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RESEARCH ARTICLE

HYDRODYNAMICS AND RELATIVE ABUNDANCY OF GREEN ALGAL SPECIES AT VISAKHAPATNAM COAST, ANDHRA PRADESH INDIA.

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Abstract

Sea weeds are now considered as most dependable living cells to address the anthropogenic demands in the fields of Food, Medicine and Metal industry. For the last decade or so researchers have started exploring new areas of the marine ecosystem to understand the Marine flora and fauna with reference to their ambient environment. The hydrographic parameters play a crucial role in studying the abundance of the marine flora and fauna. In the present study, the hydrodynamics and abundance of chlorophyceae members in Visakhapatnam coast were presented showing deviation from the previous data.

Abundance of the phytoplankton was high in the months of Dec-Feb up to Paradeep coast. In the present study, the hydrodynamics and abundancy of chlorophyceae members in Visakhapatnam coast were presented showing deviations from the previous data. Seaweeds are now focused as the most noble instincts. In just few decades research has opened doors for exploitation of seaweeds in many un imaginable areas. Mostly food and medicine got the attention as potentiality of any biological material on our planet can be mostly measured through these criteria. For studying the different aspects, it is necessary to understand the parameters like hydrodynamics, abundancy of the sample.

Introduction:-

Oceans continue to arouse some of our most noble and basic instincts. In just few decades, research has opened doors to ocean exploration and exploitations that our ancestors could only have imagined. The Marine Environment has much to offer in terms of food, medicines, metals and materials. Which are not only precious but also essential. Some resources like fisheries, oil & natural gases and mineral deposits are well recognized today. Others such as novel food products with bio active properties that can be used for number of biotechnological applications., those compounds can be used by the food industry as natural preservatives, pigments, stabilizers, gelling agents. Drugs from Marine organisms offer promising future. Perhaps, more important than anything else is the search for compounds of therapeutic value. Marine life comprises almost more than 80% of the world biota with huge quantities of bioactive compounds and secondary metabolites derived from marine invertebrates like tunicates, sponges, molluscs, bryozoans, sea slugs and many other marine organisms. These bioactive molecules and

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secondary metabolites possess antibiotic, antiparasitic, antiviral, anti-inflammatory, antifibrotic and anticancer activities. Marine plants and animals have biotechnological potential in the treatment of a wide variety of human illnesses. Coral reefs, sometimes denoted as the rain forests of the sea, contain novel chemicals that can be used to fight cancer, AIDS, diabetes and other diseases. Since the discovery of penicillin mold more than 60 years ago scientists have looked for potential drugs in soil microbes and more recently in marine microbes as well as macro organism.

While chemicals from terrestrial plants and microbial fermentations are on the decline, scientists have barely scratched the surface of the sea's molecular potential. There are several factors responsible for the slow progress in unveiling the chemistry of biologically active marine natural products. Less attention has been given to the present status of marine macro algae due to post-industrialization impact at the Visakhapatnam coast with reference to changes in algal species composition and diversity patterns. The severe cyclonic storm (Hud hud) in 2014 has changed the diversity pattern of the most of the algal communities to some extent.

A total of 27 species of marine macro algae were reported from Tenneti park of Visakhapatnam coast (**K.Prasanna Lakshmi and G.M.Narasimha Rao**,**2009)**. A total of 31 species were reported in the Bhimili coast **(K. Satya Rao, Prayaga Murty, P. and G.M. Narasimha Rao**, **2011)**. Of them the present work was focused on two species of *Caulerpa* i.e., *Caulerpa taxifolia* and *Caulerpa racemosa.(**K.Bramarambica,Y.V.K.Durga Prasad -2015**).*

The genus *Caulerpa* belonging to the Bryopsidophyceae consists of about 75 species, which are distributed worldwide in tropical and temperate regions **(Fama et al., 2002).***Caulerpa* spp. are siphonous green algae with a unique cellular organisation. Despite the fact that members of this genus can reach several meters in length, the organisms are unicellular with giant differentiated cells **(Menzel, 1988).**

Materials & Methods:-

Collection of sample:-

Seaweed sample was collected from the intertidal regions of Visakhapatnam coastal regions and was brought to laboratory and washed thoroughly with sterile water to remove the extraneous material and salt on the surface of the sample. Water was drained off and the seaweed was spread on blotting paper to remove excess water identified as *Caulerpa taxifolia* and *Caulerpa racemosa* by Dept. of Botany, Andhra University. Samples were shade dried for 20days. After drying the sample, it was grounded thoroughly to fine powder and stored in refrigerator at 4^0C until use.

Sampling of intertidal communities:-

An aluminum frame of 0.5 x 0.5 m in size was placed on the rocky surfaces, and the vegetation was sampled, following procedure described by **Saito and Atobe (1970).**Frequency is the number of sampling units (as %) in which a particular species occurs. The macro algae present in quadrats were removed with the help of scalpel and species were separated. The collections were sundried and then dried to a constant weight in an oven at 60^0 C temperature. Samples were collected and an average value of biomass was collected between March 2012 to February 2013 and was expressed as g. dry. wt./ m^2.

Hydrographical parameters of the study sites:-

Hydrographical parameters such as air and water temperature, salinity and pH were collected from all study sites. Surface water samples were taken from the seashore. Temperature, pH and salinity were measured with a thermometer, portable pH meter, and salinometer respectively in all the sampling stations. Water transparency in study sites was determined by Secchi disc. Dissolved oxygen was estimated by the method given by **Strickland and Parsons (1972).**

Physical Parameters:-

Colour:-

Suitable Nessler tube was filled to the 50-ml mark with the sample to be examined and its colour was compared with that of standards. The observation was made by looking vertically downwards through the tubes towards a white or specular surface placed at such an angle that light is reflected upwards through the columns of liquids. If turbidity is present and has not been removed by the procedure given below, the colour is reported as "apparent colour ".

Turbidity:-
Turbidity measurements are based on the light path of a suspension which just causes the image of the flame of a standard candle to disappear, i.e., to become indistinguishable against the general background illumination, when the flame is viewed through the suspension. The greater the light path, the lower the turbidity.

Temperature:-
Surface water temperature was measured with the help of a mercury filled centigrade thermometer of 0.1°C sensitivity. Temperature was recorded immediately after the collection of water sample.

pH:-
Hydrogen- ion concentration of drinking water was measured with the help of a portable p^Hmeter UC 23 manufactured by Central Kagaku Ltd., Japan and Toshniwal pH meter model No., CL 50.

Total Dissolved Solids:-
The filter paper was weighed and placed in a clean glass funnel. 100ml of the water sample was filtered. The filter paper is removed after complete filtration and it was placed on a clean dry evaporating disc. Then the filter paper was dried in an oven at 104°C per one hour and cooled in a dessicator and weighed. The volume of the solids present in the water sample was calculated.

Chemical Parameters;-
Salinity:-
Chlorinity was estimated by titration method of Knudsen **(Barnes, 1959).** The precipatable halide ions in 10 ml volume of sea water sample were determined by titration with silver nitrate solution from a burette using potassium chromate as an indicator. The silver nitrate solution was standardized periodically against 10 ml aliquot of standard sea water obtained from the National Institute of Oceanography, Goa. Corresponding salinities for chlorinates were read from the Knudsen's tables. The value was expressed as Parts per Thousand (%).

Alkalinity:-
Total alkalinity is the measure of the capacity of the water to neutralize a strong acid. The alkalinity in the waters is generally imparted by the salts of carbonates, bicarbonates, phosphates, nitrates, borates, silicates etc. together with the hydroxyl ions in free state. However, most of the waters are rich in carbonates and bicarbonates with little concentration of other alkalinity imparting ions.

Dissolved Oxygen:-
During the study, oxygen was estimated following **Winkler's method (APHA, 1971).** Immediately after collection the water sample was dispensed in 125 ml capacity corning glass stoppered bottles and a divalent manganese solution followed by alkaline iodide were added. The precipitated manganese hydroxide was evenly dispersed by shaking and samples were acidified (Conc. H_2SO_4) and the liberated iodine equivalent to dissolved oxygen originally present was titrated against standard solution of sodium thio-sulphate using starch as indicator. Dissolved oxygen was expressed as mg/l.

The algal samples used in this study were collected from rock surfaces and washed once with sea water and later with running tap water to remove all possible epiphytes, salts and small zoophytes. The samples were shade dried and powdered using a motar and pestle and stored in air tight plastic containers till further use (**Vidyashankar, S & Krupanidhi, S.,2013)**

Results:-

Table: I

Chlorophyceae	**Station I %**	**Station II%**
Ulva faciata Delile	53	68.5
Enteromorpha compressa (L.)	65	52.2
Chaetomorpha antennina (Bory)	22	49.7
Cladophora utriculosa	11	0
Spongomorpha indica	45.2	55.4
Boodlea struveoides Howe	8.36	29.3

Bryopsis pennata Lamouroux	0	15.2
Caulerpa fastigiata Montagne	18.8	21.23
C. sertularioides (Gmelin)	30	23.36
C. recemosa (Forsk.)	5.33	10.3
C. taxifolia (vahl)	36.6	40.7

Figure 1:-

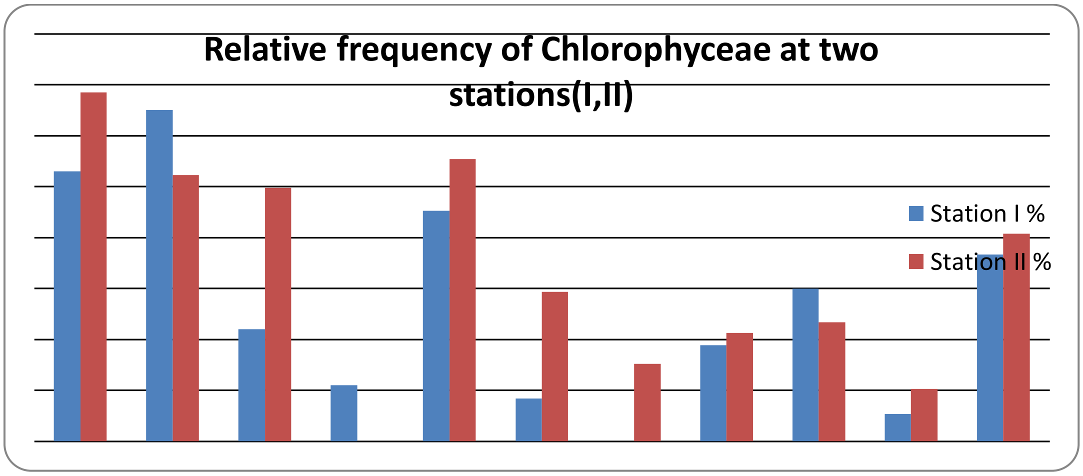
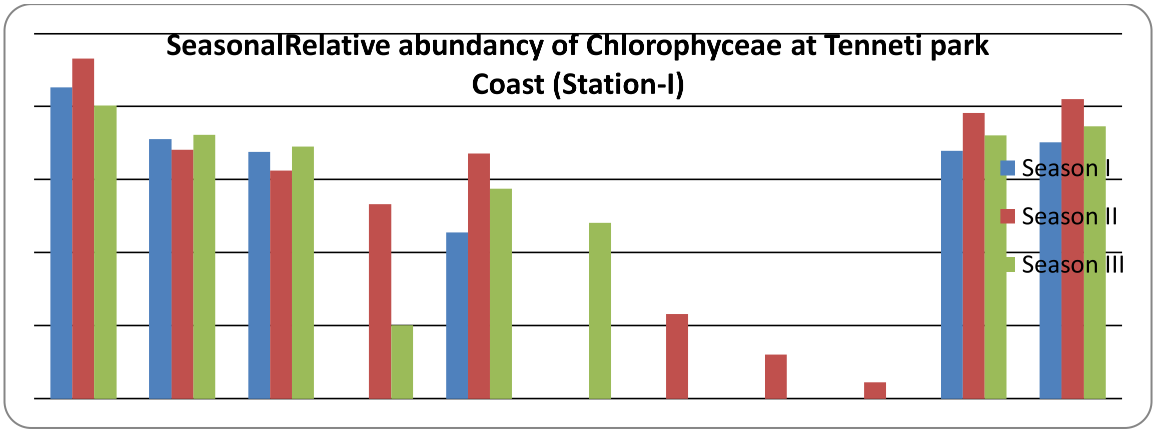


Table II:-

Chlorophyceae	Season I	Season II	Season III
Ulva faciata Delile	**85.2**	**93.1**	**80.3**
Enteromorpha compressa (L.)	71.1	68.2	72.2
Chaetomorpha antennina (Bory)	67.6	62.4	69.1
Cladophora utriculosa	0	53.2	20.1
Spongomorpha indica	45.6	67.2	57.5
Boodlea struveoides Howe	0	0	48.2
Bryopsis pennata Lamouroux	0	23.2	0
Caulerpa fastigiata Montagne	0	12.1	0
C. sertularioides (Gmelin)	0	4.5	0
C. recemosa (Forsk.)	67.9	78.2	72.1
C. taxifolia (vahl)	70.2	82.1	74.6

Figure 2:-



TableIII:-

Chlorophyceae	Season I	Season II	Season III
Ulva faciata Delile	**84.2**	**95.1**	**82.3**
Enteromorpha compressa (L.)	65.3	69.2	60.2
Chaetomorpha antennina (Bory)	63.6	68.4	70.1
Cladophora utriculosa	25.1	33.2	16.1
Spongomorpha indica	48.6	70.2	37.5
Boodlea struveoides Howe	0	0	50.2
Bryopsis pennata Lamouroux	0	19.2	0
Caulerpa fastigiata Montagne	0	1.1	0
C. sertularioides (Gmelin)	0	1.5	0
C. recemosa (Forsk.)	65.2	75.2	69.1
C. taxifolia (vahl)	78.2	85.1	75.6

Figure 3:-

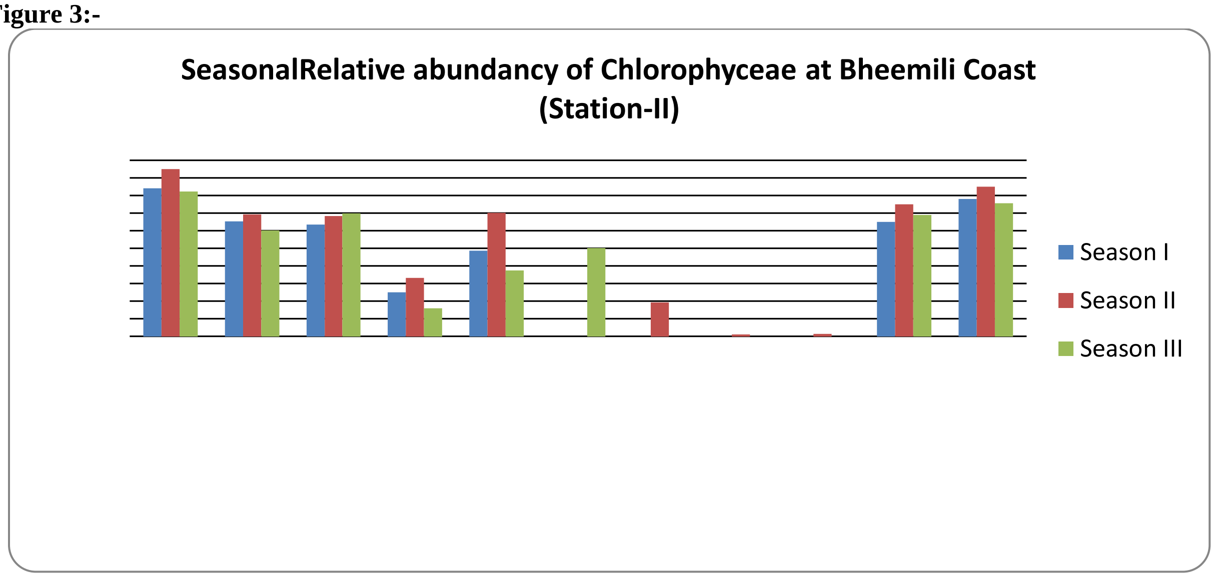


Table IV:-Relative frequency of *Caulerpa* species in two study areas of Visakhapatnam coast

Name of the algae	**Station I Tenneti Park %**	**Station II Bheemili %**
Caulerpa racemosa(Forsk.) J.Agardh	5.33	3.6
Caulerpa taxifolia(Vahl) C.Agardh	25.7	32.3

Table V:- Relative frequency of Chlorophyceae members in two study areas of Visakhapatnam coast

Chlorophyceae	**Station I %**	**Station II %**
Ulva faciata Delile	53	68.5
Enteromorpha compressa (L.)	65	52.2
Chaetomorpha antennina (Bory)	22	49.7
Cladophora utriculosa	11	---
Spongomorpha indica	45.2	55.4
Boodlea struveoides Howe	8.36	29.3
Bryopsis pennata Lamouroux	----	15.2
Caulerpa fastigiata Montagne	18.8	21.23
C. sertularioides (Gmelin)	30	23.36
C. recemosa (Forsk.)	5.33	3.6
C. taxifolia (vahl)	25.7	32.3

The hydrographical parameters such as temperature, pH, salinity and dissolved oxygen were measured and at Bheemili coast temperature is 22.4^{0}C , pH 7.4, salinity 32.3% and dissolved oxygen is 7.2 mg/L. At Tenneti park temperature 21.3^{0}C , pH 7.3, salinity 31.2% and dissolved oxygen is 7.3mg/L. The relative frequency values of two species of *Caulerpa* were estimated from the two different stations of the quadrat data are also shown in Table 4. In station I(Tenneti park) the frequency of *Caulerpa taxifolia* was high with a value of 25.7%. And *Caulerpa racemosa* showed minimum frequency of 5.33% when compared to *Caulerpa taxifolia*.

Hydrological parameter:-
Season I:-July to October
Season II:-November to February
Season III:- March to June

TABLE-VI **July-October (Season-I)**

Hydrological parameters	Station-I Tenneti park	Station-II Bheemili
Temperature	27.8^{0}C	27.5^{0}C
pH	6.0	5.4
Salinity	29.2%	30.8%
Dissolved oxygen	6.0 mg/L	7.5 mg/L
Relative frequency of *Caulerpa taxifolia*	20.7%	26.3%
Relative frequency of *Caulerpa racemosa*	5.0%	3.6%

TABLE-VII **Nov- Jan(Season -II)**

Hydrological parameters	Station-I Tenneti park	Station-II Bheemili
Temperature	21.3^{0}C	22.4^{0}C
pH	7.3	7.4
Salinity	31.2% o	32.3% o
Dissolved oxygen	7.3mg/L	7.2 mg/L
Relative frequency of *Caulerpa taxifolia*	25.7%	32.3%
Relative frequency of *Caulerpa racemosa*	5.33%	3.6%

TABLE-VIII **Feb (Season -II)**

Hydrological parameters	Station-I Tenneti park	Station-II Bheemili
Temperature	20.3^{0}C	22.4^{0}C
pH	7.3	7.0
Salinity	28.6% o	31.0% o
Dissolved oxygen	7.3mg/L	7.2 mg/L
Relative frequency of *Caulerpa taxifolia*	26.8%	31.0%
Relative frequency of *Caulerpa racemosa*	5.5%	4.0%

TABLE-IX **April (Season-III)**

Hydrological parameters	Station-I Tenneti park	Station-II Bheemili
Temperature	25.5^{0}C	26.0^{0}C
pH	6.4	6.8
Salinity	34.0%o	36.0% o
Dissolved oxygen	5.2mg/L	5.8 mg/L
Relative frequency of *Caulerpa taxifolia*	22.5%	27.0%
Relative frequency of *Caulerpa racemosa*	7.0%	5.5%

TABLE-X **May-June (Season-III)**

Hydrological parameters	**Station-I Tenneti park**	**Station-II Bheemili**
Temperature	27.^{0}C	28.0^{0}C
pH	5.9	6.0
Salinity	35.8%o	35.6% o
Dissolved oxygen	5.8 mg/L	6.1 mg/L
Relative frequency of *Caulerpa taxifolia*	20.5%	25.0%
Relative frequency of *Caulerpa racemosa*	4.0%	3.8%

TABLE-XI **June (Season-III)**

Hydrological parameters	**Station-I Tenneti park**	**Station-II Bheemili**
Temperature	27.8^{0}C	27.5^{0}C
pH	5.0	5.4
Salinity	33.2% o	31.8% o
Dissolved oxygen	5.0 mg/L	5.5 mg/L
Relative frequency of *Caulerpa taxifolia*	20.7%	26.3%
Relative frequency of *Caulerpa racemosa*	5.0%	3.6%

Discussion:-

The distribution and seasonal studies of marine algae at Visakhapatnam coast was studied by **Umamaheswara Rao and Sreeramulu (1964)** for 80 algal species. **Narasimha Rao (1984)** collected the quantitative data on marine algae and reported only 38 marine macro algae from Visakhapatnam coast. Recently, **Prasanna Lakshmi (2009)** collected the data on some numerical studies on marine algae and reported 31 marine algal species at Visakhapatnam coast. Including the species under study. *Caulerpa racemosa* shows very low biomass values as reported by **Prasanna Lakshmi and Narasimha Rao (2009)** at Visakhapatnam coast. Changes in the climatic conditions, pollution from the aqua industries near Gosthani estuary, untreated sewage from town region indiscriminate algal collection and human interference may be the reasons for the loss of bio-diversity and disappearance of algal species from Bhimili coast(**K. Satya Rao, Prayaga Murty, P. and G.M. Narasimha Rao**, **2011**).In the present study *Caulerpa racemosa* almost disappeared from bhimili coast. But the population of *Caulerpa taxifolia* was rich as reported by **K. Satya Rao, Prayaga Murty, P. and G.M. Narasimha Rao (2011)** at Bhimili coast.

The seasonal variations of the hydrographical parameters as we see here, much difference is not observed however the slightest difference in the temperature in the two stations (22.4^{0}C at Bheemili coast and 21.3^{0}C at Tenneti park) may be due to the exposure of water bodies to different anthropogenic activities which is very active near tenneti park that shows narrow range of fluctuations of temperature due to constant exposure to different kinds of pollutants. As far as the hydrogen ion concentration is concerned it remained almost as same with moderate basic properties (at Bhemili pH 7.4, at Tenneti park, pH 7.3).The variation of salinity at bhemili presented rich distribution of the two species of *Caulerpa* (32.3%$_o$)since the species favour the existing salinity, hence is abundant at this station. A salinity of 31.0%$_o$ which is recorded at station I i.,e is tenneti park due to the impact of pollutants that influence the fluctuations of salinity due to the deposition of different kinds of carbon compounds. The dissolved oxygen is 7.1mg/L at Tenneti coast this is may be due to the high anthropogenic activity that resulted in the deposition of carbon compounds of different combinations which reduce the oxygen levels in the ambient environment due to chemical reactions since the DO is low, naturally the species abundancy is naturally low when compared to Station II i,e., (Bhemili coast 7.4mg/L).

In the present study interesting facts were recorded.

1. The species earlier reported in abundant were not seen due to changing hydrographic and climatic conditions of Visakhapatnam coast.
2. As we see the table, the comparison of hydrographic parameters with the earlier data (G.M.Narasimha Rao, 2009 et.al Andhra University), a sea change in certain parameters was observed. The complete disappearance of some species of *Caulerpa* might be due to the impact of the increasing levels of coastal water pollution in and around Visakhapatnam.

3. The present study and observations of the distribution of the *Caulerpa* species in the coastal waters of Visakhapatnam revealed that only two species were predominant over the other species reported earlier. There is complete disappearance of some species like *Caulerpa fastigiata and Caulerpa sertularoides*.
4. The relative frequency distribution of the chlorophyceae members in the two stations in the present study exhibited a marked difference in showing high relative frequency at station 2 than station 1 except for two members that is *Enteromorpha compressa* and *Caulerpa sertulariodes*.
5. As mentioned in the results and analysis the relative frequency values of chlorophyceae members estimated from the two different stations and the quadrant data as shown in the Table II. In station I, high frequency of *Entermorpha compressa* was recorded(65%) followed by *Ulva faciata* (Delile)(53%), *Spongomorpha indica* (45.2%) and *Caulerpa taxifolia*(36.6%). On the other hand *Caulerpa racemosa* showed minimum frequency of (5.33%) when compared with other chlorophyceae members. In sation II, high frequency of *Ulva faciata* (Delile) (68.5%) followed by *Spongomorpha indica* (55.4%), *Entermorpha compressa* (52.2%), *Chetomorpha antennina* (Bory) (49.7%) and *Caulerpa taxifolia*(32.3%) and a minimum frequency of (3.6%) for *Caulerpa racemosa* was observed when compared to other chlorophyceae members.

Coastal areas are impacted by multiple natural and anthropogenic processes and experience stronger pH fluctuations than the open ocean. These variations can weaken or intensify the ocean acidification signal induced by increasing atmospheric pCO_2. The development of eutrophication-induced hypoxia intensifies coastal acidification, since the CO_2 produced during respiration decreases the buffering capacity in any hypoxic bottom water. To assess the combined ecosystem impacts of acidification and hypoxia, we quantified the seasonal variation in pH and oxygen dynamics in the water column of a seasonally stratified coastal basin (Lake Grevelingen, the Netherlands). Monthly water-column chemistry measurements were complemented with estimates of primary production and respiration using O_2 light-dark incubations, in addition to sediment-water fluxes of dissolved inorganic carbon (DIC) and total alkalinity (TA). The resulting data set was used to set up a proton budget on a seasonal scale. Temperature-induced seasonal stratification combined with a high community respiration was responsible for the depletion of oxygen in the bottom water in summer. The surface water showed strong seasonal variation in process rates (primary production, CO_2 air-sea exchange), but relatively small seasonal pH fluctuations (0.46 units on the total hydrogen ion scale). In contrast, the bottom water showed less seasonality in biogeochemical rates (respiration, sediment-water exchange), but stronger pH fluctuations (0.60 units). This marked difference in pH dynamics could be attributed to a substantial reduction in the acid-base buffering capacity of the hypoxic bottom water in the summer period. Our results highlight the importance of acid-base buffering in the pH dynamics of coastal systems and illustrate the increasing vulnerability of hypoxic, CO_2-rich waters to any acidifying process.

Algal communities present sensitive distribution with reference to seasonal variations of hydrographic parameters of oceanic environment. The observations made in the distribution of algal communities of Visakhapatnam coast revealed interesting factors regarding the distribution of the Algal communities as is seen in the case of *Caulerpa taxifolia* and *Caulerpa racemosa*. As the summer advances the rise in temperature influenced the fluctuations in the other parameters like salinity, pH, and dissolved Oxygen.

Temperature played crucial role in the distribution of the algal communities as mentioned in the tables VI to XI there is a gradual increase in the temperature during the summer months that resulted in decrease in the pH values of the ambient environment. The salinity values increased with increasing temperatures that resulted in gradual decrease in the algal populations throughout the Visakhapatnam coast.

The stations identified for the present study were closely monitored with reference to variable hydrographic parameters for a period of six months for two seasons, of the two species *Caulerpa recemosa* appeared to be more sensitive to hydrographic parameter changes, that reflected in the available population percentages, (tables VI-IX) the species exhibited decrease in the percentage of available populations.

The dissolved oxygen content doesn’t seem to influence much on the distribution of the two populations, namely *Caulerpa taxifolia* and *Caulerpa racemosa*. The more sensitive a species, the more affected it is by changes in pH. This is the reason why these two species could flourish even in hypoxic conditions in the Visakhapatnam coast as seen in the tables-November -January seasonal variations (table-VII hydrological parameters) In addition to biological effects, extreme pH levels usually increase the solubility of elements and compounds, making toxic chemicals more “mobile” and increasing the risk of absorption by aquatic life. There is every chance of accumulation of more trace elements in sensitive species (more than the required quantity), hence *C. racemosa* populations exhibited more fluctuations in abundance with reference to variations in hydrographic parameters.(but could survive in extremes of conditions).

Conclusion:-

The present study aims at understanding some of the ecological distribution, hydrological aspects of two different species of the marine macro alga *Caulerpa* (*C. recemosa* (Forsk.) and *C. taxifolia* (vahl)) with a view to provide detailed information that can be used in future studies. The studies revealed that the distribution of the two species namely- *Caulerpa* (*C. recemosa* (Forsk.) and *C. taxifolia* (vahl)) could survive even in extremes of climatic conditions as evident by the growth of the species after Hud-Hud cyclone that affected Visakhapatnam coast, and there is a scope to commercially exploit these species for various applications like human consumption as it is rich in protein (**K.Bramarambica, et al.,** 2014), essential fatty acids (**K.Bramarambica, et al.,** 2016)as mentioned earlier.

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