Article AR2152d

DOI: HTTPS://DOI.ORG/10.23910/1.2020.2152d

International Journal of Bio-resource and Stress Management

December 2020

Crossref

Print ISSN 0976-3988

Online ISSN 0976-4038

IJBSM 2020, 11(6):567-577

Research Article *Natural Resource Management*

Seaweed Species Diversity with Relation to Hydrological Parameters from Veraval and Sikka Coast, Gujarat, India

Shivani Pathak[1*], A. J. Bhatt[1], U. G. Vandarwala[1], Vyas U. D.[1] and Priyanka Gautam[2]

[1]College of Fisheries Science, Junagadh Agricultural University, Veraval, Gujarat (362 265), India

[2]College of Fisheries, Dholi, Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar (848 125), India

Corresponding Author

Shivani Pathak

e-mail: shivipathak3004@gmail.com

Citation: Pathak et al., 2020. Seaweed Species Diversity with Relation to Hydrological Parameters from Veraval and Sikka Coast, Gujarat, India. International Journal of Bio-resource and Stress Management 2020, 11(6), 567-577. HTTPS://DOI.ORG/10.23910/1.2020.2152d.

Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

Conflict of interests: The authors have declared that no conflict of interest exists.

Acknowledgement: Authors would like to thank Dr. A. J. Bhatt, M.Sc. (Marine Science), Ph.D., Assistant Professor, and Head, Fisheries Resource Management, and the respectable Dr. A. Y. Desai, Dean and Principal, College of Fisheries, Veraval, Junagadh Agricultural University, Gujarat for his sincere cooperation, valuable suggestions, constant help, and inspiration throughout this research work on seaweeds.

Abstract

The aim of the present investigation focused on a different group of seaweeds observed from Veraval and Sikka coast, Gujarat from September 2019 to February 2020, to understand their seaweeds diversity with subsequent analysis of relevant hydrological parameters. Seaweed diversity at Veraval and Sikka coasts has been studied for six months the using belt transect method. Some of the seaweeds are present throughout the year but most of the seaweeds are found at a specific climate. During the present study, the seawater temperature was ranging from 26.80 to 33˚C. The pattern of pH variation was similar in both areas but values varied considerably ranging from 7.7 to 8.32. Salinity was ranging from 32.4 to 35.67 ppt. The dissolved oxygen concentration varies from 5.64 to 7.55 ppm. In this study, the correlation between seaweed diversity and the hydrological parameters was investigated. A significantly negative correlation was recorded between seaweed diversity and Temperature. The hydrological parameters differ with seasonal periods, geographical location, and spatial and temporal variation at selected sites. Temperature is an important factor that was observed to play an important role in controlling seaweed diversity in the present study. The comparative study at Veraval and Sikka coasts gives an idea about the hydrological parameters that determine the water suitability for seaweed population and how it will affect seasonally available seaweed resources.

Keywords: Seaweed diversity, hydrological parameters, correlation, temperature

1. Introduction

India is one of the developing countries with rich biodiversity in the world. Indian seaweeds comprise mostly of tropical species, but temperate and subtropical elements have also been reported (Anonymous, 2005). Many of the rocky beaches, mudflats, estuaries, coral reefs, and lagoons along the Indian coast provide ideal habitats for the growth of seaweeds (Rao and Vaibhav, 2006). The latest diversity of Indian seaweed consisted of 1153 species from 271 genera (Karthik et al., 2013). There is a luxuriant growth of seaweeds along with the southeast coast of Tamil Nadu, Gujarat coast, Lakshadweep Island, and the Andaman and Nicobar Islands. Fairly rich seaweed beds are present in the vicinity of Bombay, Ratnagiri, Goa, Karwar, Varkala, Kovalam, Vizhinjam, Visakhapatnam, and few other places namely Chilka and Pulicat lakes (Chennubhotla et al., 1987). Thecurrent seaweed status of India showed 844 species distributed

Article History

RECEIVED in 29th September 2020 RECEIVED in revised form 08th December 2020 ACCEPTED in final form 27th December 2020

among 217 genera. The most abundant among them were Rhodophyta (434 species), followed by Chlorophyta (216 spp.), Phaeophyta (191 spp.), and Xanthophyta (3 spp.) (Venkatraman and Wafar, 2005).

Seaweeds are generally known as multicellular benthic marine macroalgae that possessing chlorophyll and capable ofphotosynthesis. Seaweeds can reproduce sexually as well as asexually. Seaweeds are found in the coastal region between high tide to low tide i.e. intertidal region and in the sub-tidal region up to a depth where photosynthetic light is available. They constitute one of the important living resources found mostly on a mudflat and rocky coastal wetlands, coral reefs and lagoons, estuaries, attached to the bottom on solid substrates such as rocks in the intertidal zones, washed up on beaches floating on the oceanic surface, and also in giant underwater forests, dead corals, pebbles, shells and plants (Sahayaraj et al., 2014). Seaweeds are important in human food, health, and economic wellbeing. They are a fascinating and diverse group of organisms inhabiting the oceans.

Seaweeds are nutritionally valuable as in fresh or dried form or as ingredients in a variety of prepared food (Robledo and Freile-Pelegrin, 1997). There were many studies noted that certain seaweed which is edible contains significant quantities of essential protein, lipids, fiber contents minerals, and vitamins (Wong and Cheung, 2000; Norziah and Ching, 2002; Sanchez-Machado et al., 2002). The nutrient contents vary with species, geographical location, season, and temperature of the region (Daweset al., 1993; Kaehler and Kennish, 1996).

The large demand for seaweeds for industrial products like agar-agar (china grass), algin, mannitol, and carrageenan which were consumed as food (Ramalingam et al., 2000). These industrial products are used as gelling, stabilizing, and thickening agents in food, pharmaceutical, confectionery, dairy, textiles, paper, paint, varnish industries, etc. (Kolanjinathan et al., 2014). Red seaweeds are extracted commercially valuable substances like agar-agar, Agarose, and Carrageenan. On a commercial basis, brown seaweeds are extracted such as alginic acid, mannitol, laminarian, fucoidan, and iodine.

The comparative study at two different locations gives an idea about the availability of seaweed resource diversity variation from both the sites, whereas the hydrological parameters determine the water suitability for seaweed population and how it will affect seasonally available seaweed resources. Seaweeds are mostly affected by various environmental factors include ambient temperature, amount of sunlight, and pH of the water, etc. and floristic variations of seaweed communities are controlled by several environmental factors including season, habitat, topography, duration of exposure, tidal amplitude, and other biotic factors. Seaweeds are very important organisms for studying seaweed diversity and the hydrological parameters also determine the distribution and occurrence of particular seaweeds at a particular place at a particular season. Hence the study of the hydrological characters of the marine ecosystem is also very important.

Therefore the present study was conducted to define the seaweed diversity at two different location areas of the Saurashtra region of Veraval and Sikka coast of Gujarat along with concerning relevant hydrological parameters such as surface water temperature, salinity, pH, and dissolved oxygen (DO).

2. Materials and Methods

2.1. Study area

The present study was conducted at two places of the Western coast of Gujarat, India i.e. Veraval and Sikka coasts (20°54'34"N latitude 70°21'08" Elongitudes) & (22°27'31"N latitude 69°48'17"E longitudes). The intertidal zone of Veraval coast is an inlet of the Arabian Sea in the state of Gujarat. Behind the lighthouse studied area has been selected. The Sikka coast is situated at the coast of Marine National Park, Jamnagar, and the mouth of the Gulf of Kutchh on the north-westernmost part of Saurashtra in Gujarat. At Sikka coast, particularly Gujarat State Fertilizer Company's Jetty (GSFC Jetty) studied area has been selected (Figure 1).

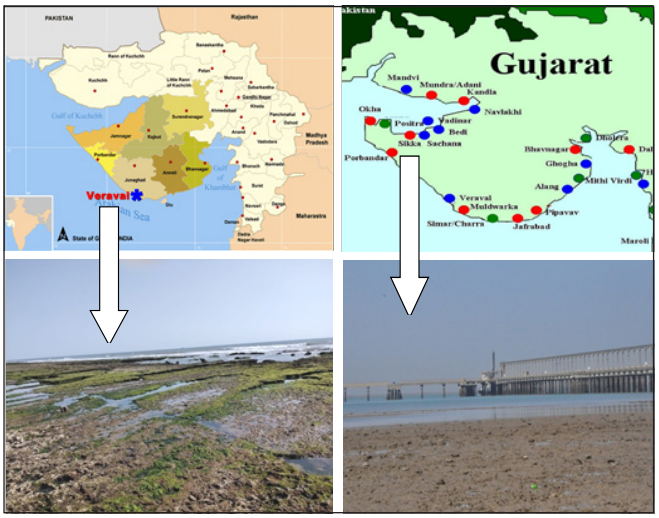

Figure 1: Map showing the study area of Veraval and Sikka coast, Gujarat

2.2. Sampling period

The study will be conducted for six months and it will be initiated from September-2019 and it will continue up to February-2020.

2.3. Sampling method

The belts transect random sampling method was used for the quantitative assessment of seaweeds in the selected sites. Six surveys per month were carried out at both the sampling stations for recording the algal species. Three transact were set for the diversity survey every month. Each transect had consisted of 10 quadrate of 1 m^{-2}. All the species of seaweeds present within the quadrant were uprooted completely along with the holdfast. The species diversity which was available

along the selected study locations were collected and at the laboratory identified by using standard references material (Kamboj et al., 2019).

2.4. Analysis of hydrological parameters of seawater

Data on the Hydrological factors such as temperature, pH, and salinity level will be recorded at the time of sample collection. Surface seawater temperatures were measured on the spot by precision mercury thermometer (Trivedy et al., 1987). Salinity was measured by using the standard refractometer (Trivedy et al., 1987). The pH of the seawater was measured by using a pH meter (Anonymous, 2006). DO was measured by using the Winkler method (Anonymous, 2006).

2.5. Data analysis

Data will be interpreted by using standard methods. The correlation analysis was done between seaweed diversity and recorded Hydrological parameters by using correlation formulae from MS-excel.

3. Results and Discussion

3.1. Seaweed diversity

At Veraval and Sikka coasts, first thoroughly surveyed to get an idea of the coastal characteristics like climatic condition and to make a qualitative assessment of the seaweed flora inhabiting there, throughout the study period. A checklist of the different seaweed species recorded during the period of investigation is presented in Table 1 and 2 classwise. From this table, it is clear that a total of 39 and 41 seaweed species were observed throughout the study period at Veraval and Sikka coasts.

A total of 50 species of seaweeds were recorded in the present study, of which 17 species belong to Chlorophyceae, 14 species belong to Phaeophyceae, and 19 species belong to Rhodophyceae. Thus Rhodophyceae group was more preponderance in the seaweed flora at both the coasts. Joshi and Murthy (2004) and Jha et al. (2009) also observed more number of Rhodophyceae compared to Phaeophyceae of the

Table 1: Species diversity of seaweed present at the Veraval coast

Sr. No.	Species	Sep' 19	Oct' 19	Nov' 19	Dec' 19	Jan' 20	Feb' 20
Chlorophyceae							
1.	*Bryopsis plumosa* (Hudson) C. Agardh	0	0	3	5	5	0
2.	*Caulerpa racemosa* (Forsskal) J. Agardh	11	3	6	10	0	12
3.	*Caulerpa taxifolia* C. Agardh	0	0	2	0	0	3
4.	*Caulerpa scalpelliformis* Var. Denticulata	4	0	2	2	0	0
5.	*Chaetomorpha spiralis* Okamura	2	1	3	0	2	3
6.	*Chaetomorpha antennina* (Bory de Saint- Vincent) Kuetzing	4	2	4	0	3	0
7.	*Cladophora socialis* Kutzing	2	0	0	2	0	3
8.	*Codium indicum* S.C Dixit	3	0	0	0	2	0
9.	*Enteromorpha compressa* (Linn.) Grev.	0	4	0	0	2	0
10.	*Valonia aegagrophila* C. Agardh	2	0	0	0	0	2
11.	*Halimeda macroloba* Decaisne	0	2	2	3	4	3
12.	*Halimeda tuna* C. Agardh	0	5	5	0	0	6
13.	*Ulva fasciata* Linnaeus	9	10	8	13	9	0
14.	*Ulva lactuca* Linnaeus	25	29	20	15	0	10
	Total number of Chlorophyceae species	9	8	10	7	7	8
	% of Chlorophyceae	52.94	42.10	37.03	28	28	27.58
Phaeophyceae							
15.	*Ectocarpus confervoides* Le Jolis	0	3	2	1	2	3
16.	*Cystoseira indica* (Thivy and Dhoshi) Mairh	4	0	3	1	0	7
17.	*Iyengaria stellata* (Borgesen) Borgesen	1	3	2	0	6	4
18.	*Padina gymnospora* (Kuetzing) Sonder	5	0	7	6	5	4
19.	*Padinatetrastromatica* Hauck	2	6	2	15	2	11
20.	*Sargassum plagiophyllum* C. Agardh	0	2	2	4	6	0
21.	*Sargassum polycystum* C. Agardh	2	3	4	8	1	7

Table 1: Continue...

Sr. No.	Species	Sep' 19	Oct' 19	Nov' 19	Dec' 19	Jan' 20	Feb' 20
22.	*Sargassum tenerrimum* J. G. Agardh	3	0	2	3	0	0
23.	*Spatoglossum asperum* J. Agardh	0	2	2	2	4	3
	Total number of Phaeophyceae species	6	6	9	8	7	7
	% of Phaeophyceae	35.29	31.57	33.33	32	28	24.13
Rhodophyceae							
24.	*Acanthophora spicifera* (Vahl) Boergesen	0	0	2	0	3	3
25.	*Ceramium cruciatum* FS Collins and Hervey	0	0	0	2	3	3
26.	*Ceramium rubram* (Huds.) Ag.	0	0	0	3	0	0
27.	*Champia indica* Boergs.	0	3	2	1	2	3
28.	*Chondria armata* (Kutzing) Okamura	2	0	3	2	3	2
29.	*Gelidiella acerosa* (Forsskal) J. Feldmann & G. Hamel	2	2	2	3	0	6
30.	*Gelidium pusillum* (Stackhouse) Le Jolis	0	3	2	0	2	2
31.	*Gracilaria corticata* (J. Agardh) J. Agardh	0	2	2	4	3	7
32.	*Gracilaria foliifera* (Forssk.) Boergs.	0	0	1	1	3	0
33.	*Gracilaria salicornia* (C. Agardh) Dowson	0	0	2	0	2	3
34.	*Halymenia venusta* Borgesen	0	0	0	0	2	4
35.	*Halymenia porphyrae formis* P.G. Parkinson	0	0	0	2	0	2
36.	*Hypnea musciformis* (Wulf.) Lamour.	0	0	0	2	1	4
37.	*Polysiphonia platycarpa* Borgesen	0	2	0	1	2	2
38.	*Scinaia moniliformis* J. Agardh	0	0	0	2	0	1
39.	*Scinaia hatei* Borgesen	0	0	0	0	1	2
	Total number of Rhodophyceae species	2	5	8	10	11	14
	% of Rhodophyceae species	11.76	26.31	29.62	40	44	48.27
	Total number of species	17	19	27	25	25	29

Table 2: Species diversity of seaweed present at the Sikka coast

Sr. No.	Species	Sep' 19	Oct' 19	Nov' 19	Dec' 19	Jan' 20	Feb' 20
Chlorophyceae							
1.	*Boodlea composita* (Harvey) Brand	3	0	0	3	0	1
2.	*Caulerpa racemosa* (Forsskal) J. Agardh	0	0	0	4	5	4
3.	*Caulerpa taxifolia* C. Agardh	0	0	3	3	0	3
4.	*Caulerpa scalpelliformis* Var. Denticulata	0	0	0	0	2	1
5.	*Chaetomorpha spiralis* Okamura	3	0	2	0	3	2
6.	*Chaetomorpha antennina* (Bory de Saint- Vincent) Kuetzing	0	0	5	3	2	3
7.	*Cladophora socialis* Kutzing	0	0	0	0	3	3
8.	*Enteromorpha compressa* (Linn.) Grev.	0	0	3	2	1	0
9.	*Vellonia* species	0	0	0	1	2	2
10.	*Halimeda macroloba* Decaisne	0	3	6	3	2	1
11.	*Halimeda tuna* C. Agardh	5	0	1	2	1	1
12.	*Ulva fasciata* Linnaeus	0	18	10	4	7	5

Table 2: Continue...

Sr. No.	Species	Sep' 19	Oct' 19	Nov' 19	Dec' 19	Jan' 20	Feb' 20
13.	*Ulva lactuca* Linnaeus	29	25	12	10	7	6
14.	*Ulva reticulate* Forsskal	0	0	5	4	0	0
	Total number of Chlorophyceae species	4	3	9	11	11	12
	% of Chlorophyceae	25	23.07	47.36	42.30	30.55	33.33
Phaeophyceae							
15.	*Ectocarpus siliculosus* (Dillwyn) Lyngbye	1	2	2	0	0	0
16.	*Cystoseira indica* (Thivy and Dhoshi) Mairh	4	0	0	0	3	2
17.	*Iyengaria stellata* (Borgesen) Borgesen	3	3	3	2	3	2
18.	*Padina boergesenii* Allender and Kraft	0	0	0	1	2	0
19.	*Padina gymnospora* (Kuetzing) Sonder	2	3	2	3	4	0
20.	*Padina tetrastromatica* Hauck	4	7	10	5	1	3
21.	*Sargassum cinclum* J. Agardh	2	2	3	1	2	1
22.	*Sargassum cinereum* J. Agardh	0	0	0	0	2	3
23.	*Sargassum johnstonii* C. Agardh	6	6	10	4	2	3
24.	*Sargassum tenerrimum* J.G. Agardh	0	0	0	3	2	1
25.	*Spatoglossum asperum* J. Agardh	0	0	0	0	1	2
	Total number of Phaeophyceae species	7	6	6	7	10	8
	% of Phaeophyceae	43.75	46.15	31.57	26.92	27.77	22.22
Rhodophyceae							
26.	*Acanthophora spicifera* (Vahl) Boergesen	0	0	0	0	3	4
27.	*Ceramium cruciatum* FS Collins and Hervey	0	0	0	2	3	1
28.	*Ceramium rubram* (Huds.) Ag.	0	0	0	1	2	1
29.	*Ceramium tenerrimum* (G. Martens) Okamura	0	0	0	0	2	2
30.	*Champia indica* Boergs.	0	0	0	0	2	3
31.	*Chondria armata* (Kutzing)Okamura	1	0	0	2	3	3
32.	*Gelidiella acerosa* (Forsskal) J. Feldmann & G. Hamel	3	6	6	5	4	4
33.	*Gelidium pusillum* (Stackhouse) Le Jolis	2	4	3	3	3	4
34.	*Gracilaria corticata* (J. Agardh) J. Agardh	4	6	8	3	4	4
35.	*Gracilaria foliifera* (Forssk.) Boergs.	0	0	0	1	2	1
36.	*Gracilaria salicornia* (C. Agardh) Dowson	4	3	4	2	1	3
37.	*Halymenia venusta* Borgesen	0	0	0	0	2	2
38.	*Hypnea musciformis* (Wulf.) Lamour	0	0	0	0	3	4
39.	*Platysiphonia delicate* (Clemente) Cremades	0	0	0	0	2	1
40.	*Scinaia carnosa* (Kutzing) J. Agardh	0	0	0	0	0	3
41.	*Scinaia hatei* Borgesen	0	0	0	0	1	2
	Total number of Rhodophyceae species	5	4	4	8	15	16
	% of Rhodophyceae species	31.25	30.76	21.05	30.76	41.66	44.44
	Total number of species	16	13	19	26	36	36

Chlorophyceae.

At the Sikka coast, the maximum number of seaweed species occurred during January 2020 and February 2020 with as many as 36 species, and a minimum of 13 was registered in October 2019 in Table 2. During the diversity survey, it is hypothesized that in general Green algae and Brown algae are observed during the initial months of the survey i.e.

September to January while the majority of Red algae are found from January to February months.

Results of the present study are satisfied with earlier reports of Thakur et al. (2008) along Port Okha, northwest coast of India, Chakraborty and Bhattacharya (2012) from Sikka and Vadinar, Gulf of Kutchh, India, and Domettila et al. (2013) along Muttom coastal waters of the southwest coast of India. A similar observation was recorded in the present investigation also. Ishakani et al. (2016) from the Veraval coast reported a total of 67 species comprises of 21 species of Chlorophyta, 14 species of Phaeophyta, and 32 species of Rhodophyta species which revealed that the results of the present study are much similar to earlierresearchers (Figure 2).

3.2. Analysis of hydrological parameters studied at veraval and sikka coasts

During the present investigation,the variation in seaweed diversity is associated with several environmental factors such as water temperature, pH, salinity, and dissolved oxygen were studied at both sites Veraval and Sikka coastal region, Gujarat every month.

Chlorophyceae - green algae species at Veraval and Sikka coasts

Ulva lactuca Linnaeus

Ulva fasciata Linnaeus

Bryopsis plumosa (Hudson) C. Agardh

Caulerpa racemosa J. Agardh

Chaetomorpha antennina Kuetzing

Halimeda tuna C. Agardh

Caulerpa scalpelliformis Var.Denticulata

Caulerpa taxifolia C. Agardh

Halimeda macroloba Decaisne

Cladophora socialis Kutzing

Figure 2: Continue...

Phaeophyceae - brown algae species at Veraval and Sikka coasts

Cystoseira indica (Thivy&Dhoshi)Mairh

Iyengari stellata Borgesen

Padina tetrastromatica Hauck

Spatoglossum asperum J. Agardh

Sargassum polycystum C. Agardh

Sargassum cinereum J. Agardh

Hypnea musciformis (Wulf.) Lamour

Gelidiella acerosa (Forsskal)

Gracilaria cortica J. Agardh

Gracilaria salicornia (C.Agardh) Dowson

Acanthophora spicifera Boergesen

Halymenia venusta Borgesen

Figure 2: Continue...

Platysiphonia delicate Cremades

Gelidium pusillum (Stackhouse) Le Jolis

Scinaia carnosa J. Agardh

Champia indica Boergs

Figure 2: Seaweed species at Veraval and Sikka coasts, Gujarat

3.2.1. Seawater temperature (˚C)

Temperature variation is one of the most important parameters in the coastal ecosystems, which influencing the hydrological characteristics of seawater and also influence the distribution and abundance of flora and fauna (Soundarapandian et al., 2009) and (Sundaramanickam et al*.,* 2008). During the present study, the seawater temperature was ranging from 26.80 to 33˚C in Table 3. During the study, the highest temperature (33˚C) was recorded in September month whereas the lowest temperature (26.80˚C) during January. The seasonal fluctuations in the water temperature were typical of this site. The mean temperature was 29.57±2.40 at the Sikka site and 29.48±2.04 at the Veraval site. The results of the correlation coefficient showed a relationship between seaweed diversity in Table 4. In the case of the Veraval coast significant negative correlation with diversity. At Sikka, similar results were observed like that of Veraval.

Studies along the Veraval coast by Raghunathan et al. (2003), reported that water temperature, salinity, pH, and dissolved oxygen was varied between 26.50-26.80˚C, 34.40-34.60 ppt, 8.32–8.34 and 4.11–4.96 ml l^{-1}, respectively during October1998, while during June 1999 these parameters ranged between 26.50–27.00˚C, 34.60 ppt. (Max.), 8.33 (Max.) and 4.36 – 5.01 ml l^{-1}, respectively. A similar result was shown by Vaghela et al. (2010) at Sikka and Vadinar coast of Gujarat. Also, Vase et al. (2018) reported along the Veraval coast, who recorded maximum temperature during summer and lowest during winter.

Table 3: Monthly value of hydrological parameters along veraval and sikka coasts (September 2019 - February 2020)

Parameters	Month wise hydrological parameters					
	Sept. 19	Oct. 19	Nov. 19	Dec. 19	Jan. 20	Feb. 20
Veraval						
Water temperature (˚C)	32	30	31.6	28	27	28.3
pH	7.8	7.7	8	7.9	7.8	8.1
Dissolved oxygen (ppm)	6.52	5.8	5.64	7.55	6.52	7.45
Salinity (ppt)	33.19	34.4	35.3	35.4	35	34.6
Sikka						
Water temperature (˚C)	33	32	28.87	28.8	26.8	28
pH	8.32	8	8.1	7.7	7.8	8
Dissolved oxygen (ppm)	5.8	5.64	7.2	6.52	7.2	7.55
Salinity (ppt)	32.47	33.25	34.75	35.67	35.25	34.75

3.2.2. Potential of hydrogen ions (pH)

The pH fluctuations are caused due to different factors like removal of CO_2 by photosynthesis, respiration, bicarbonate degradation, increased metabolic activities of autotrophs, decomposition of organic matter, precipitation, and wastewater or mining discharges, etc. (Pandit and Fulekar, 2017; Joshi et al., 2018). During the present investigation, the pattern of pH variation was similar in both areas but values varied considerably ranging from 7.7 to 8.32. Maximum pH value 8.32 during September at the Sikka site and minimum value 7.7 during December and October at Sikka and Veraval site. The present study recorded that shows a negative correlation between pH and seaweed diversity at the Sikka site in Table 4 whereas a positive correlation at the Veraval site in Table 4. According to Joshi et al. (2018), minimum pH 7.58 during April and the highest 8.38 during September was recorded at Poshitra and Narara coast of the Gulf of Kutchh. Temkar et al. (2014) minimum pH value 7.87 during April and range between 7.87 to 8.28 along the Veraval coast which is similar to the present investigation also. Therefore the present study was similar to the results of earlier researchers as comparable pH value recorded at Sikka and Veraval sites.

3.2.3. Salinity (ppt)

The seasonal variation in salinity is caused due to precipitation of rain and snow and evaporation of seawater, which is most likely to influence the faunal distribution in the intertidal zone (Kumar and Khan, 2013). During the study, salinity was ranging from 32.4 to 35.67 ppt. The minimum salinity 32.4 ppt was recorded during September month whereas the maximum salinity 35.67 ppt values were reported in December months in Table 3. The recorded average mean salinity values were 34.35±1.23 at the Sikka site and 34.64±0.81 at the Veraval site. Salinity had a significant positive correlation with diversity at Veraval and Sikka coast in Table 4. Temkaret al. (2014) reported seawater salinity varied between 34.75 ppt to 35.67 ppt along the Veraval coast which is similar to the present study. According to Joshi et al. (2018) minimum salinity, 31.15 ppt during August, and the highest, 38.08 ppt during May were recorded at Poshitra and Narara coast of the Gulf of Kutchh. The present study was similar to the results of earlier researchers as comparable salinity value recorded at Sikka and Veraval sites.

Table 4: Correlation coefficient of hydrological parameters with seaweed diversity at veraval and sikka coasts

	No. of species	Tem. (˚C)	pH	Salinity (ppt)	DO (ppm)
Veraval					
No. of species	1				
Temperature (˚C)	-0.50	1			
pH	0.83	-0.09	1		
Salinity (ppt)	0.75	-0.52	0.36	1	
DO (ppm)	0.36	-0.60	0.42	0.10	1
Sikka					
No. of species	1				
Temperature (˚C)	-0.87	1			
pH	-0.55	0.69	1		
Salinity (ppt)	0.70	-0.91	-0.84	1	
DO (ppm)	0.81	-0.90	-0.33	0.73	1

3.2.4. Dissolved oxygen (ppm)

Dissolved oxygen refers to the amount of oxygen dissolved in the water and important characteristics to support a well-balanced aquatic life (Weiss, 1970; Parmar and Mankodi, 2017). The major sources controlling dissolved oxygen concentration in seawater are photosynthesis producing oxygen and diffusion of oxygen from the atmosphere (Parmar and Mankodi, 2017; Best et al., 2007). During the study period, the dissolved oxygen concentration varies from 5.64 to 7.55 mgl^{-1} in Table 3. The mean DO value was recorded 6.65±0.79, 6.58±0.79 at Sikka, and Veraval site. The observed DO was above 5 mg l^{-1} which is also reported earlier in the Arabian Sea (Vase et al., 2018) and According to Joshi et al. (2018) recorded the total dissolved oxygen fluctuated rate of 5.48 to 7.45 mg l^{-1} with a maximum DO value of 7.45 mg l^{-1} recorded during August at Poshitra and Narara coast of the Gulf of Kutchh.

The results of the correlation coefficient are a significant positive correlation at Veraval and Sikka coast in Table 4. Therefore, it can be said that dissolved oxygen of the waters is not a critical factor for controlling seaweed diversity.

4. Conclusion

Besides providing a complete picture of the seaweed flora Veraval and Sikka coast region will also help us in the farming of economically important seaweeds, by providing information on the ideal conditions of seaweed growth and also gives an idea about the availability of seaweed resources diversity and hydrological parameters for future necessities. The temperature is an important factor that was observed to play an important role in controlling seaweed diversity in the present study.

5. References

Anonymous, 2005. Seaweeds: Wonder plants of the sea (5th Edn.). Aquaculture Foundation of India, Chennai, 30.

Anonymous, 2006. The association of official agricultural chemists (AOAC). Standard Methods for examination of water and wastewater. Published by American Public Health Association, Washington DC.

Best, M.A., Wither, A.W., Coates, S., 2007. Dissolved oxygen as a physicochemical supporting element in the water framework directive. Marine Pollution Bulletin 55(1-6), 53–64.

Chennubhotla, V.S., Kaliaperumal, N., Kalimuthu, S., 1987. Economically important seaweeds, CMFRI Bulletin 41, 3–18.

Chakraborty, S., Bhattacharya, T., 2012. Nutrient composition of marine benthic algae found in the Gulf of Kutch coastline, Gujarat, India. Journal Algal Biomass Utilization 3(1), 32–38.

Dawes, C.J., Lluisma, A.O., Trono, G.C., 1993. Clonal propagation of *Eucheuma denticulatum* and *Kappaphycus alvarezii* for Philippine seaweed farms. Hydrobiologia 260/261, 379–383. DOI: 10.1007/BF00049044.

Domettila, C., Brintha, T.S., Sukumaran, S., Jeeva, S., 2013. Diversity and distribution of seaweeds in the muttom coastal waters, South-West coast of India. Biodiversity Journal 4, 105–110.

Ishakani, A.H., Joshi, N.H., Ayaz, M., Sumara, K., Vadher, K.H., 2016. Assessment of seaweed diversity at Veraval coast, Gujarat. Journal of Experimental Zoology 19(2), 863–868.

Jha, B., Reddy, C.R.K., Thakur, M.C., Rao, M.U., 2009. Seaweeds of India, the Diversity and distribution of seaweeds of Gujarat coast. Developments in Applied Phycology, Springer Dordrecht 3, 216.

Joshi, N.H., Murthy, S., 2004. Ecological studies on Sargassum species of port Okha (Gujarat). Seaweed Research and Utilization 26(1&2), 63–71.

Joshi, A., Desai, A.Y., Bhatt, A.J., Kardani, H.K., Yusufzai, S.I., 2018. Seasonal variations of oceanographic conditions along Marine national park and sanctuary, Gulf of Kutch, Gujarat. Journal of Experimental Zoology India 20(2), 879–884.

Kaehler, S., Kennish, R., 1996. Summer and winter comparisons in the nutritional value of marine macroalgae from Hong Kong. Botanica Marina 39, 11–17.

Karthik, P., Mohanraju, R., Ramesh, C., Murthy, K.N., 2013. Distribution and diversity of seaweeds in North and South Andaman Island. Seaweed Research and Utilization 35, 8–16.

Kolanjinathan, K., Ganesh, P., Saranraj, P., 2014. Pharmacological importance of seaweeds: A Review. World Journalof Fish and Marine Sciences 6, 01–15.

Kamboj, R.D., Das, L., Palanisamy, M., 2019. Pictorial guide to seaweeds of Gulf of Kuchchh, Gujarat. Gujarat Ecological Education and Research (GEER) Foundation, Gandhinagar, 367.

Kumar, P.S., Khan, A.B., 2013. The distribution and diversity of benthic macroinvertebrates fauna in Pondicherry mangroves, India. Aquatic Biosystems 9(15), 1–18.

Norziah, M.H., Ching, C.Y., 2002. Nutritional composition of edible seaweeds *Gracilaria changgi*. Food Chemistry 68, 69–76.

Pandit, P.R., Fulekar, M.H., 2017. Quality characterization of Coastal water in Gujarat coast, India. Journal of Biotechnology and Biochemistry 3, 8–15.

Parmar, H.B., Mankodi, P.C., 2017. Variation in seawater quality of two intertidal zones of south Saurashtra coast, Gujarat, India. Research Journal of Marine Sciences 5, 1–6.

Raghunathan, C., Tewari, A., Joshi, V.H., Sravan, K.G.V., Trivedi, H.R., Khambhaty, Y., 2003. Impact of turbidity on intertidal macrofauna at Gopnath, Mahuva and Veraval coasts (West coast of India). Indian Journal of Geo-Marine Sciences 32, 214–221.

Ramalingam, J.R., Kaliaperumal, N., Kalimuthu, S., 2000. Seaweed exploitation in India. Seaweed Research and Utilization 22, 75–80.

Rao, S.P.V., Vaibhav, A.M., 2006. Indian seaweed resources and sustainable utilization: Scenario at the dawn of a new century. Current Science 91, 164–174.

Robledo, D., Freile-Pelegrin, Y., 1997. Chemical and mineral composition of six potentially edible seaweed species of Yucatán. Botanica Marina 40, 301–306. DOI: 10.1515/botm.1997.40.1-6.301.

Sahayaraj, K., Rajesh, S., Asha, A., Rathi, J.M., Raja, P., 2014. Distribution and diversity assessment of the marine microalgae at four southern districts of Tamil Nadu, India. Indian Journal of Geo-Marine Sciences 43, 607–616.

Sanchez-Machado, D.I., Lopez-Hernandez, J., Paseiro-Losada, P., 2002. High-performance liquid chromatographic determination of α-tocopherol in

macroalgae. Journal of Chromatography A 976, 277−284. DOI: 10.1016/S0021-9673(02)00934-2.

Soundarapandian, P., Premkumar, T., Dinakaran, G.K., 2009. Studies on the physicochemical characteristic and nutrients in the uppanar estuary of Cuddalore, South east coast of India. Current Research Journal of Biological Sciences 1, 102−105.

Sundaramanickam, A., Shivakumar, T., Kumaran, R., Ammaiappan, V., Velappam, R., 2008. A comparative study of physico-chemical investigation along parangipettai and cuddalore coast. Journal of Environmental Science and Technology 1, 1−10.

Trivedy, R.K., Goel, P.K., Trisal, C.L., 1987. Practical methods in ecology and environmental science. Enviro Media Publications, 340.

Temkar, G., Abdul, A.P., Metar, S.Y., Brahmane, V.T., Sikotaria, K.M., Mathew, K.L., 2014. The studies on distribution and community structure of five selected species of marine gastropod along the rocky intertidal area of Veraval, Gujarat, India. Journal of Advances in Agricultural Scienceand Technology 2(6), 94−100.

Thakur, M.C., Reddy, C.R.K., Jha, B., 2008. Seasonal variation in biomass and species composition of seaweeds stranded along Port Okha, northwest coast of India. Journal of Earth System Science 117(3), 211−218.

Vaghela, A., Bhadja, P., Ramoliya, J., Patel, N., Kundu, R., 2010. Seasonal variations in the water quality, diversity and population ecology of intertidal macrofauna at an industrially influenced coast. Water and Science Technology 61, 1505−1514.

Vase, V.K., Dash, G., Sreenath, K.R., Temkar, G., Shailendra, R., Koya, K.M., 2018. Spatio-temporal variability of physic-chemical variables, chlorophyll a, and primary productivity in the northern Arabian Sea along India coast. Environmental Monitoring and Assessment 190, 148.

Venkatraman, V., Wafar, M., 2005. Coastal and marine biodiversity of India. Indian Journal of Marine Sciences 34, 57−75.

Weiss, R.F., 1970. The solubility of nitrogen, oxygen and argon in water and seawater. Deep Sea Research and Oceanographic Abstracts 17, 721−735.

Wong, K.H., Cheung, P.C.K., 2000. Nutritional evaluation of some subtropical red and green seaweeds: Part I−proximate composition, amino acid profiles and some physico-chemical properties. Food Chemistry 71, 475−482.