals that comparatively little attention, has been paid on size specific reproductive pattern in freshwater bivalves with respect to size, most of the work on sex and seasonal gonadal changes has been done on *Indonaia caeruleus* (Bloomer, 1931) and *Anodonta caeruleus* (Bloomer, 1930, 1935). In *Anodonta natina* and in *Anodonta grandis* have one spawning season in spring. In *Corbicula fluminea* two spawning seasons, one extending from spring to summer and other extending from summer to autumn have been reported. From Indian waters few workers also directed the study in understanding the annual reproductive cycle of freshwater species (Lomte and Nagabhushnam 1969, Ghosh and Ghosh, 1972).

The gonads of Indian fresh water bivalves may be active throughout the year or the activity is restricted to a certain period Lomte and Nagabhushnam (1969) reported that freshwater bivalve, *Parreysia carrugata* showed restricted activity to a certain period of annual cycle. *Indonaia caeruleus* breeds throughout the year but with definite peaks, as reported for *Indonaia caeruleus* by Ghosh
and Ghosh (1972). In the present study, *Parreysia cylindrica* revealed gametogenesis in both male and female gonadal follicles in summer and maturation of gametes in monsoon. In winter the follicles with partial emptying of gametes predominate. In winter few developing oocytes and male gametes are also seen. However, based on the literature and on the histological sections of the gonad of *Parreysia cylindrica* the period of gametogenesis starts with rise in temperature in summer but at a slow rate since the food availability is low and energy demand for maintenance of physiological activities rise.

The activity of gametogenesis resumed vigorous in monsoon at the time the food availability increases. Thus in *Parreysia cylindrica* environmental factors synchronies the gonadal development at an early stage in its progress of maturity so that spawning can be coordinated to achieve synchronous release of gametes.

The frequency in release of gametes in *Parreysia cylindrica* from July to November and the gonad redevelopment can be correlated with several exogenous factors and the animal’s physiological development to give rise to mature sex products to be ready to release. During April, May and early June the rate of
respiration increases due to high temperature, low oxygen content of the water, lower humidity and no rainfall. This is the period (April—May) that the bank of Girna river at Jamta stratifies and the animals experience low nutritional stress. This time temperature might be an important factor affecting the animals. Much of the energy is diverted for the growth of the animal itself and the body reserves seen in adequate to support gonad development under such conditions. Due to this the gonad showed recovery condition which is extended incase of females even up to the first few rains in June. No gametogenic stage is seen in April and May in any follicles. As soon as monsoon reaches its peak the animal receives favorable environment with plenty of food material available during June and July. Since the animals are likely to pass through the starvation effect by utilizing glycogen and protein from gonad, hepatopancreas and mantle, the active gametogenesis in July slow down. This results in the late maturation of gonads in August. During this period of favorable environment active gametogenesis also, continues, the rate of respiration increases and the organic reserves are built up in different tissues. As the animals pass once again in the starvation stress (As revealed from data on respiration and biochemical constituents), the mature gametes are released less frequent so that their occurs all stages of gonads like
partially shed, many shed and fully shed gametes. The reappearance of active gametogenesis and mature stages, that coincides with the active feeding and increased rate of respiration in October, January, February and March. Since the food available arid the energy supply decreased for many gametes to reach mature stage during December to March there occurs decline in the quantity of gametes release and comparatively only a few are shed. Although the energy for reproduction ultimately comes from food supply, the gametogenic cells appear to derive nourishment from food, transfer directly from the digestive glands (Bayne, 1975; Gabbolt, 1976; Sastry, 1979). Therefore, the rate of nutrient mobilization and transfer for the gonad are influenced by the stage of gametogenesis and temperature. The experiments carried by these authors revealed that reproductive activity appears to affect the relative uptake of nutrients into the gonad, digestive gland and adductor muscles. The relationship among food, temperature and gonad development has been nicely demonstrated experimentally for the population of Aquipecten irradians (Sastry, 1968). The energy requirement for gonad growth in Indonaia caeruleus, under present study to reach mature stage, which is supplied from the hepatopancreas. The close relation between the gonad and digestive system is well documented in the literature in almost
every anatomical study of the reproductive system. The gonad is shown to be associated at least with some part of digestive system. This association may be intimate, with gonadal tissue inverting the diverticula of the digestive gland, or vice-versa, as in *Indonaia caeruleus*, *caerulids* and *chionines*; the gonad may completely envelop much of the digestive tract as in Unoidae, or the gonad may merely be adjacent to the digestive glands, as in Pisididae (Mackie, 1984). Sastry (1979) reviewed most of the literature and gave an excellent discussion of the relationship between food and gonad development. The findings can be summarized as, gonad development has higher energy demand. This energy may be derived from food ingested directly from the ambient water; from stored reserves, or from both, the relationship among food availability in the environment, storage and reproductive activity varies among species, the periods of food abundance and of gonad development are nearly coincident., the amount of nutrients mobilized for the gonads appears to depend on food concentration, temperature and basic metabolic requirements of the individual, gonad growth and gametogenesis are dependent on direct intake of food during the period of gonad development, in some species. Seasonal gonadal development is linked with the storage and
utilization of reserves accumulated in the body during the period of maximum food density.

The lipid globules are observed in the male and female gonadal follicles of both the individuals. This may be to serve food material for next breeding period. These lipid globules are conspicuous and predominantly seen in both male and female follicles of *Parreysia cylindrica*, during summer, gradually diminish in quantity as the gametes develop during early pre monsoon and post monsoon and they are disappear during winter season particularly in medium and large sized bivalves.

Many histologists have interpreted their data on the histological studies of the digestive tissues of bivalves to suit the concept of food continuously being absorbed and waste products being excreted. In bivalves, the absorption of food could occur simultaneously with the breakdown of cells and stimulation of waste material.

Histological study of digestive glands of *Mercenaria mercenaria*, *Ostrea edulis* and *Mytilus edulis* show that a number of digestive tubules are clustered around a secondary duct. (Owen, 1955, Robinson, 1980, Lonton, 1975). Because of this structural
configuration food material would simultaneously be presented to each tubule of cluster. Correspondingly similar tubule types are generally found within the same cluster of tubules. In *Parreysia cylindrica*, tubules were mostly in absorption and fragmentation phases on July during monsoon season (Saokar, 1994).

In monsoon (July - August), winter (January) and summer (April) the tubules exhibited only holding and absorption phases. The author stated that holding and absorption phases occur due to food availability and external environment fluctuations.

There is a complex interaction between the exogenous factors, like food supply and temperature and between endogenous factors, like growth and reproduction in the bivalve molluscs (Sastry, 1968). It is also known that where food production is seasonal, some species may store nutrient reserves in body organs when food availability is maximal and subsequently utilize them for gonad growth or supplement food intake to meet the reproductive requirements (Ockelmann, 1958).

In the present study on *Parreysia cylindrica* revealed that ducts and tubules grouped in the form of small lobules indistinctly separated and connected by interlobular connective tissue.
consisting of collagenous fibers. Each tubule is bounded by muscle threads which determine the contraction of tubule. Two types of cells viz. digestive and secretary cells are present in each tubule. Amoebocytes are also found at several places, especially in the connective tissue Parreysia cylindrica are pumping water into and out of mantle cavity, supposedly continually in all seasons because of permanent submergence, except during summer (May).

Digestion of ingested material in bivalves occurs in two phases comprising extracellular processes with the stomach and intracellular phase within the digestive diverticula or caeca. Correlation of fragmentation spherules from digestive tubules show that these spherules if reputed in the stomach can aid primary extracullar digestion of food (Morton 1970). Similar findings were observed in Indonaia caeruleus by Saokar (1994) and Lamellidens marginalis by Meena Nagawanshi (1997), Dhakane (2005).

Mansour and Zaki (1946) have attributed a secretory function of the digestive caeca. Morton assumed that digestion of ingested material in the bivalves occurs in two phases. Comprising an extracellular process, occurring in the stomach, followed by an absorption and dissolution of style and secretion of acid protease from the basophilic cells and intracellular phase within the
digestive caeca. The greater part of protein digestion takes place intracellularly within the digestive cells is of the tubules of diverticula (Read, 1966). In bivalve, food is typically subjected to an intracellular digestion cycle in the digestive deverticula and Nakazima (1956) was able to show for a No. of bivalves, that when they are fed, the height of digestive cells increased. The rhythm of intracellular digestion has been described for many species of bivalve molluscs. Evidence for these rhythms is based primarily on differences in the morphological appearance of digestive gland tubule between animals, over a period of time (Mathers, 1976). The sequence of events in this dynamic process can arbitrarily be divided into at least 4 phases, normal tubules (Type 1 tubules), absorptive (type 2), disintegrating (Type 3) and reconstituting (Type 4) (Platt, 1971, Robinson and Longton, 1980). According to Owen (1955), absorption and breakdown were considered to be taking place in adjacent cells of the same tubule.

The overall state of intracellular digestion within an individual bivalve is assessed by determining which tubule type is prevalent throughout the digestive gland. The digestive pattern within the population can then be established by analyzing the
fluctuations of each tubule type in a number of individuals over desired environmental factor, or the period of season.

In the present study, it is observed that fragmentation spherules occurred with the onset of rainy season. The tubules were observed in this stage on monsoon in small sized bivalve. The absorption phase was observed during winter to summer. The events of digestion of food in digestive tubules showed absorption of the digested food before the arrival of rainy season in July.

With the onset of rainy season, tubules entered in the fragmentation stage. The absorption phase occurred during winter season i.e. from December to February in large sized bivalves. The water level over the habitat was increased and the turbidity was slowly decreased. During this period tubules showed holding phase in summer and monsoon with alternate absorption phase, holding and absorption phases are considered probably to occur as the food availability and external environmental fluctuation.

The size of digestive cells was increased in monsoon and then in winter. In general, it is observe that the lumen of tubule had maximum diameter during holding phase, then followed by absorption and fragmentation phases. The height of the digestive
cells including fragmentation spherules was also maximum during fragmentation than holding and observation. The diameters of the secretary cells were decreased during absorption phase. It was also observed that the height of the digestive cells increased during monsoon, and winter because of much food intake in *Indonaia caeruleus* and this period favourable to the animals for feeding and to build up the body reserves for gonad maturation (Saokar, 1994). Amoebocytes were found scattered in the intertubular connective tissue much abundant on August, of fragmentation phase.

Cyclic pattern of feeding and digestion in *Parreysia cylindrica* is related to freshwater current over the animal bed in pre and post-monsoon, related to a greater pumping of water and long feeding and in the winter and summer is possibly related to a comparatively lesser pumping of water and short feeding that occurred during the hours of the day light. The temperature of the water decreased with the onset of winter i.e. December and January hence reorganization phase is recovered by digestive tubules.