

Studies on some ecological aspects of  
*Balanus amphitrite* (Cirripedia:Thoracica)



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March 2002

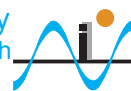
Studies on some ecological aspects of  
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Thesis Submitted to the  
Goa University  
for the degree of  
Doctor of Philosophy in  
Marine Science

**Dattesh V. Desai**



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### Statement

As required under the University ordinance 0.19.8 (vi), I state that the present thesis entitled “**Studies on some ecological aspects of *Balanus amphitrite* (Cirripedia: Thoracica)**” is my original contribution and the same has not been submitted on any previous occasion. To the best of my knowledge the present study is the first comprehensive work of its kind from the area mentioned.

The literature related to the problem investigated has been cited. Due acknowledgements have been made wherever facilities and suggestions have been availed of.

DATTESH VITHOBA DESAI

## Certificate

This is to certify that the thesis entitled “**Studies on some ecological aspects of *Balanus amphitrite* (Cirripedia: Thoracica)**”, submitted by Mr. Dattesh Vithoba Desai for the award of the degree of Doctor of Philosophy in Marine Science is based on his original studies carried out by him under my supervision. The thesis or any part thereof has not been previously submitted for any other degree or diploma in any Universities or Institutions.

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**(Dattesh Vithoba Desai)**

*Chapter 1*  
*General Introduction*

## General Introduction



Barnacle is an important component of the intertidal community and also of the marine macrofouling communities. They have drawn the attention of many investigations in marine ecology owing to their easy accessibility on the rocky intertidal regions, capacity to withstand desiccation for long duration and also because some species are dominant in marine fouling.

Populations of intertidal, fouling barnacles around the world have since been analyzed for insights into the diversity and stability of the communities they are a part of, with various emphases placed on predators, competitors and physical factors that affect recruitment and survival (Connell 1961 a,b; Dayton 1971; Denley and Underwood 1979; Underwood et al. 1983). Barnacles have also been studied for their own biology, and many such studies have adopted a comparative approach involving more than one species that occur on most shores or in fouling sequences, and the different species that exists in different parts of the world. On rocky shores barnacle zones may be very precisely defined with regard to tidal height, and are frequently visibly obvious (Foster 1987). Differential barnacle zonation on shores implies varying adaptations to the gradients of factors between tides. The upper limits are largely determined by physical factors associated with tidal immersion and, lower limits are set by complex biotic relationships. The shell is clearly a predator protection, possessed by free-living sublittoral and intertidal barnacles alike. Its relative impermeability is also handy pre-adaptation for sessile existence intertidally. But if breeding is to occur, it needs to be

combined with adequate behavior to and tolerances of physical stresses, such as reduced feeding time, wider temperature ranges and the problems of too much fresh water or water loss (Foster 1987).

Their capacity to occupy any hard substrata in the marine environment like ship hulls, sonar domes, naval acoustic devices, offshore platforms, Ocean Thermal Energy Conversion (OTEC) plants etc. has drawn attention because of the economic penalties in terms of fuel consumption, malfunctioning of devices used in the marine industries.

Barnacles are the most important component of the hard fouling community. The development of the fouling community is very complex and is regulated by physical and biological factors as well as the chemical cues released by the substratum (Barnes 1970; Crisp 1974; Crisp and Meadows 1962,1963; Crisp et al. 1985; Svane 1988; Richmond and Seed 1991; Rodriguez et al. 1993; Neal et al. 1996; Nellis and Bourget 1996; Steinberg et al. 1997). Understanding of the fouling phenomenon and the biological community is an essential prerequisite for implementation and development of protective measures against biofouling.

Several species of balanomorph or acorn barnacles are ranked among the most successful colonizers of the marine littoral zone. They are conspicuous sessile animals on rocky shores round the world. This success is all the more remarkable in view of the relatively recent evolutionary radiation of the Balanomorpha during the Miocene and Pliocene periods; indeed Darwin (1854) suggested that the recent epoch might be called as the 'Age of Barnacles'. Their success in colonizing a variety of microhabitats must be

attributed to their crustacean origin and the way typical crustacean features (such as cuticular exoskeleton, biramous jointed limbs, haemocoelic blood system and planktonic larval forms) have modified for a sessile mode of life. Adaptations of barnacles fall into two categories, those fitting the animal for sessile mode of life, and those allowing colonization of the littoral zone. The modification of the limbs related to filter feeding, shortening of the body and the loss of the eyes and antennae fall into the first category. The loss of a stalk, the adoption of a low conical profile and locking of the plates forming the shell all reflect the adaptation to the influence of waves, while other tendencies such as reduction in size, fusion of the shell, development of contractile fibers to anchor the shell to the substratum and numerous behavioral modifications are associated with improving their ability to live on the shore. Physiological modifications which enable them to survive out of water can only be interpreted as adaptations to tidal conditions and intermittent emersion.

Acorn barnacles are some of the most common creatures of the sea shore and have been widely used for studies of interspecific competition, habitat selection by planktonic larva, and life histories (Wehty 1979; Barnes and Barnes 1968; Crisp 1954; Hurley 1973; Lewis 1975; Crisp 1983). Clegg (1955), Walker (1977,1980) and Barnes et al. (1977) have described copulation and fertilization. Almost all hermaphroditic barnacles have well-developed penis. A recently molted individual, receptive as a female, signals chemically to 'her' neighbors (Walley 1965; Walley et al.1971) although initial searching by a 'male' seems to involve only a generalized direction of penis movement. Once the 'female' is found, the 'male' deposits sperms (apparently

more than needed to fertilize all the eggs) in the females mantle cavity. More than one individual may copulate with a single 'female'.

The classification of thoracican cirripedes was established by Darwin (1851 and 1854). Thoracica is the extremely diverse order, includes the ordinary barnacles found along the sea-shore. Representatives are found in almost all marine and estuarine environment and include a wide range of symbiotic associations (Newman 1987). The Thoracica, the principle order of the Cirripedia, was established and divided into three families by Darwin (1851b, 1854a): Lepadidae, the stalked or pedunculate barnacles; Verrucidae, the asymmetrical sessile barnacles; and Balanidae, the symmetrical sessile barnacles. Symmetrical sessile barnacles primitively have a fundamental primary wall of 8 plates surrounded by a number of whorls of smaller imbricating plates and surrounding an operculum of four plates or valves.

Taxonomy of *Balanus amphitrite* is complex and several investigators have addressed this issue (Harding 1962; Henry and McLaughlin 1975; Utinomi 1967; Wagh and Bal 1971; Fernando 1990; Yamaguchi 1977). Fernando (1990) worked on the systematic aspects of some fouling barnacles from Indian waters. He reported that there are several revisions of the basic Darwinian system on the taxonomy of cirripedes. The most necessary has been that of Harding (1962) who re-described and rearranged Darwin's type of the so called varieties of the *Balanus amphitrite*. Originally Darwin (1854) classified *Balanus amphitrite* complex into nine varieties namely communis, venustus, pallidus, niveus, modestus, stutsburi, obscurus, variegatus and cirratus. None of the original varieties of Darwin had type specimen, so

Harding (1962) assigned lectotypes for the varieties of Darwin's dried specimens. Harding (1962) divided nine varieties into four separate species namely *Balanus amphitrite*, *Balanus pallidus*, *Balanus venustus*, *Balanus variegatus*.

*Balanus amphitrite* var. *communis* was placed into the species *Balanus amphitrite* var. *amphitrite*. The varieties *pallidus* and *stutsburi* were placed in the species *Balanus pallidus*. Darwin's varieties *venustus*, *niveus*, *modestus* and *obscurus* were placed in the species *Balanus venustus* by Harding (1962). The varieties *variegates* and *cirratus* were placed on varieties under the species *Balanus variegatus*. He also synonymized Broch's (1927) variety *denticulata* with *Balanus amphitrite amphitrite*. The taxonomical studies of *Balanus amphitrite* (Utinomi 1967) revealed that Darwin had put two species under the same taxa; *Balanus amphitrite* and *Balanus reticulatus* which were subsequently verified by Southward (1975). Utinomi (1967) stated that Darwin's inadequate description and inadvertent muddling of separate varieties, samples and opercular valves from different sources lead to confusion among varieties of *Balanus amphitrite*. Harding attempted to re-examine original specimens of various varieties of *Balanus amphitrite* which Darwin studied and dissected and designated lectotypes and proposed a revised nomenclature which is used now.

In selecting some of Darwin's material for a lectotype of the common purple striped variety (i.e. *communis* of Darwin), Harding (1962) chose specimens which possess a multidenticulate labrum and other characters which indicate

that the world wide forms previously called *Balanus amphitrite denticulata* and *Balanus amphitrite hawaiiensis* Broch are synonyms of this common variety.

Advancement in understanding the taxonomy of *Balanus amphitrite* group came through an extensive study of morphology by Henry and McLaughlin (1975). In their taxonomic revision of the living *Balanus amphitrite* complex based on previous work and examination of numerous specimens from various localities including Indian waters. They defined 23 taxa of the amphitrite complex and concluded that only two sub species of *Balanus amphitrite* exists i.e. *Balanus amphitrite amphitrite* and *Balanus amphitrite saltonensis* (Rogern 1949). Based on the genetic analysis, Flowerdew (1985) suggested to synonymise the *amphitrite* variety *saltonensis* with the variety *amphitrite*. Thus only one subspecies of *Balanus amphitrite* occurs around the world i.e. *Balanus amphitrite amphitrite*.

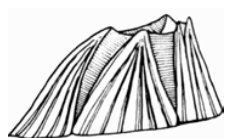
The form reported by earlier worker's occurring along the Indian coasts which are synonym of *Balanus amphitrite amphitrite* viz. *Balanus amphitrite* variety *communis* Darwin (Daniel 1955; Karande and Palekar 1966; Nilsson-Cantell 1938), *Balanus amphitrite* form a *hawaiiensis* Broch (Nilsson-Cantell 1938; Karande and Palekar 1966) *Balanus amphitrite venustus* (Sundaraj 1927) are according to the recent taxonomic revision (Henry and McLaughlin 1975) are synonyms of *Balanus amphitrite amphitrite*.

The overview of the morphological characteristics of *Balanus amphitrite amphitrite* is presented.



## Distinguishing Features

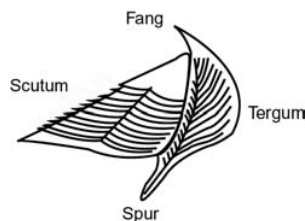
*Balanus amphitrite amphitrite* is distinguished from other members of this species complex by identifying the number of teeth on the labrum and a short spur on the turga etc. The shell is white or bluish white with longitudinal lavender or purple color stripes, variable in intensity and width.

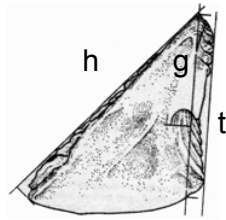


Shell is conical. Compartments are externally smooth. Dark purple longitudinal stripes. External surface of radii is smooth. Shell consists of ring of overlaying calcarious plates in the form of truncated cone. The wall plates vary in number in different species. This particular species has got six wall plates. Rostrum, lateral (left and right), carino-lateral (left and right) and carina. Shell plates are in close contact with an underlying hypodermis which is concerned directly with their formation and structure (Bourget 1977). Each wall plate is composed of a central part, paries. Overlapped portions are called alae. If the overlapping portion differ from the paries (Pilsbry 1916) it is called radius. Radii are broad quite white internally. The inner lamina is strongly ribbed equidistantly through out. The ribs nearly reach the basal margin of the inner lamia.



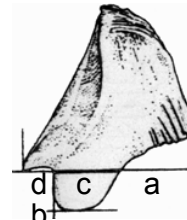
R- Rostrum  
L- Lateral  
CL- Carino Lateral  
C- Carina





Scutum

h- Length of occludent margin  
t- Tergal margin  
g- Length of articular ridge



Tergum

a- Length of basal margin  
b- Spur length  
c- Spur width  
d- Distance from basiscutal angle

### Labrum (Plate I: A-C)

Labrum is multidenticulate, a lip like extension anterior to the mouth of the barnacle. It has invariably 15 teeth on each side of the notch. Numerous very fine setules are aligned in several lines on the edge.

### Mandible (Plate II: A-B)

Mandible with 6 teeth with spinose inferior angle. The first teeth is sharply pointed and the others bluntly rounded. The last teeth is united with the inferior angle. Fine setules are present on the surface of the mandible.

### First maxilla (Plate II: C-D)

First maxilla is without notch below the upper pair of spines. First maxilla has 12 spines of different size along the nearly straight frontal margin below the upper pair of large spines. The lower part is slightly protuberant than the upper two third and bears 2 largest spines which are strong and prominent. Few short spines are present on inferior angle.

### Scutum (Plate III: A-B)

Scutum flat, basitergal angle truncate, interior of the apex is ridged. Scutum is longer than the wide. Tergal margin is cranulate. Length of the occludent

margin with widely spaced fine growth lines. Adductor muscle pit is distinct. Internally the upper part is smooth. Articular ridge is strong.

#### **Tergum (Plate III: C-D)**

Tergum is quite flat externally. Scutal margin is denticulate. Growth ridges are moderately developed. Spur is moderately rounded. Basal margin is almost straight on both sides of the spur. Carinal-basal margin with narrow groove, usually cranulate on scutal side. Interior surface is smooth and slightly rough on upper part.

#### **Rostrum (Plate IV: A-B)**

Rostrum overlaps the left and the right lateral. The interior edges are crenulate or with denticles. The edge of the radii having denticles arranged parallel.

#### **Lateral (Plate IV: C-D)**

The outer surface of the lateral is smooth. The inner surface is with ridges with denticulate edges.

#### **Carino Lateral (Plate V A-B)**

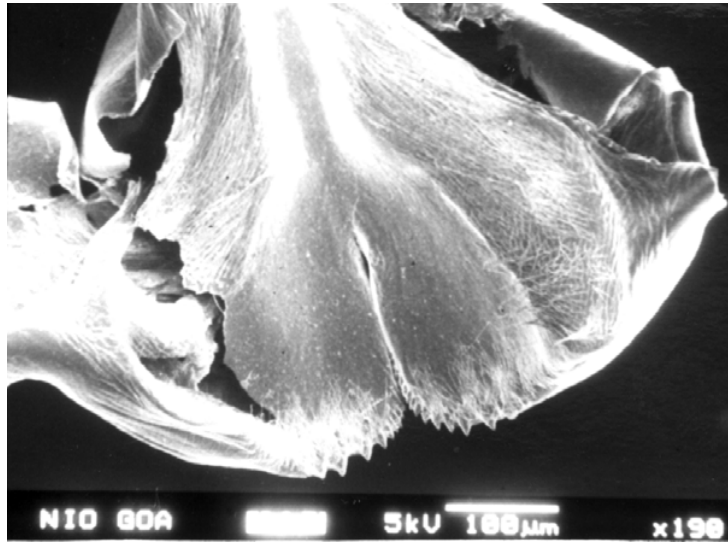
The outer surface is smooth. The radii is denticulate at the overlapping portion. Interior portion is with deep vertical ridges towards the base. Alae with fine concentric ridges.

#### **Carina (Plate V: C-D)**

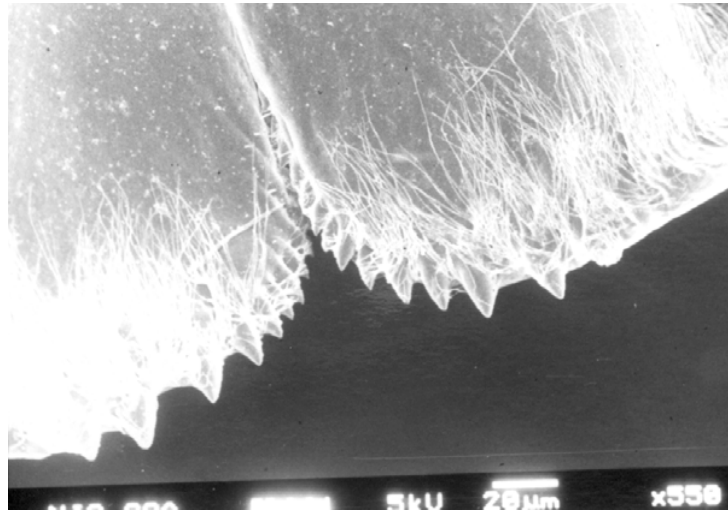
The outer surface of the carina is smooth on the paries. Alae is smooth on outer side. Both the edges are crenulate. Inner side of paries is with parallel ridges till the basal margin. Alar margins are also crenulate to hold the carino-lateral.

PLATE I

A



B



C

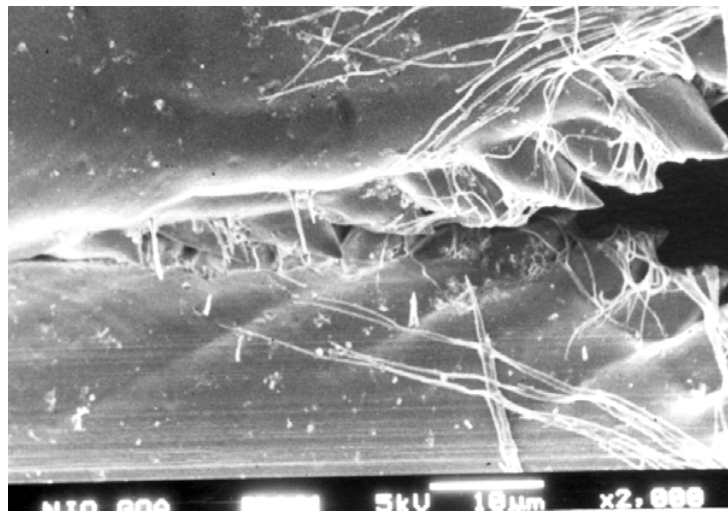
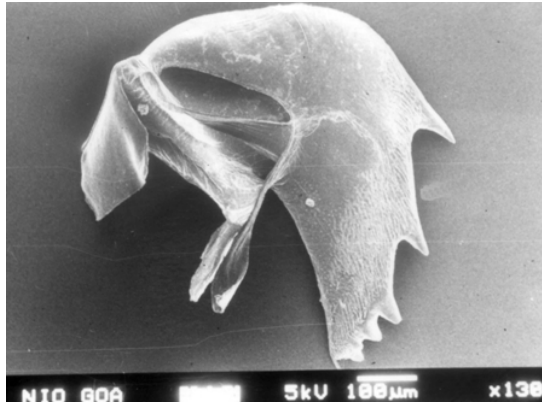
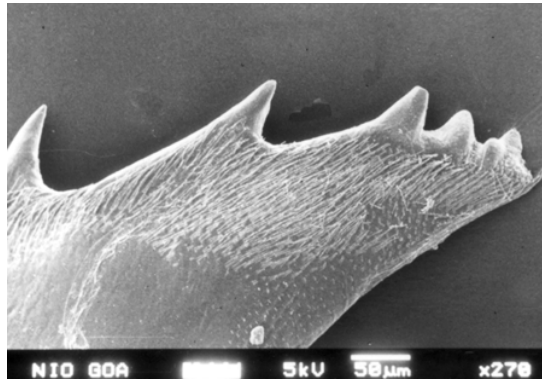


PLATE II

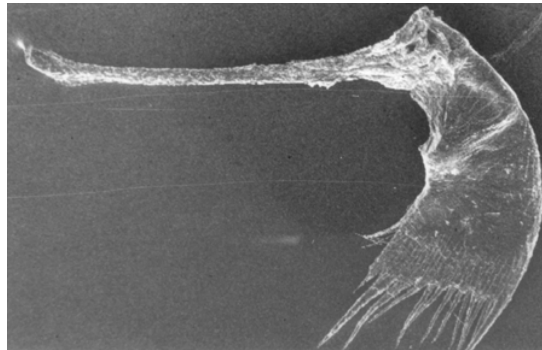
A



B



C



D

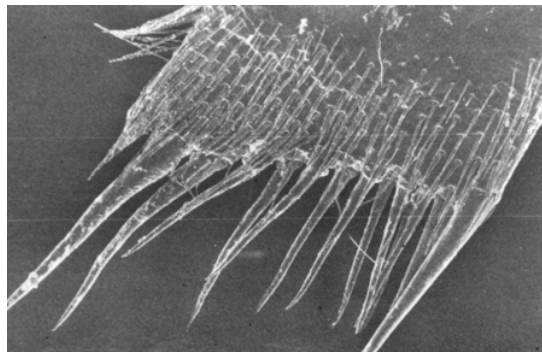
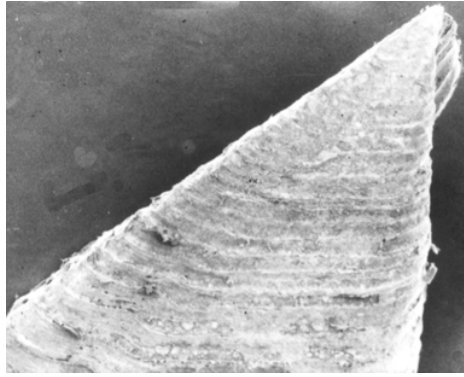
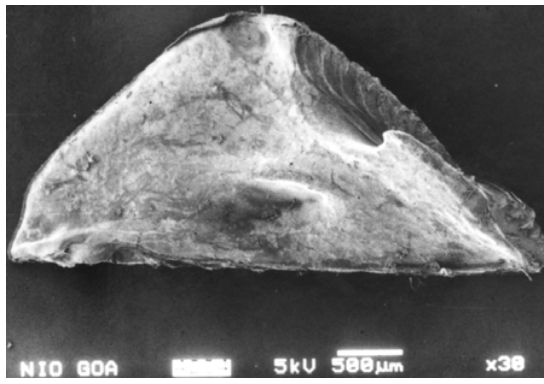


PLATE III

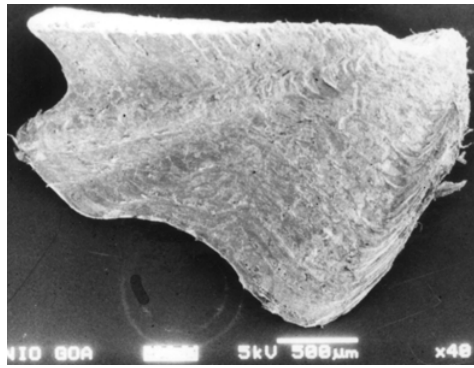
A



B



C

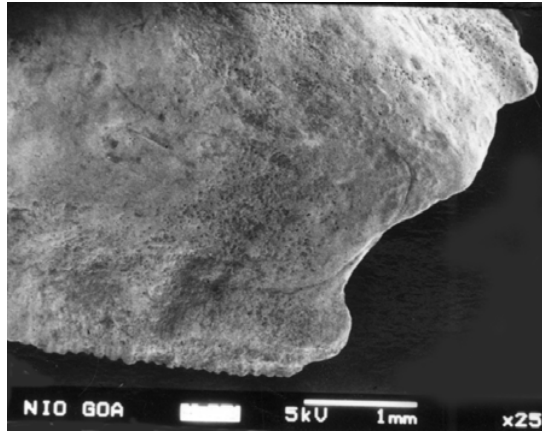


D

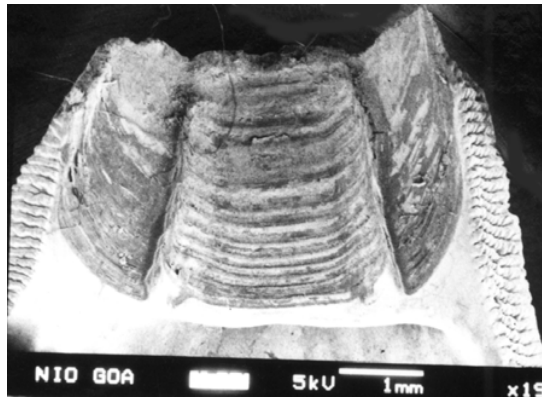


PLATE IV

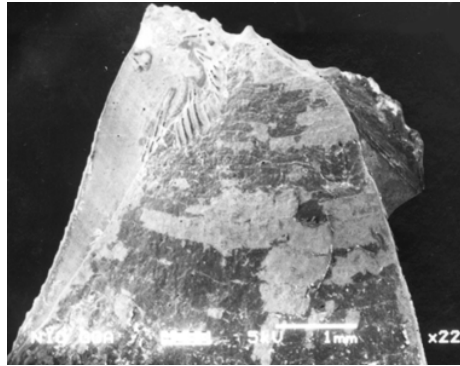
A



B



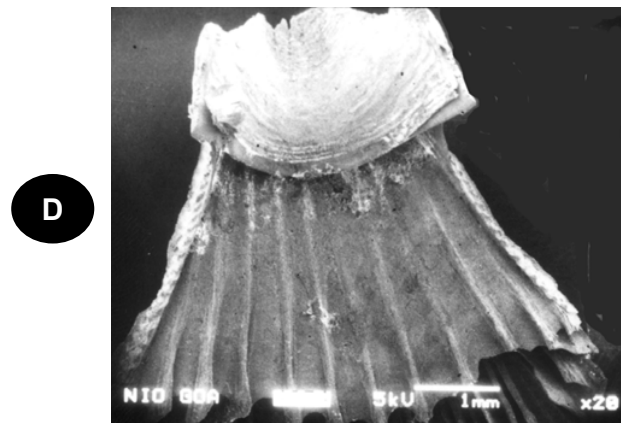
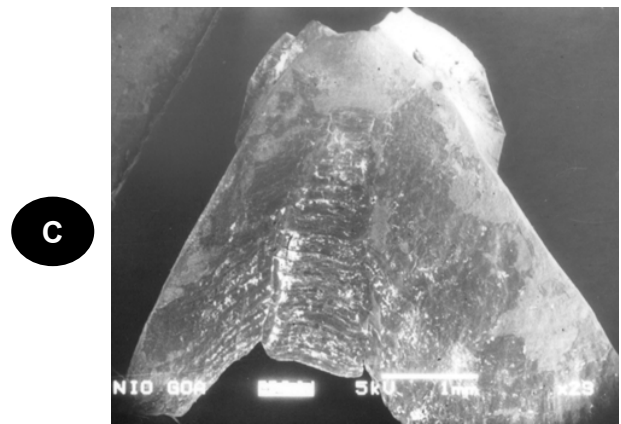
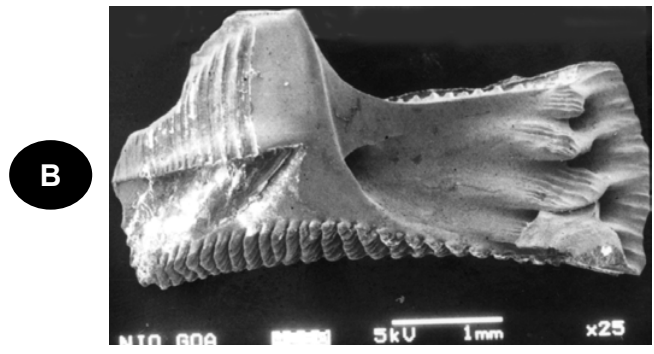
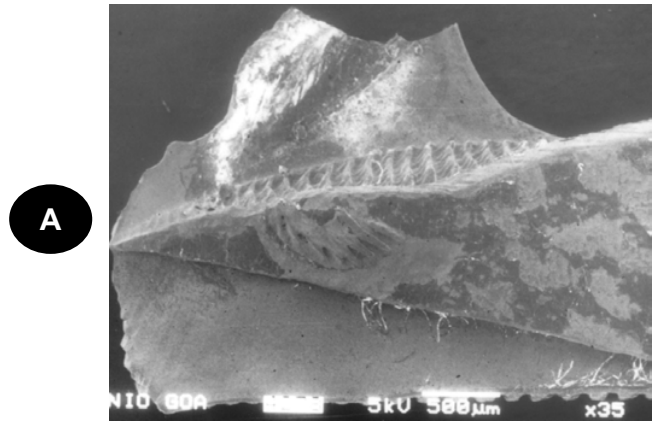
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D

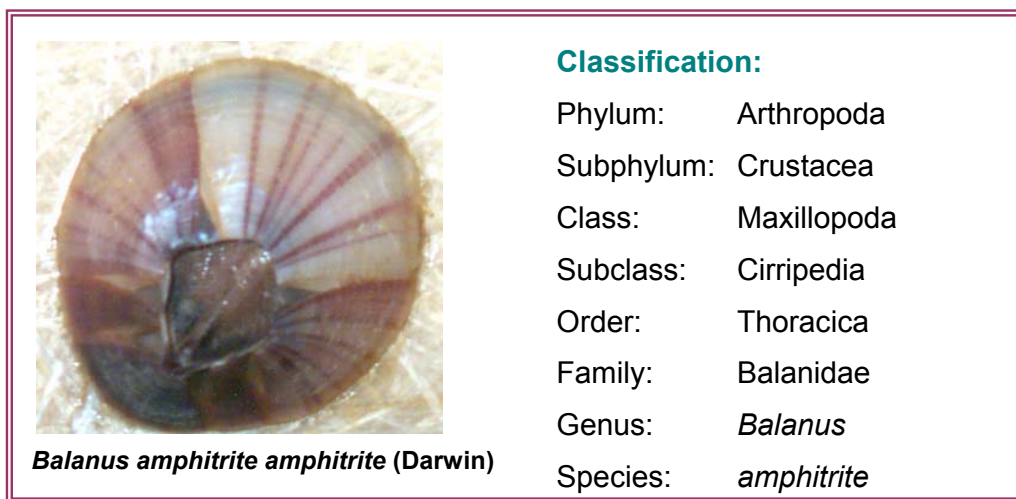


PLATE V





*Balanus amphitrite*, an acorn barnacle is cosmopolitan in distribution and its habitat extends from supra-littoral to sub-littoral zones. The euryhaline and eurythermal capability (Crisp and Costlow 1963; Iwaki 1981; Anil 1991) and fugitive biology has enabled its distribution into the fringes of marine habitats.



These distribution advantages have also aided this species to be one of the dominant fouling organisms. They occur in both warm and temperate seas. In India this species has been reported from both east and west coasts (Karande 1967,1974; Fernando 1978; Anil 1986; Pillai 1958). It is important to understand the life cycle and the role of ecological factors which will have impact on their survival and development of the specific organism that is considered important.

*Balanus amphitrite* has been extensively used in studies related to adult biology, larval descriptions and development, metamorphosis, influence of different chemical cues and in antifouling assays (Crisp 1962; Barnes 1957; Daniel 1958; Fernando 1978; Rittschof et al. 1984; Maki et al. 1988,1990;

Karande 1973 ,1999; Anil et al. 1995,2001; Anil and Kurian 1996; Dattesh and Anil 2000).

It is hermaphrodite and fertilization is internal. The larval phase includes six planktotrophic naupliar instars followed by a non-feeding pre-settling cyprid instar. The distribution and abundance of barnacle is site specific. In order to understand the population dynamics from a larger geographic context, it is important to understand the linkages between reproduction, larval and recruitment ecology. In this effort the ecology of *Balanus amphitrite* from a tropical habitat is presented based on the studies carried out in Dona Paula bay located at the mouth of the Zuari estuary (Goa , India).

#### Study area (Dona Paula bay)

