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Research Article
Seasonal Variation of Physicochemical Parameters and Their Impact on the Algal Flora of Chimmony Wildlife Sanctuary

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Abstract

Background and Objective: The lack of biodiversity knowledge and biodiversity loss are the two inevitable truths around us. Algae are the most crucial organism in our entire biodiversity. The seasonal variation of algal diversity can monitor the environmental changes of the freshwater ecosystem. The present study was conducted because the seasonal changes of algal diversity in Chimmony Wildlife Sanctuary were utterly unknown. **Materials and Methods:** The algal samples were collected and preserved from ten stations for three seasons (pre-monsoon, monsoon, post-monsoon). The physicochemical parameters of water like temperature, pH, total dissolved solids, total dissolved oxygen, total alkalinity and light intensity of the sampling stations were recorded. **Results:** The study revealed that the seasonal variation of physicochemical parameters provoked a change in the diversity of Algae. The Chimmony Wildlife Sanctuary has its highest algal diversity during pre-monsoon season. The Chlorophyceae Algae were dominant during the pre-monsoon season, while the Cyanophycean Algae were dominant during monsoon season. The ANOVA (two-way) analysis showed no significant difference between stations and there is a considerable difference between seasons for dissolved oxygen, alkalinity, temperature and total dissolved solids. While for pH, it showed no significant difference between seasons and stations but for light intensity, it showed a substantial difference between stations and seasons. A negative correlation was observed between algal species and seasons. The temperature and dissolved oxygen showed a negative correlation. **Conclusion:** The physicochemical parameters were changed according to the seasonal variation. Since Algae act as a biological pollution indicator for all the water resources, the study of algal flora according to the seasonal variation is crucial.

Key words: Algal diversity, Chimmony Wildlife Sanctuary, physicochemical parameters, seasonal variation, phytoplankton, bioindicator, freshwater ecosystem

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The most abundant aquatic organisms present in a freshwater ecosystem are Algae[1]. Algae are considered an imperative component of lakes and reservoirs because they influence biological diversity[2]. They help regulate carbon and energy transfer between the trophic levels[3]. Many aquatic plants and animals directly depend upon phytoplankton, a direct food source. Hence phytoplankton plays a vital role in the aquatic ecosystem[4]. The establishment of Algae in a water body is directly correlated to the physicochemical parameters of water[5]. Depending upon water's physicochemical parameters, the distribution of phytoplankton varies[2]. The algal diversity varies between seasons due to the seasonal fluctuations in the physicochemical parameters[6]. The seasonal changes of Algae in lakes and reservoirs provide a precise idea of the mechanism of eutrophication and its impact on the aquatic ecosystem[7]. As Algae are the most influential primary producers in a freshwater ecosystem, they act as an environmental bioindicator[8]. The information about Algae and their response to particular environmental conditions must be studied and documented because it helps assess water quality[9].

The Chimmony Wildlife Sanctuary is an unexplored area for seasonal studies of Algae. Hence the main objective of our survey was to study the seasonal variation of physicochemical parameters and study their impact on the algal flora of Chimmony Wildlife Sanctuary.

MATERIALS AND METHODS

Study area: The Chimmony Wildlife Sanctuary is located in the Thrissur District, Kerala between 10° 24" 7.2" to 10°28'58.8" East latitude and 76° 25' 1.2" to 76° 33'36" North longitude. Ten study sites are selected and the location details in (Table 1).

Sample collection, identification and sample processing: In the present study, algal samples were collected from ten different sites during pre-monsoon (February to May), Monsoon (June to September), post-monsoon (October to January). The study was conducted between December, 2019-2021. The algal samples were randomly collected from the sites and preserved in plastic containers with 4% formalin for further identification. All the physicochemical parameters were recorded at the same time of collection. The water temperature and TDS were measured using the HM Digital meter (AP-1, Range: 0-80°C, Resolution: 0.1°C, Accuracy: ±2). The pH was measured using digital pH meter (AQUASOL-AM-P-PH, Range: 0-14, Resolution: 0.1 pH, Accuracy: ±0.1).

Table 1: Latitude and longitude of sampling sites

Sampling sites	Latitude and longitude
Pookoyil thodu	10°27' 36" E and 76°28' 04" N
Kidakkapara thodu	10°27' 51" E and 76°27' 57" N
Viraku thodu	10°26' 59" E and 76°26' 40" N
Nellipara thodu	10°26' 45" E and 76°27' 50" N
Anaporu thodu	10°25' 48" E and 76°30' 25" N
Kodakallu thodu	10°26' 20" E and 76°30' 51" N
Odan thodu	10°27' 08" E and 76°30' 17" N
Mullapara thodu	10°27' 21" E and 76°29' 54" N
Payampara thodu	10°27' 16" E and 76°29' 29" N
Chimmony Dam	10°27' 38" E and 76°28' 20" N

The light intensity was measured using Equinox lux meter (LM 802, Range: 0-200000 Lux, Resolution: 0.1 Lux, Accuracy: 3%). The amount of dissolved oxygen (Range: 0-10 mg L^{-1}, Resolution: 0.1 mg L^{-1}, Accuracy: ±0.4 mg L^{-1}) and alkalinity (Range: 0-500 mg L^{-1}, Resolution: 1 mg L^{-1}, Accuracy: ±5 mg L^{-1}) were determined using Hanna HI83300 multiparameter photometer (Hanna Instruments Inc., Rhode Island, USA). The dissolved oxygen and alkalinity were measured concerning the manufacturer's standard operating procedure and kits. The seasonal rainfall details were collected from Chalakudy Hydrology Department, Kerala. The algal specimens were observed under Leica Microscope (DMi 8) and digital photomicrographs were taken using Leica DFC 7000T. The photomicrographs were taken within a few days of sample collection to capture the realistic morphology. All the algal samples were deposited in Plant Science Laboratory, Department of Life Sciences, Christ (Deemed to be University), Bangalore. The algal specimens were identified using standard literature, monographs and research papers[10-24].

Statistical analysis: All the statistical analyses were performed in SPSS software. Two-way ANOVA was conducted to determine the significant difference in physicochemical parameters between stations and seasons. Pearson correlation was performed to study the relationship between seasons and algal species and also between dissolved oxygen and temperature.

RESULTS

The data obtained shows that seasonal variation in physicochemical parameters prompted a change in the diversity of Algae in all ten study stations (Table 2). During the pre-monsoon season, the highest number of Algae was reported (i.e., 40) (Table 3), which reduced to 29 during the monsoon season (Table 4) and again increased to 34 Algal species in the post-monsoon season (Table 5).

Table 2: Seasonal variation of physicochemical parameters in Chimmony Wildlife Sanctuary

	Stations	pH	Temperature (°C)	TDS (ppm)	Light intensity (lux)	Alkalinity (mg L^{-1})	Dissolved oxygen (mg L^{-1})	Rainfall (mm)
Pre-monsoon season	S_1	7.2	32.4	52.5	42935	1.9	4.39	153.6
	S_2	7.1	26.6	48.5	36478	1.7	5.96	
	S_3	7.4	29.2	61	63493.5	3.3	5.97	
	S_4	7.6	28.7	45.5	33001	1.35	5.40	
	S_5	7	27.9	55	32103	1.1	5.67	
	S_6	6.7	29.9	39	30412.5	1.1	5.40	
	S_7	7	29.6	52	57162	2.35	5.12	
	S_8	7.4	25.2	56.5	67775	2.85	6.15	
	S_9	7	25.3	51	33040.5	1.15	6.28	
	S_{10}	7	32.2	62.5	71203	3.6	4.67	
Monsoon season	S_1	7	25.4	16.5	3150	2.85	6.32	544.5
	S_2	6.7	25	11.5	2350	2.8	6.34	
	S_3	7.7	24.2	14.5	19550	6.5	6.32	
	S_4	7.5	25.2	13	15888	4.95	5.54	
	S_5	7.3	24	11	7900	6.25	6.72	
	S_6	7	24.7	14.5	8950	5.65	6.84	
	S_7	7.4	25.2	13	1871.5	2.85	5.49	
	S_8	6.7	25.1	16.5	5982.5	3.6	6.24	
	S_9	7.2	25.3	9.75	1903	6.8	6.60	
	S_{10}	8	26	13.5	26000	6.75	7.00	
Post-monsoon season	S_1	6.4	25.2	35.5	26663	4	5.92	193.1
	S_2	7.4	26.6	39	25318	2.35	5.74	
	S_3	7.5	25.2	49	32653	2.75	6.52	
	S_4	6.7	26.5	38	27384	3.7	5.84	
	S_5	7.7	26.4	35	27804	4.3	6.57	
	S_6	6.5	25.3	37	25836.5	2.8	6.31	
	S_7	6.4	25.5	43.5	30298	4.45	6.49	
	S_8	6.9	25.1	55.5	30201.5	5.1	6.65	
	S_9	7	26.5	34.5	26234.5	2.95	5.72	
	S_{10}	7.3	28.5	15.5	31618.5	5.15	5.23	

Table 3: Pre-monsoon algal diversity in Chimmony Wildlife Sanctuary

Pre-monsoon (February to May)

	Stations									
Name of the species	1	2	3	4	5	6	7	8	9	10
Chlorophyceae										
Chlamydomonas globosa snow	-	-	+	-	-	-	-	-	-	+
Gonium pectorale mueller	-	-	-	-	+	-	+	-	-	+
Monoraphidium griffithii (Berkeley) Komarova-Legnerova	-	-	+	-	-	-	+	-	-	+
Monoraphidium indicum Hindak	-	-	+	-	-	-	+	-	-	+
Scenedesmus quadricauda var. Maximus West and West	+	-	-	-	-	-	-	+	-	+
Scenedesmus quadricauda (Turpin) Brebisson	-	+	-	-	-	-	-	-	-	+
Ulothrix aequalis Kuetzing	-	+	+	-	-	-	-	-	-	-
Coleochaete orbicularis Pringsheim	-	-	+	-	-	-	-	-	-	-
Trentepohlia aurea (L.) Martius	-	-	+	-	-	-	-	-	-	-
Bulbochaete valida Wittrock	-	-	-	+	-	-	-	-	-	-
Oedogonium areschougii Wittrock	+	-	-	-	-	-	-	-	+	-
Oedogonium croasdale Jao	-	-	-	-	-	+	-	+	-	-
Mougeotia scalaris Hassall	-	-	-	+	-	-	+	-	-	-
Spirogyra acanthophora (Skuja) Czurda	-	+	-	-	-	-	-	-	-	-
Spirogyra condensata (Vauch.) Kuetzing	-	-	-	-	+	-	-	-	-	-
Spirogyra micropunctata Transeau	-	-	-	+	-	-	-	-	+	-
Spirogyra novaeangliae Transeau	-	-	-	-	-	-	+	+	-	-
Spirogyra rhizobrachialis Jao	+	-	-	-	-	-	-	-	+	-
Cylindrocystis brebissonii (Ralfs) De Bary	-	+	-	-	-	+	-	+	-	-
Netrium digitus (Ehrbg.) Itzigs. And Rothe	-	-	-	-	-	-	-	+	-	-
Closterium ehrenbergi Meneghinii var. ehrenbergii	-	-	-	-	-	-	-	+	-	-
Closterium moniliferum Ehrenberg ex Ralfs	-	-	-	-	-	-	+	+	-	-

Table 3: Continue

Pre-monsoon (February to May)

	Stations									
Name of the species	1	2	3	4	5	6	7	8	9	10
Closterium tumidulum Gay	-	+	-	-	-	-	-	-	-	-
Cosmarium subtumidum Nordst	-	-	-	+	-	-	-	-	+	-
Micrasterias radians Turn var. Bogoriensis (Breb) G.S West	-	-	-	-	-	-	+	+	-	-
Pleurotaenium trabecula (Ehrbg) Nag	+	-	-	-	-	-	-	-	-	-
Nitella furcata (Roxburgh apud Bruzelius) Agardh	-	-	-	-	-	-	-	+	-	-
Euglena										
Euglena elastica Prescott	-	-	+	-	+	-	-	-	-	-
Euglena minuta Prescott	-	+	-	-	-	-	-	-	+	-
Phacus curvicauda Swirenko	-	-	-	+	-	-	+	-	-	+
Phacus obolus Pochmann	-	-	+	-	+	-	-	+	-	+
Phacus orbicularis var. *caudatus* Skzortzow	+	-	-	-	-	+	-	-	-	+
Lepocinclis acus (Muller) marin and Melkonian	-	-	-	+	-	-	+	-	-	+
Trachelomonas hispida var. *Papillata* Skvortzow	+	-	+	-	-	-	-	-	-	+
Rhodophyceae										
Batrachospermum ectocarpum Sirodot	-	-	+	-	-	-	-	-	-	-
Cyanophyceae										
Microcystis aeruginosa Kutz.	-	-	-	-	-	-	-	-	-	+
Oscillatoria limosa Agardh ex Gomont	-	+	-	-	-	-	-	-	-	-
Oscillatoria subbrevis Schmidle	+	-	-	-	-	+	-	-	-	-
Phormidium hansgirgi Schmidle	-	-	+	-	-	+	-	-	-	-
Phormidium microtomum Skuja	-	-	-	-	+	-	-	-	-	-

Table 4: Monsoon algal diversity in Chimmony Wildlife Sanctuary

Monsoon (June to September)

	Stations									
Name of the species	1	2	3	4	5	6	7	8	9	10
Chlorophyceae										
Tetraspora gelatinosa (Vauch.) Desvaux	+	+	-	-	-	-	-	-	-	-
Chlorococcum humicola (Naeg.) Rabenhorst	-	-	-	+	-	+	-	-	+	-
Spirogyra micropunctata Transeau	-	-	-	+	-	-	-	-	+	-
Cylindrocystis minutissima Turn.	-	+	-	-	-	+	-	+	-	-
Netrium digitus (Ehrbg.) Itzigs. and Rothe	-	-	-	-	-	-	-	+	-	-
Actinotaenium silvae-nigrae (Rabanus) Kouwets and Coesel	-	-	+	-	+	-	-	-	-	-
Cosmarium botrytis Menegh	-	-	+	-	-	-	-	-	-	-
Nitella furcata (Roxburgh apud Bruzelius) Agardh	-	-	-	-	-	-	-	+	-	-
Cyanophyceae										
Aphanocapsa pulchra (Kutz) Rabenh	+	-	-	+	-	-	-	-	-	+
Microcystis aeruginosa Kutz.	-	-	-	-	-	-	-	-	-	+
Oscillatoria limosa Agardh ex Gomont	-	+	-	-	-	-	-	-	-	-
Oscillatoria peronata Skuja	-	-	-	-	-	-	-	+	-	-
Oscillatoria vizagapattensis Rao, C. B	-	-	-	-	-	-	-	+	-	-
Phormidium abronema Skuja	-	-	-	-	-	-	+	-	+	-
Phormidium calcicola Gardner	-	-	+	-	-	-	-	-	-	-
Phormidium corium (Ag.) Gomont	-	-	-	-	-	-	+	-	-	-
Phormidium hansgirgi Schmidle	-	-	+	-	-	+	-	-	-	-
Phormidium molle (Kutz.) Gomont	+	-	-	-	-	-	-	-	+	-
Phormidium usterii Schmidle	-	-	-	-	-	-	-	+	-	-
Lyngbya hieronymusii Lemmermann	-	-	-	-	+	-	-	-	+	-
Anabaena anomala Fritsch	+	+	-	-	-	-	-	-	-	-
Anabaena sphaerica Bornet et Flahault	-	-	+	-	-	-	-	-	-	-
Pseudanabaena catenata Lauterb.	-	-	-	-	+	-	-	-	+	-
Dichothrix baueriana (Grun.) Born. et Flah	-	-	-	-	-	-	-	-	+	-
Scytonema bohneri Schmidle	-	-	-	-	-	-	+	-	-	-
Scytonema coactile Montagne ex Born. et Flah	+	-	-	-	-	-	-	-	-	-
Scytonema ocellatum Lyngbye ex Born. et Flah	-	-	-	-	+	-	-	-	+	-
Scytonema rivulare Borzi ex Born. et Flah	-	-	-	-	-	+	-	+	-	-
Stigonema aerugineum Tilden	-	-	-	-	-	-	-	-	+	-

Table 5: Post-monsoon algal diversity in Chimmony Wildlife Sanctuary

Post-monsoon (October to January)										
	Stations									
Name of the species	1	2	3	4	5	6	7	8	9	10
Chlorophyceae										
Chlamydomonas globosa Snow	-	-	+	-	-	-	-	-	-	+
Tetraspora gelatinosa (Vauch.) Desvaux	+	+	-	-	-	-	-	-	-	-
Monoraphidium griffithii (Berkeley) Komarova-Legnerova	-	-	+	-	-	-	+	-	-	+
Monoraphidium indicum Hindak	-	-	+	-	-	-	+	-	-	+
Scenedesmus quadricauda var. Maximus West and West	+	-	-	-	-	-	-	+	-	+
Scenedesmus quadricauda (Turpin) Brebisson	-	+	-	-	-	-	-	-	-	+
Pithophora oedogonia (Mont.) Wittrock	-	-	-	+	+	-	-	-	+	-
Zygnema carinatum Taft	+	-	-	+	-	-	-	+	-	-
Spirogyra acanthophora (Skuja) Czurda	-	+	-	-	-	-	-	-	-	-
Spirogyra decimina (Mueller) Kuetzing	-	-	+	-	-	-	-	-	+	-
Spirogyra fuellebornei Schmidle	-	-	-	-	-	+	-	-	-	-
Spirogyra novaeangliae Transeau	-	-	-	-	-	-	-	+	+	-
Netrium digitus (Ehrbg.) Itzigs. and Rothe	-	-	-	-	-	-	-	+	-	-
Actinotaenium silvae-nigrae (Rabanus) Kouwets and Coesel	-	-	+	-	-	+	-	-	-	-
Closterium ehrenbergii Meneghinii var. *ehrenbergii*	-	-	-	-	-	-	-	+	-	-
Closterium moniliferum Ehrenberg ex Ralfs	-	-	-	-	-	-	+	+	-	-
Cosmarium botrytis Menegh	-	-	+	-	-	-	-	-	-	-
Staurastrum zonatum Borges var. *majus* Presc.	-	-	-	-	-	+	-	-	-	+
Nitella furcata (Roxburgh apud Bruzelius) Agardh	-	-	-	-	-	-	-	+	-	-
Euglena										
Phacus curvicauda Swirenko	-	-	-	+	-	-	+	-	-	+
Phacus obolus Pochmann	-	-	+	-	+	-	-	+	-	+
Phacus orbicularis var. *caudatus* Skzortzow	+	-	-	-	-	+	-	-	-	+
Lepocinclis acus (Muller) marin and Melkonian	-	-	-	+	-	-	+	-	-	+
Rhodophyceae										
Batrachospermum ectocarpum Sirodot	-	-	+	-	-	-	-	-	-	-
Cyanophyceae										
Microcystis aeruginosa Kutz.	-	-	-	-	-	-	-	-	-	+
Microchaete uberrima Carter, N.	-	-	-	-	+	-	-	-	+	-
Phormidium microtomum Skuja	-	-	-	-	+	-	-	-	-	-
Phormidium retzii (Ag.) Gomont	-	+	-	-	-	+	-	-	-	-
Phormidium truncicola Ghose	-	-	-	+	-	-	+	-	-	-
Lyngbya hieronymusii Lemmermann	-	-	-	-	+	-	-	-	+	-
Anabaena sphaerica Bornet et Flahault	-	-	+	-	-	-	-	-	-	-
Cylindrospermum stagnale (Kutz.) Born. et Flah	-	-	+	-	-	-	-	-	-	-
Gloeotrichia echinulata (J. E. Smith) P. Richter	+	-	+	-	-	-	-	-	-	-
Nostochopsis lobatus Wood em. Geitler	-	-	+	-	-	-	-	-	-	-

Table 6: ANOVA of seasonal variation in dissolved oxygen

Sources	Type II sum of squares	df	Mean square	F	Significance
Stations	2.886	9	0.321	1.157	0.376[a]
Seasons	3.773	2	1.886	6.808	0.006[b]
Error	4.988	18	0.277		
Total	1084.160	30			

[a]p>0.05, no significant difference between stations, [b]p<0.05, significant difference between seasons

Dissolved oxygen: The dissolved oxygen concentration was found high during the monsoon season compared to other seasons (Table 2). The lowest dissolved oxygen, 6.28 mg L^{-1}, was recorded during the pre-monsoon season, which gradually increased during post-monsoon seasons (6.65 mg L^{-1}) to the highest in monsoon (7.00 mg L^{-1}). The mean dissolved oxygen in the pre-Monsoon season was 5.49 and 6.33 mg L^{-1} during the monsoon season and 6.09 mg L^{-1} during the post-monsoon season.

The ANOVA analysis of dissolved oxygen showed no significant difference between stations ($p>0.05$) but there is a considerable difference between seasons ($p<0.05$) (Table 6).

Table 7: Correlation between dissolved oxygen and temperature

Correlations		DO	Temperature
DO	Pearson correlation	1	-0.821*
	Sig. (2-tailed)		0.000
	N	30	30
Temperature	Pearson correlation	-0.821*	1
	Sig. (2-tailed)	0.000	
	N	30	30

*Implies a negative correlation between DO and temperature

Table 8: ANOVA of seasonal variation in temperature

Sources	Type II sum of squares	df	Mean square	F	Significance
Stations	30.456	9	3.384	1.525	0.213[a]
Seasons	72.085	2	36.042	16.240	0.000[b]
Error	39.949	18	2.219		
Total	21363.970	30			

[a]p>0.05, no significant difference between stations and [b]p<0.05, significant difference between seasons

Table 9: ANOVA of seasonal variation in pH

Sources	Type II sum of squares	df	Mean square	F	Significance
Stations	1.814	9	0.202	1.480	0.229[a]
Seasons	0.369	2	0.184	1.354	0.283[b]
Error	2.451	18	0.136		
Total	1526.890	30			

[ab]p>0.05, no significant difference between stations and between seasons

Table 10: ANOVA of seasonal variation in Alkalinity

Source	Type II sum of squares	df	Mean square	F	Significance
Stations	16.556	9	1.840	1.226	0.339[a]
Seasons	41.440	2	20.720	13.805	0.000[b]
Error	27.016	18	1.501		
Total	466.288	30			

[a]p>0.05, no significant difference between stations and [b]p>0.05, significant difference between seasons

There is a negative correlation between dissolved oxygen and temperature, which shows that whenever temperature increases, dissolved oxygen decreases (Table 7).

Temperature: The water temperature varied from 25.2-32.4°C in pre-monsoon seasons, 24.0-26°C in monsoon season and 25.1-28.5°C during the post-monsoon season (Table 2). The highest water temperature was recorded during the pre-monsoon season (32.4°C) and the lowest was recorded during the monsoon season (24.0°C). The mean water temperature in the pre-monsoon season was 28.7 and 25.01°C during the monsoon season and 26.08°C during the post-monsoon season. The ANOVA analysis of temperature showed no significant difference between stations (p>0.05) but there is a considerable difference between seasons (p<0.05) (Table 8).

pH: The pH of the water body fluctuated between 6.7-7.6 during the pre-monsoon season, 6.7-8 during monsoon season and 6.4-7.5 during the post-monsoon season (Table 2). During pre-monsoon seasons, mean pH values were 7.14, during monsoon 7.25 and during post-monsoon 6.98. The ANOVA analysis of pH showed no significant difference between stations (p>0.05) and between seasons. (Table 9).

Alkalinity: The alkalinity ranged between 1.1-3.6 mg L^{-1} during the pre-monsoon season, 2.8-6.8 mg L^{-1} during monsoon season and 2.35-5.15 mg L^{-1} during the post-monsoon season (Table 2). During the study, the highest mean alkalinity was reported during the monsoon season (4.9 mg L^{-1}), followed by post-monsoon (3.75 mg L^{-1}) and pre-monsoon (2.04 mg L^{-1}). The ANOVA analysis of alkalinity showed no significant difference between stations (p>0.05) but there is a considerable difference between seasons (p<0.05) (Table 10).

TDS: During pre-monsoon, TDS varied between 39-62.5 ppm, during monsoon season, it varied between 9.75-16.5 ppm and during the post-monsoon, it fluctuated between 15.5-55.5 ppm (Table 2). The highest mean TDS were reported during the pre-monsoon seasons (52.35 ppm),

Table 11: ANOVA of seasonal variation in total dissolved solids

Sources	Type II sum of squares	df	Mean square	F	Significance
Stations	515.435	9	57.271	1.067	0.430[a]
Seasons	7788.754	2	3894.377	72.576	0.000[b]
Error	965.871	18	53.659		
Total	45306.063	30			

[a]p>0.05, no significant difference between stations and [b]p>0.05, significant difference between seasons

Table 12: ANOVA of seasonal variation in light intensity

Sources	Type II sum of squares	df	Mean square	F	Significance
Stations	1718263128.908	9	190918125.434	2.480	0.048[a]
Seasons	6996775487.817	2	3498387743.908	45.437	0.000[b]
Error	1385887187.517	18	76993732.640		
Total	33910745152.250	30			

[ab]p>0.05, significant difference between stations and between seasons

Table 13: Correlation between seasons and algal species

Correlations		Seasons	Algal species
Seasons	Pearson correlation	1	-0.545*
	Sig. (2-tailed)		0.633
	N	3	3
Algal species	Pearson correlation	-0.545*	1
	Sig. (2-tailed)	0.633	
	N	3	3

*Implies a negative correlation between seasons and algal species

followed by the post-monsoon season (38.25 ppm) and monsoon season (13.37 ppm). The ANOVA analysis of TDS showed no significant difference between stations ($p>0.05$) but there is a considerable difference between seasons ($p<0.05$) (Table 11).

Light intensity: During the pre-monsoon season, the light intensity varied between 30412.5-71203.0 Lux, during monsoon, the light intensity was less compared to other seasons (1903-26000 Lux) and during the post-monsoon season, it varied between 25318-32653 Lux. The highest mean light intensity was reported during the pre-monsoon season (46760.35 Lux) followed by post-monsoon (28401.1 Lux) and monsoon (9354.5 Lux) (Table. 2). The ANOVA analysis of light intensity showed a significant difference between stations and between seasons ($p<0.05$) (Table 12).

Rainfall: During the monsoon season, the highest rainfall (544.5 mm) was recorded, followed by the post-monsoon season (193.1 mm) and the lowest rainfall was recorded during the pre-monsoon season (153.6 mm).

The statistical analysis showed a significant difference between algal species and seasonal changes ($p>0.05$). It also showed a negative correlation between algal species and seasonal changes (Table 13).

DISCUSSION

The present study's physicochemical parameters varied according to the sampling stations and seasons. The physicochemical parameters of water determine the diversity of Algae. Dissolved oxygen is one of the pivotal factors that control algal growth in water. The water body temperature controls the solubility of gasses and regulates pH and alkalinity[25]. The concentration of dissolved oxygen in a water body depends upon its temperature[26]. Temperature is a vital component that regulates the distribution and diversity of Algae in the aquatic ecosystem and regulates other parameters like dissolved oxygen, alkalinity and pH[27]. The water temperature was highest during the pre-monsoon season and lowest during the post-monsoon season. Similar results have been observed in the study[28]. The water temperature is high during the pre-monsoon season because of the high pace of chemical reactions which trigger biological activities[29]. There is a relationship between atmospheric temperature and water temperature; therefore, the water temperature will be high compared to other seasons during the pre-monsoon season[30,31]. Due to a large amount of precipitation and cloud formation during the monsoon season, the solar radiation was reduced, which caused a reduction in water temperature[32].

During the pre-monsoon season, as the temperature increases, there was a reduction in the dissolved oxygen in the study area. Due to the heavy rainfall in the monsoon season, the water flow rate increased in the study area. Hence, the dissolved oxygen was more in the monsoon season. A negative correlation has been depicted between temperature and dissolved oxygen in the present study. The optimum water temperature for algal growth is 20-30°C[33]. Similar results have been reported from Western and Eastern ghats[34]. The water temperature across Chimmony Wildlife Sanctuary falls under the optimum temperature, therefore, it can be considered as an ideal place for algal growth and diversity.

The pH of a water body regulates the growth of cyanobacteria[35]. If the pH is less than 6.5 or greater than 9, it can be lethal to the ecosystem[36]. Therefore, the optimum pH range for algal growth is 7-9[37]. In the present study, the highest pH was recorded during the monsoon season, which created a suitable condition for the growth and development of cyanobacteria. According to the study of Singh *et al*.[38], a lower pH value was reported during the post-monsoon season and the highest pH value was recorded during monsoon season due to increased decomposition. A similar phenomenon was observed in our study. The alkalinity of a water body is caused due to the presence of carbonate and bicarbonate ions[39]. Alkalinity has a vital role in equilibrating pH changes in the water body and controlling the growth of Algae[31]. According to study of Pokhrel *et al*.[40], the TDS of a water body and temperature are positively correlated, the excessive amount of heat during the pre-monsoon season causes an increase in the TDS. Similar observations have been reported in the Samaru stream, Nigeria[41]. The study of Chandra and Rajashekhar[42] has conformed with our investigation and reported high TDS in the pre-monsoon season, followed by post-monsoon and monsoon seasons.

In the current investigation, light intensity was high during the pre-monsoon season compared to other seasons. The highest algal diversity was reported during the pre-monsoon season in our study in which Chlorophyceae Algae were dominant and cyanophycean Algae were the least. Similar findings were reported in the study[5]. More algal species were reported during the pre-monsoon season due to the favourable light conditions[3]. Chlorophyceae Algae consist of chlorophyll-a and chlorophyll-b, which are sensitive to blue and red light[30]. The Cyanobacteria are sensitive to the high intensity of sunlight[5], due to which their presence was comparatively less during different other seasons. The most favourable conditions for the growth of algal species were reported during the pre-monsoon season[43].

In the current investigation, the algal flora of Chimmony Wildlife Sanctuary varied according to the seasonal physicochemical parameters across all stations. Our study unlocks a rich diversity of Algae that varies according to the physicochemical parameters of water. The investigation helps us to understand biodiversity and also helps us to conserve it for future use. Further investigation is required on the algal diversity of different biotopes in Chimmony Wildlife Sanctuary, which are vital to the bioindustry.

CONCLUSION

The current study portraits a remarkable change in the algal diversity according to the seasonal variation and physicochemical parameters. The maximum number of Algae was reported during the pre-monsoon season. The Cyanophycean Algae were dominant during the monsoon season as they are sensitive to the high intensities of sunlight. The present study revealed essential information about the algal species and their distribution across the Chimmony Wildlife Sanctuary. This can be used to monitor the ecosystem in the future.

SIGNIFICANCE STATEMENT

This study exhibits the seasonal changes of algal diversity to the scientific community. This study will help future researchers to gain information regarding the algal diversity according to the seasonal changes which can be used to monitor the environmental conditions in this wildlife sanctuary.

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