Preface

Climate change has become one of the most important issues of concern today. It has become necessary to forecast imminent climatic changes well in advance. It requires a proper understanding of interrelationship between various factors that affect the climate. Part of such understanding about the interrelationship between various climatic factors is gained by studying the climatic changes during past. But, because of absence of written records of climatic changes during the geologic past, various indirect techniques called proxies have been used for this purpose. Out of several proxies used for paleoclimatic studies, the characteristics of foraminifera are among the most often used techniques. Foraminiferal proxies to infer climatic changes during the past are developed based on study of present day distribution of foraminifera. However, there are a few drawbacks of such studies; most important is the difficulty to precisely define the physico-chemical parameter responsible for particular foraminiferal characteristics. These drawbacks can be overcome by laboratory culturing of foraminifera, wherein the foraminifera can be subjected to a known set of conditions and their characteristic response observed. Therefore, a dedicated laboratory is established at National Institute of Oceanography for laboratory experiments on foraminifera. The present work is first compressive study carried out with the objective to understand the response of a few selected benthic foraminiferal species to a known set of physico-chemical conditions in the laboratory. As the change in temperature and monsoonal precipitation are supposed to directly affect the coastal marine environment, emphasis was given to observe the effect of change in salinity, temperature and food concentration, etc. on the foraminifera.

The work is compiled in nine chapters and a brief outline of the layout of the thesis and of the various chapters is given below.

Chapter I provides an introduction to the need for laboratory culture studies of benthic foraminifera. In experimental plans, emphasis is given to changes in ‘test (hard part)’ of foraminifera which is made up of either CaCO₃ or sand grains cemented together.
Chapter II summarizes the previous work done on culture studies of benthic foraminifera throughout the world. Culture studies have been carried out at many labs throughout the world, including the Micropaleontology Laboratory of National Institute of Oceanography, India. The literature review shows that majority of benthic foraminiferal studies were carried out to understand the life-cycle of few foraminiferal species and behavior of soft part (protoplasm) of the organism. Only a few studies were aimed out with the objective to understand the response of foraminifera to various climatic parameters. Therefore, it was decided to perform laboratory culture studies on benthic foraminifera with the following objectives.

- To observe the effect of different concentrations of food on selected benthic foraminifera.
- To observe the growth and reproductive phases of a few benthic foraminifera species.
- To study the life span of selected benthic foraminifera.
- To observe the response of few benthic foraminifera species (*Cymbaloporetta plana* (Cushman), *Pararotalia nipponica* (Asano), *Rosalina leei* (Hedley and Wakefield), etc.) to different ecological parameters.
- To conduct isotopic analysis on selected benthic foraminifera.

Chapter III includes the details of sampling, which was carried out from the coastal waters off Goa (15° 27' N; 73° 48' E). Sampling area is surrounded by the Mandovi estuary to the right and Zuari estuary to the left. It is about 200 m in length and has rocky cliffs on both sides. List of the materials required for collection of sample for picking live specimens is given. The method of sampling has been elaborated in detail with the help of field photographs. Culturing of diatoms to serve as food for foraminifera is also given.

After successfully maintaining the benthic foraminifera in laboratory, it was decided to study the response of them to different amounts of food, to get an idea about the proper amount of food to be provided to benthic foraminifera. Chapter IV documents the experiment conducted on benthic foraminifera *Cymbaloporetta plana* (Cushman) which was subjected to different amount of food (0, 20, 40, 60, 80 and 100 cells/ml) at different temperatures (25°C, 27°C and 30°C). A total of 18 sets,
with 5 specimens in each set were used for the experiment. The experiment was carried out in replicate. *Navicula* sp. was added as food weekly. Based on this experiment it was inferred that the average growth of *C. plana* increases with increased amount of food and 27°C temperature is most suitable for growth and reproduction in this species.

Before starting the work, it was decided to get an idea about the life span of benthic foraminiferal species found in the coastal waters off Goa. It will help plan the experiments and selecting species with shorter life span. Therefore, Chapter V summarizes the life span and the growth stages of a few benthic foraminiferal species namely *Cymbaloporetta plana* (Cushman), *Discorbina concinna* (Brady), and *Spiroloculina* sp. All these specimens were subjected to different combinations of temperature and salinity with 100μL of food (~20 cells/ml) in order to observe growth phases, mode of reproduction and life span. Based on this work, it was noted that all the three species reproduce asexually. Juveniles of *C. plana* and *D. concinna* are formed within the parent cell whereas that of *Spiroloculina* sp. reproduces within the cyst built by the pseudopodial network. Life span range of *C. plana* was noted to be from 45-55 days, *D. concinna* from 22-25 days and *Spiroloculina* sp. from 25-30 days. In case of *C. plana* and *D. concinna*, significant relationship (R=0.88 and 0.97 respectively) is seen between the number of juveniles and the size of the parent test.

Once the selected benthic foraminiferal species were successfully maintained in laboratory and their favored preferences were known, it was decided to carry out the experiments to understand their response to various physico-chemical parameters. In coastal areas, fresh water influx during monsoon significantly changes the salinity of coastal marine water which in turn affects foraminiferal fauna. Chapter VI comprises the results of experiments conducted on benthic foraminifera *Rosalina leei* (Hedley and Wakefield) with salinity as a single parameter keeping rest of all the parameters constant. This experiment was conducted on live specimens isolated from the field material. On the basis of this experiment it is concluded that *R. leei* specimens can tolerate wide range of salinity (25% to 80%). Extremely lower salinities proved to be detrimental to this species.
Precipitations during monsoon season, does not only result in change in salinity of the coastal waters due to increased runoff, but it also lowers the seawater temperature. Additionally, there are seasonal changes in the seawater temperature. Therefore, in Chapter VII it was decided to understand the combined effect of both salinity and temperature, on benthic foraminiferal species, *Rosalina leei* (Hedley and Wakefield), *Rosalina* sp. and *Pararotalia nipponica* (Asano). It is conclude that in specimens of *R. leei* the growth rate increases with comparatively lower temperatures and higher salinities but as the temperature increases and salinity decreases the growth rate also decreases.

Specimens of *Rosalina* sp. showed maximum average growth and reproduction at 30°C temperature and 25‰ salinity, whereas, comparatively less growth and reproduction was observed in case of specimens subjected to 25°C temperature.

27°C temperature and 35‰ salinity was the best combination of seawater temperature and salinity for *P. nipponica* specimens as the maximum average growth and reproduction was observed at this combination. Comparatively less growth was observed at higher as well as lower than 27°C temperature and salinity lower than 35‰. Prolonged exposure to lower than 25‰ salinity no matter the temperature, proved detrimental to this species.

The salinity in the coastal waters off Goa becomes as low as 10‰ during monsoon season. But such low salinity conditions are short-lived and do not prevail for long. Therefore, after understanding the effect of low salinity on benthic foraminifera, it was decided to understand the response of benthic foraminifera to short-term salinity changes. Chapter VIII deals with the experiment wherein attempt has been made to find the capability of *Rosalina leei* (Hedley and Wakefield) and *Pararotalia nipponica* (Asano) to recover adverse effects of short-term salinity changes. From this experiment it was concluded that extremely lower salinities lead to dissolution of the tests in both the specimens. These specimens are able to recover (with increase in salinity) these short term salinity changes but with morphological abnormalities.

Elemental and isotopic analysis of foraminiferal tests is an important technique used for quantitative determination of past climatic parameters. The chemical composition of the foraminiferal tests varies with different physico-chemical parameters. Chapter
IX deals with the changes in stable isotopic composition of *Pararotalia nipponica* (Asano) and *Rosalina leei* (Hedley and Wakefield) with reference to temperature and salinity. It was observed that the relationship between $\delta^{18}O$ foraminifera and seawater temperature is more consistent for *P. nipponica* than for *R. leei* specimens. As compared to seawater temperature, salinity appears to have little control on $\delta^{18}O$ foraminifera, within the studied salinity and temperature range.

The final chapter (Chapter X) summarizes major findings of the present work and future scope of this study. This chapter is followed by the list of references quoted in the thesis.