INTERTIDAL MACRO-ALGAL DIVERSITY AND ZONATION PATTERNS OF THE EASTERN AND WESTERN COASTS OF GHANA

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DECLARATION

"This thesis is the result of research work undertaken by Gbedemah, Tsatsu Selorm in the Department of Marine & Fisheries Science, University of Ghana, Legon, under the supervision of Mr. A.K Armah of the Department of Marine and Fishery Sciences, and Professor G. Ameka of the Department of Botany, University of Ghana''.

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DEDICATION

This work is dedicated to the Almighty God and my family.

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I thank the Almighty God for his grace, love, care and direction

I am most grateful to my supervisors:

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ABSTRACT

Based on abundance and distribution of species along the intertidal continuum from the sublittoral to the supralittoral, rocky shores have been divided into zones globally. Rocky shore zonation has been assumed to follow broad regional and latitudinal patterns with no attention being paid to smaller scale patterns. The aim of this study is to find out if the global 3-zone division is applicable to Ghanaian shores based on multivariate analysis. Macroalgae which constitute the most visible and accessible species in the rocky intertidal were employed as the taxonomic units. The study focused on two similar rocky intertidal areas, 230 km apart, at Takoradi and Prampram, both in Ghana. A total of 36 species of macroalgae, comprising 9 Chlorophyta, 10 Phaeophyta, and 17 Rhodophyta were identified as present at the two locations. A multivariate analyses of the abundance and location of macroalgae in relationship to their level in the intertidal zone detected zonation differences in the macroalgal community structure between the western and eastern locations at Takoradi and Prampram respectively. It is observed that it is not necessary to characterize macroalgal zonation patterns based at species level but simply grouping the in major taxa such as Chlorophyta, Phaeophyta and Rhodophyta is sufficient to characterize zonation patterns satisfactorily. Multivariate analysis is a better tool in assessing vertical zonation, as it produced sub zonations or micro zonations in 5 zone method, for both sites than species occurrence. The universal zonation method might not be applicable to all shores as evidenced in this work.

CHAPTER ONE

INTRODUCTION

Rocky shores are considered primitive coasts because they are the least altered of all coasts; not having time to erode and form sediments. This is the result of a geologic event since the last Pleistocene age (Ice age) (Senechal-Brown and Dean, 1996). Worldwide rocky coasts extend over 80 % of continental and island margins. They are always subject to strong waves as compared to sandy coasts (Granja, 2006). As per wave and tidal cycle, it is characterized by high wave action, constant submersion and exposure, changing temperature and salinity, and the occurrence of tide pools thus making it a harsh environment. The rocky intertidal habitat is host to many organisms that are capable of withstanding this harsh, ever-changing environment.

The ecology of animals and plants on intertidal rocky shores has been a topic of interest for decades in many parts of the world (Underwood, 2006). Ecologists studying rocky intertidal habitats have been very concerned with spatial and temporal variability in the patterns and processes that influence distributions and abundances of animals and plants (Stephenson and Stephenson, 1949).

Although it is now recognized that scientists have been doing macro ecology for decades (Preston 1962, Pianka 1966, McArthur and Wilson 1967), the global macroalgal diversity patterns have not been well studied, with most diversity comparisons being regional, and restricted to the Northern Hemisphere (Santelice *et al.*, 2003). In intertidal systems, environmental conditions range from fully aquatic to fully terrestrial over the space of a few vertical meters. The detailed study of the relationships between these plants and their natural environment may therefore provide some clues to answering this variability.

1.1 Justification

Ecologists studying rocky intertidal habitats have been very concerned with spatial and temporal variability in the patterns and processes that influence distributions and abundances of animals and plants. Ghana's rocky shore is flanked in an east to west direction by several kilometers of sandy beaches and backed by several river bodies, which empty their contents onto the intertidal environments (Lamptey *et al.*, 2010).

In analyses of intertidal habitats, there have been several approaches to considering hierarchies of spatial scales. The influence of environmental conditions and space on species diversity has not been given much prominence in scientific literature. Oceanographic variability is a strong correlate to the abundance of dominant intertidal hard bottom faunal functional groups (Nielsen and Navarette, 2004). Variability of physical environment is important in explaining patterns of intertidal diversity (Zacharias and Roff, 2001).

In Ghana, spatial differences of rocky intertidal shore assemblage is documented by several scientists including Lawson (1956); Buchanan (1957); Gauld and Buchanan (1959); Bassindale (1961); Edmunds (1978); John (1986); John and Lawson (1990); Evans *et al* (2003); and Branoff *et al* (2009). However the extent and zonation pattern differences have not been tested statistically. All earlier works have assumed a 3-zone intertidal area based on global approach, neglecting scale and local situations.

1.2 Aim and Objectives

The primary aim of this study is to find out if there is a distinct difference in assemblages (abundance, diversity and distribution) of macroalgae between the eastern and western rocky intertidal shores of Ghana as revealed from macroalgae zonation. Postulated hypothesis is "There is no significant difference in Intertidal Macroalgal assemblages in the eastern and western parts of Ghana's coast.

The two sites lie more or less on the same geographical latitude but have local climatic differences (mainly rainfall and to a lesser degree temperature) and also level and types of human influence.

Specific objectives are:

1 Is there any significant difference in the diversity and composition of spatial taxa assemblages between identical sites in these two areas?

2 Which taxa contribute the most in observed patterns at the within site and between sites

3 Does the global intertidal vertical zonation classification method adequately describe Ghana's rocky shores?

CHAPTER TWO

LITERATURE REVIEW

2.1 What are Macroalgae?

Macroalgae are a collective term used for seaweeds and other benthic marine algae that are generally visible to the naked eye. Larger macroalgae are also referred to as seaweeds. The algae (the primary producers of the planet) are primitive photosynthetic organisms of the oceans and seaweeds that can range in size from microscopic to the massive bull kelps (*Durvillaea*) and giant kelps (*Macrocystis*). Macroalgae should not be confused with seagrasses. The latter are closely related to land plants as they have roots, vascular tissue and produce flowers and pollen. Macroalgae derive all their nutrients directly from the surrounding water through their tissue, a bit like a sponge soaks up moisture and their holdfasts are mainly for physically anchoring the thallus to the substrate (Miller, 2009).

While seaweeds do reproduce sexually, their reproductive structures are mostly microscopic and require fine dissection to be revealed. Most macroalgae fall into three basic groups: The green algae (Chlorophyta) such as *Ulva fasciata*, the brown algae (Heterokontophyta/ Phaeophyta) that include the large kelps, and the red algae (Rhodophyta) the most diverse group of all. The latter should not be confused with “red tides” which are actually caused by single-celled algae (phytoplankton) some species of which can produce toxins that can kill fish or cause paralytic shellfish poisoning. (No marine macroalgae are known to be harmful to humans) (Miller, 2009).

These different ‘colours’ of algae are the result of the different photosynthetic pigments or chlorophylls that each alga uses and these absorb different wavelengths of light. With few exceptions, macro algae are strictly benthic plants; that is they are always attached to the seabed or a solid substratum such as natural reef, rocks, shells, mangrove roots, boat hulls, jetty pilings, mooring lines etc. When dislodged, most macroalgae have a limited lifespan as free floating seaweed drift and they may only live for hours to several months.

Only a few macro algae, such as *Caulerpa* species, can grow in soft sediments and anchor themselves either with long root-like rhizoids or simply by entanglement around sea grass fronds. The largest of the chromists are the Phaeophyta, the brown algae -- the largest brown algae. Almost all phaeophytes are marine, like most photosynthetic protists, have traditionally been classified as plants. However, phaeophytes are not closely related to land plants; their cells contain different pigments, such as chlorophyll c and fucoxanthin. They also lack the plasmodesmata and starch production of land plants and their relatives. Like plants and many protists, brown algae undergo a complex life cycle involving alternation of generations.

Macroalgae grow both intertidally and subtidally. Because they derive their nutrients by diffusion through their tissue, the water movement across fronds has to be continually refreshed and by being anchored to the seabed, they increase their chances of this. When floating with the currents and tides, the water immediately surrounding them is not replenished as rapidly. The one, main exception is a species of *Sargassum*. The famous Sargasso Sea (western north Atlantic) is named after this seaweed that floats there in massive rafts and can maintain itself by simple fragmentation. Since macroalgae are true photosynthetic organisms, they can only grow in the “photic” zone of the coastal regions, where the light penetrates sufficiently for photosynthesis to occur. In clear waters, macroalgae can survive and grow at depths of over 200 meters, but in murky waters this is reduced to only a few meters. As a result of their photosynthetic activity, marine algae (macroalgae and phytoplankton) are considered to produce between 50% and 75% of the earth's oxygen as well as taking up about 25% of the carbon dioxide.

Crustose coralline algae, a very significant group of red seaweeds, make rocks look pink in colour and, when broken apart, are major contributors to the sediments of intertidal and subtidal reefs as they actively lay down Calcium Carbonate (chalk) in their tissues. Geological cores taken on the Great Barrier Reef have shown that up to 70% of the marine sediments are made up of calcium carbonate deposits from the green algal genus *Halimeda*. In fact, they should probably be called macroalgal reefs rather than coral reefs. Some macroalgae respond rapidly to, and thrive within, waters that receive increased nutrients and often can be used as indicators of water quality. At certain times of the year, especially in spring when water temperatures and day lengths increase, coupled with some heavy rainfalls supplying nutrients from runoff to the coast and estuarine environments, macroalgae can bloom in massive quantities. In all instances so far studied, the algae involved in these blooms are harmless, non-toxic, native species. They are simply responding to changes in environmental conditions as most plants do. These major blooms are mostly natural phenomena and occur all over the world (Clayton and King, 1990).

2.2 Coastal geology of Ghana

Macroalgal species diversity and distribution are dependent on, and affected by the diversity of the seabed topography and geology, and settlement of larval stages depends on the rock type (Fischer, 1981). Thus, differences in coastal geology could influence macroalgae diversity and zonation at different locations in Ghana. An appreciation of the geology of the Ghanaian coast is therefore necessary.

The coastal geological formations of Ghana were likely determined by continental drift during the Cretaceous period (about 135 million years ago), when Africa broke away from South America (Allersma and Tilmans, 1993). The geological composition consists of hard granites, granodiorites, metamorphosed lava, and pyroclastic rock. Some coastal areas are covered by Ordovician, Silurian, and Devonian sandstone and shales (Allersma and Tilmans, 1993).

The study area in the west geologically consist of is composed strongly folded rocks, more or less metamorphosed sediments, and volcanic rocks associated with granite. (Harrison and Church, 1980; Hall and Swaine, 1981).

The study area in the east geologically consists of the Birrimian Precambrian formation. This formation has strongly folded rocks, more or less metamorphosed sediments, and volcanic associated with granitic rocks. It is associated with flat undulating country (Hall and Swaine, 1981; Harrison Church, 1984).

2.3 Ghana's coastal environment

Factors affecting the distribution of species within the rocky intertidal zone include currents, wave action and tidal range; the oceanographic environment of the Ghanaian coastal waters is described in Ofori-Adu (1975, 1977), Bernacsek (1986), and Mensah and Koranteng (1988). The water masses off the coast are reported to flow under the influence of three current systems. Bernacsek (1986) and Armah (1987) described these as:

- The eastward flowing Guinea Current, which occurs on the surface from the coast to about 370 km offshore;
- A small westward counter current, which lies beneath the Guinea Current; and
- The westward flowing South Equatorial Current, which is, located offshore, beyond 370 km.

The tropical West African Flora is impoverished in contrast to the richness of the Caribbean region of the eastern Atlantic or the tropical coast of East Africa thus diversity is low. Like the western shores of other continents, coral reefs are absent and consequently so are the rich and varied life associated with these structures.

As a result of the absence of protecting coral reefs or shallow offshore shoals, much of the West African coast is very wave exposed. (Bolton et al, 2003) Seasonal upwelling, seasonal inflow of turbid, silt-laden water, seasonally lowered inshore salinity, absence of suitable shallow water substrata, low habitat diversity and heterogeneity are all factors contributing to the absence of coral reefs and the low species diversity of algae n tropical West Africa (Bolton *et al*., 2003).

2.4 Tides

Tides influence macroalgal zonation patterns and are influenced by the tidal range and frequency.

The tide on the coast of Ghana is regular and semi diurnal. The average range varies along the coast, the average range of Neap and Spring tides increases from west to east. Tidal currents are low and have an insignificant influence on coastal processes except tidal inlets (Allersma and Tilmans, 1993).

Recent advances in physiology, ecology, and biological oceanography have considerably improved our understanding of the environmental factors that generate and maintain biological pattern in the marine environment (Bertness et al. 2001; Dahlhoff et al. 2001; Helmuth and Hofmann 2001).

Although zonation is related to tides, it is influenced by other factors. Indeed, Stephenson and Stephenson (1972) note, "Zonation, although undoubtedly related to tides, is not directly caused by them."

2.5 Intertidal ecology of the macroalgae

Rocky shores and solid substrates down to the lower limit of the photic zone provide the main habitat for marine macroalgae, and this habitat, in itself, is of interest to plant ecologists because of the large variations in disturbance and stress that may occur within relatively small areas. Disturbance here refers to factors such as wave action and grazing, which limit plant biomass by causing partial or total destruction, whereas Stress is for external factors which limit rate of dry matter production by plants (Grime, 1979).

It is the excessive disturbance which prevents seaweed from colonizing mud, sand or shingle, and which restricts their development on wave beaten rocks, but limits to the vertical distribution of seaweeds on sheltered rocky shores are largely imposed by stresses associated with emersion at the top of the shore, and by low light at the bottom of the photic zone.

However, this result in increased competition between macroalgae for light and space, and the competitive ability of macroalgae becomes more important in these habitats than their ability to withstand either stress or disturbance (Grime, 1979).

2.6 Vertical Zonation

Vertical zonation occurs on shores throughout the world. The boundaries between different organisms are often so sharp and so level that it is tempting to conclude there is a direct causal relationship between such boundaries and the water level at a particular state of the tide. A change in the slope or the aspect of the shore will alter the degree of exposure to wave action, and the upper limits of most species are found to be higher in more exposed sites. For this reason many recent investigators have described the distribution of species on their shores with reference to three biological boundaries, all of which can be indentified on most rocky shores at most latitudes in every ocean,(Stephenson and Stephenson,1972)

These are:

I. Upper limit of Vurrucaria, bluegreen algae and littorinid snails
II. The upper limit of barnacles
III. The upper limit of laminarians

The resultant patterns of biological zonation are striking and have been documented worldwide (Knox, 2001). The positions of the upper and lower limits of biological zones provide easily quantifiable biological benchmarks for ecological comparisons through space (between sites separated by centimeters to hundreds of kilometers) and time (between seasons, years, decades).

The importance of biotic factors in controlling the distribution and abundance of marine organisms is generally thought to decrease with increasing height in the intertidal zones of rocky shores. Patterns of vertical zonation of intertidal organisms are caused, in general, by the effects of physical stress and biotic interactions (Connell, 1972; Menge *et al*., 2010). Several belts or assemblages of organisms have been described and delimited in terms of the dominant species (Chapman, 1974). Thus, the high littoral is characterized by snails (Littorinidae), the middle shore is defined by sessile organisms such as barnacles and mussels, and the low littoral is dominated by algae (Ellis, 2003). The principal causes of differences in assemblages were the wave exposure, larval transport, food supply and spatial heterogeneity (Menge, 1976; Menge *et al*., 1997; Schiel, 2004). In addition, settlement of larval stages depends on the rock type (Fischer, 1981).

The detailed study of the relationships between these “organisms’’ and their natural environment may, therefore provide some clues about why marcroalgae are so different. Rocky shores and solid substrates down to the lower limit of the photic zone provide the main habitat for macroalgae, and this habitat, in itself, is of interest to plant ecologists because of the large variations in the degree of disturbance and stress that may occur within small areas. It is excessive disturbance which prevents macroalgae from colonizing mud, sand or shingles, and which restricts their development on wave beaten rocks, but the limits to the vertical distribution of macroalgae on sheltered rocky shores are largely imposed by the stresses associated with emersion at the top of the shore, and by low light at the bottom of the photic zone (Dring, 1982).

In addition to being shaped by aspects of climate, intertidal habitats especially intertidal zonation patterns are strongly influenced by species interactions, such as predation, competition, facilitation, and indirect interactions. Ultimately, these interactions feed into the food web structure, described above. Intertidal habitats have been a model system for many classic ecological studies, including those introduced below, because the resident communities are particularly amenable to experimentation. One dogma of intertidal ecology supported by such classic studies is that species' lower tide height limits are set by species interactions whereas their upper limits are set by climate variables. Classic studies by Robert Paine established that when sea star predators are removed, mussel beds extend to lower tide heights, smothering resident seaweeds. Thus, mussels' lower limits are set by sea star predation. Conversely, in the presence of sea stars, mussels' lower limits occur at a tide height at which sea stars are unable to tolerate climate conditions. Competition, especially for space, is another dominant interaction structuring intertidal communities. Space competition is especially fierce in rocky intertidal habitats, where habitable space is limited compared to soft-sediment habitats in which three-dimensional space is available. Although intertidal ecology has traditionally focused on these negative interactions (predation and competition), there is emerging evidence that positive interactions are also important (Bruno *et al.*, 2003).

Facilitation refers to one organism helping another without harming itself. In similar examples, many intertidal macroalgae provide physical structures that are used as refuges by other organisms. Mussels, although they are tough competitors with certain species, are also good facilitators as mussel beds provide a three-dimensional habitat to species of snails, worms, and crustaceans (Dring, 1982).

CHAPTER THREE

METHODOLOGY

3.1 Study Sites

This research was done at sites located at the eastern and western parts of Ghana's coast namely Prampram and Takoradi respectively which have distinct climatic conditions. Sampling was done in November (representing the end of the rainy season where its effects are most felt) and March (representing the end of the dry season where the effects are most felt). The climate of Ghana is tropical, but temperatures vary with season and elevation. Except in the north two rainy seasons occur, from April to July and from September to November. In most areas the highest temperatures occur in March.

PLATE A: The coast of Ghana showing study sites - Takoradi and Prampram
(Source: Google earth)

3.2 General Description of Sites

PRAMPRAM

Plate B: Rocky intertidal shore at Prampram

Plate C: Quadrat sampling on the rocky beach at Prampram

Located less than 50 km, east of Accra, Ghana’s capital, the Prampram Township is the largest community in the Dangme West District. As a coastal community, the primary occupations are fishing and selling of fish, but also include small farmers and artisans.

The sampling site (5°42'17.68"N 0° 6'55.08"E) is chosen close to the old fort where artisanal canoes are moored. This place also serves as a landing site for the fisher folk,

TAKORADI

PLATE D: Rocky intertidal shore at Takoradi.

It is the third largest city in Ghana (4°52'41.78"N 1°45'22.91"W). The capital of the Western Region, Sekondi-Takoradi, is an industrial and commercial centre of Western Ghana.

The sampling site (4°52'41.78"N, 1°45'22.91"W) chosen is behind the Fisheries Commission office which offers a rocky beach with a wide sandy backshore beach. The beach slopes gently and is relatively level. The area is relatively sheltered shore. Encrusting algae were generally noted on the rocks.

3.3 Field Sampling Protocol

3.3.1 Biota

The method of sampling biota used was the point interception method (Hawkins and Jones, 1992). A 100×100 cm^2 square quadrat were placed randomly from the upper to the lower intertidal zones along each belt transect at both sites. The number of quadrats depended on the beach width which in turn results from tidal levels and the geography of the area.

For each site the random stratified method of sampling was employed. Sampling along vertical transect across the rocky shore. Sampling was done to investigate current diversity and zonation patterns of macroalgae. Vertical transects were chosen randomly and then coordinates fixed with a GPS. The field sampling was done at low tide. Tidal level predictions were determined using tide tables. This period offered opportunity for the widest possible area of the beach to be sampled. Four (4) belt transect lines were randomly obtained at each site within a site perpendicular to the shore.

Each of the sites was visited on days during the period of lowest tides. Random alternative 100m horizontal belt transects along the shore were obtained at each site. Sampling for biodiversity was done by random placement of 1 m^2 quadrant (N=frequency of throws or quadrant placement).

3.3.2 Abiota

The following physicochemical parameters were measured: dissolved oxygen, air and water temperatures and nutrients (NO_3, PO_4). Air and water temperature were measured *in situ*.

Separate samples were taking for dissolved oxygen and nutrients analysis. There were kept under ice and stored in thermos chest cooler and then transported immediately to the laboratory for analysis.

3.4 Field and laboratory analyses

The percentage cover of macroalgae was quantified using taxonomic guides and manuals (e.g. Edmunds 1978, Lawson *et al*., 2000, John *et al* 2003). All flora species that would not identified on the field were stored in a refrigerator. Using the appropriate guide and compound microscope they were later identified.

Nutrients and dissolved oxygen levels in the water samples were measured *in-situ* using a multi parameter probe.

3.5 Statistical/Data Analysis

All data collected were analyzed in Excel software package 2007®. Univariate and multivariate techniques were employed in analyzing data to describe biological communities.

Univariate Techniques Employed

3.5.1 Shannon-Wiener diversity index (H)

Shannon and Wiener independently derived the function which has become known as Shannon index of diversity. This indeed assumes that individuals are randomly sampled from an independently large population. The index also assumes that all the species are represented in the sample. Log_2 is often used for calculating this diversity index but any log base may be used. It is of course essential to be consistent in the choice of log base when comparing diversity between samples or estimating evenness. The value of Shannon diversity is usually found to fall between 1.5 and 3.5 and only rarely it surpassed 4.5. It has been reported that under log normal distribution, 105 species will be needed t produce a value of Shannon diversity more than 5. Expected Shannon diversity was also used (Exp H') as an alternative to H'. Exp H' is equivalent to the number of equally common species required to produce the value of H' given by the sample.

(H') is always compared with maximum Shannon diversity (Hmax) which could possibly occur in a situation where all species were equally abundant. Shannon diversity is the very widely used index for comparing diversity between various habitats (Clarke and Warwick, 2001).

3.5.2 Margalef's species richness

This has a good discriminating ability. However it is sensitive to sample size. It is a measure of the number of species present for a given number of individuals.

3.5.3 Pielou's evenness (J)

Evenness index is also an important component of the diversity indices. This expresses how evenly the individuals are distributed among the different species. Pielou's evenness index is commonly used.

Multivariate Techniques Employed

All multivariate analysis and calculation of biodiversity indices were done using the PRIMER (Plymouth Routine in Marine Ecological Research) for Windows computer Program (Carr, 1996). Fourth-root transformation of data to preserve information concerning relative abundance and minimize differences in scale among variables was carried out (Clarke, 1993). Samples were standardized by dividing each transect by the number of quadrat forming it.

A further analysis was done by Multi-Dimensional Scaling Ordination which was used to construct a configuration for comparison with all sites and assemblages. The similarity matrix shows the distances between pairs of samples in the result plot, so that dissimilarities are easily visible. A Bray-Curtis similarity plot is was used to determine the overall similarity between stations with respect to all species present and was graphically shown by use of dendrogram. The percentage cover of macroalgae was quantified using taxonomic guides and manuals (Edmunds 1978; John et al 2003).

Principal component analysis (PCA) is a statistical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called principal components.

SIMPER (Similarity Percentage) is a simple method for assessing which taxa are primarily responsible for an observed difference between groups of samples (Clarke 1993).

Vertical zonation classification scheme types

An early attempt to characterize the main species seen on rocky shore was made by Stephenson and Stephenson (1949). The Stephensons identified three main zones common to many shores around the world.

- The upper zone, called the supralittoral fringe, is mainly characterized by lichens, cyanobacteria and small grazing snails, the periwinkles.

- The much broader midlittoral (eulittoral sensu Lewis, 1964) zone exists in the midshore and is dominated by suspension feeding barnacles and mussels.
- Finally, the narrow, low shore infralittoral (sublittoral sensu Lewis, 1964) fringe is dominated by the red algae and kelps, species that usually extend into the permanently immersed sublittoral zone.

Macroalgal vertical zonation was analyzed using Principal Component Analysis and SIMPER (This tool identifies the species primarily providing the discrimination between two observed sample clusters). In assessing the vertical zonation pattern of macroalgae at the sites, a number of methods were adopted traditionally; the rocky intertidal zone was divided into 3 zones representing two extreme ends of the intertidal continuum with the third sandwiched between them. A 4-zone delineation approach was adopted in addition to the traditional 3-zone method. This approach was considered appropriate because the intermediate zone (mid-tidal/mid-littoral) often comprises of indicative species from the two ends of the continuum.

Both Stephenson's and Lewis schemes are based upon the position of key communities along a vertical gradient of the shore. Tidal heights are ignored thus, allowing ecologists to perform fieldwork simply and effectively.

The use of multivariate analyses to establish zonation removes bias and has the potential to reveal smaller scale but distinct differences in zonation By employing the multivariate tool, it would be possible to establish the zonation pattern that best describes the rocky shores its applicability to the entire rocky intertidal of Ghana.

Three approaches were adopted in this study, namely:

1. The Continuous Block Assessment
2. Stephensons Classical Universal Three (3) Zones Assessment
3. Four (4) zones assessment (this study)

Continuous Block Assessment

Using a serial continuous method of sampling along the transect. We ran a Bray Curtis cluster analysis on all quadrats with respect to distance along the transect and position within the intertidal environment.

Stephensons Universal 3 Zones Assessment

Quadrats were grouped into 3 equal zones along the transect namely with the number of quadrats ranging from 30-40 quadrats.

- Upper intertidal (supralittoral/supratidal),
- Mid-intertidal (midlittoral/eulittoral) and
- Lower intertidal (infralittoral/sublittoral)

Four (4) Zones Assessment

Quadrats were grouped in 4 equal zones along the transect as below:

- 1m-10 m: Supralittoral
- 1m-20 m: upper midlittoral
- 21m-30 m: lower midlittoral
- 31-40 m: infralittoral

5 Zone Assessments

Quadrats are grouped in 5 zones along the transect, that is

- 1m-8 m
- 9-16 m
- 17-24 m
- 25m-32 m
- 32m-40 m

CHAPTER FOUR

RESULTS

The results after analyzing the diversity of sampled macroalgae at Prampram and Takoradi are shown below:

UNIVARIATE

4.1 Species Richness and Diversity

DIVERSITY

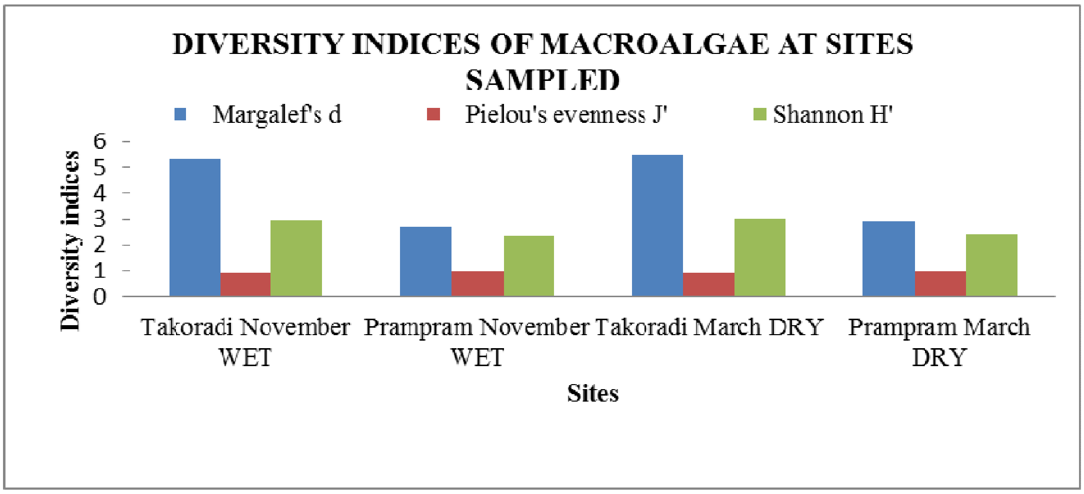


Figure 1: Diversity indices of all macroalgae between sites for dry and wet seasons.

The diversity plot shows that Shannon H diversity and Margalef species richness for macroalgae sampled at Takoradi was relatively higher than those sampled at Prampram.

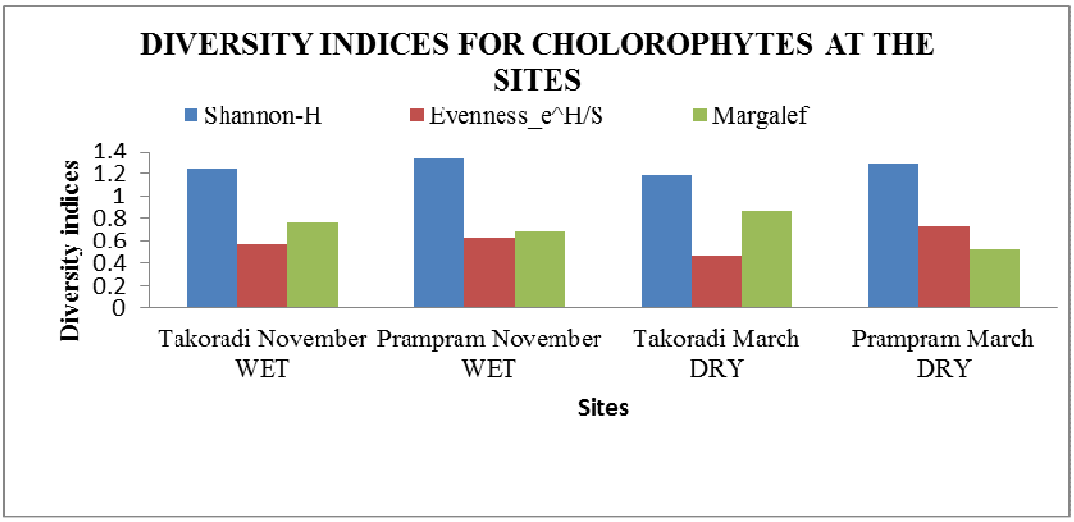


Figure 2: Diversity indices for sampled Chlorophytes between sites for dry and wet seasons at the sites.

Chlorophytes Shannon-wiener (H) diversity at Prampram was relatively higher than that of Takoradi; Pielou's evenness was relatively lower at Takoradi though species richness was relatively higher than that of Prampram.

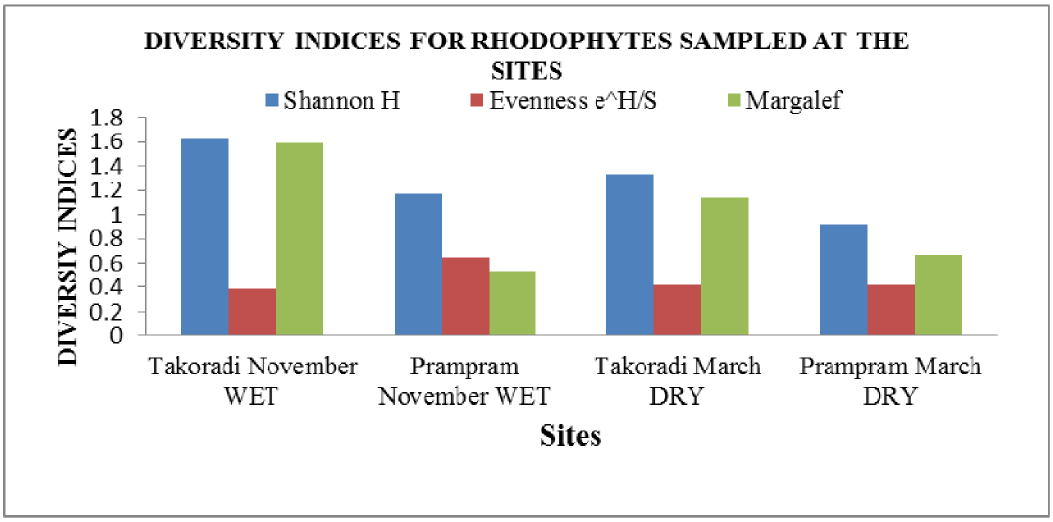


Figure 2: Diversity indices Rhodophytes between sites for dry and wet seasons

Diversity indices for Rhodophytes sampled showed that Shannon-wiener (H) diversity was relatively high at Takoradi compared to Prampram; the same is seen for species richness. Pielou's evenness was relatively the same for all sites.

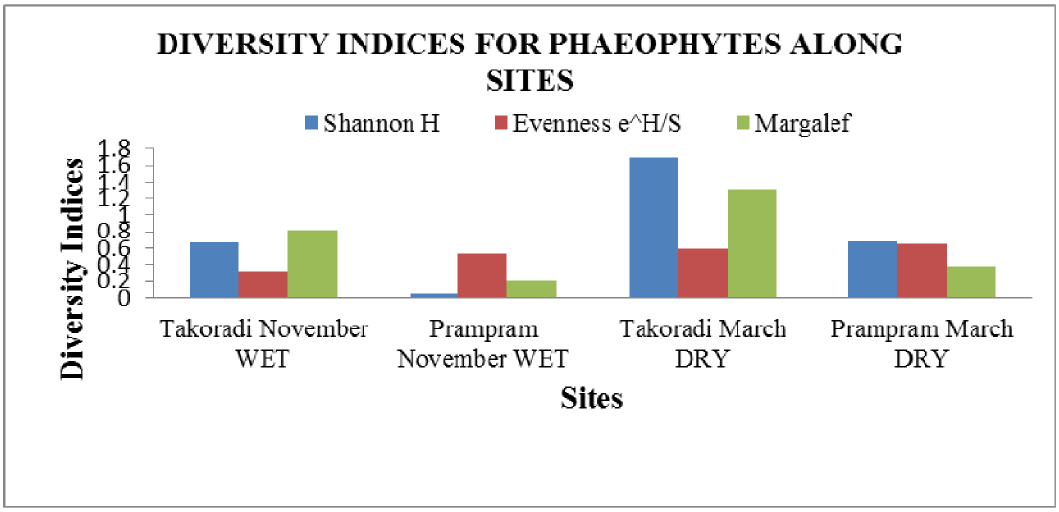


Figure 3: Diversity indices Phaeophytes between sites for dry and wet seasons

Shannon-wiener (H) diversity for Phaeophytes was a similar as the Rhodophytes where diversity and species richness were relatively higher at Takoradi than at Prampram but Pielou's evenness was slightly higher at Takoradi than at Prampram.

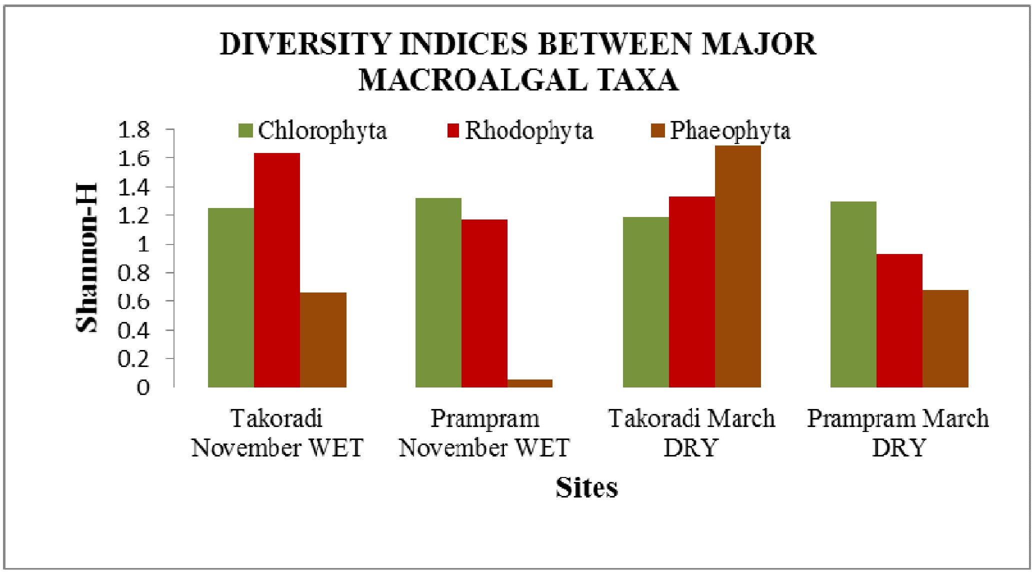


Figure 4: Diversity between major macroalgal taxa for the wet and dry seasons.

There were different levels of diversity of major macroalgal group taxa sampled for sites and for times sampled. Chlorophytes and Rhodophytes were highly diverse at the two sites. But Phaeophytes recorded a high at the second time of sampling for both sites. (T=Takoradi, P=Prampram).

4.2 Species Abundance

Species abundance of sampled macroalgae at sites in the eastern and western parts of Ghana's coasts in the wet and dry seasons.

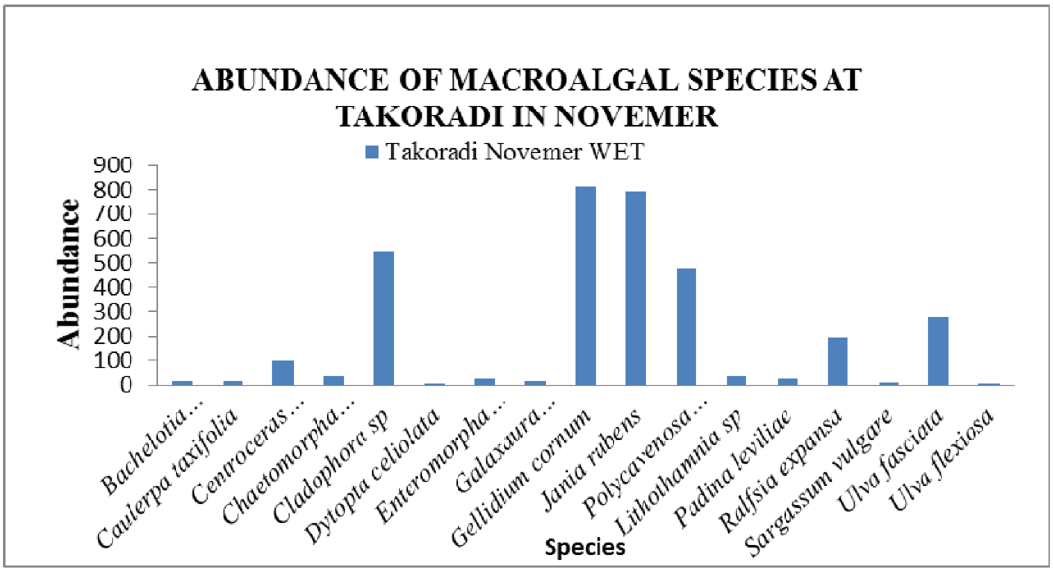


Figure 5: Relative abundance of macroalgal species sampled at Takoradi.

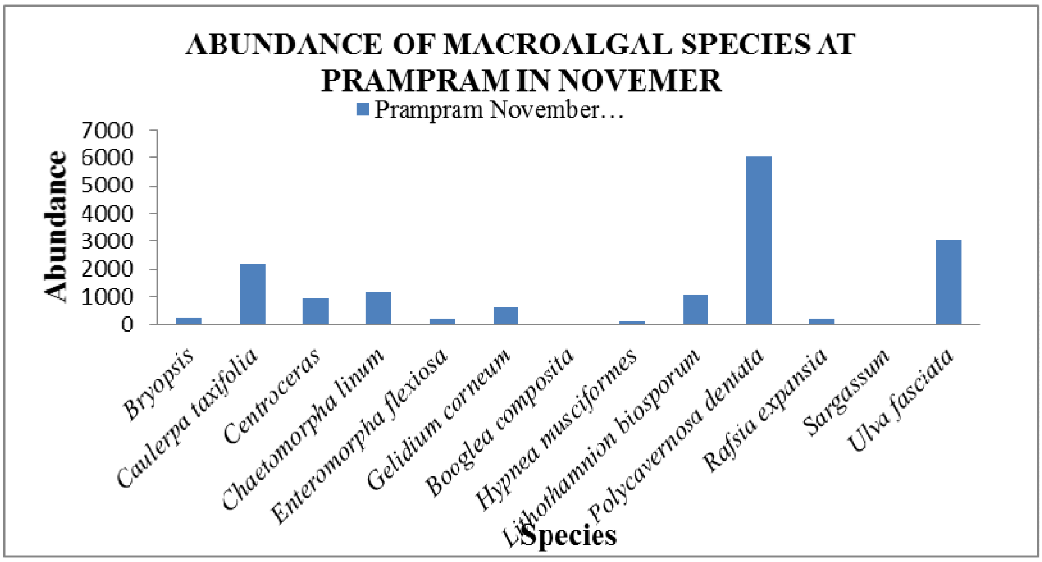


Figure 6: Relative abundance of macroalgal species sampled at Prampram

Gellidium corneum is the most abundant at Takoradi (814) followed by *Jania rubens* (791). *Polycavenosa dentata/rangiferina* (6012) is the most abundant at Prampram in the wet season

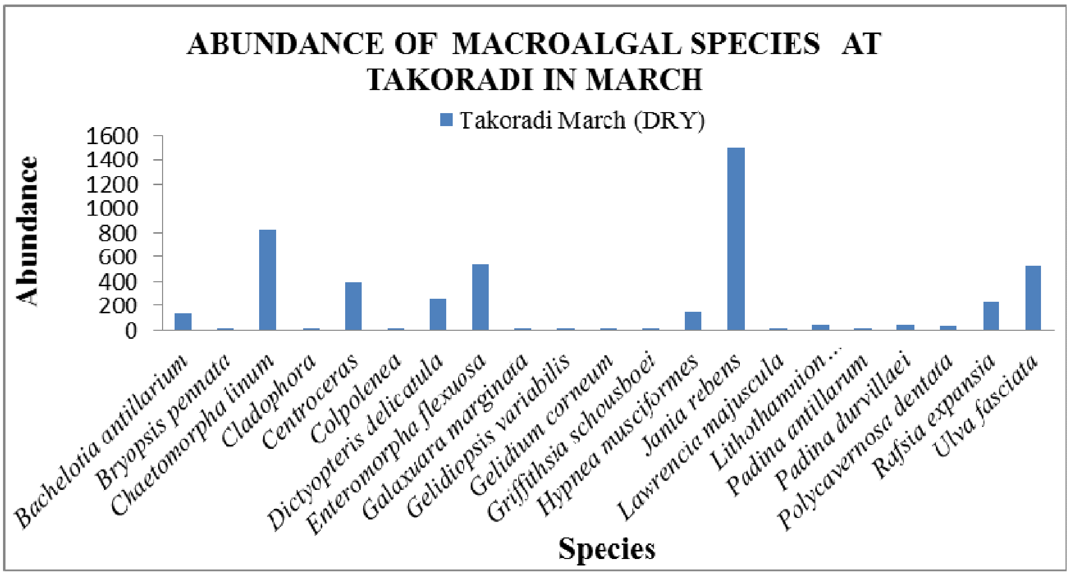


Figure 7: Relative abundance of macroalgal species sampled at Takoradi

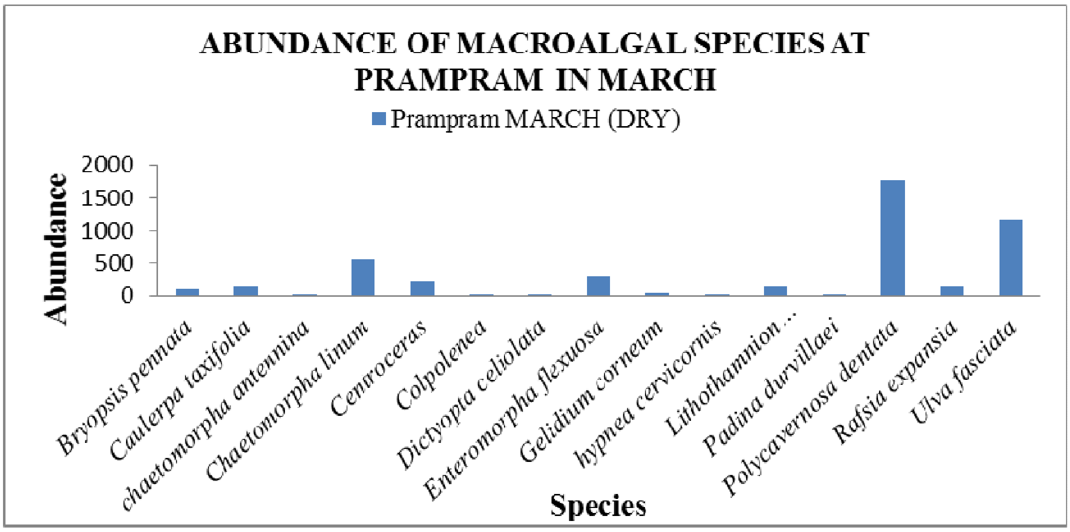


Figure 8: Abundance of macro algal species sampled at Prampram.

Abundance chart shows: *Jania rubens* was relatively the most abundant species at Takoradi whilst *Polycavenosa rangiferina* (Gurgel & Fredericq, 2004) was the most abundant at

Prampram for the dry season. Gelidium corneum was the least abundant Species at Prampram ; Padina durvilliae was the least abundant at Takoradi.

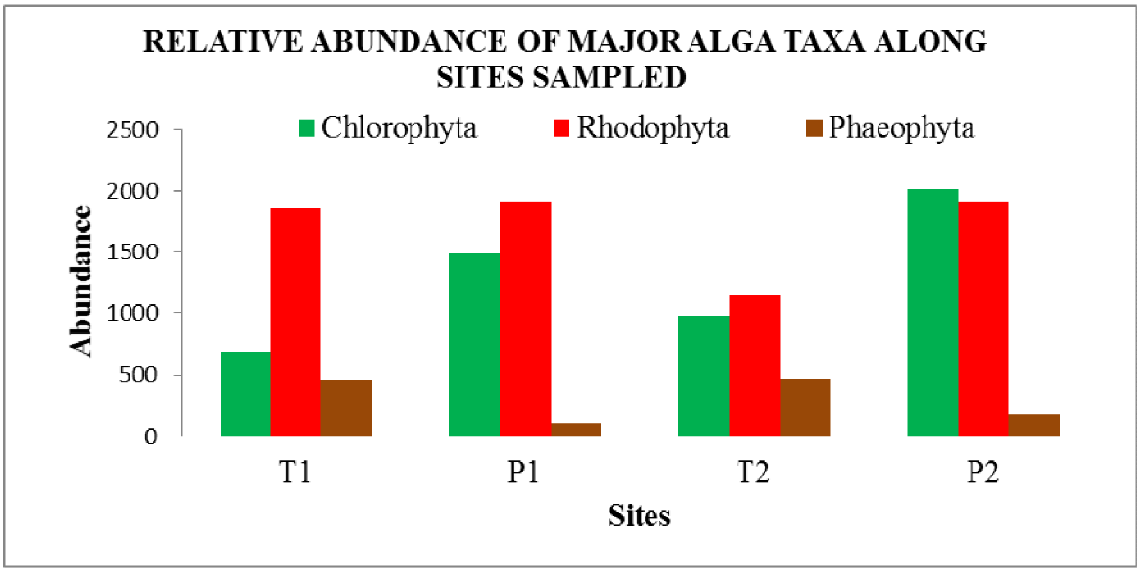


Figure 9: Diversity between major macroalgal taxa for the wet and dry seasons.
(T=Takoradi, P=Prampram)(1=Wet 2=Dry).

Relative abundance chart depicts that Chlorophytes and Rhodophytes were more abundant in Prampram than Takoradi but the opposite trend was observed for Phaeophyta where they were the least abundant.

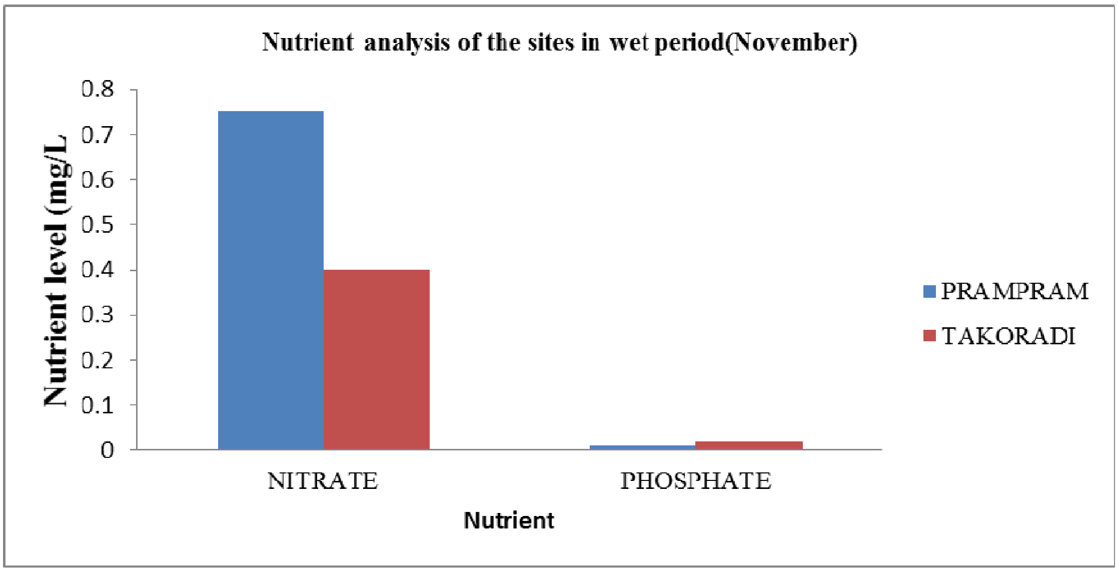


Figure 10: Nutrient analysis of the sites in wet period.

Nutrient levels for sites showed that in wet season nutrient levels significantly were higher in Prampram (Nitrate 0.75mg/L and Phosphate 0.01 mg/L) than in Takoradi (Nitrate 0.4 mg and Phosphate 0.02 mg).

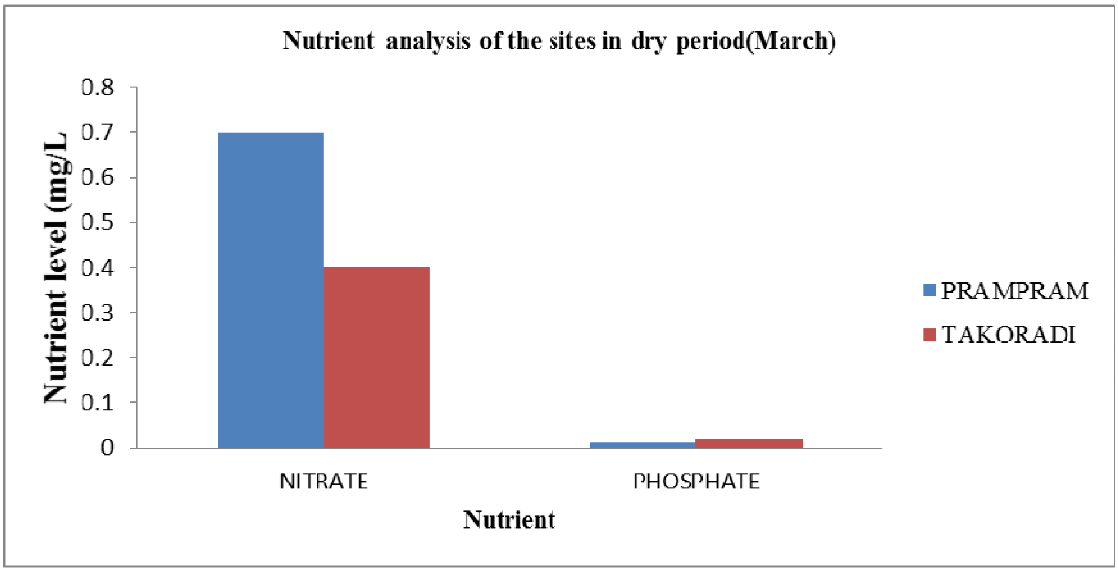


Figure 11: Nutrient analysis of the sites in dry period.

Nutrient levels for sites indicated that in dry season nutrient levels were significantly higher in Prampram (Nitrate 0.7mg/L and Phosphate 0.01 mg/L) than in Takoradi (Nitrate 0.4 mg and Phosphate 0.02 mg)

Multivariate:

4.3 Relative Abundance

Relative Dominance Curve of Samples Taken From Sites

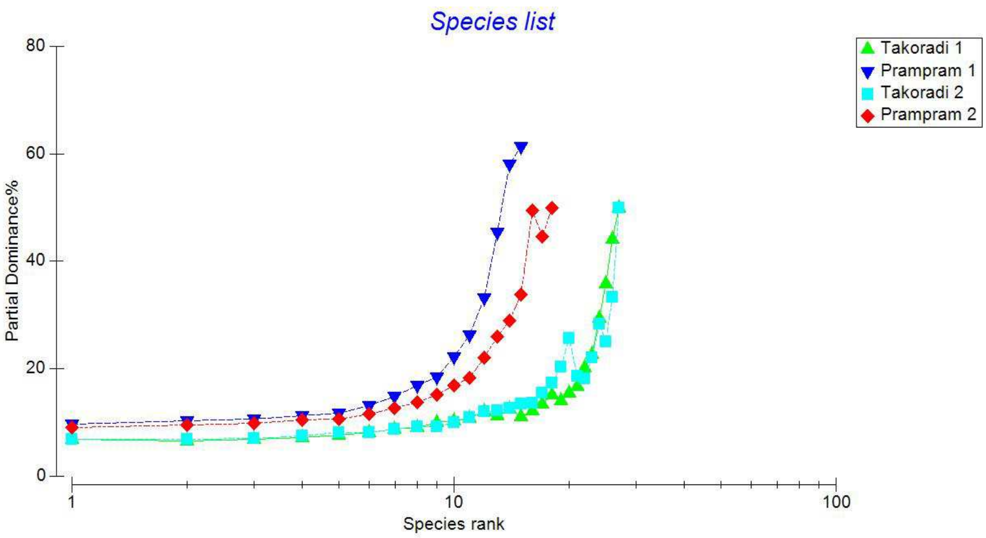


Figure 12: Relative dominance curve plot of samples taken from sites

4.4 Cumulative abundance

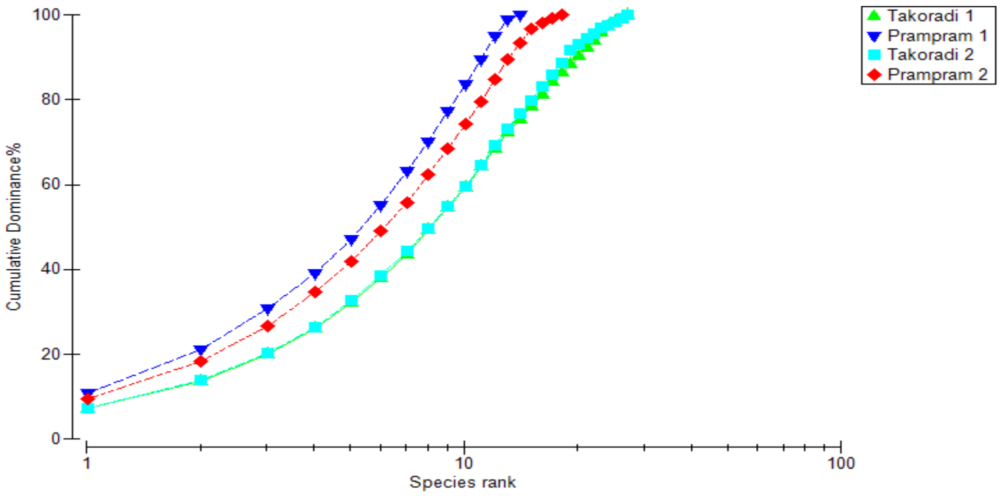


Figure 13: Cumulative dominance curve plot of samples from sites.

The relative and cumulative dominance curves depicts that few species in Takoradi gain dominance unlike Prampram which may be due to stress or biological factors such as predation which is evident in Takoradi, large number of sea urchin holes and presence of underdeveloped Chaetomorpha linum in Takoradi.

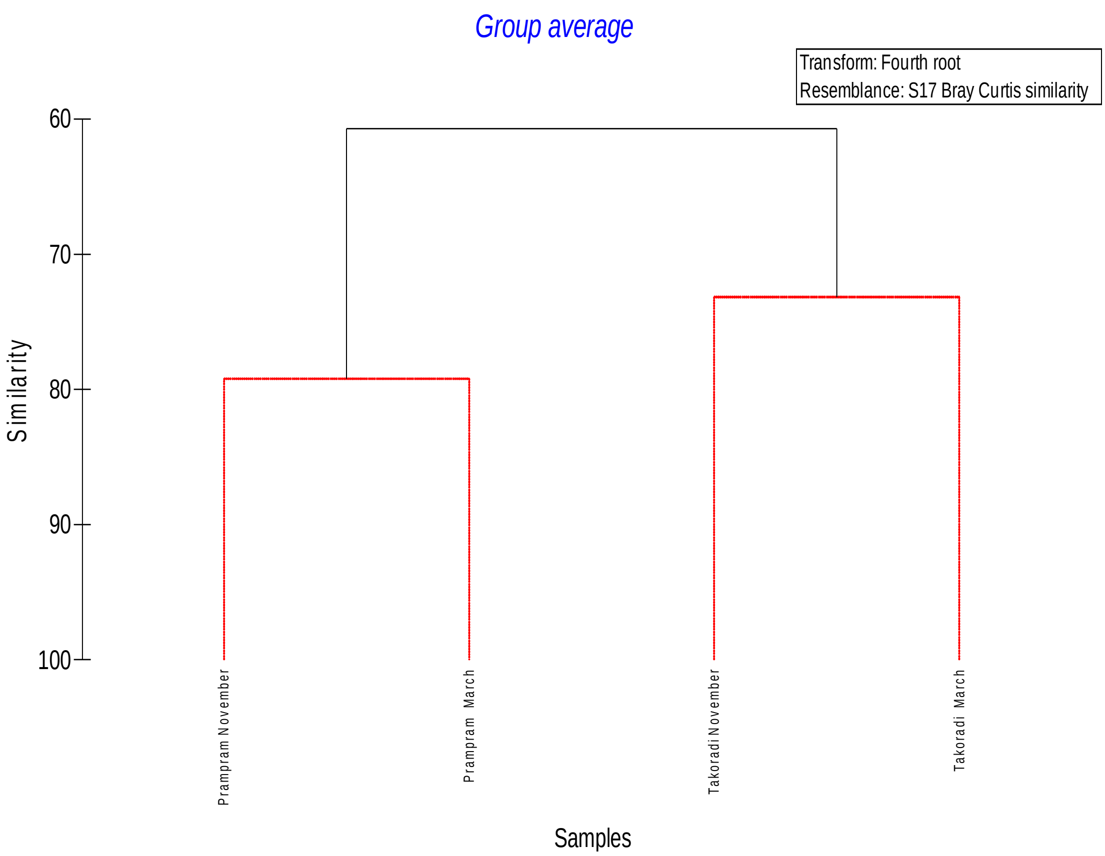


Figure 14: Bray Curtis similarity cluster representation of samples taken from the west (Takoradi) and east (Prampram) sites

This diagram showed that samples from the sites were identical that is samples taken from a site were similar in species richness, diversity and evenness. Samples from the same site were not that different.

WESTERN COAST (TAKORADI) VERTICAL ZONATION ASSESSMENT

The methods used in accessing the vertical zonation patterns at the sites is as follows

Continuous Block Assessment

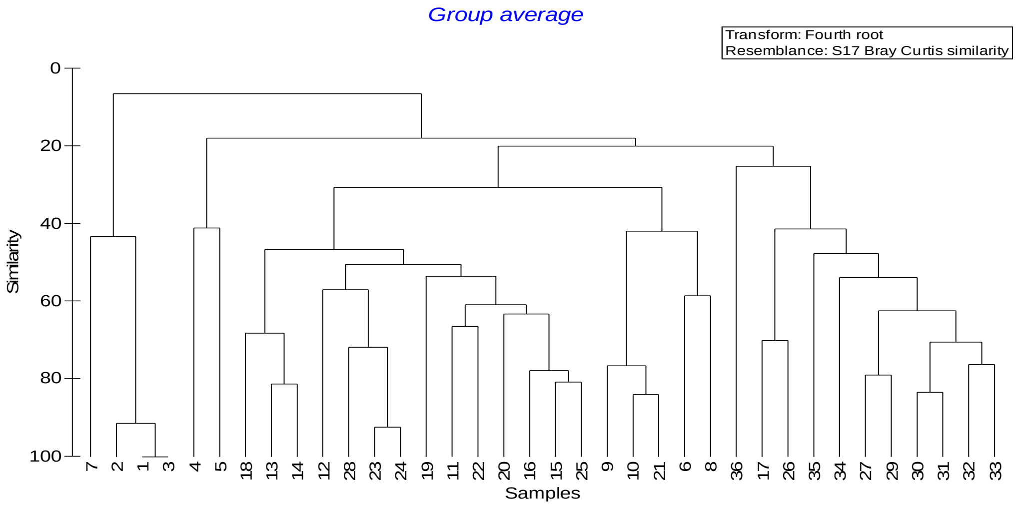


Figure 15: Bray Curtis Dendogram plot of continuous block assessment of macroalgae sampled at Takoradi.

For the continuous block assessment quadrat distances cluster in a unique fashion but for example 8-9 m cluster in a peculiar way, further investigation reveals the presence of *Ralfsia expansa* occurring here because it was a microhabitat, normally it occurs in the 11 m-20 m zone. This area was slightly depressed ranging between 0 m-5 m, with salinity at 35 ppt.

Three Zone Block Assessment

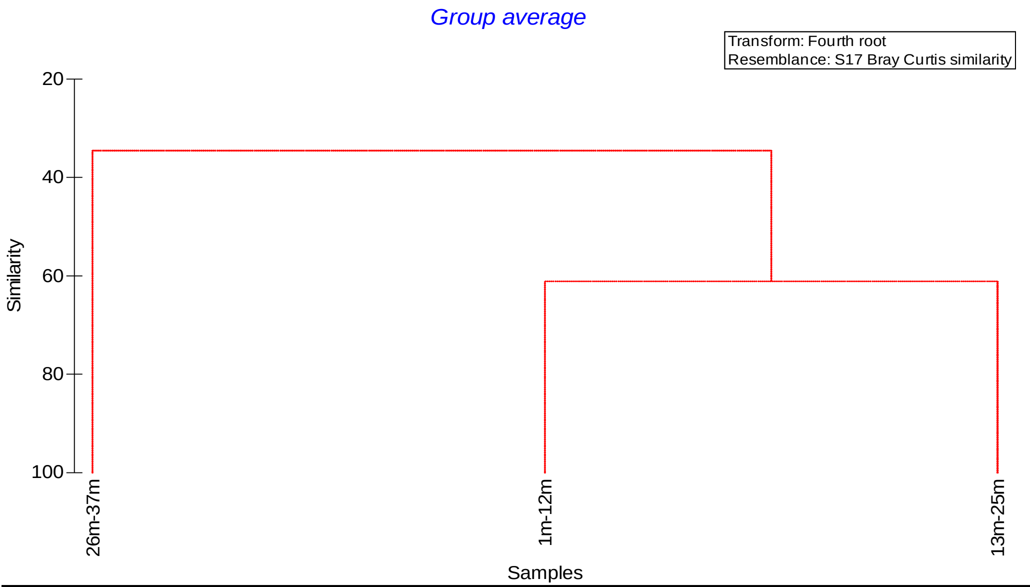


Figure 16: Bray Curtis Dendogram plot Three Zone Block Assessment of macroalgae sampled at the West (Takoradi).

Four (4) Zone Block Assessment.

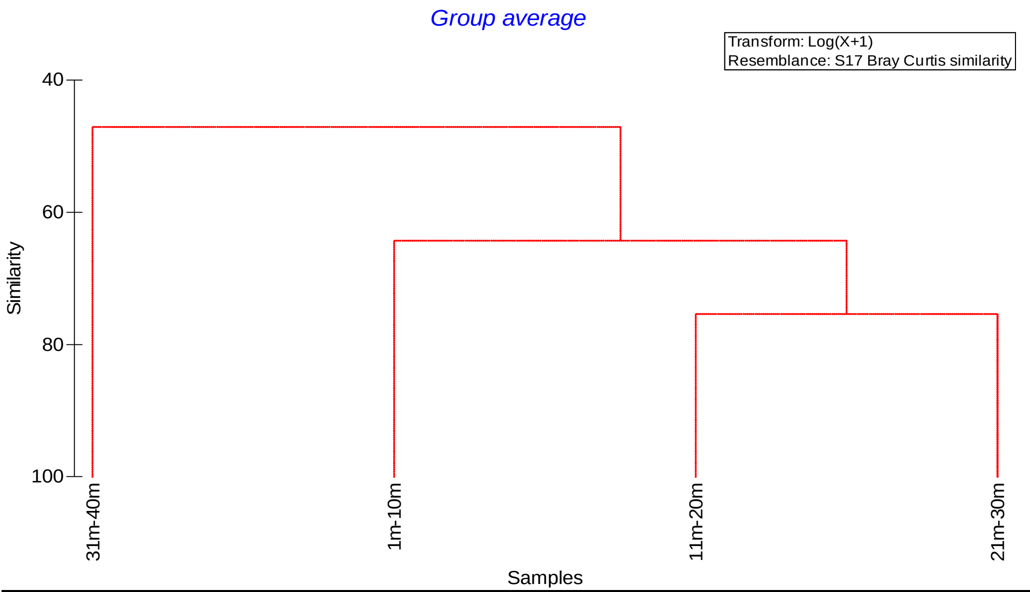


Figure 17: Bray Curtis Dendogram plot for 4 Zone Block Assessment of macroalgae sampled in the West at Takoradi.

Five (5) Zone Block Assessment.

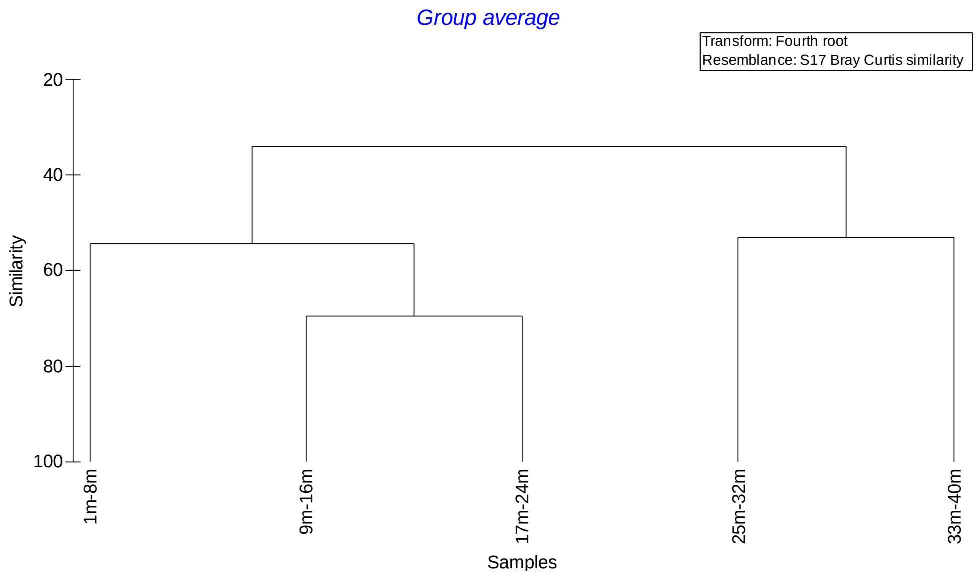


Figure 18: Bray Curtis Dendogram plots for 5 Zone Block Assessment of macroalgae sampled at Takoradi.

From this dendogram it is observed that there is occurrence sub-zonation or micro-zonation in the sampled macroalgae across the shore at Takoradi

PCA: Principal Component Analysis

Principal component analysis result scores used in assessing vertical zonation and principal species characterizing such zonation patterns

Table 1: PCA Eigen values of sampled Macroalgae at Takoradi in November (Wet)

PC	Eigenvalues	%Variation	Cum.%Variation
1	6.01	59.2	59.2
2	2.93	28.8	88
3	1.22	12	100
4	6.00E-04	0	100

Table 2: PCA Eigen values of sampled Macroalgae at Takoradi in March (Dry)

PC	Eigenvalues	%Variation	Cum.%Variation
1	5.84	62	62
2	2.89	30.6	92.6
3	0.698	7.4	100
4	0	0	100

Table 3: PCA Eigenvectors of sampled zones at Takoradi in November (Wet)

Zones	PC1	PC2	PC3	PC4
1m-10m	-0.128	0.894	0.429	0.001
11m-20m	0.142	0.445	-0.884	-0.017
21m-30m	0.684	0.032	0.139	-0.715
31m-40m	0.704	0.042	0.121	0.699

Table 4: PCA Eigenvectors of sampled zones at Takoradi in March (Dry)

Zones	PC1	PC2	PC3	PC4
1m-10m	0.729	-0.128	0.673	0
11m-20m	0.684	0.152	-0.713	0
21m-30m	-0.011	0.98	0.198	0
31m-40m	0	0	0	1

SIMPER: Similarity Percentages - species contributions at Takoradi in November.

One-Way Analysis

Similarity percentages of major macroalgal groups and the zones they characterize.

Table 5 : Group Phaeophyta Average similarity 38.94

Zones	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
11m-20m	1.84	38.94	3.23	100	100

Table 6 : *Group Rhodophyta* Average similarity: 44.85

Zones	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
11m-20m	2.53	13.65	0.9	30.43	30.43
31m-40m	2.33	13.24	0.91	29.53	59.95
21m-30m	2.28	13.03	0.91	29.05	89
1m-10m	1.35	4.93	0.41	11	100

Table 7 : *Group Chlorophyta* Average similarity: 48.98

Zones	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
11m-20m	2.99	22.18	0.9	45.28	45.28
21m-30m	2.64	13.4	0.91	27.36	72.64
31m-40m	2.68	13.4	0.91	27.36	100

SIMPER: Similarity Percentages - species contributions at Takoradi in March.

One-Way Analysis.

Similarity percentages of major macroalgal groups and the zones they characterize.

Table 8: *Group Phaeophyta* Average similarity: 34.44

Zones	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
21m-30m	1.62	29.02	0.77	84.27	84.27
11m-20m	1.12	3.26	0.26	9.47	93.73

Table 9: *Group Chlorophyta* Average similarity: 46.39

Zones	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
11m-20m	2.69	18.88	1.08	40.7	40.7
21m-30m	1.49	16.27	0.89	35.06	75.76
1m-10m	2.49	11.25	0.61	24.24	100

Table 10 : *Group Rhodophyta* Average similarity: 44.77

Zones	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
21m-30m	2.19	39.02	1.33	87.16	87.16
11m-20m	1.15	4.17	0.38	9.31	96.48

PCA plots showing the zonation patterns and the principal species characterizing such patterns.

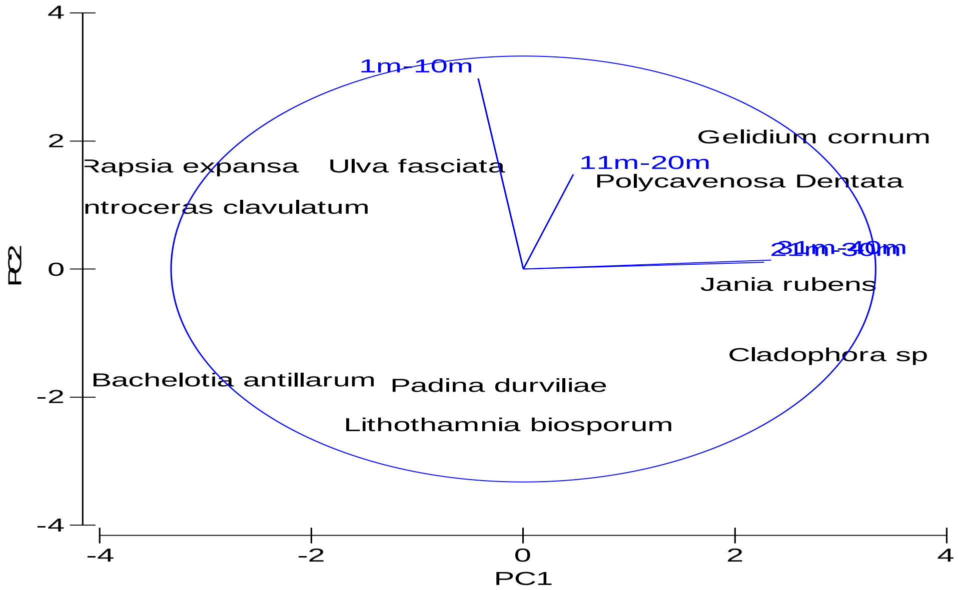


Figure 19: Principal component graph illustrating the principal species and their zones at Takoradi in November. (WET)

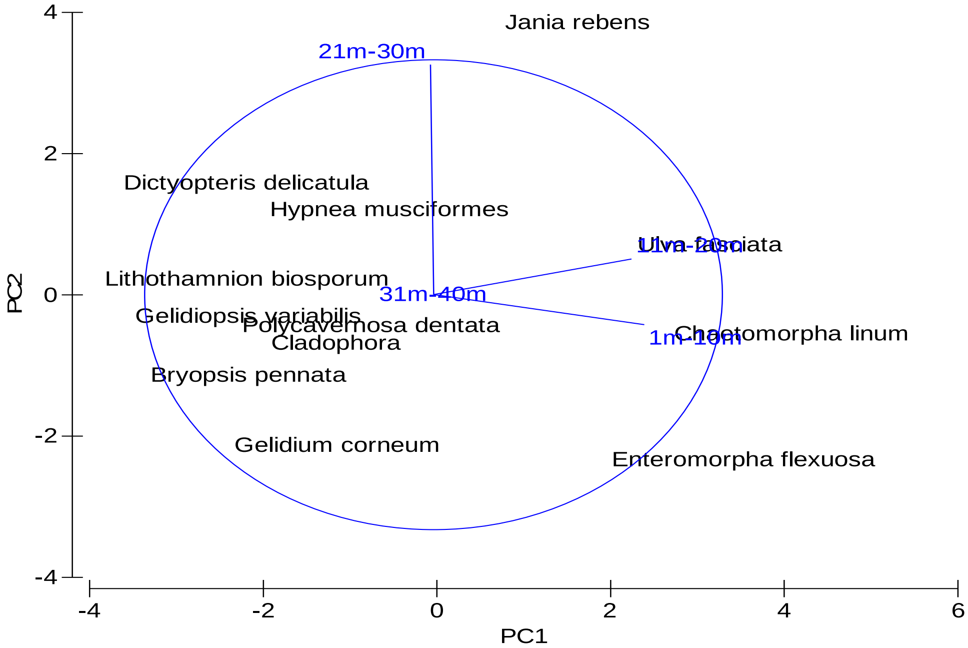


Figure 20 : Principal component graph illustrating the principal species and their zones at Takoradi in March (Dry).

PRAMPRAM VERTICAL ZONATION ASSESSMENT

Continuous Block Assessment

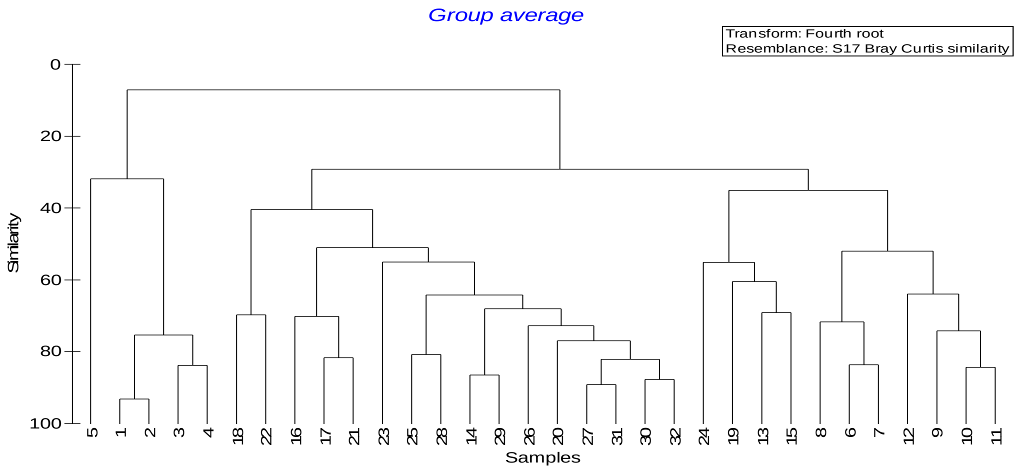


Figure 21: Bray Curtis Dendogram plot of continuous block assessment of macroalgae sampled at Prampram

Three Zone Block Assessment

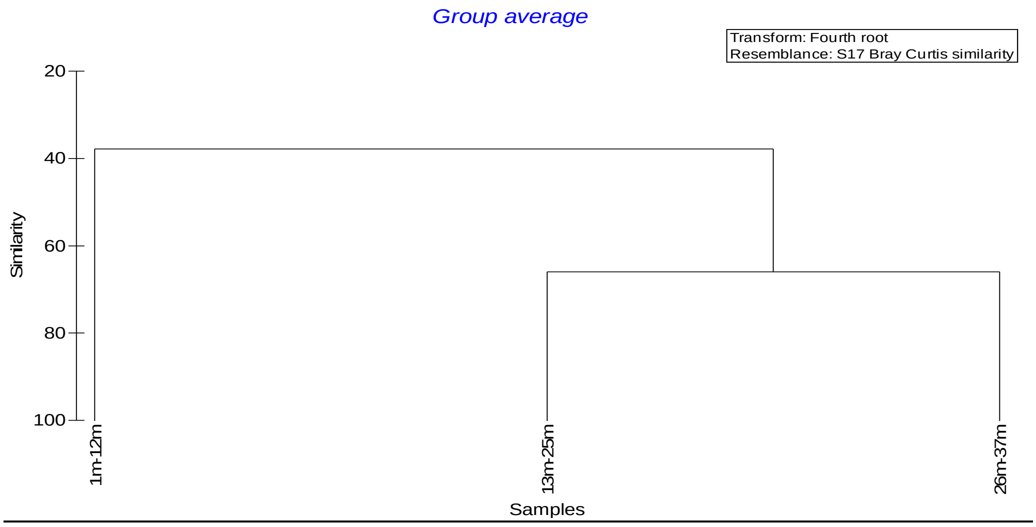


Figure 22: Bray Curtis Dendogram plot Three Zone Block Assessment of macroalgae sampled at Prampram.

4 Zone Block Assessments.

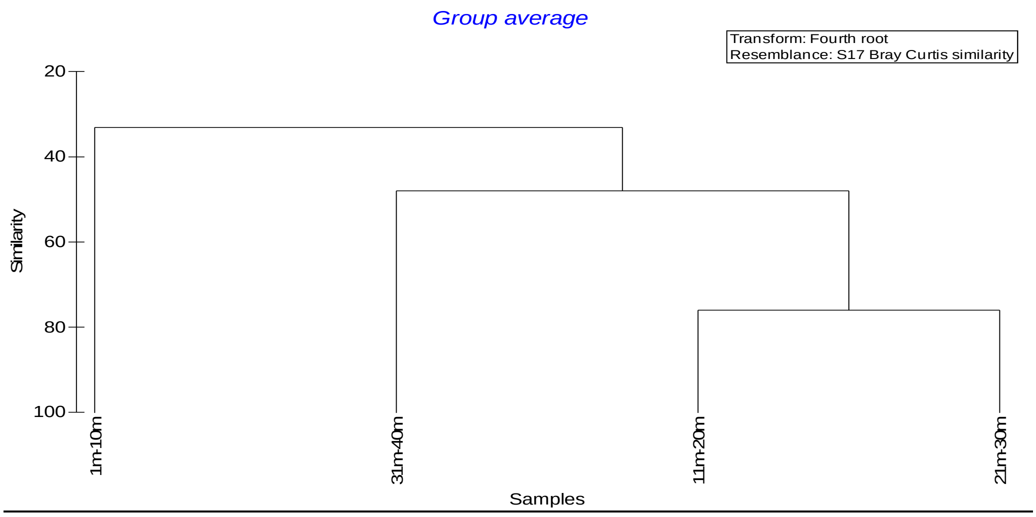


Figure 23 : Bray Curtis Dendogram plot 4 Zone Block Assessment of macroalgae sampled at Prampram.

Five (5) Zone Block Assessment.

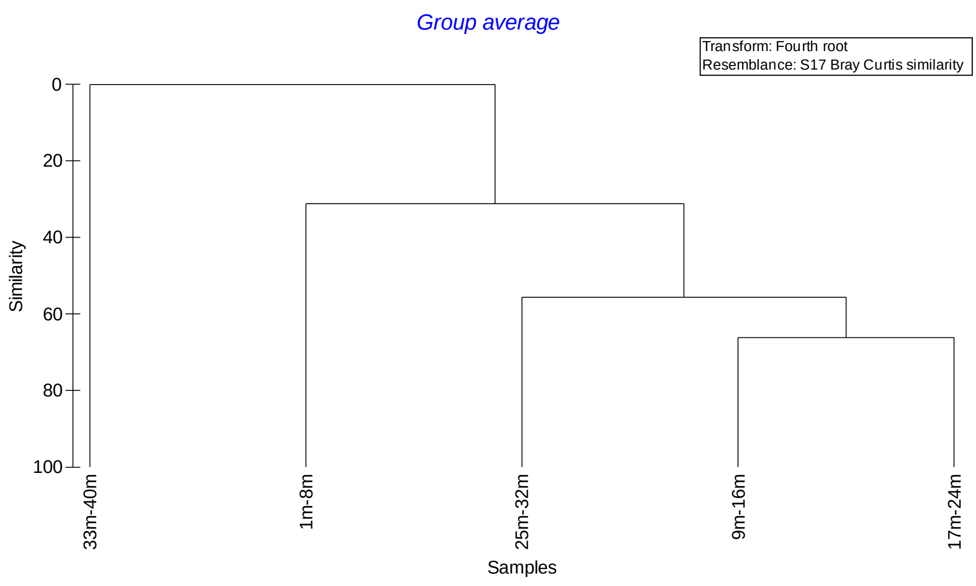


Figure 24 : Bray Curtis Dendogram plots for 5 Zone Block Assessment of macroalgae sampled at Prampram.

From this dendogram it is observed that there is occurrence sub-zonation or micro-zonation in the sampled macroalgae across the shore at Takoradi

PCA: Principal Component Analysis

Table 11 : PCA Eigen values of sampled Macroalgae at Prampram in November (Wet)

PC	Eigenvalues	%Variation	Cum.%Variation
1	6.84	62.9	62.9
2	2.8	25.8	88.7
3	1.07	9.8	98.6
4	0.157	1.4	100

Table 12 : PCA Eigen values of sampled Macroalgae at Prampram in March (Dry)

PC	Eigenvalues	%Variation	Cum.%Variation
1	5.44	43.4	43.4
2	4.53	36.2	79.6
3	2.06	16.5	96.1
4	0.494	3.9	100

Table 13 : PCA Eigen vectors of sampled zones at Prampram in November (Wet)

Zones	PC1	PC2	PC3	PC4
1m-10m	0.343	0.805	-0.456	0.162
11m-20m	0.48	0.243	0.834	0.123
21m-30m	0.807	-0.494	-0.305	-0.113
31m-40m	-0.025	-0.222	-0.065	0.973

Table 14 : PCA Eigenvectors of sampled zones at Prampram in March (Dry)

Zones	PC1	PC2	PC3	PC4
1m-10m	0.343	0.805	-0.456	0.162
11m-20m	0.48	0.243	0.834	0.123
21m-30m	0.807	-0.494	-0.305	-0.113
31m-40m	-0.025	-0.222	-0.065	0.973

SIMPER: Similarity Percentages - species contributions at Prampram in November. (Wet)

One-Way Analysis

Simper values of major taxa that characterize zonation in Prampram

Table 15 : Group Phaeophyta Average similarity: 33.13

Zones	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
21m-30m	1.54	33.13	#######	100	100

Table 16: Group Chlorophyta Average similarity: 30.66

Zones	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
1m-10m	2.13	19.43	0.73	63.38	63.38
11m-20m	1.7	5.75	0.47	18.76	82.14
21m-30m	1.43	5.48	0.48	17.86	100

Table 17 : Group Rhodophyta Average similarity: 46.89

Zones	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
11m-20m	2.66	19.51	1.09	41.61	41.61
21m-30m	2.75	16.45	1.11	35.08	76.69
1m-10m	1.73	9	0.55	19.19	95.89

SIMPER: Similarity Percentages - species contributions at Prampram in March (Dry).

Table 18 : Group Chlorophyta Average similarity: 33.96

Zones	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
21m-30m	1.87	12.79	0.74	37.67	37.67
1m-10m	2.3	12.57	0.66	37.01	74.68
11m-20m	1.91	8.6	0.71	25.32	100

Table 19 : *Group Rhodophyta* Average similarity: 29.32

Zones	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
11m-20m	1.89	9.6	0.61	32.73	32.73
21m-30m	2.13	9	0.58	30.7	63.43
1m-10m	1.71	7.51	0.6	25.61	89.04
31m-40m	0.93	3.21	0.32	10.96	100

Table 20: Group Phaeophyta Average similarity: 33.33

Zones	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
21m-30m	0.79	33.33	0.58	100	100

PCA plots showing zonation patterns in Prampram and the principal component species that characterize such zonation.

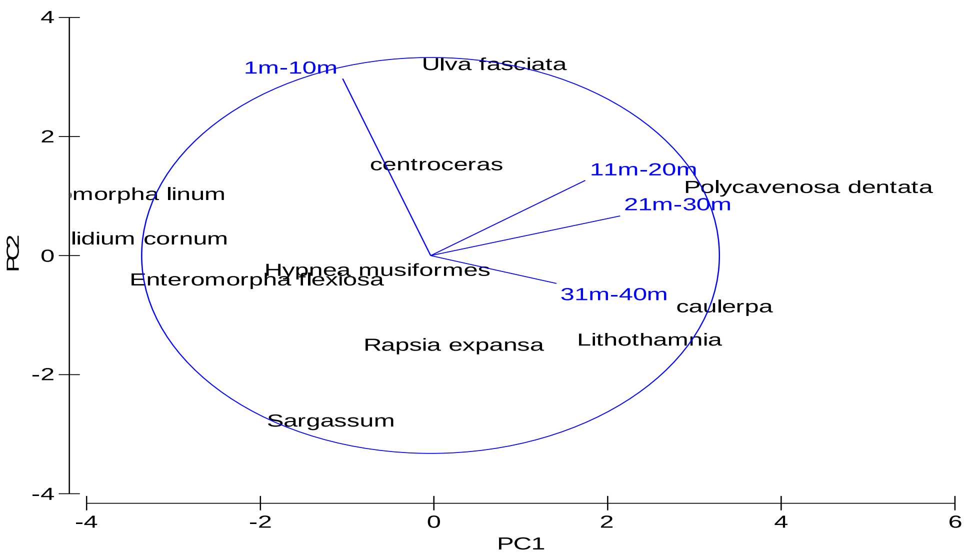


Figure 25: Principal components graph illustrating the principal species and their zones at Prampram in November. (WET)

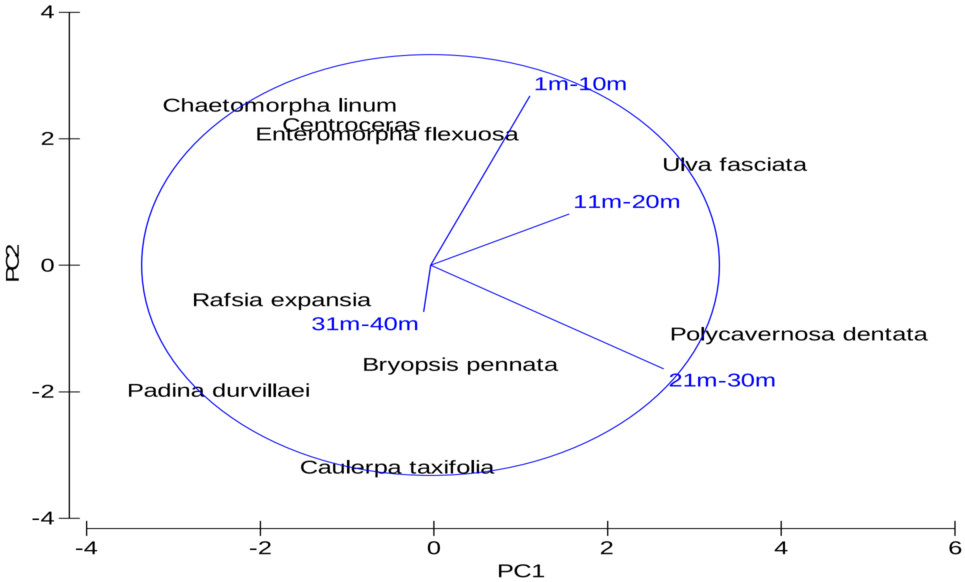
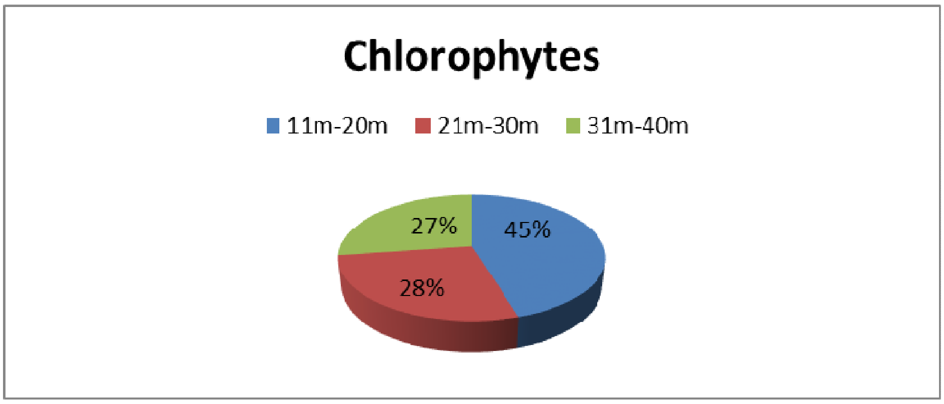
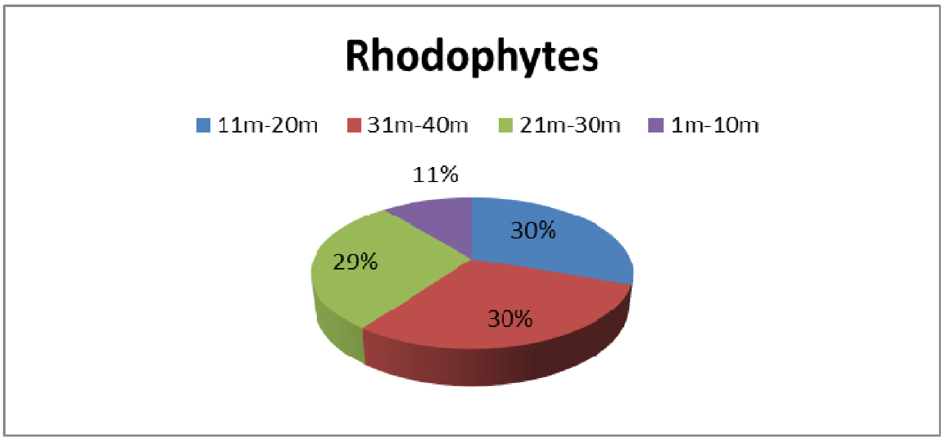


Figure 26 : Principal components graph illustrating the principal species and their zones at Prampram in March. (DRY)





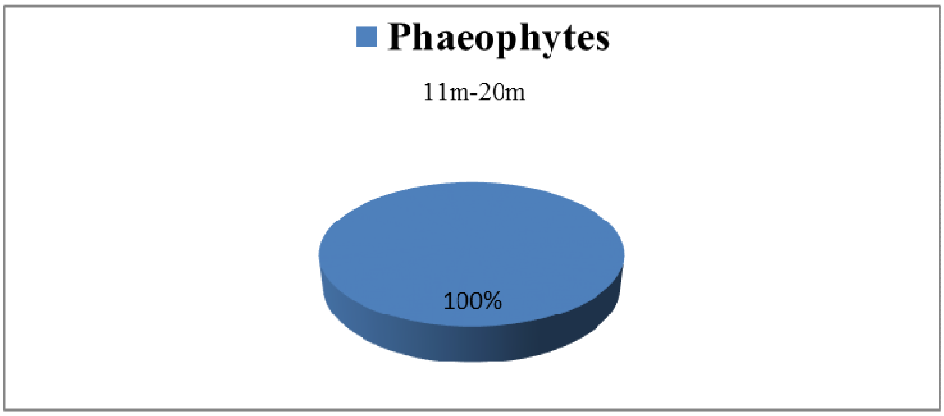


Figure 27: Percentage distribution of major macroalgal types across the zones at Takoradi in November. (Wet)

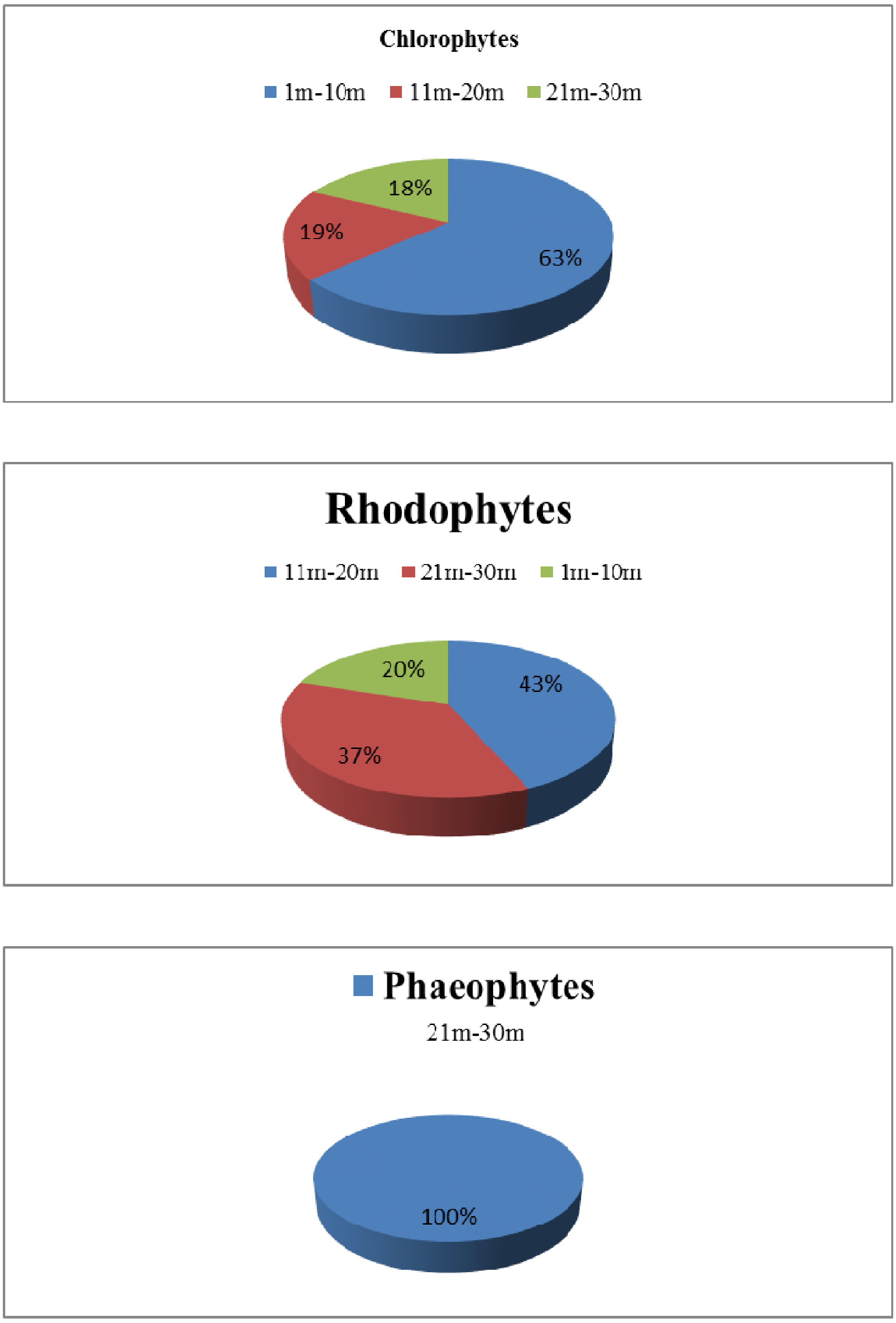


Figure 28: Percentage distribution of major macroalgal types across the zones at Prampram in November. (Wet).

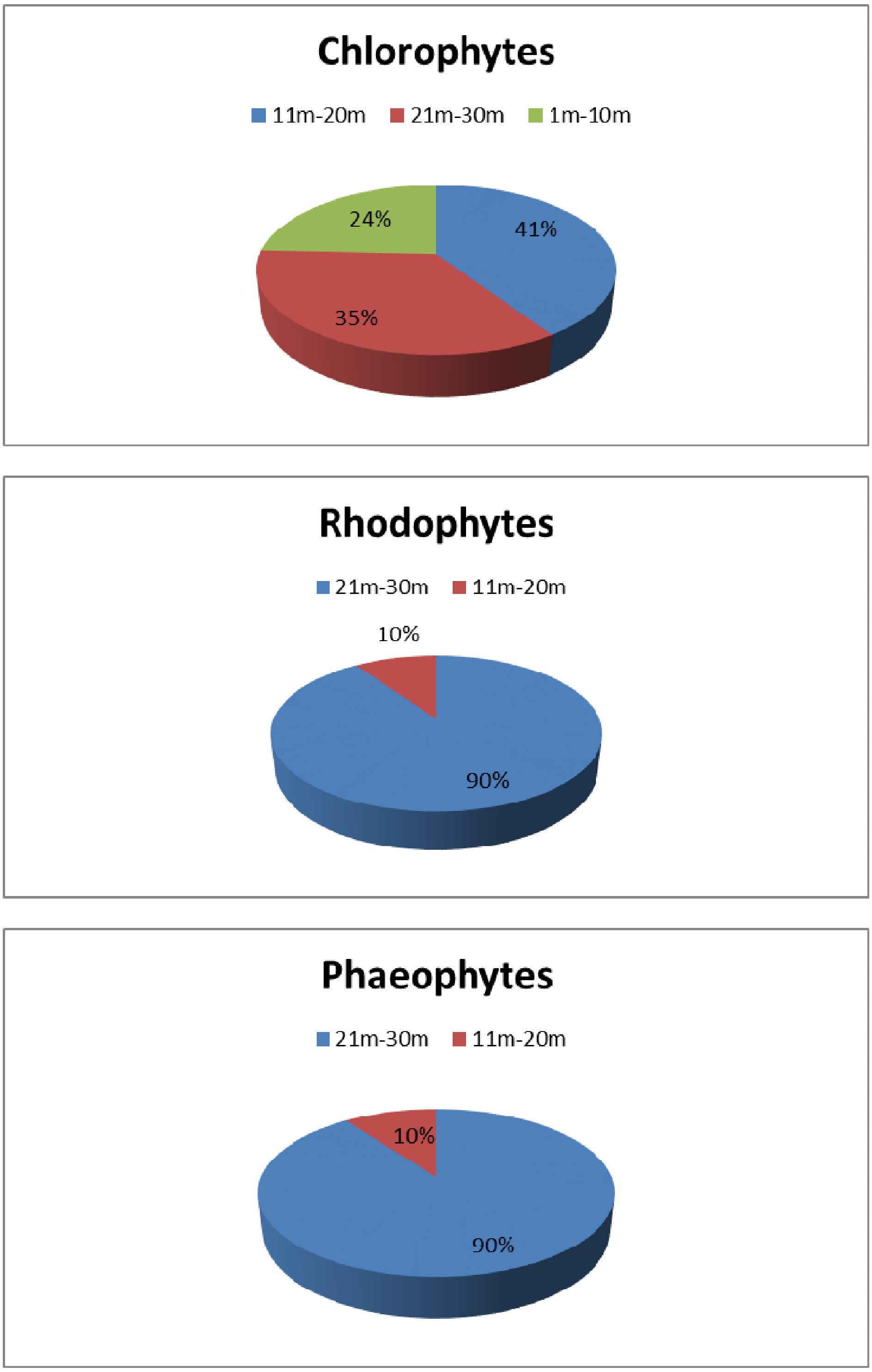


Figure 29: Percentage distribution of major macroalgal types across the zones at Takoradi in March. (Dry).

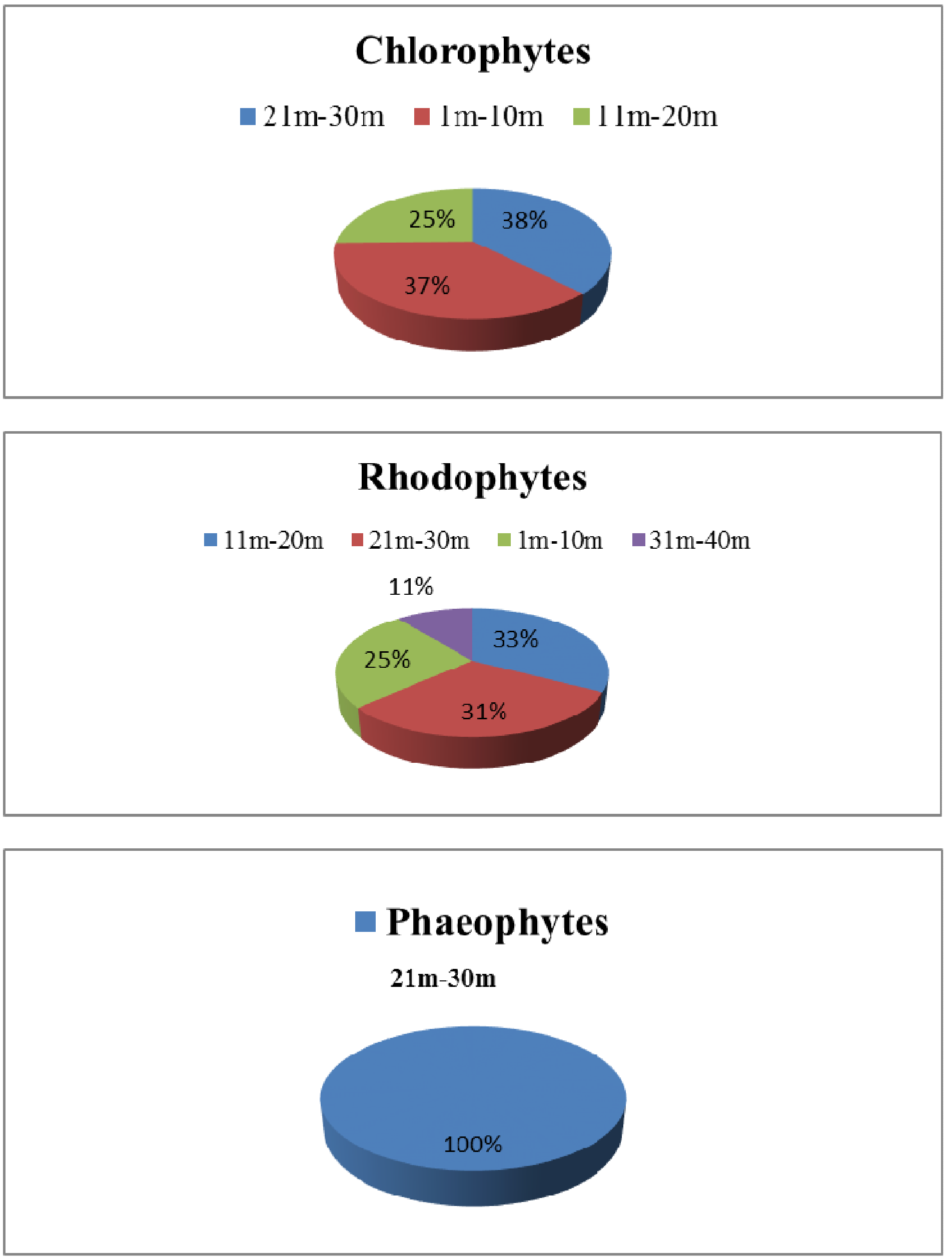


Figure 30: Percentage distribution of major macroalgal types across the zones at Prampram in March. (Dry)

CHAPTER FIVE

DISCUSSION

5.1 Floral Ecology

Far above the high water mark beyond the sandy back shore we encountered some xerophytes species notably *Paspalum varginatum*.Generally both sites have relatively flat rocks, with intermittent tidepools occurring in low depressions on the sites. There was presence of sea urchin (*Echinometra* spp.) As seen from the number of occurrence of sea urchin (*Echinometra* spp.) holes and at the uppermost elevations of the rocks there were no algae but presence of barnacles (*Balanus* spp.) In the habitats occupied by *Balanus* spp it is often associated with sponges and encrusting red seaweeds on shady overhanging rocks and cave entrances and also bryozoans and ascidians in deeper shade (Patel & Crisp, 1960). The rock-boring urchin feeds mostly at night from their burrows, consuming clumps of drift algae, or venturing out of the burrow to feed and then usually returning to the same hole (McPherson 1969, Abbott et al. 1974, Ogden 1976). In Panama, individuals were observed to clear the area around their burrows of all organisms except calcareous algae (Hendler et al. 1995).

In the mid littoral portions of the intertidal shore we have rocks covered with a mixture of beautifully developed *Chaetomorpha linum* on the higher levels and just below *Enteropmorpha flexiuosa*, in some areas we have Bachelotia antilarum. *Chaetomorpha sp* is found capping the rock projections. Tide pools are dominated by *Polycavenosa dentata and Cladophora* species with *Littorina* sp covering the rock overhangs. *Ulva flexiousa* (*Enteromorpha flexiousa*) has a thinner parenchyma and is filamentous compared to *Ulva fasciata* hence *Ulva fasciata* dominates the upper littoral and *Ulva flexiuosa* dominates the lower littoral.

The Rhodophytes and Phaeophytes dominated the lower littoral. It was noted that in the west (Takoradi) *Ulva fasciata* was not very well developed compared to Prampram and this was due also to a greater abundance of sea urchins (*Echinometra* Sp.) in Takoradi. Low abundance this is due to the community inhabitants (people) feeding on the Echinoderms hence their numbers were lower in Prampram.

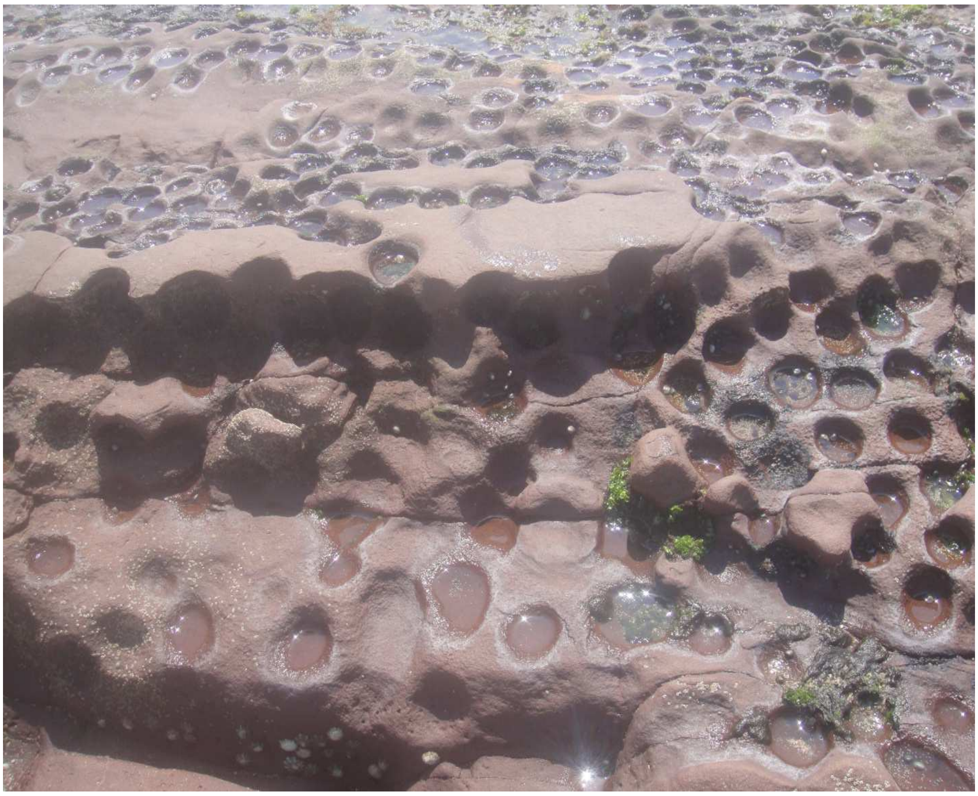


PLATE F: High Abundance of Sea Urchin Holes in Takoradi

The was no significant difference in species diversity between the west and the east as postulated by Lawson (1956) and Evans (1993) though the direction of the Guinea Current was suspected to affect species occurrences. As the two sites are different through hydrological and climatic factors as such difference in species is expected to be prevalent.

There was a higher level of dissolved nitrates in Prampram (0.75mg/l) than in Takoradi (0.40 mg/l). This was perhaps due to high amount of human excreta at Prampram (Figures 16 and 17). This coupled with the low abundance of sea urchins may enhance the growth of Chlorophytes in Prampram. This was evident as *Chaetomorpha linum* and *Enteromorpha flexuosa* were better developed and covered a wider area in Prampram than in Takoradi (Plate F).

From the Bray Curtis dendogram plot (Group average) for the two sites at 80% dis(similarity), samples taken for both wet and dry periods clustered together for their respective sites. Samples for Takoradi clustered at 70% similarity whilst those for Prampram clustered at 80 % similarity (Figure 13).

5.2 Species Composition and Distribution

5.2.1 Floral composition

The floral species encountered represented Chlorophyta, Rhodophyta and Phaeophyta. These species were grouped under 3 phyla, 27 families and 36 species in general. For Takoradi an average of 34 species were encountered at sampling and 28 species for Prampram.

Amongst the species observed, 33 of them were observed by Lawson in (Lawson & John 1987), (John et al (2003) and john et al (2004). They are notably;

Asparagopsis taxiformis (*Trevisan de Saint-Léon, 1840*), *Bachelotia antillarium* (*Gerloff, 1959*), *Bostrychia radicans* (*Montagne, 1842*), *Boodlea composita* (*F.Brand, 1904*), *Bryopsis pennata* (*J.V.Lamouroux, 1809*), *Caulerpa taxifolia* (*C.Agardh, 181*), *Centroceras clavulatum* (*P.L.Crouan & H.M.Crouan, 1878*), *Chaetomorpha antennina* (*Kützing, 1847*), *Chaetomorpha linum (Kützing, 1845). Chnoospora minima (Papenfuss, 1956), Chondracanthus acicularis (Fredericq, 1993), Cladophora sp (Kützing, 1843), Codium guineënse (G.W.Lawson & D.M.John, 1982), Colpomenia sinuosa(Derbès & Solier, 1851), Corrallina sp (Linnaeus 1758), Cryptonemia crenulata (J.Agardh, 1851), Cryptonemia seminervis (J.Agardh, 1846), Enteromorpha flexuosa* (*J.Agardh, 1883*), *Enteromorpha prolifera (J.Agardh, 1883),Ernodersmis verticillata (Børgesen,1912), Galaxaura marginata (J.V.Lamouroux, 1816), Gelidiopsis variabilis (F.Schmitz, 1895), Gelidium corneum (J.V.Lamouroux, 1813), Jania rubens (J.V.Lamouroux, 1816), Hydropuntia rangiferina/Polycanvenosa dentata* (*Gurgel & Fredericq, 2004*), *Hypnea cerviconus/Hypnea spinella (J.Agardh, 1851), Hypnea musiformes (J.V.Lamouroux, 1813), Griffithsia schousboei (Montagne, 1839), Lawrencia majuscula (A.H.S.Lucas, 1935), Lithothamnia sp (Heydrich, 1897), Lobophora variegata (E.C.Oliveira,1977), Padina antillarum (Piccone, 1886), Padina durvillei (Bory Saint-Vincent, 1827), Polycyphonia ferulacea/Neosiphonia ferulacea (J.Agardh, 1863)Ralfsia expansa (J.Agardh, 1848), Sargassum vulgare (Agardh, 1820), Ulva fasciata* /*Ulva lactuca (Linnaeus, 1753)*

Jania rubens (*J.V.Lamouroux, 1816*) accounts for 22% of the macroalgal individuals sampled at Takoradi and *Hydropuntia rangiferina* (Gurgel & Fredericq, 2004) accounting for 32% of macroalgal individuals sampled at Prampram. Generarally *Cladophora* species were mostly abundant in tidal pools. These were mostly at the upper portions of the beach.

Ulva fasciata(Linnaeus, 1753) was commonly found in tide pools in the upper and middle part of the shore where nutrients are high, wave forces are low and herbivory is reduced. *Gelidium corneum* occurred on rocky substrata, often on top of coralline crusts, normally associated with high levels of water movement, extending up to 1.5 m of intertidal elevation and down to 25 m deep, *Ralfsia expansa*, *Hydropuntia rangiferina* (Gurgel & Fredericq, 2004) was generally found in shallow subtidal habitats but at times to 11 m depths (Abbott 1988)., *Centroceras clavulatum* was found on rocks in middle to lower intertidal zones along strongly wave exposed shorelines.

Ulva fasciata was the most abundant Chlorophyte species at both sites with relative abundance values of 275.8 {Takoradi} and 3016.5{Prampram} for wet period, 523.2{Takoradi} and 1170{Prampram} for dry period (Figures 6, 7, 8 and 9 respectively). For Rhodophytes *Jania rubens* was the most abundant (1500 and 791) in Takoradi whilst *Hydropuntia rangiferina* (Gurgel & Fredericq, 2004) was the most abundant Rhodophyte in Prampram with values 6012 and 1780 for wet and dry periods respectively. *Ralfsia expansa (J.Agardh, 1848)* was the most the most abundant Phaeophyte at both sites with 196 and 240{Takoradi}, 150 and 216 {Prampram}.(Figures 6, 7, 8, and 9).

5.2.2 Notable differences in species distribution:

Some notable species were found to express peculiar abundance at one site then occurs in lower degree or otherwise absent in the other. *Hydropuntia rangiferina* /*Polycavenosa dentata* (Gurgel & Fredericq, 2004) occurred notably in the lower shore at Prampram in higher abundances (relative abundance; 1056) within the quadrat data than in Takoradi where it was far less or negligible. *Ulva fasciata* occurred at a higher relative abundance and was well spread across shore whilst its relative abundance was lower in Takoradi and occurred in the midlittoral region. *Bachelotia antillarium* occurred only at Takoradi from the sampling data gathered. *Bryopsis pennata* also occurred at Prampram only, from the sampling data gathered.

Caulerpa Taxifolia and *Enteromorpha flexiuosa* had a higher abundance in Prampram from the sampling data (Figures 6, 7, 8, and 9).

5.2.3 Temporal changes in distribution

Bachelotia antillarium, *Caulerpa* sp, *Padina durvillei*, and *Polycyphonia ferulacea* exhibited an increase in abundance in March on second time of sampling Takoradi. *Sargassum vulgare* also exhibited such a trend: its abundance increased at Prampram in March. For both sites *Ulva fasciata*, *Polycavenosa dentata*, *Hypnea musiformes*, *Enteromorpha flexiosa*, *Colpolenea sp*, *Chaetomorpha linum species* tend to increase in abundance in March. *Gellidium cornum* and *lithothamnia* sp exhibited a decrease in abundance in March for both sites on second time of sampling. *Jania rubens* found distinctly at Takoradi decreased in abundance on second sampling time (Figures 6, 7, 8, and 9).

5.2.4 Frequency Distributions:

Gelidium corneum exhibited a clumped distribution at both sites. *Ulva fasciata* also exhibited a uniform distribution from the transect data at both sites. All other species exhibited a random distribution within quadrat data.

General floral description for both sites

Upper shore: Floral species for instance Chlorophyte species such as *Chaetomorpha linum* (Kützing, 1845), *Enteromorpha flexiuosa*, *Ulva fasciata* (Linnaeus, 1753) and Rhodopyte species such as *Gellidium corneum*, were distinctively found in upper shore. The Phaeophyte *Bachelotia antilarium* (Gerloff, 1959) was also distinctly found at the upper shore.

Middle Shore: Chlorophyte species like *Ulva fasciata* was found at the middle shore with a higher relative abundance compared to the upper shore. Rhodophyte species like *Gelidium corneum*, *Hydropuntia rangiferina* (Gurgel & Fredericq, 2004) occur at a higher relative abundance compared to the upper shore. *Centroceras clavulatum* occurred in a high abundance distinctively only in the middle shore. *Jania rubens* (*J.V.Lamouroux, 1816)* occurs at the end of the middle shore and increases in abundance into the lower shore.

Lower shore: *Lithothamnion* sp, *Jania rubens*, *Corolina sp* which are Rhodopyte species predominate the lower shore. *Dictyopta celiolata*, *Padina durvillae*, *Lobophora* sp, *Gelidiopsis* sp,*Galaxaura margianata* also occurred predominantly in the lower shore but at a less degree.

Ralfsia expansia occurs across shore but it tends to have a variable abundance which fluctuates across upper to the lower shore and this coincides with the increase in the bar rock exposure encountered during quadrat sampling. (Figures 6, 7, 8, and 9).

5.3 Vertical Zonation

From the illustration of biotic features on the vertical transect axes showing the relationship of shore height and sea depth, with substratum (rock and grades of sediment), and the exposure of rocky habitats to wave action Costello & Emblow, 2005. The study sites fall into an exposed rocky intertidal environment due to the following observations

- Observed presence of Barnacles and mussels (Mytilus) in the eulittoral zone
- Observed presence of Red Macroalgae and Corrallina in the eulittoral zone

- Sea anemones , sponges & colonial ascidians in the infra littoral or sub-tidal zone of the rocky shore (Costello & Emblow, 2005)

At both sites we encountered some algal tuft or mats as well as lichens: which were rather rare in occurrence, ephemeral green and red seaweeds in the supralittoral zone. In the eulittoral we encountered Barnacles and Corrolina sp. In the infralittoral we observed an abundance of sponges and anemones.

Rocky shores are often characterized striking horizontal ands of species or species assemblages. An example the abundance of *Balanus balanoides* in the midlittoral zone on most sheltered West African shores.(Stephenson and Stephenson, 1969). The rocky intertidal region can be divided into four vertical zones. These zones are based on height and tidal influence. These four zones include from the highest to the lowest: the splash zone, the high intertidal zone, the mid-intertidal zone, and the low intertidal zone. Ecologically, the intertidal zone is a diverse community where organisms are divided by the vertical zonation of the tidal zones.

This supralittoral (spray zone) zone is above the highest high tide mark. It is moistened by saltwater spray from waves and freshwater runoff by rain and streams. This relatively dry area is sparsely populated. Few organisms can withstand the extreme fluctuations in moisture, temperature, and salinity found in this zone. The spray zone is never submerged and only receives ocean water due to the splash from crashing waves.

The Upper intertidal zone, usually termed the littorina zone, named after the small herbivorous gastropods (periwinkles) that occupy this zone that must survive long periods of exposure. This zone extends higher than the highest tide where there is great exposure with spray from the various waves causing the organisms to extend higher into the littoral zone. Parts of this region are exposed to the air for long periods as the tides recede. The inhabitants of this area are sturdy individuals. They can remain wet even if they are exposed to the sun and wind. The midlittoral zone, a broader zone dominated by barnacles and mussels. The middle tide zone is regularly both exposed and submerged by the tide. The middle intertidal zone can accommodate more life than the upper intertidal zone due to its length of time that it is submerged in water. The organisms worry less about desiccation. The organisms in this zone vary, but in greater quantity.

The low littoral zone dominated by red algae, often with brown seaweeds. The low tide zone is mostly submerged and only exposed to the air during the lowest tides. The lower intertidal zone is mostly submerged underwater most of the time and is only exposed when it is low tide. The lower intertidal zone is richer in organisms, more so than the middle intertidal zone. There is more species richness in the lower intertidal because most of the time the organisms are submerged in water, so more interaction takes place.

The width and upper limit of each zone generally increase as wave action ecomes intense (Lewis, 1964). The wave action gradient also affects the species which might be found in any zone. On more sheltered shores, however, midshore levels are often dominated by fucoids and the zones are less clear cut.

An obvious factor contributing to these zonation patterns is the emersion gradient. It is well known that zonation of communities occurs along stress gradients. The best known examples are at the larger scales of altitude and latitude. An intuitive explanation for observed zonation patterns might be that the vertical distribution of each species is set by its tolerance to the stresses of prolonged exposure to the air during emersion and prolonged submergence during immersion.

The cause of zonation have received a good deal of attention in laboratory and field studies dating back to the beginning of the 20th century (Baker, 1909).these studies have shown that while physical factors directly influence the upper limits of the distribution of many species illogical interactions play a significant role in shaping zonation patterns. Biological factors act primarily on lower limits but can sometimes set upper limits. The majority of species found in the littoral zone are of marine origin. For such species, stress increases with shore height. It is true that higher shore species are more tolerant of the emersion stress than species found at lower shore level (Norton, 1985). Physiological, behavioral and morphological adaptations allow high shore species to survive periods of emersion. However, low shore species are usually able to withstand periods of emersion greater. Many species do not occupy higher shore levels despite able to tolerate the physical conditions found there. From the Bray-Curtis Cluster analysis of all methods, taking a 100% level of (Dis) similarity it is observed that the 4 zone assessment gives a better explanation of results.

The 4 zone method gives a better percentage similarity in explaining patterns observed, gives a less cluttered result unlike the continuous block method of aggregating quadrat distances. It goes much to detail than the 3 zone method (Stephensons Universal Zonation classification scheme).

Vertical zonation and principal species at western shore (Takoradi)

The principal species found in Takoradi are: *Centroceras clavulatum*, *Corralina pilulifera*, *Jania Rubens*, *Polycavenosa dentata*, *lithithamnia biosporum*, *Padina durvilliae*, *Ralfsia expansa* and *Ulva fasciata* (Figure 14).

From the PCA(Figures 19 and 20) and SIMPER analysis done it is observed that: *Centroceras clavulatum* is dominant mostly in the 11m-20m zone in Takoradi occurring least in the 11m-20m zone in Prampram occurring least in the 1m-10m and 31m-40m, *Corralina pilufera* is most abundant in 31m-40m zone less or absent in the 1m-10m and 11m-20m. *Jania rubens* starts from the 11m-20m zone and is much abundant in the 21m-30m still abundant in the 31m-40m. *Polycavenosa* dentata occurs in high abundance in the 11m-20m and then recedes in abundance in the 21m-30m. *lithothmnia biosporum* occurs in the 31m-40m zone but starts from the 21m-30m. *Ralfsia Expansa* has a moderately constant distribution from the 1m-10m zone to the 21m-30m zone. It is less abundant in the 31m-40m zone. *Ulva fasciata* was the principal Chlorophyte species, its abundance was highest in the 1m-10m, 11m-20m and 21m-30m zones but was lowest in the 31m-40m zones.(Tables 1-4)

Table 21: Principal species that characterize the zones: arranged by level of highest importance and abundance.

1m-10m	11m-20m	21m-30m	31m-40m
Ralfsia expansa, Bachelotia antillarum	*Centroceras clavulatum, Polycanvenosa dentata, Ralfsia expansa and Ulva expansa*	*Jania rubens, Ralfsia expansa, Ulva fasciata and lithothamnion biosporum.*	*Jania rubens, Ralfsia expansa, Ulva fasciata and lithothamnion biosporum.*

Differences in the zonation patterns during Wet and Dry periods

From the SIMPER analysis: Chlorophytes in November occurred 11m-20m, 21m-40m and 31m-40m zones whilst in March they also occurred in the 11m-20m and 21m-30m zone also but had a lower average abundance than in November (Tables 7 and 9). They also occurred in the 1m-10m zone in March. Rhodophytes occurred in the all zones in November but they tend to occur only in the 21m-30m and 11m-20m zones in March with a lower average abundance (Tables 6 and 10). Phaeophytes occurred in the 11m-20m zone for both periods but average abundance was higher in November (Tables 5 and 8).

Vertical zonation and principal species at the eastern shore (Prampram)

The principal species from the PCA analysis (figures 25 and 26) which characterize the macroalgal community at Prampram are: *Centroceras clavulatum, Gelidium corneum, Polycavenosa dentata*, *Rafsia expansa*, *Enteromorpha flexuosa*, *Chaetomorpha linum*, *Hypnea musciformes*, *Bryopsis penata*, *Sargassum vulgare*, *Boodlea composita*, *Litothamnia biosporum*, *Caulerpa taxifolia* and *Ulva fasciata.*

Centroceras clavulatum occurs in the 1m-10m zone and 11m-20m zone. *Gelidium corneum* occurs abundantly in 31-40m zone. *Polycavenosa dantata* occurs in abundance 10m-20m zone, 21m-30m zone and 31m-40m zone. However it is most abundant in the 21m-30m zone. *Ralfsia expansa* occurs dominantly in the 11m-20m zone but has significant distribution in the 21m-30m zone. It is absent in the 1m-10m zone and 31m – 40m zone.

Enteromorpha flexuosa occurs in the 1m-10m and 11m-20m zones. *Hypnea musciformes* occurs highly in the 11m-20m and 21m-30m zones. It also occurs in the 1m-10m zone however at a much lower abundance. *Bryopsis pennata* occurs only in the 21m-30m in Prampram. *Sargassum vulgare* occurs at a lower relative abundance in the 21m-30m zone and the 31m-40m zone. *Boodlea* composita occurs only at low abundance in the 21m-30m zone. *Lithothamnion biosporum* occurs predominantly in the 11m-20m and 21m-30m zones. It also occurs in the 31m-40m zones but at a lower abundance. *Ulva fasciata* only occurs in the supra 1m-10m zones.

Table 22: Principal species that characterize the zones: arranged by level of highest importance and abundance.

1m-10m	11m-20m	21m-30m	31m-40m
Chaetomorpha linum, Ulva fasciata, Gellidiun corneum and Centroceras clavulatum	*Polycavenosa dentata. Caulerpa taxifolia. Ulva fasciata. Centroceras clavulatum.*	*Polycavenosa denta, Lithothamnia biosporum, Caulerpa taxifolia and Ulva fasciata.*	*Polycavenosa dentata, Caulerpa taxifolia, lithothamnia biosporum.*

Differences in the zonation patterns during Wet and Dry periods.

Chlorophytes were more abundant in the 1m-10m zone in November whilst in March they were abundant in the 21m-30m zone (Tables 16 and 18). Rhodophytes occurred at 11m-20m, 21m-30m and the 1m-10m zone for both periods but average abundance was higher in the November (Tables 17 and 19). Phaeophytes occurred at 21m-30m for both periods but average abundance was higher in November (Tables 15 and 20)

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

From the data gathered the view that there is no clear difference in intertidal macroalgal assemblages in the eastern and western parts of Ghana's coast is flouted. Diversity trends (Figures 1) show that species richness and diversity is higher in Takoradi than Prampram because Prampram has a slightly stressed environment (Figures 11 and 12) with nitrates (NO_3) being higher compared to Takoradi and high exposure to waves as such macroalgal species with narrow tolerance level to increased nitrates and wave exposure would have limited abundance giving way to the most adaptable to flourish competitively. Hence species richness and diversity would be low in Prampram compared to Takoradi. Chlorophytes are more diverse in Takoradi than Prampram, Margalefs richness higher and evenness lower compared to Prampram same trend is observed for Rhodophytes and Phaeophytes. For Shannon-Wiener diversity, it is observed that samples for Takoradi are more diverse than Prampram. Rhodophytes are most abundant at both sites with Chlorophytes coming in next. The relative abundance for both Rhodophytes and Chlorophytes sampled from Prampram is higher than those from Takoradi. Phaeophytes at the other hand are higher in Takoradi than in Prampram.

The principal component species in Takoradi are *Centroceras clavulatum*, *Corralina pilulifera*, *Jania Rubens*, *Polycavenosa dentata*, *lithithamnia biosporum*, *Padina durvilliae*, *Ralfsia expansa* and *Ulva fasciata.* With *Jania rubens* being the most abundant species occurring in the wet and dry periods. The principal species in Prampram are: Centroceras clavulatum, Gellidium corneum, *Polycavenosa dentata*, *Rafsia expansa*, *Enteromorpha* *flexuosa*, *Chaetomorpha linum*, *Hypnea musciformes*, *Bryopsis penata*, *Sargassum vulgare*, *Boodlea composita*, *Litothamnia biosporum*, *Caulerpa taxifolia* and *Ulva fasciata.* With *Polycavenosa dentata/Hydropuntia rangiferina* being the most abundant species occurring in the wet and dry periods. It occurs in the 10m-20m zone, 21m-30m zone and 31m-40m zone. Some peculiar species from the sampling data occurred only at Takoradi these being *Jania rubens*, *Polysiphonia ferulacea*, and *Bachelotia antillarium*. Species structure remains almost constant in the same site for both wet and dry periods though it is distinct from one site to the other. Predation was most evident in Takoradi with the high abundance of sea urchin hole and presence of underdeveloped *Chaetomorpha linum*.

Zonation patterns change slightly in a site for November (Wet period) and March (Dry period) but average abundance is higher in the November for all Major Macroalgal taxa due to increase in tidal range and shortening of the tidal cycle as viewed from the tide prediction tables. The four zone method of vertical zonation clearly gives a better spatial representation from the SIMPER and PCA analysis done for the zones created from the aggregation of quadrats it is observed that Macroalgal communities in Prampram is characterized by Chlorophytes and Rhodophytes and Communities in Takoradi is characterized by Rhodophytes and Phaeophytes. It is observed that it is not necessary to characterize macroalgal zonation patterns based at species level but simply grouping the in major taxa such as Chlorophyta, Phaeophyta and Rhodophyta is sufficient to characterize zonation patterns satisfactorily. Multivariate analysis is a better tool in assessing vertical zonation, as it produced sub zonations or micro zonations in 5 zone methods for both sites than species occurrence. The universal zonation method might not be applicable to all shores as evidenced in this work

6.2 Recommendations

From the conclusions it is observed that there is a difference in the Macroalgal assemblages found at Prampram on the east coast and Takoradi on the west coast. Hence from that, I give the following recommendations.

From the conclusions it is observed that there is a difference in the macroalgal assemblages found at Prampram on the east coast and Takoradi on the west coast. Hence from that, I give the following recommendations

1. This work is done at two important sites on the west and east parts of Ghana’s coast, more sites should be taken both in the western and eastern parts of the coast of Ghana, The time duration should be increased to capture long terms changes in the macroalgal community and subsequent vertical zonation (years and decades).
2. If possible, the phenological aspects of the macroalgal species of both Western and Eastern parts of Ghana’s coast could be studied to clearly document the life cycle of the principal macroalgae found at these sites, this would help tell when principal macroalgae reproduce and its effect on the average abundance of macroalgae for both wet and dry periods.

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APPENDIX

Table 23 : Relative abundance of species sampled for November and March at Prampram and Takoradi

		species list	(RELATIVE ABUNDANCE)		
		Takoradi November	Prampram November	Takoradi March	Prampram March
CHLOROPHY	Boodlea composita	5	48	0	0
	Bryopsis pennata	0	34	1	59.3
	Caulerpa taxifolia	5	209	15	196.1
	Chaetomorpha linum	96	222	372	280
	Cladophora	289	0	3	0
	Codium Guineense	0	0	1	0
	Enteromorpha flexuosa	41	160	303	477.5
	Ernodersmis verticillata	0	0	0	0
	Ulva fasciata	250	811	283	1006.05
RHODOPHYT	Asparagopsis taxiformis	0	0	0	0
	Bastrychia radicans	0	0	0	0
	Centroceras clavilatum	183	505	277	244.05
	Chondracanthus acicular	0	0	0	0
	Corralina pilulifera	131	0	0	0
	Cryptonemia crenulata	0	0	0	0
	Gelidium corneum	312	65	24	20
	Galaxuara marginata	13	0	0	0
	Gelidiopsis variabilis	2	0	0	0
	Griffithsia schousboei	1	0	2	0
	Hypnea musciformes	14	94	140	152.25
	Jania rubens	827	0	597	0
	Lawrencia majuscula	1	0	2	0
	Lithothamnion biosporum	94	190	16	90.75
	Polycavernosa dentata	266	1056	81	1383.5
	Polysiphonia ferulacea	4	0	12	0
	Sargassum vulgare	7	0	0	11.55
PHAEOPHYT/	Bachelotia antillarium	15	0	78	0
	Chnoospora minima	0	0	1	0
	Colpomenia	3	1	32	2.05
	Dictyopta celiolata	0	0	13	0
	Dictyopteris delicatula	0	0	88	0
	lobophora	4	0	0	0
	Dictyota cervicornis	0	0	13	0
	Padina antillarum	16	0	2	0
	Padina durvillaei	38	0	71	54.55
	Rafsia expansia	382	101	169	119.1

Table 24 : Species list of sampled macroalgae for November and March

		Species list presence-absence			
		Takoradi November	Prampram November	Takoradi March	Prampram March
Chorophyta	Boodlea composita	+	+	-	-
	Bryopsis pennata	-	+	+	+
	Caulerpa taxifolia	+	+	+	+
	Chaetomorpha linum	+	+	+	+
	Cladophora	+	-	+	-
	Codium Guineense	-	-	+	-
	Enteromorpha flexuosa	+	+	+	+
	Ernodersmis verticillata	-	-	-	-
	Ulva fasciata	+	+	+	+
Rhodophyta	Asparagopsis taxiformis	-	-	-	-
	Bastrychia radicans	-	-	-	-
	Centroceras clavilatum	+	+	+	+
	Chondracanthus acicularis	-	-	-	-
	Corralina pilulifera	+	-	-	-
	Cryptonemia crenulata	-	-	-	-
	Gelidium corneum	+	+	+	+
	Galaxuara marginata	+	-	-	-
	Gelidiopsis variabilis	+	-	-	-
	Griffithsia schousboei	+	-	+	-
	Hypnea musciformes	=	+	+	+
	Jania rubens	+	-	+	-
	Lawrencia majuscula	+	-	+	-
	Lithothamnion biosporum	+	+	+	+
	Polycavernosa dentata	+	+	+	+
	Polysiphonia ferulacea	+	-	+	-
	Sargassum vulgare	+	-	-	+
Phaeophyta	Bachelotia antillarium	+	-	+	-
	Chnoospora minima	-	-	+	-
	Colpomenia	+	+	+	+
	Dictyopta celiolata	-	-	+	-
	Dictyopteris delicatula	-	-	+	-
	lobophora	+	-	-	-
	Dictyota cervicornis	-	-	+	-
	Padina antillarum	+	-	+	-
	Padina durvillaei	+	-	+	+
	Rafsia expansia	+	+	+	+

ZONES	UP1 (1m-10m)			UP2 (11m-20m)			L1 (21m-30m)			L2 (31m-40m)		
ALGAL TYPE	CHLOROPH	RHODOPHY	PHAEPHYTES	CHLOROPHY	RHODOPHY	PHAEPHYTES	CHLOROP	RHODOPH	PHAEPHY	CHLOROP	RHODOPH	PHAEPHY
PRAMPRAM	Chaetomorpl	Gelidium corneum,		Caulerpa taxifo	Centroceras clavulatum		Caulerpa ta	Polycavenosa dentata,		Caulerpa ta	Polycavenosa dentata,	
	Ulva fasciata	Centroceras clavulatum		Ulva fasciata			Ulva fascia	Lithothamnion biosperu		Ulva fascia	Lithothamnion biospo	
		Hypnea musciformes										
TAKORADI			Ralfsia expans	Ulva fasciata	Polycavenos	Ralfsia expansi	Ulva fascia	Jania ruben,			Jania ruben	
			Bachelotia antillarum		Centroceras clavulatum			Lithothamnion biosperum			Lithothamnion biospo	
											Corallina pilulifera	
	DRY										WET	

Table 25 : Sampled macroalgae and the zones they characterize from upper (dry) shore to Lower (wet) shore at Prampram and Takoradi