

Biota Structure in Relation to Physiography of Rockpools of Visakhapatnam, Middle East Coast of India

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Abstract: *Investigations on the physiographical and biological configuration of rockpools located at different places such as Palm Beach, Rushikonda, Bhimunipatnam, Yarada and Gangavaram were carried out during the period May 1996 to February 1997. Rockpools at Visakhapatnam coast are categorized into supra - littoral, mid - littoral and sub- littoral depending on the tidal level. The intertidal region of Visakhapatnam is composed of numerous rockpools of varying dimensions and topographical conditions. The community composition of the rockpools represents the following taxonomic groups such as sponges, coelenterates, isopods, amphipods, crabs, tanaids, gastropods, echinoderms and fishes. A survey has been made on the spatial distribution of macrofauna and macroalgae associated fauna. Both fauna and flora are identified at generic level. During the course of the study the abundance of organisms are recorded for selected pools. The results obtained from the study showed that these environmental conditions gave the specific faunistic features for individual pools.*

Keywords: Biota, Physiography, Rockpools, Visakhapatnam

1. Introduction

Rock pools are conspicuous ecosystems of the rocky intertidal zone which are isolated habitats with well-defined boundaries. Rockpools are considered a "natural microcosms", which have long attracted naturalists. Rockpools are given several denominations 'Tidepool' (Ambler & Chapman, 1950); 'Salt pools' (Copeland, 1967); 'Felsentumpel' (Lindberg, 1944); 'Cuvette' (Lami, 1941) and 'Vanna' (Ghilarov, 1967) and 'Vodojem' (Zhyecoubikas, 1968) in different parts of the world.

The rockpool ecosystems have attracted the attention of many investigators and information on ecology and faunal composition of rockpools is available in plenty. Contributions on the rockpool environments were made by several scientists. Some of the noteworthy investigations on rockpools were those of Klugh (1924); Stephenson et al (1934); Pyefinch (1943); Stephenson and Stephenson (1950); Utinomi et al (1950); Zhyubikas (1968); Ganning (1970, 1971a, 1971b); Gustavsson (1972); Metaxas et al (1994); Metaxas and Scheibling (1993, 1994) and Seoh Choi & Kwang Young (2004). Although a notable work has been done on the rockpool environments in different parts of the world a few studies were carried in India.

A survey of literature indicates that most of the work in India pertains to emergent substrata of rocky intertidal zones in India are very few, which are mainly concentrated on Visakhapatnam coast. Umamaheswara Rao (1963) initiated the work on the ecology of intertidal algae of Visakhapatnam coast. Rao (1966) worked on the ecology of algae of rockpools of Gujarat coast. A thorough survey of available literature shows that most of the work done on Rockpool fishes and foraminiferans of Visakhapatnam (Viswaswara Rao and Dutt, 1965; Kaladhar, 1981); Prasada Reddy, 1982 and Siva Ram Prasad Rao, 1984).

Till now there are no studies in the country on the community composition of rockpools. The present investigation was carried out during the period May 1996 - February 1997 on physiography and spatial distribution of macroalgae and macro fauna of rockpools situated at widely separated places such as Palm beach, Rushikonda, Bhimunipatnam and Yarada. Our aim was to provide distribution of biota in various levels of rockpools based on the physiography of rockpools. These observations contribute to our knowledge about the physiography as well as variety of flora and fauna inhabiting different levels of rock pools of Visakhapatnam Coast.

2. Material and methods

The intertidal zone of Visakhapatnam extends to a maximum width of 75 m at the rocky coasts. The coast of Visakhapatnam is unique in its way. Visakhapatnam is situated between latitudes 17°40'30" and 17°45'N and longitudes 83°16'25" S on the east coast India, half way between Chennai and Calcutta. The principal rock type found on the coast are Archaeon (Pre-cambrian) Khondalites, leptynite and charnockites. The Visakhapatnam coast lies to the east of the town about 11 km between Rushikonda in the north of Visakhapatnam to Dolphin's Nose in the South. The beach is sandy bearing rocky boulders of different sizes and shapes, which afford different kinds of substrata for the settlement of luxuriant flora and fauna.

Rockpools found at many places along the coast between Balacheruvu to the South and Bhimunipatnam to the North. Palm Beach, Rushikonda, Bhimunipatnam, Yarada and Gangavaram rocky shores were observed for rockpools and for the study of hydrographical conditions and the distribution of flora and fauna in the rockpools.

A. Palm Beach

This station is interspersed with groups of boulders projecting high above sea level; separated by narrow stretches of land. The rocks seen here offer a variety of habitats for the flora and fauna. Here the rocks provide three different type of surfaces, exposed surfaces are those which are directly influenced by severe wave action. Semi exposed surfaces are those which are partly exposed to wave action. Protected surfaces are those which are totally away from wave action i.e. by the presence of other rocks around them or by not facing the sea. Starting from the North side of Scandal point up to the extreme South side 23 pools were observed. The pools vary in dimensions from 0.15m x 0.08 m x 0.32 m to 2.20 m x 1.23 m x 4.00 m respectively. The physio-chemical and biological parameters of mid and supra-littoral pools were observed. The sub-littoral pools were not observed as the period of exposure is very less and also because of severe wave action. At the centre of Palm Beach i.e in front of scandal point big boulders are observed. Definite pools are seen at South wards and centre of Palm Beach but no definite pools are formed towards north side except these two pools (Figure.1 & Figure. 2)

B. Rushikonda

This is located 11km away from Visakhapatnam. Here large flat rocks with several shallow pools are observed. The pools vary in dimensions from 1.57 m x 0.23 m to 2.20 m to 1.59 m x 0.42 m x 4.22 m respectively. In Supra-littoral, mid-littoral and sub-littoral pools are studied along with associated flora and fauna.

C. Bhimunipatnam

This collection spot lies 30 km north of Visakhapatnam. A small rivulet opens into the sea in the north. Here the shore is seen with flat rocks, medium to small rocks. Some pools are located in between the rocks.

D. Yarada

This collection spot, Yarada hills are located at 2km south of Visakhapatnam. This area is covered with moderate to large sized boulders and shingles offering a variety of ecological niches such as exposed and protected rock surfaces, crevices, gullies, overhangs and rockpools. The flora and fauna of Yarada were collected to report which flora and fauna are found in rock pools.

E. Gangavaram

Gangavaram is about 32 km from south of Visakhapatnam. It is characterized by large sized boulders. But no distinct rockpools are formed near Gangavaram shore.

Biological Sampling

The microscopic algae and fauna of rockpools were collected during low tide period at regular intervals, between May 1996 and February 1997. All the fauna and algae were collected with the help of forceps. After collection, the material was brought to the laboratory and rapidly preserved in 5% formaldehyde to prevent within the samples and

identified visually. At the time of collection the abundance and location of fauna in the pools was noted. The method to determine the abundance of the animals was direct counting, without extracting the total sample. The flora and fauna, of individual pools are examined and preserved separately. After sampling, the associated fauna were sorted under a binocular microscope. At every sampling the abiotic parameters were measured.

The identification of microalgae was made from the contribution of Umamaheswara Rao (1963). The macrofauna of all pools are identified as far as possible up to the lowest generic level from Ridley and Dendy, 1887; Stephenson, 1935; Fauvel, 1953; Fabricius, 1798; Dana, 1852; Herbst, 1782- 1804; Milne-Edwards, 1867; Pillai, 1954; Barnard, 1914; Stebbing, 1899, Gravely, 1927, 1941; Roeding, 1798; Sowerby, 1847; Clark, A.H., 1947; Day, 1878 – 1888, Bianchi, 1984 and Munro, 1955.

3. Results

Physiography of Rockpools

The rockpools are distributed along the rocky intertidal zone of Visakhapatnam coast. The pools are irregularly shaped with minimum dimensions ranging from 0.15 m x 0.08 m x 0.32 m and maximum ranging to 2.20 m x 1.23 m x 4.0 m. Comparatively more number of rockpools are found at Rushikonda area. The rockpools are completely lacking at Gangavaram. A few number of pools are distributed at Bhimunipatnam coastline. The Palm Beach intertidal zone is interspersed with numerous pools of varying size. These are not static and stable biotopes, they are ever changing and dynamic ones and are outside all strict classifications. In the present area of investigation it has been found convenient to recognize 3 major types of pools.

Super-littoral Pools

These pools are isolated almost all the time from the open sea. These pools are seen higher on the shore than mid-littoral pools. They receive sea water from splashing during strong winds and extreme high waters during strong winds and extreme high waters during spring tide. These pools are subjected to wide variations in salinity, temperature and dissolved oxygen conditions. They often dry up during summer also because of high solar radiation and evaporation. Therefore in these pools few varieties of flora are observed.

Mid-littoral pools

These are the shallow pools with variable size. These pools receive sea water intermittently through wave action. These pools are subjected to very high insolation, solar radiation and wind action. These pools are seen with rich flora and fauna.

Sub-littoral Pools

These are the pools generally situated in between the boulders, shingles or at the periphery of rocks shelves at low tide mark. These are seen totally submerged for sometimes and for sometimes there is a continuous influx of sea water. So sub-littoral pools were not taken into consideration, while carrying out the present study. Here severe wave action was noticed. The biota and ecology may be reasonably expected to be identical to the conditions of nearby coastal waters.

A. Palm Beach

In general this area is covered with small to big boulders and shingles providing a variety of ecological niches such as exposed and protected rock surfaces, crevices, gullies, overhangs and rockpools. Rockpools of Palm Beach are recognized into supra-littoral, mid-littoral and sub-littoral pools. But in the present study attempts have been made to study the supra-littoral and mid-littoral pools. Twenty three pools are studied in Palm Beach to give a spatial distribution of flora and fauna inhabiting in rock pools. Some pools were submerged during the month of June due to cyclonic disturbance. The supra-littoral pools are ranging dimensions from 0.15 m x 0.08 m x 0.32 m to 2.20 m x 3.00m. These pools are surrounded by small to medium sized and big boulders. Some formed by a depression in a big boulder etc. The bottom of the pools covered with sand, pebbles and small stones and rocks. As the pools are higher on the shore water replaced only during extreme high water of spring tides. These pools have no direct connection with the sea. Poor fauna observed in these pools.

The flora and fauna observed in supra-littoral pools are *Ulva fasciata*, *Chaetomorpha antennina*, *Spongomorpha indica*, *Enteromorpha compressa*, *Grapsus strigosus*, *Cellana radiata radiata*, *Nerita albicilla*, *Cerethium obeliscus*, *Turbo intercostalis* and the fish *Abudefduf vaigiensis*, *Halichoeres pardaleocephalus*, *Gobius* sp. *Ulva fasciata* is a foliaceous plant with irregularly lobed fronds, occurring throughout the study period in some period in some pools, its growth is affected by the sand movements on beach. This algae is found on the sheltered portions of pools.

Chaetomorpha antennina, is one of the dominant green algae of this coast. The thallus is filamentous, unbranched and fixed at the bottom by an elongated basal cell and found along with *Ulva fasciata*.

Enteromorpha compressa also found in some pools forming as a thin layer on the walls of the pool.

Spongomorpha indica (Figure. 4), is a green bushy plant and also a member of chlorophyceae family. It gives shelter to many small forms. There are associates in this algae.

Platynereis dumerelli (Audouin and Milne-Edwards) has light yellow colour body, elongated prostomium with swollen palps. Long peristomial tentacles. Tiny paragnatha arranged in transverse pectinate rows with eversible proboscis. These are very commonly found among this algae. Some attached and some are moving around the holdfast of algae.

Nymphon longicaudatum (Carpenter) was dull white colour in the living condition and brown in alcohol. The length of the body is 4 mm. The 3 thoracic segments are longer than head segment. 5 jointed palps are observed. Legs long and very slender with slender claws. When algae was washed with water this form was found in that water.

Dynamenella quilonensis (Pillai) (Figure. 10): These isopods are collected from the washings of algae from Palm Beach, Rushikonda, Bhimunipatnam and Yarada. Male

specimens are whitish in colour. Its body is oblong – oval with sub parallel sides. Its body is two and half times longer than its width. Front margin of cephalon obtusely triangular, eyes oval, situated postero-laterally. Telson is triangular in shape with broad base. Uropods extend beyond the tip of the telson.

The amphipod *Lembos kergueleni* (Stebbing) found associated with algae. First antenna is longer than the second antenna. Accessory flagellum is present. First gnathopod is smaller than second gnathopod in male is broader than the first gnathopod and heavily setose. The palm has a round sinus and is defined by a small tooth at the distal end and a subterminal spine. First and second uropods similar, first longer than the second, both ramified and peduncle spinous. Third uropod is much shorter than the other two. Telson five-sided, with the dorsal side concave.

The tanaid, *Aapseudes avicularia*, (Barnard) (Figure.11) is an associated fauna of algae occurring in Palm Beach and Rushikonda. Elongated body, the base of cephalon is broad with a prominent anteriorly cleft rostrum. Telson broader than the length of the body and its ventral margin rounded with a small median ventral cleft.

Grapsus strigosus (Herbst) crabs are moving here and there in the pools and hiding under the rocks to withstand the fluctuations in these pools. Carapace colour is dirty green and pereopods are yellow with molted red. Palm and wrist are violet in colour. Tip of the finger is red in colour, carapace flat, keeled and sub acute teeth at the inner angle of the orbit. The posterior border of propodite of all legs terminated as a spine.

The gastropod, *Cellana radiata* (Born) is slightly conical with oval outline and without any spine. The dark coloured shell is conical with tubercular spires on the surface. It is about an inch in length.

Cerethium rugosum (Wood) gastropods are more abundant than any other gastropods among rocks and rock pools. Under every rock and stone we find them. These are black and conical in shape. On the surface tubercular spires are seen.

Turbo intercostalis (Roeding) is also found abundant in the pools of this coast under the rocks and crevices to withstand environmental and hydrographical fluctuations. This form also attaches to the rock with the help of foot. To withstand high temperature, wave action and insolation, it has hard shell.

Abudefduf vaigiensis (Quoy and Gaimard) fish were observed in pools thorough out the period of study. It is small and its body is moderately elongated, laterally compressed. Mouth relatively small. Dorsal fin with 13 spines 13 rays. Anal fin with 2 spines and 13 rays. Pectoral fin with 17 rays. Caudal fin forked. Head and body covered with ctenoid scales. Colour consisting of 5 alternating light and dark bars.

Halichoeres pardaleocephalus (Bleeker) fishes are moving here and there and hiding under the rocks in the pools, to

withstand wave action and predation by birds. Body of moderate depth. Dorsal profile of head slightly curved. Dorsal fin continuous with 9 spines and 11 soft rays. Anal fin with 3 spines and 11 soft rays. Lateral line abruptly curved scales are cycloid. Adult male bearing a blue black spot between the fourth and sixth dorsal spine, extending to the membrane beyond sixth spine. Juveniles are blue black in color and commonly occurring in pools.

Two types of *Gobius* sp. (Figure. 8) Fish are seen with elongated body. Gill opening of moderate width. Caudal obtuse. Scales ctenoid. Abdomen scaled and short snout. Two separate dorsal fins with flexible dorsal spine. First dorsal fin with 6 spines and second dorsal with 1 spine and 10 rays. Anal with 1 spine and 10-11 rays. Pelvics basally united forming a disc. These fish are found in almost all pools in Palm Beach, Rushikonda, Bhimunipatnam and Yarada.

The mid-littoral pools are found below the supra-littoral region i.e in the mid-littoral region. These pools are surrounded by small to medium sized boulders and some formed as a deep depression in a big boulder. The bottom of some pools is covered with only sand and some pools found with an uneven floor of stones and small rocks. Water replaced during strong winds and spring tides. Some pools present in the lower portion of mid-littoral zone showed narrow connection with the sea, some have no direct connection with the sea. The fluctuations in hydrographical conditions here are not high, so varieties of fauna was observed. The observed ranges of dimensions are 0.75 m x 0.30m x 0.95m to 2.17m x 1.23 m x 4.00 respectively.

The flora and fauna observed in these mid-littoral pools are identified as *Hypnea valentiae*, *Gracilaria corticata*, *Ulva fasciata*, *Chaetomorpha antennina*, *Spongomorpha indica*, *Callyspongia fibrosa*, *Bunodactis* sp., *Grapsus strigosus*, *Charybdis orientalis*, *Charybdis lucifera*, *Charybdis truncate*, *Xantho bidentatus*, *Cellana radiate radiate*, *Thais rudolphi*, *Nerita albicilla*, *Turbo intercostalis*, *Tropiometra encrinus*, *Abudofduf vaigiensis*, *Halichoeres pardaleocephalus* and two types of *Gobius* sp.

Hypnea valentiae, this is a Rhodophyceae family member. *Thallus* is erect and ramified with short thorny shaped branches, found on the sheltered portion of the rock pools along with other algae.

Gracilaria corticata is also a Rhodophyceae member, found along with *Ulva fasciata*, *Chaetomorpha antennina*, *Hypnea valentiae* in one pool.

Ulva fasciata is a foliaceous plant with irregularly lobed fronds occurring throughout the study period in some pool, its growth is affected by the sand movements on the beach.

Chaetomorpha antennina is found along with other algal members in some pools on the sheltered areas. *Thallus* is filamentous, unbranched and fixed at the bottom by an elongated basal cell. *Spongomorpha indica* is a green bushy plant. Luxurious growth of this algae was found in some pools. The associates of this algae are *Platynereis dumerelli*,

Dynamenella quilonensis, *Apseudes avicularia* and *Lembos kergueleni*.

Callyspongia fibrosa, Ridley and Dendy, 1887 is found among algae in pool 1, on the side walls of the pool and also along with *Bunodactis* sp. The colour in life is pale blue. The surface is rough to touch. The texture is somewhat firm but moderately compressible.

Bunodactis sp. (Stephenson,1935) is found attached to the side walls of the pools particularly on the shelter side. Firmly fixed by disc. Column is flesh in colour. We find numerous suckers arranged irregularly to which sand, pebbles and shells attached.

Decapod crabs: *Grapsus strigosus*, *Charybdis truncate*, *Charybdis orientalis*, *Charybdis lucifera*, *Xantho bidentatus* are found moving here and there in pools and hiding under the rocks to withstand severe wave action, temperature, insolation.

Xantho bidentatus, (Milne-Edwards, 1867) it is dark brown in colour, the fingers of the chelate legs are black. Carapace smooth, flat and a groove is there which separates gastric region from the hepatic and branchial region. Unequal chelate legs and are smooth. The anterior border of merus posterior border of propodus, dactylus are hairy.

Charybdis lucifera (Fabricius,1798) has brown carapace with four pale spots. Out of these 4 spots, two are oval which are on the mesobranchial region. The remaining two are smaller, at the side of the first pair. Front portion is cut into 6 teeth. Posterior border of propodus bears spinules. There is no ridge below metabranchial region.

Charybdis truncatea (Fabricius,1798) (Figure. 9) possesses brown colour carapace, chelate legs and pereopods are also brown. Tip of the fingers of chelate leg are white. Carapace covered by dense pile and crossed by granular ridges. Chelate legs are more than twice in length when compared with the length of carapace. Largest chelate's hand is more swollen than that of the other.

Charybdis orientalis (Dana, 1852) crabs are seen with molted brown colour carapace. Chelate leg fingers are having white tips. Pereopods are brown with red stripes. Front cut into 6 teeth are smaller, the second antero- lateral teeth are smaller than the other anterolateral teeth.

The other forms observed in mid-littoral pools are *Cellana radiate radiate*, *Nerita albicilla* and *Turbo intercostalis* attached to the rocks of the pools.

Thais rudolphi (Larmark) are hardly 2 inches in length, generally shell is brown in colour. They exert fairly strong hold on the rocks of the pools to withstand wave action.

The Crinoid, *Tropiometra encrinus* (Clark, A.H, 1947) (Figure. 3) was observed in two pools in the month of August. They have five branched arms, total number being 10. They attach themselves to the substratum by means of jointed stalks on the aboral surface of the body. These forms hide among the rock, rockpools and crevices well protected from the wave action.

Abudefduf vaigiensis, *Halichoeres pardaleocephalus* and two types of *Gobius* sp. are observed in these mid-littoral pools.

B. Rushikonda

The rocks in Rushikonda are flat and large with several shallow pools. The pools vary in dimensions from 4.22 m x 0.23 m x 1.57 m to 0.95 m x 0.25 m x 1.83 m respectively. These pools are encountered throughout the intertidal zone. Supra-littoral pools, mid-littoral pools are observed. The sub-littoral pools are present at the periphery of the rock bed, as these pools are always connected with the sea. These pools are influenced by the sea than atmosphere. All these pools were covered with sand grains, pebbles and empty shells at the bottom.

Gracilaria corticata was observed on the walls of the pool. Sponges, *Callyspongia fibrosa* is observed among *Gracilaria corticata* on the side walls of the pools along with *Bunodactis* sp.

Bunodactis sp. (Figure. 6) is present on the side walls of the pools upto the water layer, along with *Callyspongia fibrosa*. The number is not more than 6 in each pool.

The other fauna observed here are *Platynereis dumerelli*, *Apsudes avicularia* (Figure. 11), *Lembos kergueleni*, *Grapsus strigosus* and *Charybdis lucifera* are moving here and there in these pools and hidden under the rocks.

Gastropods, *Nerita albicilla*, *Turbo intercostalis*, *Cerethium obeliscus*, *Thais granulata* are found under the rocks and on the side wall of the pools. *Conus biliosus* (Roeding, 1798) is more or less conical shaped gastropod. The spire is very short. Shell is about 1 inch in length and is pale grey or pink in colour. It occurs below the rocks in the rock pools. Two types of *Gobius* sp. fish are observed in these pools.

C. Bhumunipatnam

In this collection spot varying pools are formed. Definite mid and sub-littoral pools are found among small to medium sized rocks and biota was collected. This area is poor in flora and fauna. The sub-littoral pool dimensions are 0.40 m x 0.28 m x 1.60 m. This pool is surrounded by medium sized boulders with an uneven floor covered with sand and small stones which are covered with – *Ulva fasciata*, *Gracilaria corticata* and the walls of the pool covered with *Ulva fasciata*, *Centroceras clavulatum*, *Gracilaria corticata* and *Caulerpa fastigiata*. *Cellana radiata radiata* attached to the walls of the pool. *Platynereis dumerelli*, *Dynamenella quilonensis*, *Lembos kergueleni* are found in the washings of algae. The mid-littoral pool is surrounded by small sized rocks. The bottom of the pool is not uniformly covered with sand, but small rocks covered with *Caulerpa fastigiata* and *Gracilaria corticata*. This pool has no direct connection with the sea. The dimensions of the pool are 1.08 m x 0.75 m x 0.17 m respectively. The walls which are surrounding the pool are covered from the bottom up to the water layer with *Ulva fasciata* and *Centroceras clavulatum*, which is a Rhodophyceae family and thallus is very much thin.

Two types of *Gobius* sp. fish are present in this pool. *Platynereis dumerelli*, *Dynamenella quilonensis*, *Lembos kergueleni* are found in the washings of algae. No other fauna found in this pool. The other mid-littoral pools taken is formed as a depression widened flat rock. Bottom of the pool is covered with sand only. This is an algal pool. This pool has no direct connection with the sea. The pool is covered with green algae members *Caulerpa fastigiata* whose thallus is long thread like and *Chaetomorpha antennina*. The dimensions of this pool are 2.30 m x 0.10 m respectively.

D. Yarada

In this collection spot very few pools are formed. Definite mid and sub-littoral pools are found among small to medium sized rocks and biota was collected. This area is poor in flora and fauna. The sub-littoral pool dimensions are 0.40 m X 0.28 m x 1.60 m. This pool is surrounded by medium sized boulders with an uneven floor covered with sand and small stones which are covered with – *Ulva fasciata*, *Gracilaria corticata* and the walls of the pool covered with *Ulva fasciata*, *Centroceras clavulatum*, *Gracilaria corticata* and *Caulerpa fastigiata*. *Cellana radiata radiata* attached to the walls of the pool. *Platynereis dumerelli*, *Dynamenella quilonensis*, *Lembos kergueleni* are found in the washings of algae. The mid-littoral pool is surrounded by small sized rocks. The bottom of the pool is not uniformly covered with sand, but small rocks covered with *Caulerpa fastigiata* and *Gracilaria corticata*. This pool has no direct connection with the sea. The dimensions of the pool are 1.08 m x 0.75 m x 0.17 m respectively. The walls which are surrounding the pool are covered from the bottom up to the water layer with *Ulva fasciata* and *Centroceras clavulatum*, which is a Rhodophyceae family member and thallus is very much thin. Two types of *Gobius* sp. fish are present in this pool. *Platynereis dumerelli*, *Dynamenella quilonensis*, *Lembos kergueleni* are found in the washings of algae. No other fauna found in this pool. The other mid-littoral pool taken is formed as a depression in a widened flat rock. Bottom of the pool is covered with sand only. This is an algal pool. This pool has no direct connection with the sea. The pool is covered with green algae members *Caulerpa fastigiata*, whose thallus is long, thread like and *Chaetomorpha antennina*. The dimensions of this pool are 2.30 m x 0.78m x 0.10 m respectively.

E. Yarada

This area is covered with moderate to large sized boulders and shingles, offering a variety of ecological riches such as exposed and protected rock surfaces, crevices, gullies, overhangs and rock pools. The supra-littoral pool is far on the shore and it has no direct connection with the sea, water replaced only at extreme high water of spring tides. This pool is formed as a depression in a flat rock. The bottom is covered with sand and pebbles. The dimensions of this pool are 0.75 m x 0.21 m x 1.23 m respectively. *Ulva fasciata* is observed as a border i.e. the surrounding walls are covered with *Ulva fasciata* and *Cellana radiata radiata* is also attached to the walls of the rock in between *Ulva* and walls of the pool.

The second pool is present at the middle portion of mid-littoral zone. The pool is formed as a prolonged depression in flat rock with an uneven floor of small stones and sand. The bottom stones are giving place to *Nereis albicilla*. The dimensions of this pool are 0.84 m x 0.17 m x 3.30 m and water replaced only during strong winds. The walls of the surrounding rocks are covered with luxurious growth of *Spangomorpha indica* and here and there *Padina tetrastomatica*. The thallus of *Padina tetrastomatica* is erect conical, brown in colour and fan shape. The associates of *Spangomorpha indica* are *Dynamenella quilonensis*, *Lembos kergueleni*.

Cyprea arabica (Linnaeus) (Figure. 5) is attached to the algae and some are found among algae. The shell is showing irregular net work of brown markings. The fauna attached to the rocks which are at the bottom of the pool and also at the base of the surrounding rocks of the pools are *Cerethium obeliscus*, *Cerethium rugosum*, *Thais granulata*, *Nerita albicilla*.

Thais intermedia (Kiener) gastropods are attached to the bottom rocks where there is a rich growth of algae. Shell is generally covered with some algae. Outer surface of the shell is tuberculated. Near the opening inner surface of the shell is violet in color. 3 to 5 *Adudefduf vaigiensis* are moving in this pool and sometimes they are hiding under the rocks.

Istiblennius sp. (Figure. 7) is a small and elongated fish with supra-orbital cirrus. Fleshly crest is present on the top of the head of males, in females it is absent. Scaleless body. Maxilla extends to below the posterior border of its eyes. Dorsal fin with 13 spines. Anal fin with 20 rays. Pectoral fin with 14 rays, with irregular darker crossbars on the upper part of the body. Found moving in this pool.

The third pool is present at the lower portion of mid-littoral zone. This pool is surrounded by medium sized boulders and bottom is with an uneven floor of small to medium sized big rocks covered with *Caulerpa racemosa* and *Spongomorpha indica*. The dimensions of the pool are 1.83 m x 0.22 m x 1.75 m and water is replaced by wave splash.

Green algae, *Caulerpa racemosa* is with long profusely branched stolon. Due to the presence of spherical brachlets of foliar branches this looks like "Bunches of grapes". *Cyprea arabica* found attached to this algae. The associates of *Spongomorpha indica* are *Platynereis dumerelli*, *Dynamenella quilonensis* and *Lembos kergueleni*. *Bunodactis* sp. attached to the surrounding rocks up to the water layer and found among *Spongomorpha indica*.

Cerethium rugosum is found at the sheltered portion of the rocks of the pool and *Nerita albicilla* is also found abundant in this area. *Turbo intercostalis* is found at the bottom of the rocks.

Stomopneustes variolaris (Lamarck) is found under big rocks and also among algae. 3 forms were observed in this pool. This form is provided with black spines which are stout and pointed. The oral spines are very short and flattened. These forms adhere to the rocks so firmly by means of tube feet, it is very difficult to dislodge these forms from the substratum.

Abudefduf vaigiensis, and two types of *Gobius* sp. are observed not more than 2 of each species.

The physiographical and biological conditions of rockpools at different localities are represented in Tables .1 and 2.

4. Conclusion

The rockpools are dynamic and ever-changing habitats which differ from both the emerged rocks and the surrounding sea water. The rockpools occupy different positions on the rocky shore and are subjected to various environmental factors. As these pools are found with obvious distinctions in flora and fauna, several attempts have been made to classify them in different types. Based on the nature of flora, Bohlin (1897) classified them and described three main types. Subsequently, Levander (1900) divided the pools depending on the salinity. Gislen (1930) described three different types such as supra-littoral, mid-littoral and sub-littoral pools. Jarnefelt (1940, Ridley and Dendy, 1887) used salinity as a basis for the classification of pools and also stressed the importance of the nature of the substratum and the composition of plankton and water. Most comprehensive system of classification was proposed by Forsman (1951). Clark's (1968) classification is based partly upon the salinity and partly upon the flora and fauna. Ganning (1971a) recognized five main types of pools depending on salinity along Swedish coast. In the present study it has been found convenient to classify them into three types i.e. supra-littoral, mid-littoral and sub-littoral pools depending on the tide levels.

The rocky intertidal region of Visakhapatnam is composed of numerous rock pools of varying size occupying different localities. The physiography of rockpools indicates that no two pools are identical. In Palm Beach some others are surrounded by small to medium size boulders and some others are formed as a depression or somewhat basin-like pools. In Bhimunipatnam some pools are noticed as a basin in rocky platform and some are surrounded by small rocks. The observed rockpools at Yarada are surrounded by medium sized boulders. The rockpools found at Rushikonda are found among small rocks.

During the period of study, the macrofauna collected from various localities are assigned to the following taxonomic groups: sponges, Coelenterates, Polychaetes, amphipods, isopods, tanaids, crabs, gastropods, echinoderms and fish. The distribution of organisms was not uniform among all rockpools. The topographical and ecological conditions provide significant faunistic features for individual pools. Variability in the biological communities has been attributed to the differences in the physical characteristics of rockpools such as area, volume and depth which provide a greater range of physical gradient. The difference in wave exposure can result in variability among tidal pool composition at the same composition at the same intertidal height. It was found that the species diversity decreased in rockpools located at the extreme high shore (Supra-littoral zone) in the present study. Decreased diversity in pools that are located high on the shore may be attributed to increase physiological stress during extended periods of isolation from tidal input. This may result in low food abundance, high temperature and high

salinity due to evaporation in summer. Therefore, the fauna of pools located at the high shore can withstand the extreme variation in physical conditions. According to Metaxas and Scheibling (1993) species diversity tend to decrease with increasing intertidal height.

In this study, the species diversity increased in pools located lower on the shore because of abundance of food, constant temperature and salinity similar to the neighboring sea water.

The pools that are located at high shore have exclusively more number of fish, a thin layer of *Enteromorpha compressa* and occasionally crabs moving from one pool to another. Fishes were found in all mid-littoral pools except third algal pool which were studied so far. The gastropod, *Cellana radiata radiata* found in all mid-littoral pools. In first two pools the barnacles, *Chthamalus* sp. were observed in October and November, 1996. *Tropiometra encrinus* was observed in one pool in August, 1996. Starfishes *Acanthasterina sarasinini* were noticed only in the month of September 1996. The specific characteristics of rockpools such as pool depth, volume, orientation, shading and flushing rate make the individual pool unique. Each pool is unique in flora and fauna

The fauna settled in different positions in the pools given us information about the nature as well as adaptations of fauna. The fauna settled on the upper region i.e. at the mouth of the pool or on the top of the rocks of the pool are photopositive and can tolerate high illumination, high temperature and severe wave action. The fauna settled in bottom, on the side walls of the pool and under the rocks of pool are photonegative to avoid direct illumination, high temperature, strong wave action and predation by birds etc. The fauna settled among the algae is an adaptation to rescue from the predation by other fauna. The fish which are found in the pools feed on the invertebrates and also fauna associated with algae. The fauna found among algae and between the wall of the pool and algae can tolerate high temperature because algae conserves temperature and rise temperature of the pools up to 1 or 2^o C higher than the open sea and surrounding pools which have low density of algae.

The sea was calm from December to April. It was noticed that the isolation of rockpools was more during this period. The temperature of rockpools closely related to the local climate especially air and sea water temperature, the number of sun shine hours per day and the wind activity. Due to the restricted volume of water in rockpools their temperatures were often in accordance with that of air but with less variations.

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Figure 1: Rockpool at Palm Beach , Visakhapatnam exposed during low tide .



Figure 2: Rockpool (0.91m x 1.23x 0.95m) exposed during low tide at Palm Beach, Visakhapatnam



Figure 3: *Tripiometra encrinus* (crinoid)

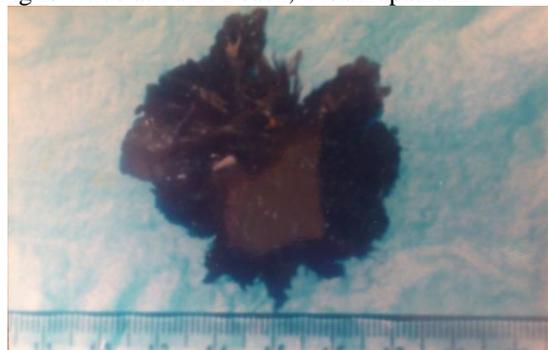


Figure 4: *Spongomorpha indica* from Palm Beach



Figure 5: *Cyprea arabica* from Yarada



Figure 6: *Bunodactis sp.* Encrusted with sand particles from Palm Beach



Figure 7: *Istiblennius sp.* From Yarada



Figure 8: *Gobius sp.* From Palm Beach



Figure 9: *Charybdis truncata* (crab)

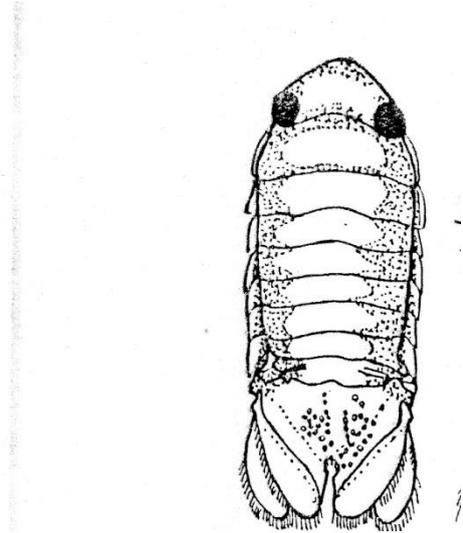


Figure 10: *Dynamenella quilonensis* (Isopod)

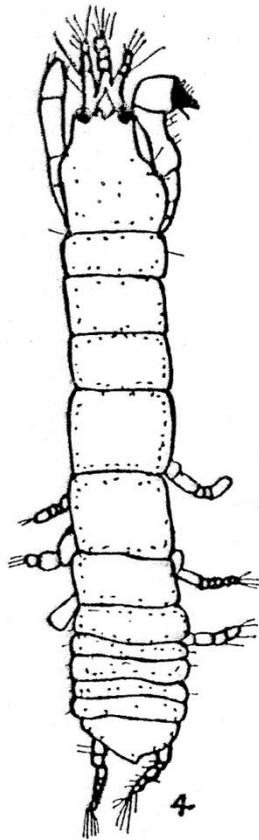


Figure 11: *Apeudes avicularia* (tanaid)

Table 1. Physiographical and hydrographical conditions of rockpools at various locations of Visakhapatnam coast from May 1996 to February 1997

SNo	Date	Tide Time	Tide Height	Locality	Pool Diameter (m)	Depth (m)	length	Position of the Pool
1.	31-5-'96	13.26	0.31	RK	1.57	0.23	4.22	SL
2.	31-5-'96	13.26	0.31	RK	1.59	0.42	2.20	ML
3.	31-5-'96	13.26	0.31	RK	1.59	0.45	2.09	SML
4.	4-6-'96	16.28	0.16	PBNS	1.40	0.21	2.40	ML
5.	5-6-'96	17.20	0.21	PBSS	1.28	0.25	2.10	ML
6.	2-7-'96	15.28	0.14	PBSS	1.59	0.42	2.20	ML
7.	2-7-'96	15.28	0.14	PBSS	1.59	0.71	2.09	ML
8.	2-7-'96	15.28	0.14	PBSS	1.59	0.13	1.54	SL
9.	3-7-'96	16.66	0.12	PBSS	1.57	0.35	3.07	ML
10.	3-7-'96	16.66	0.12	PBSS	0.91	1.23	0.95	ML
11.	30-7-'96	14.28	0.14	PBSP	1.28	0.42	2.20	ML
12.	30-7-'96	14.28	0.14	PBNS	1.81	0.42	2.32	ML
13.	30-7-'96	14.28	0.14	PBNS	0.62	0.13	0.32	SL
14.	1-8-'96	15.36	0.06	PBSS	2.17	0.36	4.00	ML
15.	2-8-'96	16.39	0.09	PBSS	0.91	1.23	0.95	ML
16.	2-8-'96	16.39	0.09	PBSS	0.75	0.60	1.00	ML
17.	13-8-'96	14.18	0.37	PBSS	0.35	0.09	1.10	SL
18.	13-8-'96	14.18	0.37	PBSS	1.01	0.09	1.60	SL
19.	14-8-'96	14.45	0.32	PBSS	0.15	0.08	1.50	SL
20.	28-8-'96	14.11	0.13	PBSP	0.60	0.30	2.50	ML
21.	28-8-'96	14.11	0.13	PBSP	2.10	0.16	1.57	SL
22.	29-8-'96	14.52	0.07	PBNS	1.50	0.30	1.50	ML
23.	30-8-'96	15.31	0.07	PBSP	0.80	0.10	1.15	SL
24.	30-8-'96	15.31	0.07	PBNS	0.70	0.15	1.50	SL
25.	30-8-'96	15.31	0.07	PBNS	2.20	0.15	3.00	SL
26.	31-8-'96	16.09	0.11	PBNS	1.36	0.37	1.21	ML
27.	23-12-'96	13.22	0.25	BH	0.40	0.28	1.60	SUL
28.	23-12-'96	13.22	0.25	BH	0.75	0.17	1.08	ML
29.	23-12-'96	13.22	0.25	BH	0.78	0.10	2.30	ML
30.	24-2-'97	15.30	0.04	YD	0.75	0.21	1.23	SL
31.	24-2-'97	15.30	0.04	YD	0.84	0.17	3.30	ML
32.	24-2-'97	15.30	0.04	YD	1.83	0.22	1.75	ML

RK: Rushikonda; PBNS: Palm Beach Northern side from Scandal point; YD: Yarada; PBSS: Palm Beach Southern side from Scandal point; PBSS: Palm Beach Scandal point; SL: Supra-littoral; ML: Mid-littoral; SUL: Sub-littoral; BH: Bhimuniapatnam

Table 2: List of species Macroalgae and Macrofauna present in different pools of Visakhapatnam coast sampled during May 1996 – February 1997

S. No	Date	Tide Time	Tide Height	Locality	Macroalgae	Macrofauna and Associate Fauna						
						Sponges	Coelenterates	Annelides	Arthropodes	Molluscs	Echinoderms	Fishes
1	31-5-'96	13.26	0.31	RK	8	A	B	C	E,F, H, J	M, O	-	I
2	31-5-'96	13.26	0.31	RK	8	A	-	-	H	M, O, Q,V	-	-
3	31-5-'96	13.26	0.31	RK	8	A	-	-	H	M, O	-	-
4	4-6-'96	16.28	0.16	PBNS	-	-	B	-	H	N., O	-	I
5	5-6-'96	17.20	0.21	PBSS	1,2,7,8	A	B	C	H	N	-	I
6	2-7-'96	15.28	0.14	PBSS	1,7,8	-	B	-	-	N	-	-
7	2-7-'96	15.28	0.14	PBSS	3	-	-	-	D,E,F	N	-	I
8	2-7-'96	15.28	0.14	PBSS	1	-	-	-	-	N	-	-
9	3-7-'96	16.66	0.12	PBSS	1	-	-	-	H	N	-	I
10	3-7-'96	16.66	0.12	PBSS	1,2,7,8	A	B	-	H	N	-	I
11	30-7-'96	14.28	0.14	PBSP	1	-	-	-	-	N, U	-	-
12	30-7-'96	14.28	0.14	PBNS	3	-	-	-	-	M,N,O	-	I, II
13	30-7-'96	14.28	0.14	PBNS	1	-	-	-	-	M,N,R,V	-	-
14	1-8-'96	15.36	0.06	PBSS	1, 8	-	-	C	H,I	N	-	I, II
15	2-8-'96	16.39	0.09	PBSS	1,2,7,8	A	B	-	-	-	-	II
16	2-8-'96	16.39	0.09	PBSS	-	-	B	-	H	N	-	II
17	13-8-'96	14.18	0.37	PBSS	-	-	-	-	H	N	-	-
18	13-8-'96	14.18	0.37	PBSS	1	-	-	-	-	N	-	-
19	14-8-'96	14.45	0.32	PBSS	1	-	-	-	-	N	-	-

20	28-8-'96	14.1	0.13	PBSP	3	-	B	-	H,J	-	Y	I, II
21	28-8-'96	14.1	0.13	PBSP	2	-	-	-	H	-	Y	I
22	29-8-'96	14.52	0.07	PBSN	-	-	-	-	H,K	-	-	I,II,III
23	30-8-'96	15.31	0.07	PBSP	6	-	-	-	-	N,O,Q	-	-
24	30-8-'96	15.31	0.07	PBSP	1,3	-	-	-	F	-	-	III
25	30-8-'96	15.31	0.07	PBSP	2	-	-	-	-	-	-	II
26	31-8-'96	16.09	0.11	PBNS	1	-	-	-	-	-	-	I
27	23-12-'96	13.22	0.25	BH	1,4,8,10	-	-	C	D,E	N	-	-
28	23-12-'96	13.22	0.25	BH	1, 8	-	-	C	D,E	-	-	I
29	23-12-'96	13.22	0.25	BH	4, 10	-	-	-	-	-	-	-
30	24- 2-'97	15.30		YD	1	-	-	-	-	N	-	-
31	24-2-'97	15.30		YD	3, 11	-	-	-	D,E	M,Q,R,T,V, W		II,IV
32	24-2-'97	15.30		YD	3, 5	-	B	C	D, E	M,O,R,W	Z	I, II

RK: Rushikonda PBNS:Palm Beach Northern side from scandal point

PBSS:Palm Beach Southern side from scandal point

PBSP: Palm Beach scandal point BH: Bhimunipatnam

YD: Yarada

Table 2: Contd - Abbreviations

Macroalgae	Macrofauna and Associate fauna	Fishes
1 <i>Ulva fasciata</i>	A <i>Callyspongia fibrosa</i>	I <i>Gobius sp. (two types)</i>
2 <i>Chaetomorpha antennia</i>	B <i>Bunodactis sp.</i>	II <i>Abudefduf vaigiensis</i>
3 <i>Spongomorpha indica</i>	C <i>Platynereis dumeralli</i>	III <i>Halichoeres</i> <i>Paradaleocephalus</i>
4 <i>Caulerpa fastigiata</i>	D <i>Dynamenella</i>	IV <i>Istiblennius sps.</i>
5 <i>Caulerpa race</i>		
6 <i>Enteromorpha compressa</i>	F <i>Lembos kergueleni</i>	
7 <i>Hypnea valentiae</i>	G <i>Nymphon lingicaudatum</i>	
8 <i>Gracilaria corticata</i>	H <i>Grapsus strigosus</i>	
9 <i>Jania rubens</i>	I <i>Xantho bidentatus</i>	
10 <i>Centroceras clavulatum</i>	J <i>Charybdis lucifera</i>	
11 <i>Pandina tetrastomatica</i>	K <i>Charybdis orientalis</i>	
	L <i>Charybdis truncate</i>	
	L.g. <i>Alpheus pacificus</i>	
	M <i>Nerita albicilla</i>	
	N <i>Cellana radiata radiata</i>	
	O <i>Turbo intercostalis</i>	
	P <i>Conus biliosus</i>	
	Q <i>Cerethium obeliscua</i>	
	R <i>Cerethium rugosum</i>	
	S <i>Chthamalus sp.</i>	
	T <i>Thais intermedia</i>	
	U <i>Thais rudolphi</i>	
	V <i>Thais granulatus</i>	
	W <i>Cyrea Arabica</i>	
	W, b <i>Bursa granularis</i>	
	X <i>Acanthasterina sarasini</i>	
	Y <i>Tropiometra encrinus</i>	
	Z <i>Stomopneustes variolaris</i>	