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ZONATION OF INTERTIDAL ORGANISMS ON THE ROCKY SHORES OF BOMBAY

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ABSTRACT

Zonation of intertidal organisms on the rocky shores of Cuffe Parade, Chowpathy, Breach Candy and Mahim around Bombay was studied. In all the four shores it was possible to recognise the following general pattern of zonation.

(i) Upper littoral zone dominated by littorinids-four littorinid species were abundant in all the four localities. Major species showed definite vertical zonation.

(ii) Mid littoral zone characterised by barnacles and oysters, was divisible into three or four belts-dominated by distinct set of animals.

(iii) Lower littoral zone (wide zone), had a large number of species and maximum number of animals-trochids in general dominated this zone.

INTRODUCTION

The study of biotic divisions of the intertidal region is very fascinating. The environment is subjected to interaction between the sea, land and atmosphere and is covered and uncovered every day by the flood and ebb tides, with the result that the organisms inhabiting the intertidal region acquire the capacity to endure the variations in temperatures and desiccation during the exposure which continuously changes from day to day and from season to season. The striking feature of such an environment is reflected in the vertical zonation of the organisms. The zones where the animals of one type predominate are named after them. This is because that these organisms are generally restricted to definite limits and concentrate at levels where optimum living conditions exist. One characteristic feature of the shore fauna is that the composition and the order of the communities are almost the same everywhere; thus the littorinids inhabit the higher levels of the shore throughout the world, but the individual species are different in different parts of the world. Barnacles are found on the midlittoral rocks in the cold as well as in tropical seas. The algae dominate the lower levels. Similarly the members of Trochidae are also found at about the same levels in many places.

Stephenson (1939) visualized the possibility of evolving a universal system for zoning the intertidal regions of the world. Stephenson and Stephenson (1949) recognised three zones viz. (1) Supralittoral fringe extending from the upper

limit of the barnacle line to the upper limit of littorinids, (2) Midlittoral zone and (3) the Infralittoral fringe at the point where the large algae such as the laminarians cease to become dominant. These authors have also pointed out that the limits of these zones and the indicator organisms vary from place to place as these get modified by the various environmental factors. Other investigators in the field such as Womersley and Edmonds (1952) and Chapman and Traverthan (1953) have given different names to different zones of the intertidal regions. Bhatt (1959) has shown from his studies on distribution of the organisms on four rocky shores around Bombay i.e. Cuffe Parade, Chowpatty, Breach Candy and Mahim that the three zonation present support the scheme drawn by Stephenson and Stephenson (1949). However, it is felt that the terminology proposed by them and subsequently adopted by many workers needs certain modifications and this aspect has been mainly discussed in this paper.

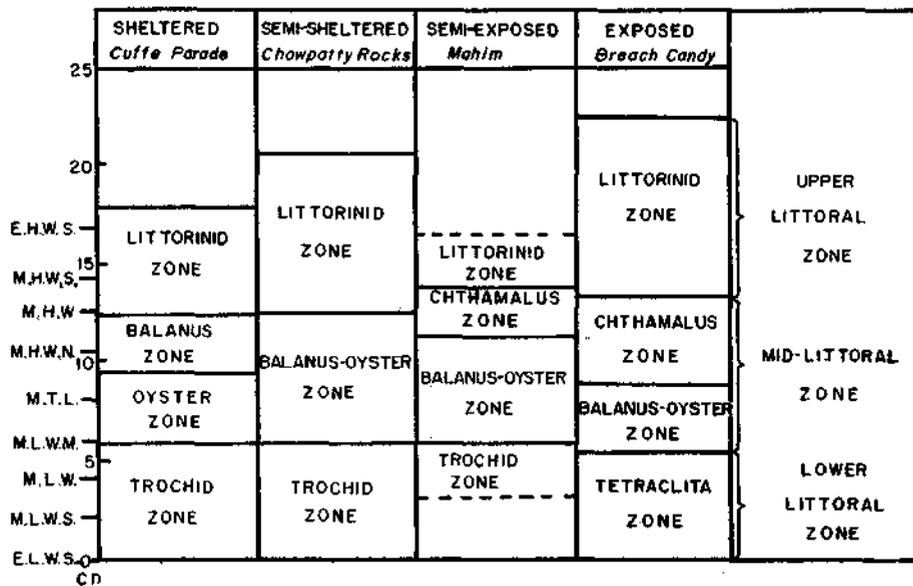


Fig. 1. Diagram showing the different types of zonation met with on some rocky shores at Bombay.

- EHWS - Extreme High Water of Springs - 5.2 meters
 MHWS - Mean High Water of Springs - 4.4 meters
 MHW - Mean High Water - 3.8 meters
 MHWN - Mean High Water of Neaps - 3.2 meters
 EHWN - Extreme (lowest) High Water of Neaps - 2.7 meters
 ELWN - Extreme (Highest) Low Water of Neaps - 2.6 meters
 Local Mean Sea Level of Survey of India Levelling or MTL - Mean Tidal Level - 2.5 meters.
 MLWN - Mean Low Water of Neaps - 1.9 meters
 MLW - Mean Low Water - 1.3 meters
 MLWS - Mean Low Water of Springs - 0.8 meters
 ELWS - Extreme Low Water of Springs - 0.0 meters above Chart Datum
 C.D. - Chart Datum

CUFFE PARADE SHORE

The Cuffe parade is a sheltered boulder beach, facing north-west. It lies in a small shallow bay and is bounded on one side by a sea wall which is parallel to the shore and acts as a breakwater. This sea wall and the boulders at the entrance to the bay reduce the wave action. To the south of this is a mangrove swamp, separated by a uniformly 3 meters wide storm-water-drain. The wall of this drain is about 2.2 meters high with its top situated at the level of MHWS.

The shore is 457.5 meters long of this about 305 meters is exposed at ordinary spring tides. The rocks extend down to the level of MLWS, below this the bottom is of soft sand and clayey mud. Most of the Bay gets uncovered at the lowest spring Tides (Plate I, Fig. 1). It is divisible into three sections. In the first section one finds sloping embankment of stones and extending from over a 0.3 meters above the EHWS to about MHW. The stones chiefly harbour littorinids and the Isopod (*Ligia*). In the next section which is about 183 meters wide, there are large boulders and rocky ledges parallel, to the shore with mud deposits in between them. Most rocks are from 1 to 1.5 meter high. Small pools also exist as a result of the construction of fish-traps. The boulders are covered with oysters and along with these *Planaxis*, *Nerita* and *Cerithium* are also found. Trochids and muricids are often found near the base of the boulders. In the third section which is near the low water, there are rocky platforms, boulders and stones largely covered with borers. In some parts the substratum is made of gravel. The beach in general is very irregular. The deposition of mud and sand, over the rocks limit the distribution of animals. Thus although no clear zonation of some of the common species was found, the following four zones could possibly be recognised (1) Littorinid zone upward, (2) *Balanus* zone, (3) Oyster zone and (4) Trochid zone.

Littorinid zone : This was the uppermost zone, extending from the level of EHWS to the barnacle line. The population of the littorinids was rather sparse. *Tectarius malaccanus* was present from EHWS to MHW on the exposed rocks which were dry due to sunlight. When the temperature was high, they moved into the crevices or along the shaded sides of the stones. *Littoriana intermedia* was the most abundant species of the littorinids. It had its maximum density from EHWS to MHW. *L. ventricosa* and *L. subgranosa* were in fewer numbers and formed a horizontal zonation, the former being present along the stones nearer the storm water drain and the latter which was rare was found on the stones exposed to the wave action near the adjacent sandy beach. Other animals associated with the littorinids in this zone were *Ligia exotica* in small numbers, a few *Balanus amphitrite* upto MHW and *Planaxis sulcatus* with its upper limit at MHWS. *Neritina pulchella* was common in the rock pools which had brackish water.

Balanus zone : This zone was a narrow belt largely composed of *Balanus amphitrite* var. *communis* on stones. The barnacles were predominant from

about MHW down wards upto MHWN. They also extended upto MLW but were absent along the sheltered sites. Their maximum density was on rocks which were not shielded by the seaward rocks. Deposition of mud and sand over the rocks adversely affected their settlement and growth. Wherever the wave action was less, they were replaced by the oysters. The barnacles were absent in permanent pools. A negative correlation was noticed between the barnacles and the oysters. The lower boundary of the barnacles here in the storm-water-drain was MHWN. Below that the oysters were present. The upper limit where the barnacles occurred in greater density was recognised as the boundary separating the midlittoral from the supralittoral zones.

Neritina pulchella predominated the brackish water pools from MHW to ELWN. *Planaxis sulcatus* also was abundant in this zone. At the base of the embankment where there was black and foul smelling mud, the polychaete *Onuphis*, the bivalve *Coecella*, and many sea anemones, chiefly *Anemonia* and some anthopleura were common (from MHWN to MHW). *Crossostrea cucullata*, *Nerita polita*, *N. Oryzarum* and *Cerithium morus* were fewer in numbers as this zone was their upper limit.

Oyster zone : This zone extended from MHWN to MLWN. At its lower limit pronounced change was noticed in the fauna and flora, even though the rock oyster, *Crossostrea cucullata* was abundant upto MLWN with its lower limit at MLWN. Thick encrustations were found over boulders and rocks at MTL. Dominant forms were *Planaxis sulcatus*, *Nerita polita* and *Cerithium morus*, while *Nerita oryzarum*, *Thais tissoti* and the black algae, *Caloglossa* were only sub-dominant; the last mentioned species was found mostly in patches covering the side and the top of boulders and very often over the oysters themselves. The alga, *Ulva lactuca* appeared seasonally in this zone. It was seen in November in rock pools and in the next two months it grew fast and covered the entire muddy area and the rock pools. However, it disappeared fast towards the end of February, from the zone. Below MLWN, *Ulva* was replaced by several brown algae, many of which occurred throughout the year.

Along the seaward side there was a small mud flat at MTL, where the snail *Potamides cingulatus*, the mud skipper *Boleophthalmus* and fiddler crabs of the genus *Gelasimus* occurred. Here polychaetes belonging to the families Nereidae and Glyceridae were also common.

The negative correlation between barnacles and oysters, was again noticed in this zone. The slopping seaward sides of the rocks were covered with barnacles while the landward sides had thick deposits of oysters and *caloglossa*. However, there were places where both these animals occurred together. Among other typical inhabitants of this zone were the crabs *Ozium rugulosus*, *Leptodius crasimanus*, *Lytocheria angustifrons* and *Metagrasmus messor* which tended to hide under the rocks. The bivalve *Trapezium vellicatum* was common in rock crevices in between the oysters.

Some of the inhabitants of the next zone (Trochid) were also found in this zone. There were the ascidians and molluscan (*Calliostoma scobinatum*, *Oncidium verruculatum*, *Cerithium rubus*, *Cellanaradiata*, *Bursa tuberculata* and *Aplysia cornigera*). The eel *Pisodonophis* and the brittle star *Ophiactis* were sometimes found in the rock pools. Spat-falls of oysters and the cyprids of barnacles occurred in this midlittoral zone during late May and early June indicating that both these groups spawn at the same time. The spat settlement commenced at the lower levels and of barnacles at the higher levels.

Trochid zone: This extended from MLWN downwards and merged into the sublittoral zone. The main species of the oyster zone were regularly present upto the lower limit of the MLWS. Its upper limit was about MLWN, for at this level there was a pronounced change in the composition of fauna. The animals from the understone increased enormously both in types and numbers.

Of the molluscan family Trochidae, *Calliostoma scobinatum* which is an endemic species, was abundant between MLWN and MLWS, along with other species such as *Trochus radiatus*, *Clanculus depictus*, *Euchelus asper*, *E. indicus*, *E. tricarinatus* and *Gibbula swainsonii*. Among other molluscs were *Bursa tuberculata*, *Cellana radiata*, *Scutus unguis*, *Cypraea pallida*, *Astrea stellata*, *Aplysia cornigera*, *Bursatella leachii*, *Onchidium verrauculatum* and *Lithophagus cinnamomea*. *Aplysia* and *Bursatella* were seasonal in their appearance and occurred in December and January. Among the other animals of this zone were *Tethya lyncurium*, *Balanus tintinabulum*, *Dendrostomum spinifer* (Sipunculoidea), *Harmathoe ampullifera* (Polynoid) and *Petrolisthes boscii* (Anomura). small encrusting algae were present in all the months while those with bigger thalli were common only in the winter months (December and January).

T. vellicatum and some ascidians were also abundant here. Some members of the family Zoanthidae were present in the rock pools between MLWS and MLWN. *Ophiactis savighvi*, some chitons and nudibranchs were very common under the stones and in rock pools. Some of the stones and rocks were bored by *Lithophaga* and *Martesia*. This region extend from MLWN to MLWS. In the same region some species of corals were also seen. In general the fauna here was very rich and varied. Most of the animals present were small in size and generally lived in protected situations. some forms were also found at higher levels in rock pools. *Tethya* was found in pools upto MLWN. Members of this zone could often be collected from the sublittoral zone and a few from below the tidal range occasionally moved into this zone.

CHOWPATHY SHORE

The area surveyed was about 488 meters located at the foot of the Malabar Hill where boulders and stones are resting on a substratum of sand and gravel. (Plate I, Fig. 2). The shore towards the land has a high stone-wall for the protection of the road. This wall had many littorinids. Most boulders

were covered with animals, barnacles and littorinids were found along the upper half of the stones and trochids and muricids towards the bottom. The gravel and stones also had holothurians. At the bottom the echiuroid, *Ochaetostoma bombayensis* was also found. Other animals such as *Martesia striata* and *Perineris* spp. were seen burrowing into the rocks.

The vertical limits of the faunal distribution was not as clear here as at the Cuffe Parade Shore. The lower limit of the midlittoral zone could not be found as a distinct belt of any one dominant species. However, the following three zones could still be distinguished. (1) Littorinid zone, (2) Balanus-oyster zone and (3) Trochid zone. The zonation here was at about the same level as in the earlier shore except that the midlittoral was not divided into separate Balanus and Oyster zones.

On the seawall along Bay, the oysters were seen as 1.5 meters belt from MLW to MTL. Above this upto MHWS (1.5 metres height), the barnacles were predominant. The height of MTL coincided with the level at which the *Balanus* and oyster zones were identified at the Cuffe Parade shore. The topmost littorinid zone was followed by a belt of oysters and *Balanus*. Below this was the zone of *Polydora* and *Anemonia*.

Littorinid zone : Was at the same level as at the Cuffe Parade. *Littorina intermedia* was very plentiful. The lower limits of distribution of these species was greater than at Cuffe Parade.

Balanus-Oyster zone : The barnacles had a slightly bigger belt than that of the oysters. *B. amphitrite* was represented by three subspecies *communis*, *hawaiiensis* and *cochinensis*, of these, the first was more abundant. On some rocks the barnacles were present only on the sheltered fronts. The upper and lower limits of *Crossostrea cucullata* were greater by two feet than that of their distribution at the Cuffe Parade. *C. lacerata* and *C. bicolor* were also seen. *C. bicolor* was often found on the underside of the stones. The distribution of the other faunal elements in this zone was very much the same as at Cuffe Parade. The trachytes had *B. amphitrite* on top along with a few oysters. Below this there was a band of *Caloglossa*. *Martesia* and *Perineris* burrowed into the soft substratum while *Arca* and *Bundosoma* occurred in the crevices and clefts. The animals in the Trochid zone, such as *Drupa*, *Bursa* and *Calliostoma* extended over a much greater area than at the Cuffe Parade.

Trochid zone : The fauna was rich both by species and in numbers. Trochids were fewer than in the previous locality and occurred on the underside of the stones. Among the non-cryptic forms of this shore were *Balanus tintinabulum*, *Thias*, *Bursa*, *Crossostrea*, *Drupa* and *Cantharus*. The understone inhabitants were *Scutus*, *Arca*, *Cyprea*, *Cancellaria* and *Astrea*. The two bivalves, *Gafarium divaricatum* and *Chione imbricata* were often found buried in the subs-

tratum. Ophisthobranchs, Patellids and oysters were at the same level as in the previous locality. Here *Crossostrea madrasensis* occurred below the lower limits of *C. cucullata*. Egg capsules of *Thais* and other muricids occurred on the upper sides of the boulders. Among the crustaceans the usual crabs, the alphiids and isopods were commonly seen. Holothurians were found in isolated areas of stones and gravel on the sandy bottom with puddles. Some polychaetes such as *Dasychone* and *Spirographis* were present in muddy sand below MLWS.

BREACH CANDY SHORE

The area studied was about 366 meters along the coastline which was almost entirely rocky with only a few sandy patches found above MHW and below MLWS (Plate II, Fig. 1). Sewage outlets were very few. Here the water was cleaner than that of the other localities. About 304 meters was exposed at the spring low tides. The first belt of sand was lying above MHW. It was bound by halophytic plants and mangroves. Below this was the area of stones, gravel and boulders followed lastly by big boulders and raised terraces on the seaward side. These reduced the wave action considerably on the shore. The littoral region could be divided into four zones viz. (1) Littorinid zone, (2) *Chthamalus* zone, (3) *Balanus*-Oyster zone and (4) *Tetraclita* zone.

Littorinid zone : Was dominated by *T. malaccanus* which was plentiful between MHW and EHWS. *L. intermedia* was common here and occurred upto EHWN. Other littorinids and *Ligia exotica* had a similar distribution as in the other localities.

In the *Chthamalus* zone, *L. challengeri* replaced *Balanus amphitrite communis*, and occurred from MHWS to MLWN, with a maximum between MHWS and MTL. Its extreme lower limit coincided with the upper limit of another barnacle, *Tetraclita*. There was a negative relation between *Chthamalus* and *Balanus*. The former genus occurred where the wave action was maximum along on the seaward sides of the boulders. *B. amphitrite hawaiiensis* also occurred in fewer numbers along with *C. Challengeri*, *Caloglossa*, *Planaxis* and *Cerithium*. Some Neretids and sea anemones were also present. Almost midway along the gravely substratum where there was a mixture of sewage water and sea water, *Neritina* and *Potamidis* were seen.

In the *Balanus*-oyster zone which was narrow in between MSL and MLWN there was a preponderance of *C. cucullata* and some times of *B. amphitrite communis*, depending upon the extent of the sheltered area available on the rocks. Oysters in this locality were not abundant at this shore. Along with *C. cucullata* there were *C. bicolor* and *C. madrasensis* in fewer numbers.

Caloglossa, *Planaxis*, *Nerita* and *Bunodosoma* were common here. *N. oryzarum* and *C. radita* were also found. *Thais tissoti* was abundant on rocks. *Gafrarium*, *Drupa*, *Arca*, *Trapezium*, *Perineris*, *Nudibranchs* and *Spirorbis* were also present in this zone.

Here *Tetraclita* zone corresponded with the Trochid zone of the other localities and extended lower than MLWN. The barnacle *Tetraclita purpurascens* which was present along the sides of the rocks and on the under surface of the overhangs, was the dominant species in this zone. The other species *Cellana radita* was also abundant. The trochid molluscs *Euchelus*, *Clanculus*, *Trochus* and *Calliostoma* were also common. The crevice dweller such as *Arca symmetrica* were also commonly seen. *Lima lima* was seldom seen. The gastropods *N. polita* and *Drupa* and numerous other organisms so characteristic of this zone were also present at the lower levels. The zoanthids formed a thick mat on the rock platform with their associate fauna.

MAHIM SHORE

About 305 meters long shore line off the Mahim Causeway, located between Bandra and Mahim and facing west was selected for study. The rocks here were smaller and occurred between MHWN and MLWN levels. These were covered with *B. amphitrite* and *C. cucullata*. (Plate II, Fig. 2). The numerous rockpools had numerous sea anemones (*Anemonia*) in them. The landward side of rocks had littorinids and *Chthamalus*, but these rocks did not extend above EHWS. On its landward side at the highest level, there was strip of sand. Below the rocks there were sand-bars which harboured *Katylisia* and *Meretrix*. These were exposed at low water spring tides. The adjacent mud flats and sandy areas were inhabited by the crab *Dotilla*. *K. marmorata* and *K. opima* were abundant below MLWN. *A. granosa* and some sea anemones were also present. The seaweed *Ulva* and *Enteromorpha* were common during the winter months. *Natica* sp. were also found in this locality.

Four zones were recognised in this locality i.e., the (1) Littorinid zone, (2) *Chthamalus* zone (3) *Balanus*-oyster zone and (4) Trochid zone.

These zones had fauna characteristic of similar to those of other shores described earlier. In the littorinid zone, *L. intermedia* was most abundant. The *Chthamalus* zone was dominated by *C. withersi* unlike *B. amphitrite* of which was so abundant at the Cuffe Parade and Chowpatty shores and *C. challengeri* of the Breach Candy shore. In the *Balanus*-oyster zone *B. amphitrite* and *C. cucullata* were predominant on the rock platforms. In the trochid zone the trochidae were represented by a number of species which were not very abundant excepting *Euchelus tricarinata*. Most of the species were found attached to the under surface of the stones.

GENERAL CONSIDERATIONS

By taking all the above four shores into account, it is possible to recognize a general pattern of zonation (1) the upperlittoral zone was dominated by littorinids, (2) the midlittoral zone by barnacles and oysters, (3) the lower-

littoral zone by a rich variety of fauna of which the trochids generally dominate.

Upperlittoral zone : In all the four localities, four littorinid species were found. These were *L. ventricosa*, *L. subgranosa*, *L. intermedia* and *Tectarius malaccanus*. The last species was widely distributed and was the most abundant member of the group. *L. ventricosa* was rare and was found only in sheltered areas. *L. subgranosa* was sparse everywhere except at the Breach Candy. All the major species showed a definite vertical zonation. *T. malaccanus* was abundant and occurred as high as EHWS. *L. intermedia* had an upper limit but not higher than EHWS. Its lower limit was even below MLWN. All the littorinids and *Ligia exotica* present in this zone, were generally seen in rock crevices. This habit according to Stephenson (1943) was not so much for shade as for the protection from the wave action. Penetration of species belonging to the midlittoral zone into this zone was a common feature. The animals concerned were *Planaxis sulcatus*, *C. cucullata* and *balanids*.

Midlittoral zone : In all the shores, this zone was dominated by barnacles and oysters and was usually divisible into three or four belts. Each belt was dominated by a distinct set of animals. Except for the Chowpatty shore, it could be divided into two recognizable bands at the three other shores, each having a set of indicator animals. In the Cuffe Parade Shore this zone could be divided into *Balanus* and oyster belts and at Mahim and Breach Candy into *Chthamalus* and *Balanus*-oyster belts.

A greater wave action was found to increase the settlement of barnacles and decreased the oysters in numbers. Thus at the Chowpatty rocks *Balanus* occupied the entire width of the zone mixed with oysters, and formed the *Balanus*-oyster belt. The very striking belt of *Balanus* and *Crossostrea* at the Cuffe Parade was not there, because of competition for space as it was due to the severity of surf action at different levels. With an increase in the wave action, *Balanus* was replaced at higher levels by *Chthamalus*. It is interesting to note that *Chthamalus withersi* formed a narrow belt upto about MHW, thus raising the upper limit of the barnacle distribution. *C. withersi* were found on the leaves and bark of *Avicennia*, this feature suggests that this species had a preference for mangrove swamps or similar marshy or swampy conditions. *Avicennia* were plentiful at Mahim but no barnacle were seen on its leaves.

Lowerlittoral zone : This zone had the larger number of species and the maximum number of animals. It was a wide zone extending from ELWS to MLWN and had the presence of trochids. Various algae were found in this zone during winter in sheltered areas. With an increase in the wave action trochids decreased both in the numbers and species. At the Breach Candy shore trochids were fewer in numbers and did not extend higher than MLWN. The fauna at the Breach Candy was restricted as compared to the other places. The belt of *Tetraclita purpurascens* occurred at very low levels. Previous accounts on its vertical distribution indicate that the species is confined to midlittoral zone along the Australian and Tasmanian coasts.

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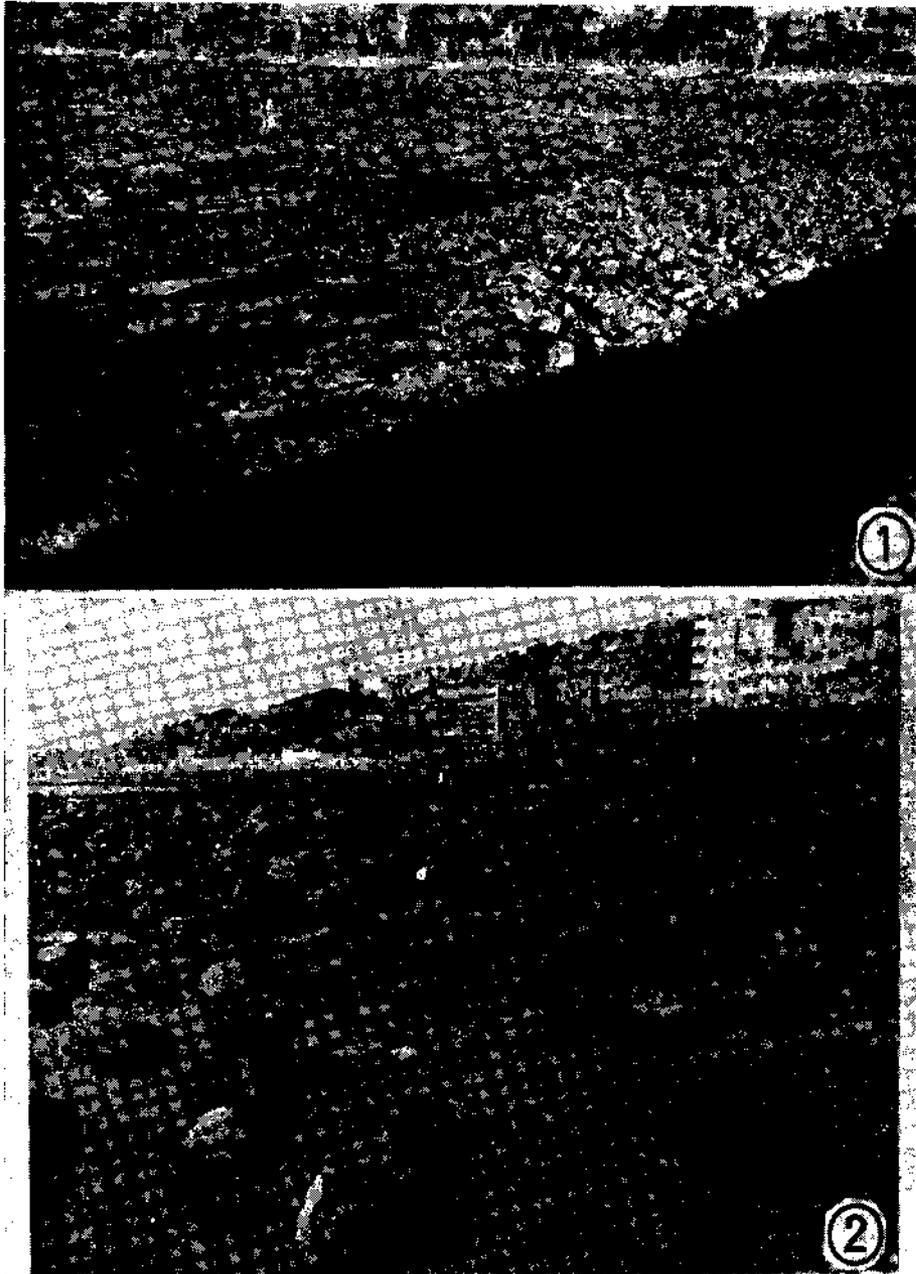


Plate I. 1. Cuff Prade (Bombay) photographed at low water spring tide.
2. Exposed rocks at Chowpathy during the ebb tide.



Plate II. 1. A view of the Breach Candy Shore at the ebb tide.
2. A view of the Mahim Beach at the ebb tide.