CHAPTER I

INTRODUCTION
Biological communities are an intricately intertwined part of our ecosystem. Their functioning can be understood by studying either the community as a whole or its component species populations separately. The latter approach unveils their complexity and is useful for developing simulation models of natural ecosystems. The intertidal zone has been the arena for many field studies, primarily due to their diversity and easy accessibility.

Among the rocky intertidal inhabitants, one of the most conspicuous and successful group are the limpets. These molluscs have a shell, consisting of a low wide cone with a more or less central apex and large rounded or oval aperture, filled with a broad foot. This animal, unlike other gastropods, cannot withdraw into the shell but, instead, has developed habits like clamping its foot and shell edge to rocks or other firm substratum.

1.1 ECOLOGY OF LIMPETS

Limpets show a cosmopolitan distribution invading both the marine as well as the fresh water regimes. They vary in their size, shape, structure and color pattern. Their ecology has been
extensively reviewed by Branch (1981). Limpets, inhabiting the intertidal regime, are subjected to many physiological stresses. The physical factors that affect intertidal organisms are temperature, desiccation, salinity and wave action. The first two factors are more critical since they determine the limits of distribution of the organisms in the intertidal zone.

1.1.1 PHYSICAL FACTORS

The temperature tolerances of littoral gastropods have been studied by several investigators (Davies, 1969; Vermeij, 1971; Wolcott, 1973; Simpson, 1976). Limpets are poor regulators of temperature due to increased degree of body contact with the substratum (Vermeij, 1971). Absorption or heat uptake mainly depends on the area exposed, limpet orientation and absorptivity of its surface (Branch, 1981). The entire surface area of the conical shell is available for reradiation which increases with increasing surface irregularity (Vermeij, 1973). Though field temperatures do not generally exceed thermal tolerance of limpets (Wolcott, 1973), there are several reports on the death and disappearance of limpets from the upper shore due to extreme temperatures (Walker, 1972; Simpson, 1976). One of the physical effects of increasing temperature is an increase in evaporation rates, desiccation and metabolism (Branch, 1981). In the subantarctic limpet, *Nacella concinna*, the intertidal population migrates downshore during winter when temperature reaches -20°C (Walker, 1972).
Dessication is the most important factor that affects limpets during tidal exposure since it determines their upper limits (Wolcott, 1973; Underwood, 1979; Branch, 1981). It causes detrimental reduction in the uptake of oxygen. Shotwell (1950) observed that smaller species of *Acmaea* sp., *Notoacmaea scutum* and *Collisella pelta* occurred higher on the shore than its larger counterparts due to a higher proportion of extra visceral water (between body and shell). Shell shape can also influence rate of water loss. Limpets at higher tidal levels have a taller and more domed shell (Rao & Ganapati, 1971a; Walker, 1972; Bannister, 1975). A taller shell also aids in reduction of desiccation (Vermeij, 1973; Davies, 1969). To avoid desiccation, limpets migrate upwards during wetter conditions (Frank, 1965; Haven, 1971; Choat, 1977) and downwards during drier conditions (Branch, 1975; Lewis, 1954). Homing is also considered to be an adaptation to desiccation.

Organisms inhabiting the intertidal region are subject to varying degrees of wave action, particularly on rocky shores where zonation patterns are evident (Lewis, 1964). In rocky habitats, organisms find refuge in the crevices and depressions in the rocks to prevent dislodgement due to high wave action (Emson & Faller-Fritch, 1976). Wave action is also responsible for limiting the distribution of organisms in rocky shores with organisms shifting further upshore with increasing wave action (Lewis, 1968).

The only defence limpets have against changing salinities is
to clamp their shell tightly to the substratum, thus temporarily excluding the external medium. Rao and Ganapati (1972) reported that *Cellana radiata* is temporarily tolerant to salinities between 20% and 37%. Experimental studies have shown that when uncovered during low tides, limpets react to splashes of sea water by raising their shells from their position assumed during tight closure (Arnold, 1957). Tolerances to salinities are different in high and low shore limpets. *Patella lusitanica*, a high shore species was less tolerant to salinity variations than *P. coerulea*, a low shore species (Bannister, 1970). Salinity does not however fluctuate widely enough to limit their distribution (Wolcott, 1973; Simpson, 1976).

1.1.2 HOMING

Homing to a fixed scar is well documented in limpets and has evoked considerable interest. There are many variations between species and within species in the rigidity of homing behaviour. The proportion of the population homing, can be influenced by size of animals, the texture and stability of the rock, availability of food and the amount of desiccation (Branch, 1981). Though there are numerous reports on homing by limpets the mechanism has not been clearly understood. In general, small individuals do not home. Territorial species home rigidly and homing is more precise in high shore species. There are however low shore and even subtidal species that have well developed scars and homing behaviour suggesting that desiccation is not the
only deciding factor. The advantage of homing could be a reduction in mortality due to dessication (Lewis, 1954; Davies 1969) or an even dispersion in the distribution of limpets (Aitken, 1962; Underwood, 1977).

1.1.3 POPULATION STUDIES

These studies encompasses not only population abundance and age structure but several other life history traits such as birth rates, death rates, longevity, mode of reproduction, partitioning of energy resources, etc. These are necessary to understand the population dynamics of species, which provides a rationale basis to explain changes in their density taking into account the role of the environment. Many authors have investigated the life history characteristics of different species to unravel common patterns. Attempts to analyse these differences in species is compounded since it is difficult to pinpoint whether these exist due to habitats, the species or due to an interaction between the two (Fletcher, 1984a).

Studies on intertidal gastropods especially limpets are abundant and have been reviewed by Underwood (1979) and Branch (1981). These studies have been restricted to Patella vulgata (Lewis and Bowman, 1975; Thompson, 1979), Acmaea scabra (Sutherland, 1970, 1972), P. granularis (Branch, 1976), Notoacmaea petterdi (Creese, 1980) and Cellana tramoserica (Fletcher, 1984a). The growth and population dynamics of these
species vary widely among different habitats and are attributed to intra/interspecific competition and physical factors (Fletcher, 1984a) and variations in food supply (Busman & Hockey, 1988). There are marked variations in the biological characteristics of Cellana spp. over small geographic distances and any attempt to comment on life history strategies must take into account such variability of the biology of a single species (Fletcher, 1984a).

1.1.4 THE ENERGY BUDGET

Bioenergetics is a study which deals with the energy flow in an organism, population or an ecosystem. Information on the efficiencies of energy transformations can also be obtained. The units are standardised and hence data on the energy partitioning for various biological processes can be obtained.

The food consumed by an animal is basically diverted into two pathways. One is to maintain and increase its structure and secondly to drive its metabolic machinery. Feeding rates are chiefly influenced by temperature and salinity (Newell et al. 1971), time of day and season, past feeding history, body size, state of tide (Newell et al. 1971), size of prey (Broom, 1982), and nutritional quality of food (Carefoot, 1967). Consumption rates in limpets are difficult to estimate (Branch, 1981).

Energy lost as heat through metabolism is represented by
respiration. Internal physiological factors which may effect the metabolism of animals are body size, age, developmental stage (Sutherland, 1972), nutritional state (Newell & Kofoed, 1977), state of stress (Calow, 1974), state of activity (Newell & Pye, 1971). External factors are diurnal and seasonal changes in temperature (Newell & Branch, 1980), relative humidity, state of tide (Sutherland, 1972; Branch 1981; Wright & Hartnoll 1981; Parry 1982a) and also tidal levels (Davies 1966; Rao 1980). The differential exposure to air complicates the effects of other environmental factors on the rate of oxygen consumption.

Energy rich waste products are eliminated from animals through faeces and urine. Faeces arise from food material which has not been digested or assimilated. Urine contains the nitrogenous products of catabolism with ammonia, urea and uric acid being the most common. The contribution of faeces and urine to the energy of the limpets is seldom measured. Faecal production has been correlated with growth rates (Branch, 1981). Wright and Hartnoll (1981) determined the absorption efficiency of the limpet *P. vulgata* and then derived the energy of the faeces from the energy content of the consumed food. Faecal production in *C. tramoserica* is seasonal (Parry, 1977). Many organisms convert nitrogenous waste products such as ammonia into urea or uric acid before elimination (Duerr, 1967). The main excretory product in *Patella* is ammonia (Fretter & Graham, 1962).

The balance of absorbed energy left after expenditure on metabolism is mainly available for the production of somatic and
reproductive tissues as well as storage products and secretion. Mucus secretion and production is generally important not only for locomotion and adhesion but also for faecal production (Calow, 1974). Growth in gastropods is generally measured as a linear increment of the shell and converted to growth by using the relationship between weight and shell size. Estimating somatic growth from shell growth assumes a direct relationship between the two. However, shell growth can occur when there is no scope for tissue growth, such as during starvation, and the reverse also holds good (Palmer, 1981).

The cost of reproduction is referred to as reproductive effort. Methods of measurement ranges from the ratio of gonad to somatic weight (Fletcher, 1984b) to the ratio of gamete output to flesh weight (Branch, 1974a; 1975) to the proportion of annual production of gonad and gametes to assimilated energy (Parry, 1982b). There are basically two patterns of reproduction in limpets: species that breed continuously and intermittently. Species which live in an occasionally suitable environment will allocate more energy for reproduction while those which reproduce continuously will invest little towards reproduction, implying that optimal reproductive effort is determined by natural selection (Giesel, 1976).

1.2 REVIEW OF PREVIOUS WORK CARRIED OUT ON C. radiata

Among the earliest studies carried out on C. radiata along
the Indian coast is that of Sukumaran and Krishnaswamy (1961) who investigated the response of limpets, collected from the rocks of Madras Harbour, to changes in salinity. The most detailed study on limpets has been carried out along the Waltair coast. Rao and Ganapati (1971a, b) described its ecology with special reference to their distribution and shell structural variations in relation to tidal levels. In addition, investigations on its resistance to variations in temperature, salinity and desiccation (Rao & Ganapati, 1972), reproductive cycle (Rao, 1973), spawning behaviour and larval development (Rao, 1975a), growth rates (Rao, 1976) and the effect of the body size and tidal rhythms on the respiratory metabolism (Rao, 1980) have also been reported.

Other studies include observations on feeding anatomy, histology of the digestive tract and digestive enzymes (Rao, 1975b) the relationship of the radula fraction and shell length at different tidal levels (Rao & Ganapati, 1967). Along the Saurashtra coast (West coast of India), seasonal variations in biochemical constituents of limpets and the response of limpets to desiccation and salinity stresses have been studied (Suryanarayan & Nair, 1976). Population density in the polluted waters of Porbandar have also been studied (Prasad and Mansuri, 1982). Seasonal variations in the biochemical constituents of C. rota at Ratnagiri have also been reported (Patil & Mane, 1982).

At Anjuna, results on a short term study on the spatial distribution of the limpet and intraspecific variations in shell characteristics have been reported (Balamani, 1990). The
densities of prosobranch gastropods including *C. radiata* at several locations along the Goa coast were investigated by Coutinho (1993).

1.3 OBJECTIVES OF THE PRESENT STUDY

It is thus seen that information on limpets, particularly along the west coast, is limited. Reports on the quantitative abundance and distribution of *C. radiata* along the Goa coast are restricted to Balamani (1990) and Coutinho (1993). There are no reports on production estimates or reproductive effort for limpets along the Indian coast. It was thus proposed to carry out a long term study with the following objectives:

- To study the environmental conditions prevailing at Anjuna, the study area where the limpets, *Cellana radiata*, were observed.

- To study the variation in its shell characteristics.

- To study its diet through gut content analysis.

- To study its reproductive pattern.

- To investigate its movement pattern.

- To gain an insight into its population structure and
successive changes with time and estimate its longevity.

- To analyse the seasonal variations in growth rates.

- To estimate its monthly, seasonal and annual somatic, gonadial and gamete biomass and production.

- To estimate its monthly, seasonal and annual respiratory losses.