



Research article

Seaweed diversity within intertidal zone of Olaikuda and Vadakkadu, Rameshwaram, southeast coast of India

Suparna Roy^{*}

Centre of Advanced Study in Marine Biology, Faculty of Marine Sciences, Annamalai University, Annamalai Nagar, Tamilnadu, India

ARTICLE INFO

Keywords:

Environmental science
Ecology
Plant biology
Environmental analysis
Environmental assessment
Seaweeds
Diversity
Seasonal changes
Statistical analysis

ABSTRACT

Seasonal variation of seaweed diversity was studied in Olaikuda and Vadakkadu, the two unexplored coastal areas in Rameshwaram Island in south coast of India. An extensive survey on seasonal changes of seaweed diversity was made study and the data were analyzed for different diversity indices. In each location, 3 transects at 100 m gap were taken and in each transect 10 quadrates, a total of 30 quadrates were taken for seaweeds diversity. The diversity data were analyzed with statistical methods such as graphical and statistical analysis K-dominance curve with software PRIMER package, cluster analysis, multivariate methods, anosim and diversity indices such as Shannon Weaver diversity index, Simpson species richness index, Fisher alpha index, Pielou's evenness, and taxonomic species diversity (delta) index were analyzed by using the software R statistic version 3.1.4. Package (vegan). Totally 74 species including 28 species of Chlorophyceae, 18 species of Phaeophyceae and 28 species of Rhodophyceae were recorded. The study areas are flourishing with 49–59 seaweed species. It is inferred that the seaweeds are well diversified seasonally except summer. The baseline data generated in this work will help in conservation of the seaweeds in the areas.

1. Introduction

Seaweed diversity is largely known along the Indian coasts. Earlier reports are of Krusadai Island (Iyengar, 1927), west coast seaweed diversity (Boergesen, 1928), Indian coast (Thivy, 1948; Krishnamurthy, 1957; and Umamaheswara Rao, 1969). A checklist of seaweeds in India based on secondary data has reported 844 species, which include 434 red, 194 brown and 216 green seaweeds (Oza and Zaidi, 2001) for coastal India; 198 species that include 109 red, 62 green and 54 brown seaweeds for Gujarat and Tamil Nadu (Jha et al., 2009). The seaweed diversity of Arockiapuram, Kootapuli, Uvari, Manapad, and Punnakayal districts of Tamil Nadu recorded is 53 species including 21 Chlorophyta, 15 Phaeophyta and 17 Rhodophyta (Janet Rani et al., 2013). Totally, 57 seaweed species of which 18 Chlorophyta, 14 Ochrophyta and 25 Rhodophyta have been recorded during June 2009 to June 2010 from four southern districts (Kanyakumari, Tirunelveli, Tuticorin and Ramanathapuram) of Tamilnadu (Sahayara et al., 2014). In Tuticorin coast is reported with total 86 seaweeds including 32 Rhodophyceae; 27 Chlorophyceae and 27 Phaeophyceae (Canciya et al., 2014). During December 2014 to February 2016, along the water lagoons of Chennai are reported with 25 seaweeds (Bhagyaraj and Kunchithapatham, 2016).

The Manapad coastal region is recorded with 20 seaweeds (Doss and Rukshana, 2016). During August 2015 to February 2016, a total of 73 seaweeds have been recorded in west coast of Maharashtra (Waghmode, 2017). Seaweeds are marine macro algae. They are ecologically and economically important component of coastal and marine resources. They grow mostly on hard substrate areas of intertidal region, which are regularly exposed during low tides and submerged during high tides. They contribute to primary productivity of coastal and marine environment. They are also commercially important as a source of food, fodder, fertilizer, cosmetics, and medicines (Harley et al., 2012). Hence, understanding the seaweed diversity deserves attention for sustainable utility of the resources. It is necessary to map the distribution and diversity of seaweed flora of any particular area. This will help to regulate and combat the entry of invasive harmful species; to implement protective measures for saving the gradually extinct and endangered species; and to undertake environment impact assessments. Seaweed diversity is known along the Indian coasts. Earlier reports are of Krusadai Island (Iyengar, 1927), west coast seaweed diversity (Boergesen, 1928), Indian coast (Thivy, 1948; Krishnamurthy, 1957; and Umamaheswara Rao, 1969). A checklist of seaweeds in India based on secondary data has reported 844 species, that include 434 red, 194 brown and 216 green seaweeds (Oza

^{*} Corresponding author.

E-mail address: roysuparnacasau@gmail.com.

and Zaidi, 2001) for coastal India; 198 species that include 109 red, 62 green and 54 brown seaweeds for Gujarat and Tamil Nadu (Jha et al., 2009). The seaweed diversity of Arockiapuram, Kootapuli, Uvari, Manapad, and Punnakayal districts of Tamil Nadu recorded is 53 species including 21 Chlorophyta, 15 Phaeophyta and 17 Rhodophyta (Janet Rani et al., 2013). Totally, 57 seaweed species of which 18 Chlorophyta, 14 Ochrophyta and 25 Rhodophyta have been recorded during June 2009 to June 2010 from four southern districts (Kanyakumari, Tirunelveli, Tuticorin and Ramanathapuram) of Tamilnadu (Sahayara et al., 2014). In Tuticorin coast is reported with total 86 seaweeds including 32 Rhodophyceae; 27 Chlorophyceae and 27 Phaeophyceae (Canciya et al., 2014). During December 2014 to February 2016, along the water lagoons of Chennai are reported with 25 seaweeds (Bhagyaraj and Kunchithapatham, 2016). The Manapad coastal region is recorded with 20 seaweeds (Doss and Rukshana, 2016). During August 2015 to February 2016, a total of 73 seaweeds have been recorded in which west coast of Maharashtra (Waghmode, 2017). Although the seaweeds have extensively been studied in India, several places which are rich in seaweeds are unexplored. There are two such places namely Olaikuda and Vadakkadu in Rameshwaram Island. Hence, the present study was made on biodiversity of seaweeds in those new areas.

2. Material and methods

An extensive survey was made in two stations viz. Olaikuda and Vadakkadu coast, Rameshwaram. The quadrates were laid at intertidal zone during low tide. The line transects were taken from land towards seashore. In each location, 3 transects at 100 m gap were taken and in each transect 10 quadrates were laid. In each location, a total of 30 quadrates were taken for seaweeds diversity study. The survey was done for four seasons during the year 2016. The whole seaweeds with holdfast were preserved in 5% formalin and taken to the laboratory for taxonomic identification by using authentic taxonomic keys (Dawes and McIntosh, 1981).

2.1. Comparison of diversity using graphical and statistical analysis K-dominance curve

The collected data of seaweeds diversity including number of species were analyzed with the software PRIMER package. The abundance of species was plotted on X-axis which is known as logarithmic scale and the percentage dominance was plotted on the Y-axis which is called as cumulative scale. Thus, the dominance curve of species was drawn.

2.2. Multivariate methods

The species identity and the pattern change in community were predicted with the help of analysis by multivariate methods. The multivariate method is beneficial than diversity indices analysis (Gray et al., 1990). This method involves analysis after pre-processing of data.

2.3. Cluster analysis

The similarity of groups was found out with the help of cluster analysis. The hierarchical agglomerative method is the most common technique used to know clustering between groups. The clusters are represented as dendrogram. In cluster graph of dendrogram, the samples were plotted with X-axis and the similarity level was represented at Y-axis. The dendrogram graph was drawn (Bray and Curtis, 1957). The Co-efficient was analyzed with using the formula as stated below: The coefficient was calculated by the following formula:

$$S_{jk} = 100 \left(1 - \frac{\sum_i |Y_{ij} - Y_{ik}|}{\sum_i |Y_{ij} + Y_{ik}|} \right) = 100 \sum_i P_i = 12 \min(Y_{ij}, Y_{ik})$$

$$\sum_i P_i = 1(Y_{ij} + Y_{ik})$$

Here Y_{ij} indicated the data of column of i and j where i is the species and j is the sample and \sum indicated the matrix overall rows, K_{th} represent the absolute value of the sample.

2.4. Anosim

The difference or dissimilarity of the groups of samples was analyzed by one-way permutation. The formula of permutation test as explained as: $R = (rB - rW)/(M/2)$. In this equation, $M = n$ is the total number of sample, rB is representing the average of rank of similarity, and accordingly, rW is representing the replicates of similarity rank average.

2.5. Analysis of diversity indices

The biodiversity indices such as Shannon Weaver diversity index, Simpson species richness index, Fisher alpha index, Pielou's evenness, and taxonomic species diversity (delta) index were analyzed by using the software R statistic version 3.1.4. Package (vegan).

In this equation, the i th species proportion is denoted by p_i and number of species represents as S . The b is the logarithm base and commonly natural logarithm is used for this equation [equation (i) and (ii)]. In equation (iv) f is denoted for expected total number of species and n is representing the total number of species and x is representing nuisance parameter.

3. Description of the study area

Two stations at Rameshwaram, Tamilnadu, southeast coast of India, had been selected for this study. Rameshwaram is a small island, in the

$i = 1H = -\sum p_i \log p_i$	Shannon-Weaver index.	(i)
$D1 = 1 - \sum_{i=1}^s p_i^2$	Simpson species richness index.	(ii)
$J = H0 = \log(S)$	Pielou's evenness.	(iii)
$f_n = \infty x^{n/n}$	Fisher's log-series.	(iv)

Gulf of Mannar, 570 km away from south of Chennai. This famous pilgrimage centre, geographically located at 09°18'.390"N and 079°20'.076"E with the area coverage of 51.8 sq. Km. The Pamban Bridge connects the mainland with Rameshwaram Island. The first station, the Olaikuda is located at 09°18'.853"N and 079°20'.141"E near the Rameshwaram temple. This is influenced by tourism pressure throughout the year. The second station is Vadakkadu located at 09°19'.700"N and 79°19'.072"E, 8 km away from Rameshwaram temple. This is an undisturbed area.

4. Results

The two study stations were well diversified with three groups of seaweeds such as Chlorophyceae, Phaeophyceae and Rhodophyceae. Totally, 74 species of seaweed were found in two stations; of which 28 species belong to Chlorophyceae, 18 species Phaeophyceae and 28 species belong to Rhodophyceae. This survey recorded 37.83% Chlorophyceae, 37.83% Rhodophyceae, followed by 24.32% Phaeophyceae (Figure 1). The dominant species of Olaikuda are *Ulva lactuca* Linnaeus, *Enteromorpha intestinalis* (Linnaeus) Nees, *Caulerpa racemosa* (Forsskal) J.

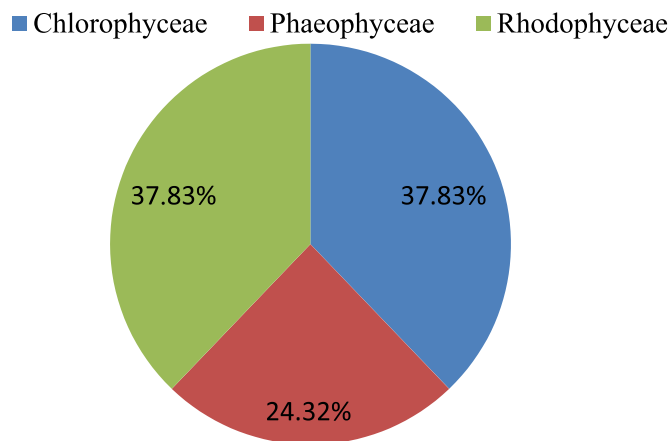


Figure 1. Percentage of Chlorophyceae, Phaeophyceae and Rhodophyceae at two stations.

Agardh and *Chaetomorpha antennina* (Bory de Saint-Vincent) Kutzing (Chlorophyceae), *Turbinaria ornata* (Turner) J. Agardh, *Hydroclathrus clathratus* (C. Agardh) Howe and *Lobophora variegata* (Lamouroux) Womersley ex Oliveira (Phaeophyceae) and *Amphiroa anceps* (Lamarck) Decaisne, *Hypnea valentiae* (Turner) Montagne, *Gracilaria corticata* (J. Agardh) J. Agardh and *Acanthophora spicifera* (Vahl) Boergesen (Rhodophyceae). The dominant species of Vaddakadu were *Caulerpa racemosa* (Forsskal) (Chlorophyceae), *Padina boergesenii* Allender & Kraft, *Sargassum ilicifolium* C. Agardh, *Sargassum polycystum* C. Agardh *Turbinaria ornata* (Turner) J. Agardh (Phaeophyceae) and *Amphiroa anceps* (Lamarck) Decaisne, *Amphiroa fragilissima* (Linnaeus) Lamouroux, *Kappaphycus alvarezii* Doty (Rhodophyceae). The most common and dominated species of two stations were *Caulerpa racemosa* (Forsskal), *Turbinaria ornata* (Turner) J. Agardh, and *Amphiroa anceps* (Lamarck) Decaisne.

4.1. Olaikuda seaweed diversity

In Olaikuda (station I), a total of 59 seaweeds species were found. Of which, 26 species belong to Chlorophyceae, followed by 22 Rhodophyceae and 11 Phaeophyceae (Figure 2). The seasonal diversity of Olaikuda revealed that species diversity was equal during post monsoon and summer, in other words, 53 seaweed species were recorded in the two seasons. In post monsoon, the Chlorophyceae was 23, followed by 20 species under Rhodophyceae and 10 under Phaeophyceae. During post monsoon, the genus diversity was the highest with 16 under Rhodophyceae, followed by Chlorophyceae. During summer, the genus

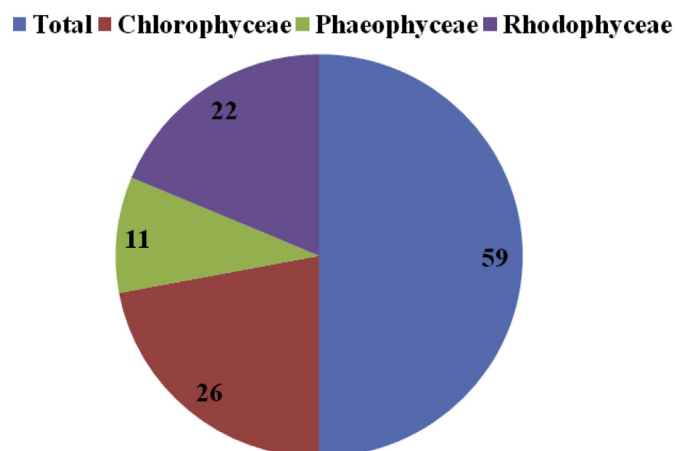


Figure 2. Diversity of seaweeds at Olaikuda.

diversity was the highest for Rhodophyceae. During post monsoon and summer, the species diversity was found maximum under Chlorophyceae while the maximum genus diversity was found under Rhodophyceae. During pre-monsoon, 21 seaweeds were found; of which, 9 species belong to Chlorophyceae and 7 species belong to Rhodophyceae, followed by 5 species of Phaeophyceae. In monsoon season, seaweed diversity was very less and only 5 species recorded under Chlorophyceae and Rhodophyceae. During monsoon, no brown seaweed was found (Figure 3). Olaikuda was dominated with green and red seaweeds during four seasons. However, very less number of brown seaweeds was recorded.

4.2. K-dominance plot

The k dominance plot drawn on seasonal basis for seaweed diversity pattern in Olaikuda (Station-I). The k dominance curve of summer laid at lower side and started slowly increase to the above indicated the higher number of species found in this season. The k dominance curve for post monsoon was just above and also united with the k dominance curve of summer season also indicated the higher diversity in summer season. But the k dominance curve for pre-monsoon and monsoon revealed very less species rank indicating the less diversity at these two seasons (Figure 4).

Cluster analysis (species assemblage): Species assemblage was studied using the dendrogram drawn with four seasons. The seaweed diversity formed 1 group between post monsoon and summer with the highest level of similarity of 71.25 % (Figure 5).

4.3. Analysis of biodiversity indices

The value of Shannon Weaver diversity index ranged from 3.60 to 1.16 which indicated that seaweeds diversity was good during four seasons. In post monsoon and summer, diversity was high in comparison with pre monsoon and summer. The Shannon Weaver index was 3.35 during post monsoon and 3.60 during summer which indicated high seaweed diversity during these two seasons, similarly, Shannon Weaver index was 2.72 during pre-monsoon and 1.16 during monsoon indicating less seaweed diversity during pre-monsoon and monsoon. The calculated value of Simpson species richness was the highest during summer (0.96) and also in post monsoon (0.95) as compared to pre monsoon (0.91) and monsoon (0.60). The value of Pielou's evenness explained the highest species evenness during summer, followed by post monsoon as compared to post monsoon and monsoon. Similar results were found in case of Fisher alpha index and taxonomic diversity index which clearly revealed that post monsoon and summer had maximum seaweeds diversity with high species richness than pre monsoon and monsoon (Table 1).

4.4. Vaddakadu seaweed diversity

At Vaddakadu, totally 49 seaweeds were recorded which included 9 Chlorophyceae, 15 Phaeophyceae and 25 Rhodophyceae (Figure 6). The seasonal survey at Vaddakadu showed that post monsoon and summer had higher seaweed diversity than pre-monsoon and monsoon. The seaweed diversity was 35 species during summer and 30 during post monsoon. The seaweed diversity of pre-monsoon was 14 species and 16 in monsoon. In post monsoon, Rhodophyceae was dominated with 13 species, and with the highest genus diversity. During post monsoon, less number of Chlorophyceae, and Phaeophyceae with 4 species each and the total species of 8 were recorded. The summer survey recorded totally 35 seaweed species, of which 21 species were Rhodophyceae with the highest genus diversity of 15, followed by 9 species of Phaeophyceae and 5 species of Chlorophyceae. The survey of pre-monsoon and monsoon recorded with 14 species and 16 species respectively with maximum brown seaweeds during monsoon season but no Chlorophyceae was recorded during pre-monsoon.

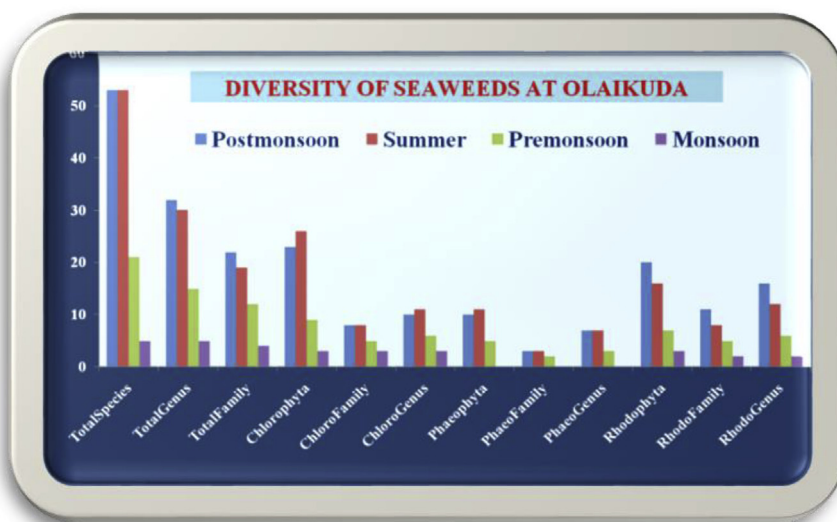


Figure 3. Seasonal distribution of seaweeds at Olaikuda.

A total of 10 species of brown seaweeds was recorded during monsoon, followed by 6 species of Rhodophyceae, but no species of Chlorophyceae was recorded during monsoon 266 (Figure 7).

4.5. K-dominance plot

The k-dominance plot drawn season wise for Vaddakadu (station-II) revealed the seaweed diversity pattern. The k dominance curve of summer and post monsoon laid at lower side and started slowly increase to the above indicated the higher number of species found in both of the seasons. The k dominance curve of summer and post monsoon united together at the bottom of the plot but the dominance plot curve of summer laid below the dominance curve of post monsoon which indicated the highest seaweed diversity during summer and the next highest diversity was found during post monsoon. But the k dominance curve for pre-monsoon and monsoon was with very less species rank indicating less diversity at these two seasons. Both seasons species dominance plot followed at same position (Figure 8).

4.6. Cluster analysis (species assemblage)

Species assemblage was studied using the dendrogram for Vaddakadu. Among diversity of seaweeds of four seasons, two seasons such as

post monsoon and summer formed one group with the highest level of similarity of 68.46% (Figure 9).

4.7. Analysis of biodiversity indices

The diversity indices mentioned in Table 2 for two stations indicated that two stations had good seaweed diversity. The Shannon Weaver diversity index was maximum during post monsoon (3.11), followed by summer (3.06) in comparison to monsoon (2.41) and pre-monsoon (2.26), indicating that the seaweeds diversity was higher during post monsoon and summer. The values of Simpson species richness indicated that the species richness was also the highest during post monsoon (0.94) and summer (0.93). The evenness of species was also good during post monsoon and summer according to species Pielou's evenness analysis (Table 2). Similar result was recorded from Fisher alpha index and taxonomic species diversity analysis, indicating that post monsoon and summer had maximum seaweeds diversity as compared to pre-monsoon and monsoon (Table 3).

4.8. Comparison between two stations

At two stations, the maximum seaweed diversity was recorded during summer and post monsoon in comparison with monsoon and pre-monsoon. Seaweed growth was abundant during post monsoon and

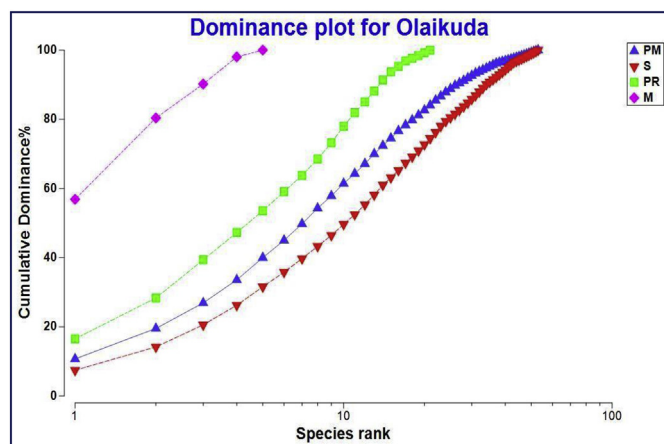


Figure 4. Season wise K dominance curve, PM - post monsoon, S - summer, PR - pre-monsoon and M - monsoon.

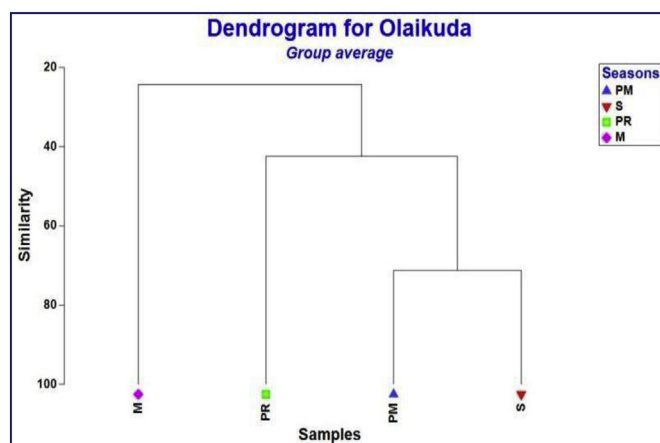


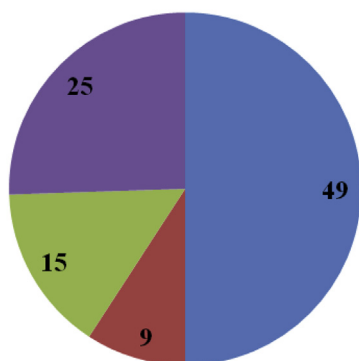
Figure 5. Season wise cluster analysis at Olaikuda.

Table 1. Values of diversity indices of four seasons at Olaikuda.

Seasons	Shannon Weaver	Simpson richness	Pielou's evenness	Fisher alpha index	Taxonomic diversity
Post monsoon	3.35913	0.951190	0.84606	16.05093	69.23077
Summer	3.60745	0.964790	0.90861	19.27990	69.23077
Pre monsoon	2.72970	0.918593	0.89659	7.168801	53.84615
Monsoon	1.16588	0.605515	0.72440	1.373138	53.84615

Vaddakadu Seaweeds Diversity

■ Total ■ Chlorophyceae ■ Phaeophyceae ■ Rhodophyceae

**Figure 6.** Diversity of seaweeds at Vaddakadu.

summer. Annotated checklists of species of two stations is compiled and presented (Tables 4 and 5). The taxonomic description and photographs of 74 species recorded are listed with their systematic position. The seaweed diversity was higher at Olaikuda in comparison to Vaddakadu for four seasons. Total number of seaweeds recorded was 59 for Olaikuda and 49 in Vaddakadu. Totally 53 seaweed species were recorded during post monsoon and summer at Olaikuda which was higher than in remaining two seasons and also higher than Vaddakadu. Red seaweeds were dominant during post monsoon and summer seasons at both stations. The maximum number of 21 species under Rhodophyceae was

found during summer at Vaddakadu, followed by 20 red seaweeds at Olaikuda during post monsoon.

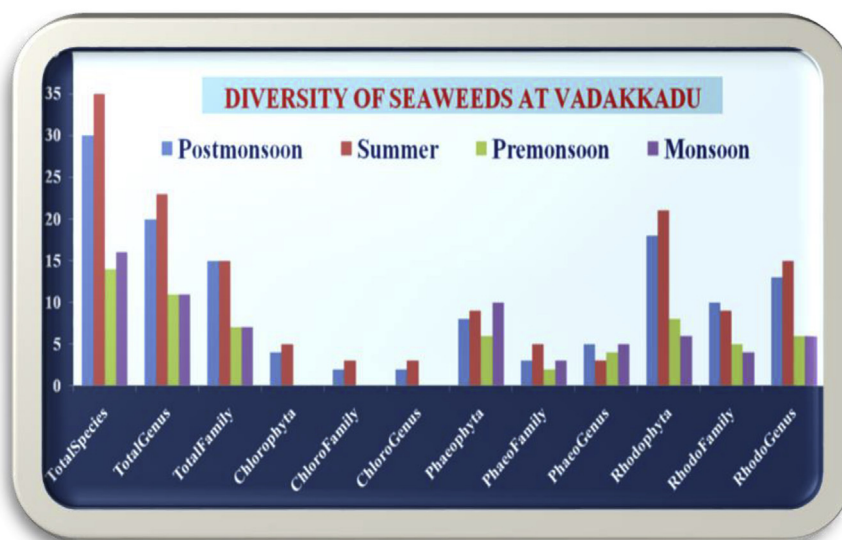
Both stations had less seaweed diversity during pre-monsoon and monsoon. The second dominating seaweeds were green seaweeds at both stations. A total of 26 species of green seaweeds were recorded at Olaikuda during summer, followed by 23 green seaweeds during pre-monsoon. The brown seaweeds were less dominating at both stations. But brown seaweed diversity was more at Vaddakadu than that at Olaikuda. The green seaweed diversity was more at Olaikuda than Vaddakadu. But red seaweeds were equally dominated at both stations (Figure 10).

4.9. K-dominance plot

The k dominance plot was drawn for two stations. In dominance plot 'O' denotes Olaikuda and 'V' Vaddakadu. The k dominance curve of summer and post monsoon of Olaikuda station laid at lower side and started slowly increase, indicating the higher number of species found at Olaikuda. The k dominance curve of summer and post monsoon of Vaddakadu was above the k dominance plot of Olaikuda indicating less seaweed diversity at Vaddakadu. The k dominance curve of monsoon season at Olaikuda positioned at above all the k dominance curve indicating very less diversity during monsoon at Olaikuda (Figure 11).

4.10. K-dominance plot

The k dominance plot is drawn season wise for both stations. In dominance plot 'OP', 'OS', 'OPR', and 'OM', denote Olaikuda post monsoon, summer, pre-monsoon and monsoon and 'VP', 'VS', 'VPR' and 'VM' denote Vaddakadu post monsoon, summer, pre-monsoon and monsoon. The k dominance curve of summer and post monsoon of Olaikuda station laid at lower side and started slowly increase to the above, indicating higher number of species found at Olaikuda. The k

**Figure 7.** Seasonal distribution of seaweeds at Vaddakadu.

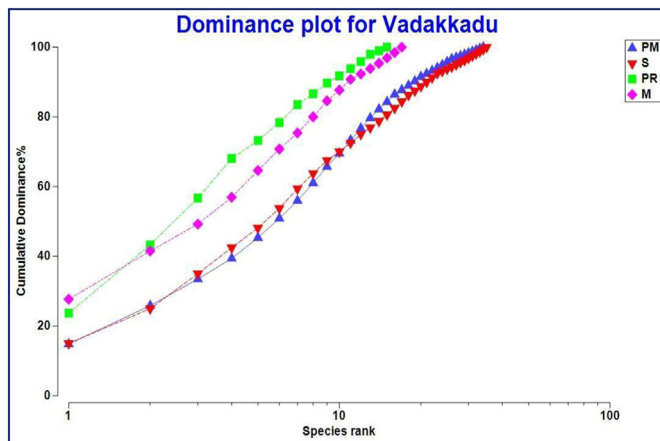


Figure 8. Season wise K dominance curve, PM - post monsoon, S - summer, PR - pre-monsoon and M - monsoon.

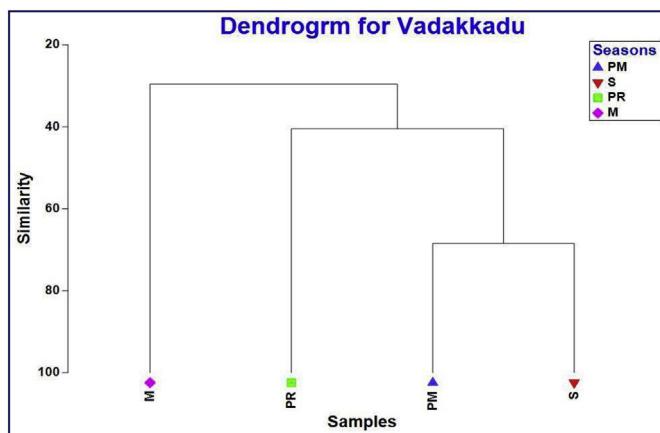


Figure 9. Season wise cluster analysis at Vadakkadu.

dominance curve of post monsoon and summer of Vadakkadu was above the k dominance plot of Olaikuda indicating the second highest seaweed diversity at Vadakkadu. The Olaikuda pre monsoon k dominance curve laid below the k dominance plot of pre-monsoon of Vadakkadu revealing

that Olaikuda had more seaweeds diversity than Vaddakadu at pre-monsoon season.

The k dominance plot of monsoon season at Vaddakadu laid lower than the k dominance plot of monsoon of Olaikuda revealing that seaweeds diversity was higher at Vaddakadu during monsoon season. The k dominance curve of monsoon season at Olaikuda positioned at above all the k dominance curve indicating very less diversity during monsoon at Olaikuda (Figure 12).

4.11. Cluster analysis (station wise)

Species assemblage was studied using the dendrogram drawn with four seasons of two stations. The seaweed diversity for two stations formed 3 groups. The first group formed between post monsoon and summer of Olaikuda with the highest level of similarity of 75.50 %. The second group formed between Vaddakadu summer and post monsoon with comparatively higher similarity of 72.50 %. The third group formed at Olaikuda two seasons with less similarity of 37.50 % (Figure 13).

4.12. Cluster analysis (seasons wise)

Species assemblage was studied using the dendrogram drawn with four seasons. The seaweed diversity for two stations formed 3 groups. The first group formed between post monsoon and summer with the highest level of similarity of 75.50%. The second group formed between post monsoon and summer with 72.50% similarity (Figure 14).

4.13. Anosim analysis (stations)

The analysis of similarity was carried out to find out significant variations for seaweeds diversity between two stations. The statistical significance of the variation in species between two stations and four seasons was tested using ANOSIM. With respect to difference between the species in stations, the R value ranged from (-0.30) to (+0.45). The global R value of 0.427 which fell away from the histogram showed significant difference at 2.9% level (Figure 15).

4.14. Anosim analysis (seasons)

The analysis of similarity of species diversity among four seasons was carried out to find out significant variations within seaweeds diversity. With respect to difference between the species in seasons, the R value ranged from - 0.60 to +0.60. The global R value of 0.167 which fell away from the histogram showed significance level of 24.8%. The global 'R'

Table 2. ANOSIM data for similarity analysis.

Groups	R statistic	Significance level %	Possible permutation	Actual permutation	Number observed
P, S	-0.5	100	3	3	3
P, PR	0.75	33.3	3	3	1
P, M	0	66.7	3	3	2
S, PR	0	66.7	3	3	2
S, M	0	66.7	3	3	2
PR, M	-0.25	66.7	3	3	2
PR, M	-0.25	66.7	3	3	2

Table 3. Values of diversity indices of four seasons at Vaddakadu.

Seasons	Shannon Weaver	Simpson richness	Pielou's evenness	Fisher alpha index	Taxonomic diversity
Post monsoon	3.110299	0.9417944	2.243606	11.79115	53.84
Summer	3.068711	0.9346898	2.213607	13.72829	53.84
Pre monsoon	2.264811	0.8627909	1.633716	4.962445	23.07
Monsoon	2.416406	0.8796444	1.743069	6.854845	23.07

Table 4. Checklist of seasonal diversity of seaweeds at Olaikuda (Station-I).

Sl. No.	Species Name	Phylum	Family	PMS' 16	S' 16	PEMS' 16	M' 16
1.	<i>Bryopsis plumosa</i> (Hudson) C. Agardh	Chlorophyta	Bryopsidaceae	+	+	-	-
2.	<i>Caulerpa chemnitzii</i> Lamouroux	Chlorophyta	Caulerpaceae	-	+	-	-
3.	<i>Caulerpa racemosa</i> (Forsskal) J. Agardh	Chlorophyta	Caulerpaceae	+	+	+	-
4.	<i>Caulerpa racemosa</i> var. <i>macrophyta</i> (Sonder ex Kützing) W. R. Taylor	Chlorophyta	Caulerpaceae	+	+	-	-
5.	<i>Caulerpa scalpelliformis</i> (R. Brown ex Turner) C. Agardh	Chlorophyta	Caulerpaceae	+	+	+	-
6.	<i>Caulerpa sertularioides</i> (S. Gmelin) Howe	Chlorophyta	Caulerpaceae	+	+	-	-
7.	<i>Chaetomorpha aerea</i> (Dillwyn) Kützing	Chlorophyta	Cladophoraceae	+	+	+	-
8.	<i>Chaetomorpha antennina</i> Bory de Saint-Vincent) Kützing	Chlorophyta	Cladophoraceae	+	+	+	+
9.	<i>Chaetomorpha aerea</i> (C. Agardh) Kützing	Chlorophyta	Cladophoraceae	+	+	-	-
10.	<i>Chaetomorpha linum</i> (O. F. Mueller) Kützing	Chlorophyta	Cladophoraceae	-	+	-	-
11.	<i>Chlorodesmis hildebrandtii</i> A. Gepp & E. Gepp	Chlorophyta	Udoteaceae	+	+	+	+
12.	<i>Cladophora glomerata</i> (Linnaeus) Kützing	Chlorophyta	Cladophoraceae	+	+	-	-
13.	<i>Cladophora vagabunda</i> (Linnaeus) van den Hoek	Chlorophyta	Cladophoraceae	+	+	-	-
14.	<i>Codium tomentosum</i> Stackhouse	Chlorophyta	Codiaceae	+	+	-	-
15.	<i>Ulva compressa</i> (Linnaeus) Nees	Chlorophyta	Ulveae	+	+	-	-
16.	<i>Ulva flexuosa</i> (Wulfen) J. Agardh	Chlorophyta	Ulveae	+	+	+	-
17.	<i>Ulva intestinalis</i> (Linnaeus) Nees	Chlorophyta	Ulveae	+	+	+	-
18.	<i>Halimeda gracilis</i> Harvey ex J. Agardh	Chlorophyta	Halimedaceae	+	+	+	-
19.	<i>Halimeda macroloba</i> Decaisne	Chlorophyta	Halimedaceae	+	+	-	-
20.	<i>Halimeda opuntia</i> (Linnaeus) Lamouroux	Chlorophyta	Halimedaceae	+	+	-	-
21.	<i>Halimeda tuna</i> (Ellis & Solander) Lamouroux	Chlorophyta	Halimedaceae	+	+	-	-
22.	<i>Ulva fasciata</i> Delile	Chlorophyta	Ulveae	+	+	-	-
23.	<i>Ulva lactuca</i> Linnaeus	Chlorophyta	Ulveae	+	+	+	+
24.	<i>Ulva reticulata</i> Forsskal	Chlorophyta	Ulveae	+	+	-	-
25.	<i>Valonia utricularis</i> (Roth) C. Agardh	Chlorophyta	Valoniaceae	-	+	-	-
26.	<i>Valoniopsis pachynema</i> (G. Martens) Børgesen	Chlorophyta	Valoniaceae	+	+	-	-
27.	<i>Colpomenia sinuosa</i> (Mertens ex Roth) Derbes & Solier	Ochrophyta	Scytosiphonaceae	+	+	-	-
28.	<i>Dictyota dichotoma</i> (Hudson) Lamouroux	Ochrophyta	Dictyotaceae	+	+	+	-
29.	<i>Hydroclathrus clathratus</i> (C. Agardh) Howe	Ochrophyta	Scytosiphonaceae	+	+	-	-
30.	<i>Lobophora variegata</i> (Lamouroux) Womersley ex Oliveira	Ochrophyta	Dictyotaceae	+	+	-	-
31.	<i>Padina boergesenii</i> Allender & Kraft	Ochrophyta	Dictyotaceae	+	+	-	-
32.	<i>Padina tetrastromatica</i> Hauck	Ochrophyta	Dictyotaceae	+	+	+	-
33.	<i>Padina boryana</i> Thivy	Ochrophyta	Dictyotaceae	+	+	-	-
34.	<i>Sargassum cinereum</i> (J. Agardh)	Ochrophyta	Sargassaceae	+	+	-	-
35.	<i>Turbinaria conoides</i> (J. Agardh) Kützing	Ochrophyta	Sargassaceae	+	+	+	-
36.	<i>Turbinaria decurrens</i> Bory de Saint Vincent	Ochrophyta	Sargassaceae	-	+	+	-
37.	<i>Turbinaria ornata</i> (Turner) J. Agardh	Ochrophyta	Sargassaceae	+	+	+	-
38.	<i>Acanthophora spicifera</i> (Vahl) Boergesen	Rhodophyta	Rhodomelaceae	+	+	-	-
39.	<i>Aghardiella subulata</i> (C. Agardh) Kraft and Wynne	Rhodophyta	Solieriaceae	+	+	+	-
40.	<i>Amphiroa anceps</i> (Lamarck) Decaisne	Rhodophyta	Corallinaceae	+	+	+	-
41.	<i>Amphiroa fragilissima</i> (Linnaeus) Lamouroux	Rhodophyta	Corallinaceae	+	+	+	-
42.	<i>Centroceras clavulatum</i> (C. Agardh) Montagne	Rhodophyta	Ceramiales	+	+	-	+
43.	<i>Ceramium diaphanum</i> (Lightfoot) Roth	Rhodophyta	Ceramiales	+	+	-	+
44.	<i>Gelidiella acerosa</i> (Forsskal) J. Feldmann & G. Hamel	Rhodophyta	Gelidiellaceae	+	+	-	-
45.	<i>Coelarthrum opuntia</i> (Endlicher) Boergesen	Rhodophyta	Rhodymeniaceae	+	-	-	-
46.	<i>Cryptonemia undulata</i> Sonder	Rhodophyta	Corynomorphaceae	+	-	-	-
47.	<i>Digenea simplex</i> (Wulfen) C. Agardh	Rhodophyta	Gelidiellaceae	+	+	-	-
48.	<i>Ceratodictyon variabile</i> (J. Agardh) R. E. Norris	Rhodophyta	Rhodymeniaceae	+	-	-	-
49.	<i>Gracilaria canaliculata</i> Sonder	Rhodophyta	Gracilariaceae	-	+	-	-
50.	<i>Gracilaria dura</i> (J. Agardh) J. Agardh	Rhodophyta	Gracilariaceae	+	+	-	-
51.	<i>Gracilaria corticata</i> (J. Agardh) J. Agardh	Rhodophyta	Gracilariaceae	+	+	-	-
52.	<i>Gracilaria edulis</i> (S. Gmelin) P. Silva	Rhodophyta	Gracilariaceae	+	+	-	-
53.	<i>Gracilaria textorii</i> (Suringar) De Toni	Rhodophyta	Gracilariaceae	+	-	-	-
54.	<i>Grateloupia filicina</i> (Lamouroux) C. Agardh	Rhodophyta	Halymeniaceae	+	-	-	-
55.	<i>Halymenia floresii</i> (Clemente & Rubio) C. Agardh	Rhodophyta	Halymeniaceae	+	-	-	-
56.	<i>Hypnea valentiae</i> (Turner) Montagne	Rhodophyta	Hypneaceae	+	+	+	-
57.	<i>Laurencia obtusa</i> (Hudson) Lamouroux	Rhodophyta	Rhodomelaceae	-	+	+	-
58.	<i>Palisada perforata</i> (C. Agardh) Greville	Rhodophyta	Rhodomelaceae	+	+	+	-
59.	<i>Liagora albicans</i> Lamouroux	Rhodophyta	Liagoraceae	+	+	+	-

Table 5. Checklist of seasonal diversity of seaweeds at Vadakkadu (Station-II).

Sl. No.	Name of Species	Phylum	Family	PM' 16	S'16	PRM'16	M'16
1.	<i>Halimeda gracilis</i> Harvey ex J. Agardh	Chlorophyta	Halimedaceae	+	0	0	0
2.	<i>Cladophora vagabunda</i> (Linnaeus) van den Hoek	Chlorophyta	Cladophoraceae	+	+	0	0
3.	<i>Halimeda macroloba</i> Decaisne	Chlorophyta	Halimedaceae	+	0	0	0
4.	<i>Halimeda tuna</i> (Ellis & Solander) Lamouroux	Chlorophyta	Halimedaceae	+	+	0	0
5.	<i>Caulerpa chemnitzia</i> Lamouroux	Chlorophyta	Caulerpaceae	0	+	0	0
6.	<i>Caulerpa racemosa</i> (Forsskal)	Chlorophyta	Caulerpaceae	0	+	0	0
7.	<i>Caulerpa racemosa</i> var. <i>macrophyta</i> (Sonder ex Kützinger) W.R. Taylor	Chlorophyta	Caulerpaceae	0	+	0	0
8.	<i>Caulerpa serrulata</i> (Forsskal) J. Agardh	Chlorophyta	Caulerpaceae	0	0	0	0
9.	<i>Phyllocladon anastomosans</i> J. Agardh	Chlorophyta	Siphonocladaceae	+	+	+	+
10.	<i>Turbinaria conoides</i> (J. Agardh) Kützinger	Ochrophyta	Sargassaceae	+	+	0	+
11.	<i>Turbinaria ornata</i> (Turner) J. Agardh	Ochrophyta	Sargassaceae	+	+	+	+
12.	<i>Turbinaria decurrens</i> Bory de Saint Vincent	Ochrophyta	Sargassaceae	0	0	+	+
13.	<i>Sargassum cinctum</i> J. Agardh	Ochrophyta	Sargassaceae	+	+	0	+
14.	<i>Sargassum ilicifolium</i> C. Agardh	Ochrophyta	Sargassaceae	+	+	+	+
15.	<i>Sargassum cinereum</i> J. Agardh	Ochrophyta	Sargassaceae	0	+	0	+
16.	<i>Sargassum polycystum</i> C. Agardh	Ochrophyta	Sargassaceae	+	+	+	+
17.	<i>Sargassum swartzii</i> Greville	Ochrophyta	Sargassaceae	0	0	0	0
18.	<i>Padina boergesenii</i> Allender & Kraft	Ochrophyta	Dictyotaceae	+	+	0	0
19.	<i>Padina tetrastrum</i> Hauck	Ochrophyta	Dictyotaceae	0	0	+	0
20.	<i>Hydroclatharus clathratus</i> (C. Agardh) Howe	Ochrophyta	Scytosiphonaceae	+	+	0	0
21.	<i>Fucus vesiculosus</i> Linnaeus	Ochrophyta	Fucaceae	0	0	0	+
22.	<i>Polycladia indica</i> (Thivy and Doshi) Mairh	Ochrophyta	Cystoseiraceae	0	0	0	+
23.	<i>Dictyota dichotoma</i> (Hudson) Lamouroux	Ochrophyta	Dictyotaceae	0	0	0	0
24.	<i>Stoechospermum marginatum</i> (C. Agardh) Kützinger	Ochrophyta	Dictyotaceae	0	0	0	0
25.	<i>Gelidiella acerosa</i> (Forsskal) J. Feldmann & G. Hamel	Rhodophyta	Gelidiellaceae	+	+	+	0
26.	<i>Kappaphycus alvarezii</i> Doty	Rhodophyta	Solieriaceae	+	+	0	+
27.	<i>Acanthophora spicifera</i> (Vahl) Boergesen	Rhodophyta	Rhodomelaceae	+	+	0	+
28.	<i>Gracilaria corticata</i> (J. Agardh) J. Agardh	Rhodophyta	Gracilariaceae	+	+	0	+
29.	<i>Hypnea valentiae</i> (Turner) Montagne	Rhodophyta	Hypneaceae	+	+	+	0
30.	<i>Gracilaria edulis</i> (S. Gmelin) P. Silva	Rhodophyta	Gracilariaceae	+	+	+	0
31.	<i>Gracilaria foliifera</i> (Forsskal) Boergesen	Rhodophyta	Gracilariaceae	+	+	0	0
32.	<i>Amphiroa anceps</i> (Lamarck) Decaisne	Rhodophyta	Corallinaceae	+	+	+	0
33.	<i>Amphiroa fragilissima</i> (Linnaeus) Lamouroux	Rhodophyta	Corallinaceae	+	+	+	0
34.	<i>Liagora albicans</i> Lamouroux	Rhodophyta	Liagoraceae	+	0	+	0
35.	<i>Palisada perforata</i> (C. Agardh) Greville	Rhodophyta	Rhodomelaceae	0	+	0	0
36.	<i>Laurencia obtusa</i> (Hudson) Lamouroux	Rhodophyta	Rhodomelaceae	+	+	0	+
37.	<i>Hypnea pannosa</i> J. Agardh	Rhodophyta	Hypneaceae	0	0	+	+
38.	<i>Ceramium diaphanum</i> (Lightfoot) Roth	Rhodophyta	Ceramiaceae	+	+	0	0
39.	<i>Centroceras clavulatum</i> (C. Agardh) Montagne	Rhodophyta	Ceramiaceae	+	+	0	0
40.	<i>Gracilaria opuntia</i> Durairatnam	Rhodophyta	Gracilariaceae	+	+	0	0
41.	<i>Digenea simplex</i> (Wulfen) C. Agardh	Rhodophyta	Gelidiellaceae	+	+	+	0
42.	<i>Coelarthrum opuntia</i> (Endlicher) Boergesen	Rhodophyta	Rhodymeniaceae	+	+	0	0
43.	<i>Ceratodictyon variabile</i> (J. Agardh) R.E. Norris	Rhodophyta	Rhodymeniaceae	+	+	0	0
44.	<i>Halymenia floresia</i> (Clemente & Rubio) C. Agardh	Rhodophyta	Halymeniaceae	+	0	0	0
45.	<i>Gracilaria textorii</i> (Suringar) De Toni	Rhodophyta	Gracilariaceae	0	+	0	0
46.	<i>Halymenia venusta</i> Boergesen	Rhodophyta	Halymeniaceae	0	+	0	0
47.	<i>Grateloupia filicina</i> (Lamouroux) C. Agardh	Rhodophyta	Halymeniaceae	0	+	0	0
48.	<i>Sarconema filiforme</i> (Sonder) Kylin	Rhodophyta	Solieriaceae	0	+	0	+
49.	<i>Gracilaria canaliculata</i> Sonder	Rhodophyta	Gracilariaceae	0	0	0	0

value showed heterogeneity in the biodiversity of seaweeds. The 'R' values of ANOSIM are tabulated in Table 2 [Figure 16].

5. Discussion

It was observed from the survey that Olaikuda was dominated with Chlorophyceae but Vaddakadu was with Rhodophyceae during post monsoon and summer. The monsoon season was dominated with Phaeophyceae at Vaddakadu, but this was not found at Olaikuda, during monsoon season. The two coastal areas were dominated with industrially

important seaweeds, such as *Gracilaria*, *Gelidiella* which is utilized seaweed for agar production and *Sargassum*, *Turbinaria*, which are exploited for alginates production. The brown seaweed *Fucus vesiculosus* and red seaweed *Aghardhiella subulata* were the uncommon species newly reported from this area. The variation of seaweeds diversity in various seasons may be due to variation of nutrients supply, salinity and temperature, light availability and a wave action during different seasons (Lobban and Harrison, 1994; Nybakken, 2001). But in post monsoon and summer, the less wave action and less turbidity might have favoured the growth of more species of seaweeds, and the seaweed diversity was found

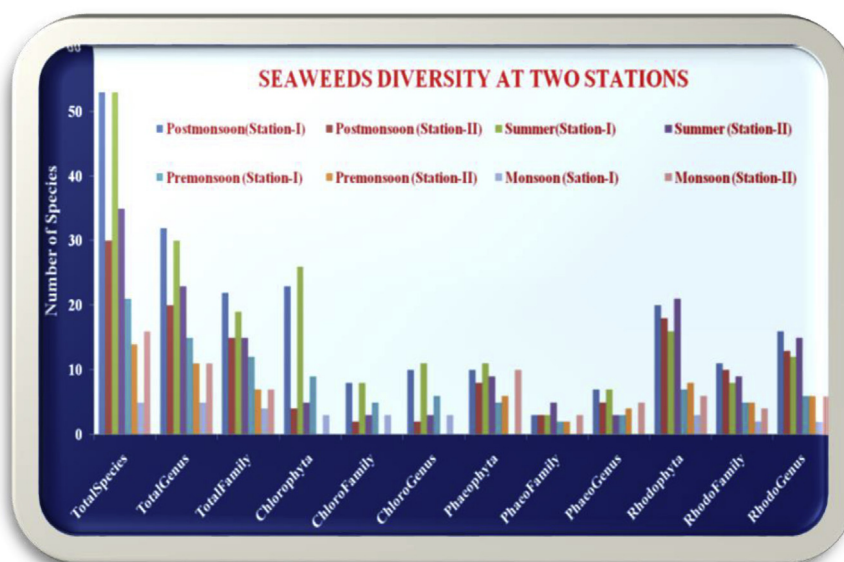


Figure 10. Seasonal distribution of seaweeds at Olaikuda and Vaddakadu.

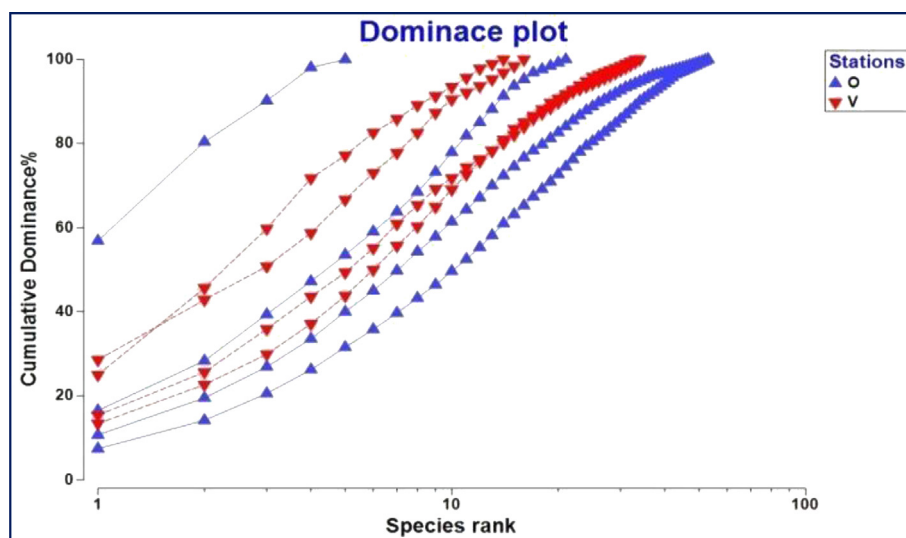


Figure 11. K dominance curve of two stations together where O and V denoted Olaikuda and Vaddakadu.

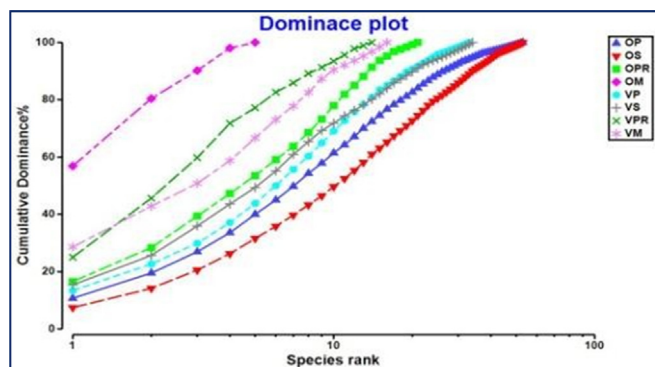


Figure 12. K dominance curve season wise, PM-post monsoon, S - summer, PR-pre monsoon and M-monsoon of both stations.

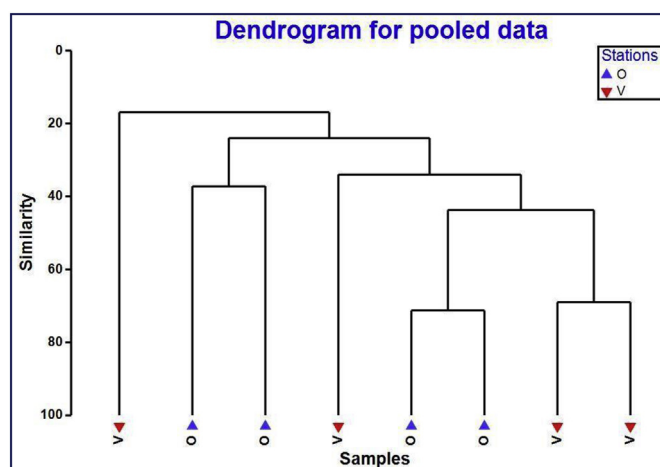


Figure 13. Cluster analysis of both stations combined, where O and V denoted Olaikuda and Vaddakadu.

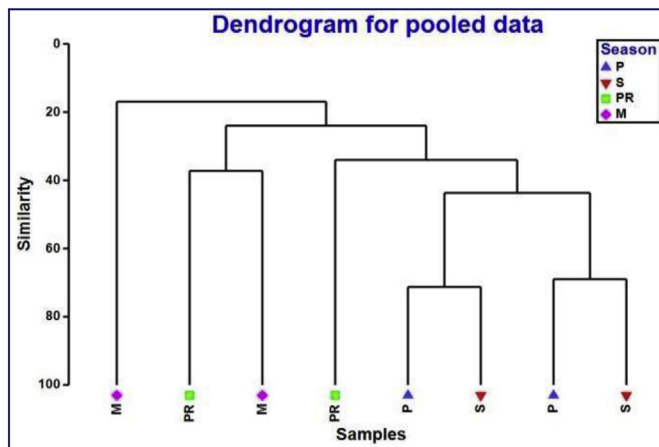


Figure 14. Cluster analysis of four seasons combined, where P denoted post monsoon, S denoted summer, PR denoted pre-monsoon and M denoted monsoon.

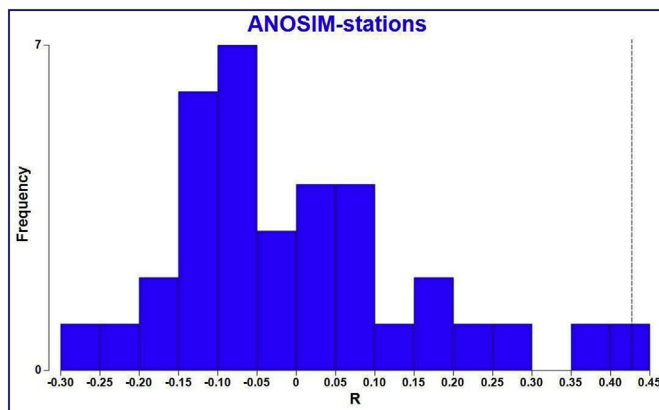


Figure 15. Similarity histogram of seaweed diversity between two stations.

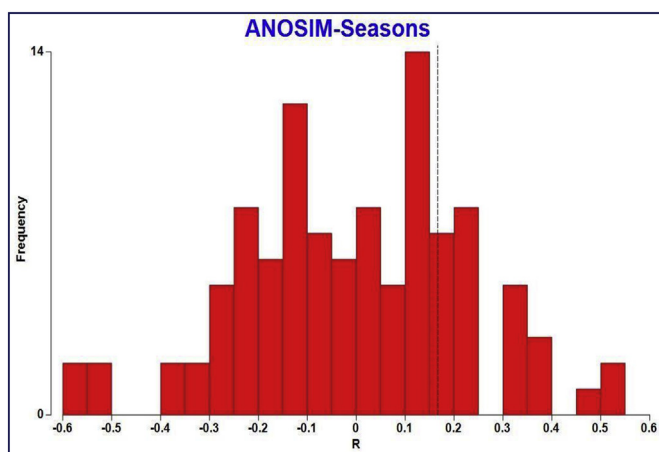


Figure 16. Similarity histogram between four seasons seaweed diversity.

high during post monsoon and summer in comparison to pre-monsoon and monsoon in both stations.

It is interesting to note that though, Vaddakadu is quite undisturbed but diversity is lower than Olaikuda. Despite heavy anthropogenic disturbances, in Vaddakadu, the growth of the seaweeds was abundant and dense but in Olaikuda growth of seaweeds was less and scatterly distributed along the coast. Vertical distribution of seaweeds land to seaward side was also observed during survey. Seaweeds growth and

vegetation cover were more in seaward side but the seaweed diversity was less in shallow coastal water on landward side. The seasonal variation, succession and vegetation patterns of seaweed diversity may be due to the variation of intensity of light, rainfall, and salinity and nutrients supply. Seaweed diversity and distribution along the Indian coast have been reported by many researchers (Untawale et al., 1989; Kalimuthu et al., 1995; Jayachandran and Ramaswamy, 1997; Stella et al., 1997; Selvaraj and Selvaraj, 1997; Mohammed et al., 1999; Kerkar, 2004; Rath and Adhikary, 2006; Satheesh and Wesley, 2012; Roy et al., 2015). However, the present study areas were not explored for their macro algal diversity. Current work is the first survey record of seaweeds diversity at Olaikuda and Vaddakadu. The baseline data on seaweed diversity of the two coastal areas will be useful for future monitoring and conservation of seaweed resources.

6. Conclusions

The seasonal diversity of seaweeds in two stations viz. Olaikuda and Vaddakadu, Rameshwaram, Gulf of Mannar was investigated for the first time during 2016. Totally 74 species including 28 species of Chlorophyceae, 18 species of Phaeophyceae and 28 species of Rhodophyceae were recorded. At Olaikuda coast, there were 59 seaweeds species including 26 Chlorophyceae, 22 Rhodophyceae and 11 Phaeophyceae, while at Vaddakadu, there were 49 seaweeds species with 9 Chlorophyceae, 15 Phaeophyceae and 25 Rhodophyceae. The seasonal survey showed that green and red seaweeds were found with more number of species than brown seaweeds. At both stations, seaweed diversity was the high during post monsoon as well as monsoon as compared to pre-monsoon and summer. This seasonal pattern of diversity was also revealed by k dominance curve and the groups formed by species assemblage cluster in dendrogram Olaikuda had more diversity than Vaddakadu. The biodiversity indices of Shannon Weaver Diversity index, Simpson species richness, Pielou's evenness, Fisher alpha index and taxonomic species diversity index also indicated the similar pattern of seasonal diversity at the two stations. Both stations had higher seaweed diversity during post monsoon and summer than in pre monsoon and summer. The post monsoon and summer had higher species evenness and richness than monsoon and pre-monsoon.

Declarations

Author contribution statement

Suparna Roy: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Funding statement

This work was supported by the Department of Science and Technology (DST), Govt. of India.

Competing interest statement

The authors declare no conflicts of interest.

Additional information

No additional information is available for this paper.

Acknowledgements

Author thanks to Prof. P. Anantharaman C.A.S in Marine Biology for his support, Author acknowledges her sincere thanks to Dean and Director, C.A.S in Marine Biology and authorities of Annamalai University for providing facilities.

References

- Bhagyaraj, I., Kunchithapatham, V.R., 2016. Diversity and distribution of seaweeds in the shores and water lagoons of Chennai and Rameshwaram coastal areas, South-Eastern coast of India. *Biodiversity Journal* 7 (4), 923–934.
- Boergesen, F., 1928. On *Rosenvingea stellata*, a new Indian alga and on an interesting littoral algal vegetation in which this species is characteristic constituent. *Dansk Botnisk Arkiv* 5, 511.
- Bray, J.R., Curtis, J.T., 1957. An ordination of the inland forest communities of southern Wisconsin. *Ecol. Monogr.* 27, 325–349.
- Canciyaal, J., Mogalekar, H.S., Jawahar, P., 2014. Seaweed diversity of Tuticorin coastal waters along south east coast of India. *International Journal of Current.*
- Dawes, C.J., McIntosh, R.P., 1981. The effect of organic material and inorganic ions on the photosynthetic rate of the red alga *Bostrychia binderi* from a Florida estuary. *Mar. Biol.* 64, 213–219.
- Doss, A., Rukshana, M.S., 2016. Distribution pattern of marine seaweeds in the Manapad coastal region. *Saudi J. Pathol. Microbiol* 1 (1), 10–13.
- Gray, J.S., Clarke, K.R., Warwick, R.M., Hobbs, J., 1990. Detection of initial effect of pollution on marine benthos: an example from the Ekofish and Eldfish, oilfields, North Sea. *Mar. Ecol. Prog. Ser.* 66, 285–299.
- Harley, C.D.G., Anderson, K.M., Demes, K.W., Jorve, J.P., Kordas, R.L., Coyle, T.A., 2012. Effects of climate change on global seaweed communities. *J. Phycol. Phycological Society of America* 48 (5), 1064–1078.
- Iyengar, M.O.P., 1927. Krusadai island flora. *Bulletin of madras government museum.* New Ser. Nat. Hist. Sect. 1, 185–188.
- Janet Rani, R., Parthipan, b., Sundar, sk., John Peter Paul, J., 2013. Seaweed diversity and distribution in the south-east coast of Tamil Nadu, India. *IJBPA* 2 (3), 675–682.
- Jayachandran, V., Ramaswamy, V., 1997. Algae from pondicherry coast. *Seaweed Res. Utiln.* 19 (No. 1 & 2), 17–20.
- Jha, B., Reddy, C.R.K., Thakur, M.C., Rao, M.U., 2009. Seaweeds of India: the Diversity and Distribution of Seaweeds of the Gujarat Coast. Springer, Dordrecht, p. 198.
- Kalimuthu, S.N., perumal, Kalia, Ramalingam, J.R., 1995. Distribution of algae and sea grasses in the estuaries and backwaters of Tamilnadu and Pondicherry. *Seaweed Res. Utiln.* 17, 79–86.
- Kerkar, V., 2004. Addition to marine algal flora of Goa. *Seaweed Res. Utiln.* 36, 19–21.
- Krishnamurthy, V., 1957. The genus *bangiopsis* schmitz from south India. *Phytomorphology* 7, 102–112.
- Lobban, C.S., Harrison, P.J., 1994. *Seaweed Ecology and Physiology*. Cambridge University Press, New York, New York, USA, pp. 134–145.
- Mohammed, G., Nasser, A.K.V., Koya, C.V.K., 1999. Distribution and abundance of seaweeds on the coral reef at Minicoy island Lakshadweep. *Seaweed Res. Utiln.* 22, 7–13.
- Nybakken, J.W., 2001. *Marine Biology: an Ecological Approach*, fifth ed. Benjamin Cummings, San Francisco, California.
- Oza, R.M., Zaidi, S.H., 2001. A Revised Checklist of Indian marine Algae. CSMCRI Publication, Bhavnagar, India, p. 296.
- Rath, J., Adhikary, S.P., 2006. Marine macro algae of Orissa, East coast of India. *ALGAE* 21, 49–59.
- Roy, S.S., Harshad, B., Bhargav, V., Nilesh, D. Lopamudra, Pathak, B., 2015. Diversity and distribution of marine macro algae of selected reefs and islands of the Gulf of kachchh. *Seaweeds Research and Utilization Journal* 37 (1), 12–19. ISSN0971-7560.
- Sahayara, K., Rajesh, J.S., Asha, A., Rathi, J.M., Raja, P., 2014. Distribution and diversity assessment of the marine macro algae at four southern districts of Tamil Nadu, India. *Indian Journal of Geo-Marine Sciences* 43 (4), 607–617.
- Satheesh, S., Wesley, S.G., 2012. Diversity and distribution of seaweeds in the Kundakulum coastal waters, South-Eastern coast of India. *Biodiversity Journal* 3 (1), 79–84.
- Selvaraj, R., Selvaraj, R., 1997. Distribution and Diversity of Seaweeds in Tiruchendur and Idianthakarai, 19. *Seaweed Research and Utilization*, pp. 115–123.
- Stella, R., Rosakutty, P.J., Lazarus, S., 1997. A study on the flora and fauna of arckiapuram coast of Tamil Nadu. *Seaweed Research and Utilisation* 19, 55–61.
- Thivy, F., 1948. A revision of the genus *Turbinaria* Lamax. In: *Proceedings of the Thirty-Fifth Indian Science Congress*, Patna.
- Umamaheswara Rao, M., 1969. *Liagora visakhapatnamensis*, a new species from India. *Hydrobiologia* 33, 201–208.
- Untawale, A.G., Reddy, C.R.K., Ambiyee, V.D., 1989. Marine algal flora of submerged angria bank (arabian sea). *Indian J. Mar. Sci.* 18, 207–209.
- Waghmode, A.V., 2017. Diversity and distribution of seaweeds from the west coast of Maharashtra. *J. Algal Biomass Utiln.* 8 (3), 29–39.