INTRODUCTION

Molluscs such as oysters, clams, mussels, scallops and several species of gastropods are rich in protein and among seafoods they are considered as delicacy in many parts of the world (Narasimham and Kripa, 1995). The marine food resources of India are vast and varied and molluscs contribute much to this resource. Clam wealth of India could be judged from a number of families that are exploited along the coasts. They are Arcidae, Corbiculidae, Donacidae, Mesodesmatidae, Solenidae, Tellinidae, Tridacnidae and Veneridae. Among these families Veneridae is the most important one because it holds commercially exploited clams belonging to the genus \textit{Katelysia}, \textit{Meretrix} and \textit{Paphia}. Apart from these \textit{Villorita cyprinoidies} belonging to the family of Corbiculidae is a major resource noted for its commercial value and its distribution in several backwaters, lakes and estuaries of Kerala in west coast of India (James and Narasimham, 1994).

The list of commercially important molluscs consists of mussels of the family Mytilidae with \textit{Perna viridis}, Oysters belonging to family Ostreidae having \textit{Crassostrea madrasensis}, \textit{C.cucullata}, \textit{C.gryphoides} and \textit{C.discoidea}; ark shell \textit{Anadara granosa} of the family Arcidea and pearl oysters of the family Pteridae consisting of \textit{Pinctada fucata} and \textit{P. margaratifera}. Notable among gastropod are sacred chank, \textit{Xancus pyrum}, \textit{Trochus niloticus} and \textit{Turbo murmoratus}, which are economically important (Nayar and Mahadevan, 1974).

Among the molluscs, the clams are nutritious and well known that they are rich in protein, glycogen and minerals (Nayar and Mahadeven, 1974). In general molluscan shells are used for making lime, mortar, cement, ornament, curios and also
for obtaining shell calcium in the preparations of medicine (Alagarswami and Narasimham, 1973 and Nair, 1974). In view of the economic importance of edible clams, it was decided to select *Marcia recens* Chemnitz for the present work.

These marine clams are present throughout the year at Royapuram fish landing centre, Madras and is consumed as food by local population. The study of taxonomical position of the bivalves becomes imperative and it enables the identification and popularization of the commercially cultivable clams. Taxonomical position of *Marcia recens* is studied initially with the available description in Reeve (1884), Gravely (1941) and Satyamurthi (1956). The taxonomy of *Marcia recens* was done by Fischer - Piolette and Metivier (1971). This species has been reported to be widely distributed in Beyapore, Mangalore, Kumta and Karwar at Goa in West coast of India (Fischer-Piette, 1976).

Edible value of this clam in association with wide distribution determines the selection of this species for the present study. It was also proposed to conduct a survey on the occurrence of this clam along the east and west coasts of India.

In any species growth is defined as an increase in body size, weight or volume. It is already established that variations in factors like temperature, light, salinity, nature of substratum and availability of the food influence the rate of growth in molluscs (Wilton and Wilton, 1929; Newcombe, 1935 and Newcombe et al., 1938). Studies on the dimensional relationship in bivalves carried out by Glatsoff (1931) and Newcombe (1950) indicate that animals of different locality show differences in dimension due to variations in environmental condition. Seed (1976) has suggested that food supply is probably the most important single factor in determining the growth rate. The growth rate is retarded when the food is scarce, regardless of all other conditions in bivalves.
Changes in the dimensional relationship between length to other parameters such as height, depth, wet flesh weight, dry flesh weight and total weight were assessed in order to understand the growth and impact of various ecological parameters on various bivalves such as *Donax cuneatus*, *D. incarnatus*, *Gafrarium pectinatum*, *Modiolus metalifer*, *Meretrix casta*, *M. meretrix*, *Anadara granosa*, *Perna viridis* and *Placenta placenta* present along the Indian coast (Durve and Raja, 1965; Nair *et al.*, 1978; Parulekar *et al.*, 1978; Mohan, 1980; Narasimham, 1984; Apparao *et al.*, 1984; Victor, 1985; Ansari *et al.*, 1986; Narasimham, 1988 and Narasimham *et al.*, 1988).

Polymorphism is a well known phenomenon in primitive molluscs. Among the bivalves this phenomenon has been reported in *Donax rugosis* with five morphs. Many gastropods are reported to exhibit polymorphism in shell pigmentation (Grunberg, 1980 and 1982; Singh, 1981 and Rajagopal, 1990). This feature is also noticed among Amphineura (Hartwick, 1981).

In the present investigation it was found that shell colour of *Marcia recens* exhibits polymorphism and thus the description of various morphs of the shell collected at Madras was undertaken. Effort was also made to describe the shell of *Marcia recens*, following the basic characteristic features of a bivalve shell.

Seasonal studies on reproduction is significant since the data collected will be of immense use to the aquaculturist regarding the availability of ripe clams, the peak period of spawning activity and information regarding the seed clam availability of the chosen bivalve in a location.
It is aimed to observe the various environmental parameters such as pH, salinity and temperature of the ambient sea water at the animal collection site i.e., Royapuram fish landing centre, Madras. The clam's habitat, especially the nature of sand varies for different species (Radhakrishna and Ganapathi, 1968 and Narasimham et al., 1984). Hence efforts were made to perform sieve analysis on sand samples collected from various places in which different clams were present.

Seasonal studies on reproduction are of value in ecological investigation since they provide important data relating to the distribution and population structure and also enables accurate prediction to be made concerning recruitment of population (Seed, 1976).

The reproductive cycle of invertebrates are determined usually by various methods as listed by Giese and Pearse (1974). Observation of reproductive stage by histological and smear method have been employed by a number of investigators to assess the reproductive activity of bivalves (Nagabhushanam and Mane, 1975; Nagabhushanam and Dhamne, 1977; Nagabhushanam and Talikhedkar, 1977 and Victor, 1985 and Jasim and Brand, 1989).

In addition to this there are reports on gonad index, condition index, observation of spawning animal and sampling of eggs, embryos, larvae, juveniles and spat fall to get better understanding of the reproductive cycle of the bivalves (Natarajan and George, 1983; Sloan and Robinson, 1984; Briceli et al., 1987; Sause et al., 1987; Shelley and Southgate, 1988 and Narasimham, 1988).
In the present work, the reproductive cycle of *M. recens* was studied by smear observation and histological preparation, following Nagabhushanam and Dhamne (1977). And condition index study was also proposed to be carried out in the present investigation. In addition to this consistent efforts were taken up to record the seed clam occurrence at the collection site for the entire study period. Apart from the above methods organ index study was also performed in different reproductive stages of male and female *M. recens* to study the role of other organs on gamete production.

Reproductive cycle is an event comprising of activation of gonad, multiplication of oogonial cells and their subsequent development leading to the production of ripe eggs, period of release of eggs, recession or resorption of gonad (Giese and Pearse, 1974; Seed, 1976). A reproductive period is a part of the event occupying the reproductive cycle in which a species undergoes a series of gametogenic cycle each followed by a spawning (Seed, 1976).

The nature of reproductive cycle for any given species differs from one locality to that of a different locality (Nagabhushanam and Mane, 1975; Lowe, 1982 and Newell et al., 1982). Population occupying different geographical localities show remarkable difference at time, in their reproductive pattern which are governed by exogenous and endogenous factors (Giese and Pearse, 1974). In tropical marine waters, where the sea water temperature fluctuates a little seasonally, such as Madras, many invertebrates are reported to reproduce throughout the year (Stephenson, 1934; Pannikar and Aiyar, 1939; Paul, 1942; Durve, 1964; Rao et al., 1975; Subramoniam, 1977; Raja, 1979; Varadarajan and Subramoniam, 1982 and Narasimham, 1988).
Whereas, in temperate and Arctic seas there are marked seasonal changes in temperature and illumination and increase in food supplies. These factors confine the organism to a limited period of breeding activity (Loosanoff and Nomejko, 1951; Loosanoff and Davis, 1952 and Loosanoff, 1965). Thus, there will be a period of increasing metabolic activity with the growth and maturation of gonads and a triggering mechanism, probably at threshold temperature initiating spawning (Purchon, 1968).

The pattern of reproduction in bivalves stands as no exception to the above generalisation observed. Survey of literature confirms that the reproductive cycle of bivalves in tropical waters has been correlated with fluctuations in salinity (Paul, 1942; Rao, 1950; Durve, 1965 and Alagarswami, 1966). On the other hand in temperate regions the gonad development and reproduction of marine bivalves has been correlated with the wide range of fluctuation in temperature (Loosanoff and Davis, 1952).

Studies on temperate water oysters at different depths revealed differences in quantum of spawning because of differences in food availability. Further oysters of different physiological races spawned at different times. This was also confirmed by laboratories experiments (Loosanoff and Nomejko 1951 and Loosanoff and Davis 1952 a and b).

It is interesting to note that there is a wide difference in the reproductive pattern of the same bivalve between the east and west coast of India and also within the east coast species. The species studied were *Meretrix casta* and *Donax cuneatus* (Abraham, 1953; Nayar, 1955; Rao, 1968; Durve, 1964; Parulekar et al., 1977; Nagabhushanam and Talikhedkar, 1977 and Victor, 1985).
In addition to the clams mentioned above, reproductive biology of Anadara granosa, A. rhombea, Meretrix meretrix, Donax faba, Placenta placenta, Mytilus viridis, Ostrea madrasensis, Katelysia opima, Paphia malabarica, P. laterisulca, Crassostrea gryphoides and Villorita cyprinoides were also studied in Indian coasts (Hornell, 1922; Rai, 1932; Paul, 1942; Rao, 1950; Rao et al., 1962 and 1975; Alagarswami, 1966; Rao, 1968; Nagabhushanam and Dhamne, 1977; Sreenivasan, 1983; Natarajan and John, 1983; Thangavelu and Sanjeevaraj, 1985; Jayabal and Kalyani, 1986; Mane and Nagabhushanam, 1988; Narasimham, 1988; Narasimham et al., 1988 and Rao, 1988). These studies reveal the importance of reproductive biology of these clams.

Thus, the study of reproductive biology of commercially important species gains greater significance, as it enables the aquaculturists to know the pattern of reproduction of that species which is of immense help in culturing them.

In temperate regions the rate of growth of bivalves varies. Bivalves differ greatly in the age at which they reach the sexual maturity. Many species such as the common mussel Mytilus edulis reach sexual maturity at the age of one year (Seed, 1975), while other species such as the pacific clam Siliqua patula takes from 2 to 6 years (Weymouth et al., 1925). Studies on Mytilus edulis by Seed (1969) and in Modiolus modiolus by Jasim and Brand (1989) reveal that the attainment of first sexual maturity was related to age and not to size in temperate waters. However, studies on the edible cockle Cardium edule by Hancock and Franklin (1972) revealed that the size is a major factor for the attainment of maturity rather than age.
In tropical climates growth is fast and the maturity is attained at an early size. Hence size of the clam was employed as the criterion, in the present study to assess the first sexual maturity. Studies on *Donax cuneatus* carried out at different areas at east coast of India confirms that there was not much difference in the size with regard to the attainment of sexual maturity (Victor, 1985). Sexual maturity of clams such as *Meretrix casta*, *M. meretrix*, *Katelysia opima* by Jayabal and Kalyani (1986), ark shell *Anadara granosa* by Narasimham (1988) and *A. rhombea* by Natarajan and George (1983) have been studied. Thus it is proposed to determine the size at which sexual maturity is attained in *Marcia recens* as it enables to determine the size by which clams may be chosen for the study of reproductive pattern.

Biochemical studies have been carried out in several bivalves. (Nagabhushanam and Deshmukh, 1974; Nagabhushanam and Dhamne, 1977; Nagabhushanam and Bidarkar, 1982 and Trider, 1980). In *Crassostrea madrasensis* biochemical analysis was done on mantle, gill, adductor muscle and visceral mass in both sexes during different reproductive stages by Easterson and Kandasami (1988). Whole oysters meat of the same species was also studied irrespective of the reproductive stages at Ennore, Madras by Venkataraman and Chari (1951). Balasubramaniyan and Natarajan (1988) have studied the seasonal changes of protein, carbohydrate and lipid in body components viz. gonad, digestive glands adductor muscle, foot, gill, mantle and siphon in *Meretrix casta*. The results were compared with the annual reproductive cycle of the same clam collected from the Vellar estuary for the period studied. The biochemical composition and calorific value of commercially exploited clams *Meretrix casta* and *Villorita cyprinoides* occuring at Cochin backwaters has been analysed by Lakshmanan and Namibisan (1980).
Seasonal variation in whole body composition of *Donax cuneatus* has been worked out by Nagabhushanam and Talikhedkar (1977). Studies on the biochemical composition of *Donax cuneatus* with respect to individual stages viz. immature, developing, ripe, partially spent and spent clams have also been made by Victor (1985).

Thus the approaches to analyse the biochemical constituents in bivalves have three modes namely 1. the understanding of seasonal variations and their influence on reproductive pattern, 2. changes in different organs with regard to reproductive stages and 3. to estimate its nutritive potential.

In the present investigation it was proposed to assess the nutritive value and changes in biochemical constituents in different organs at various reproductive stages in *Marcia recens*. Thus biochemical analysis was conducted to determine the protein, carbohydrate and lipid in gonad, hepatopancreas, adductor muscle, foot and other tissues of the clam at various stages of reproduction in males and females of *Marcia recens* to study the influence of reproduction. Whole clams were also subjected to the biochemical analysis, ash content and calorific values.

Changes in biochemical composition are usually reported as differences in the level of a given constituent (% dry weight) or as changes in biochemical content (weight per animal) (Giese, 1967). The disadvantage of expressing the results as a percentage is that changes in one biochemical component are reflected by changes in all other components. On the other hand, the biochemical content is dependent on size and on growth. When considering seasonal changes in biochemical composition it is useful to express the results in terms of composition of a standard animal of a given size (Bayne *et al.*, 1976).
Calorimetric determination have been carried out by a number of earlier investigators (Mukerji and La roux, 1969; Venkatesan, 1978; Lakshmanan and Nambisan, 1980 and Victor, 1985). Such calorimetric determination are conducted to calculate the energy budget of the water bug Diplonicus indicus and compared the variation with the type of prey provided to the predator (Venkatesan, 1978) or to understand nutritive value of the organisms (Lakshmanan and Nambisan, 1980 and Victor, 1986). In the present study, the calorific value of the meat of M.recens was carried out to understand its nutritive potential. In addition to this ash content has also been analysed.

In molluscs, the yolk protein arise mainly from intraovarian production and are of both hetero and autosynthetic in origin (Selman and Wallace, 1978). In bivalves such as Mytilus edulis oocytes were believed to produce yolk proteins autosynthetically (Pipe, 1987). Autosynthetic yolk formation is thought to be the main type of vitellogenesis in bivalves and prosobranchs (Jong-Brink et al., 1983). Evidence for this is also noticed in the Pacific oyster Crassostrea gigas in which a vitellin-like protein was found to be synthesized inside ovary not in other somatic tissue such as digestive diverticula (Suzuki, 1992).

In Marcia recens the differences in protein profile between sexes for gonad, hepatopancreas, adductor muscle and foot are studied by polyacrylamide gel electrophoresis. And SDS-PAGE is employed to analyse the variation that occur in protein profile in different stages of ovary to understand the sequential accumulation or synthesis of proteins during the growth of the oocytes.
The yolk substances in molluscan eggs consists partly of protein yolk and partly of fatty yolk. The extent of protein yolk granules present in the eggs of molluscs other than lamellibranchs varies greatly. In *Limnaea* eggs, it is above 50% in nudibranchs this amounts to 60-75% in *Crepidula* it is more than 75%. In most marine bivalves the egg reserves form a fatty yolk, consisting mainly of Neutral lipids. The bivalve ovary have been found to consist of considerable quantity of lipids by quantitative estimation (Raven, 1958; Raven, 1966).

Lipid levels have been found to be more in female, presumably due to fatty reserves in the eggs. The lipid and fatty acid composition has been the focus of attention by many workers on Molluscs (Trided et al., 1980; Pollero et al., 1981; Pollero et al., 1983 and Gorden et al., 1982).

Wilbur and Yonge (1965) have stated that hepatopancreas in bivalves are actively involved in secreting enzymes, absorbing food, excrete wastes and store nutrients. Biochemical analysis and studies on changes of relative organ size (body component index), further indicate an inverse relationship between the hepatopancreas and the gonad suggesting a transfer of nutrients from the digestive gland to the gonad (Giese, 1969). An attempt has been made to study different lipid classes in ovary adductor muscle, hepatopancreas and foot in *Marcia recens* by thin layer chromatographic analysis.

Bivalves are an important source of commercial fishery in bays and estuaries, areas prone to risk from domestic and industrial pollution. Pollution can diminish the landing of these commercially important marine resources (Nelson, et al., 1988).
The population growth and urbanization around the Bay of Bengal is accelerating and there is a rapid industrialisation in the large part of the region. Also the condition in this part of the Indian coast is subjected to pollution because of such pressure. The Coovum river entering Bay of Bengal in Madras is also polluted by effluent of industries, slaughter houses, numerous workshops, heavy industry and sewage (UNEP, 1982).

The collection site at Royapuram is polluted by harbour activities, spillage of oil and petroleum products. Hence, it was proposed to assess the impact of pollution on *Marcia recens*.

Among the various aquatic organisms, benthic filter feeding molluscs are noted for their ability to concentrate these metals from water and sediments to a very high level. These bivalves have so far attracted quite a lot of workers (Zingde et al., 1976; Sankaranarayanan et al., 1978; Lakshmanan and Nambisan, 1983; Phillips et al., 1986; Jasmine et al., 1988; Lakshmanan, 1988 and Pillai and Valsala, 1995). Various elements analysed were iron, copper, zinc, lead, nickel, cobalt, cadmium, silver, manganese, chromium and mercury.

Study of the concentration of trace elements in marine food organisms is important in view of their possible toxic effects on human beings through food chain. Thus studies were carried out in edible bivalve molluscs such as *Villorita cyprinoides*, *Meretrix casta* and *Perna viridis* with regard to seasonal variation by Lakshmanan and Nambisan (1983).
Aforesaid literature stresses the vital need to test the safety of meat with regard to trace element accumulation. Hence, efforts were made to analyse the content of trace element in the edible clam *Marcia recens* in order to know whether they are within the permissible limits and thereby the safety of its consumption for human beings is ensured.

It was stressed by GESAMP (Group of Experts on the Scientific Aspects of Marine Pollution) that in assessing pollution in Marine environment it will be better to include biological monitoring in that area as they will express the impact better than analytical methods (GESAMP, 1980).

The concept of "Mussel Watch" was proposed to monitor the contaminants introduced into the environment (Bayne, 1989). The bay mussel *Mytilus edulis* was successfully used as a sentinel organism (Goldberg *et al.*, 1978). Bivalves, such as oysters are also used to detect trace metal contamination (Frew *et al.*, 1989). The concentration of heavy metals in oysters is a function of water quality, seasonal factors, temperature, salinity, diet, spawning and individual variation (Farstner and Wittmann, 1981).

Suggesting the up growth of chemical industries in coastal areas, studies on the accumulation of iron, copper, zinc and manganese in different organs of the oyster *Crassostrea madrasensis* were carried out by Rajendran *et al.*, (1988). It is inevitable to study the bioaccumulation of metals in molluscs in order to assess the preservation or deterioration of an ecosystem. It enables to assess the damage caused due to anthropogenic sources, industries, mining operation and thereby it plays a significant role in environmental regulations (Bayne, 1989; Phillips, 1976).
Many bivalves were analysed from Fiji’s coastal waters because of their contribution to local diet and to identify the sentinel organism among them. The study stresses the need of different species in the list of pollution monitoring so that indigenous species may be used for the purpose of meeting the level of international standards (Dougherty, 1988).

Thus from the above literature it is clear that the impact assessment on environmental pollution is better served with local species to meet international standards or to augment the monitoring system in future. The data obtained in the present work was investigated for the suitability of the clam to serve the purpose of indicator or supplementary indicator organism. Hence, it is decided to analyse the concentration of metals such as zinc, cadmium, lead, nickel and copper the most prevalent pollutants tested by many authors in areas receiving similar kind of discharges. Thus, the metal accumulation capacity was interpreted for sex and in terms of season for the selected clam Marcia recens.

It is generally observed that there exist a threshold concentration which varies in magnitude from metal to metal and from animal to animal, depending upon the environmental parameters above which the metal is toxic. Metals are required in certain concentration for the growth of marine organism and where it exceeds the limit it become hazardous (Sengupta, 1978). However, it should be emphasized that the optimum monitoring programme will include physical, chemical and biological observations in the field. Moreover these observations should be supported by appropriate experimental work (GESAMP, 1980).
In addition to the estimation of trace metal content in *Marcia recens* toxicity tests were conducted for Cu, Zn, and Cd to understand their tolerance capacity.

From the public health point of view it is much essential to conduct analysis on the presence of various pathogenic bacteria such as *Staphylococcus* spp, *Escherichia coli*, *Clostridium* spp., *Salmonella* spp., *Shigella*, *Vibrio cholerae*, *V.parahaemolyticus*, and *Lactose* - *Vibrios* (*V. vulnificus*) as stated by FAO and WHO (1974) and Llobrera et al., (1986). From Japan and European countries there are also reports available on toxic dinoflagellates bloom and their impact on the fish and shellfish (Fukuyo and Ishimaru, 1986). The consumption of such contaminated seafoods results in stomach infections, different types of diarrhoea, hepatitis and cholera (Rosario et al., 1982 and Holmgren, 1992).

Hence, it is essential to conduct test on the microbial quality of the meat and according to the range of contamination cleansing these bivalves has to be carried out by subjecting them to depuration. The studies were conducted on the bacterial quality and relevant methods for depuration were developed in India for *Villorita cyprinoides* and for the mussel *Perna viridis* by Surendran and Balanchandran, (1988), for *Crassostrea madrasensis* by Pillai and Selvam, (1988) for *Perna indica* by Selvam and Pillai, (1988) and at Phillipines for *Crassostrea iredalei* by Palpal-lactoc et al., (1986) and Gacutan et al., (1986). As raw consumption of molluscan meat is practised, besides being processed, it becomes essential to conduct bacteriological investigation to be more aware of the quality of this nutritious meat. Hence in the present work the meat of *Marcia recens* was tested for its bacterial quality.
The present investigation is undertaken in response to the problems outlined above. The main aim of this work has been to investigate the following:

- Efforts are made to describe the shell colour polymorphism and other characteristic features of the shell.

- Survey of *M. recens* along the east and west coasts of India is taken up to identify their distribution.

- Changes in the dimensional relationship between length to other parameters such as height, depth, wet flesh weight, dry flesh weight and total weight were assessed in order to understand the growth pattern.

- Environmental parameters are recorded to assess the impact of it in the pattern of reproductive activity.

- Classification of various gonadal stages by histological method is carried out in both sexes. It is proposed to analysed the reproductive cycle in *M. recens* based on monthly percentage frequency of various reproductive stages.

- First sexual maturity is determined and Sex-ratio is analysed.

- It is proposed to perform condition index study to get better understanding of the reproductive cycle.

- It is proposed to observe the organ indices to understand the changes in various organs with regard to reproductive activity.
• It is aimed to analyse the level of various biochemical components in different organs with regard to reproductive stages.

• Qualitative analysis is taken up to understand the nature of protein and lipid profile in both sexes.

• Biochemical content is determined to assess the nutritive value of the clam.

• It is proposed to conduct trace element analysis in order to ensure the safety of meat for human consumption. However, the data obtained is also intended to be analysed in the light of indicator organism.

• It is decided to conduct toxicity studies to predict the lethal doses that could be detrimental to the survival of the clam.

• Microbial test is conducted to understand the bacterial quality of the clam meat.

• Finally, in the present investigation it is aimed to provide the information with recommendation and suggestions for culture practices of this clam in India.