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The initial record of phytoplankton in Hon Lao islet of Cu Lao Cham World Biosphere Reserve, Quang Nam Province

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ABSTRACT

The study was conducted to assess the phytoplankton biodiversity in Hon Lao Islet. The investigated sites included streams and lakes located on the islet. We identified 126 phytoplankton species, belonging to 62 genera, 43 families, 27 orders, 11 classes, and 6 divisions, including Cyanobacteria, Ochrophyta, Bacillariophyta, Chlorophyta, Euglenophyta, and Dinophyta. Among these groups, Chlorophyta and Bacillariophyta were the most dominant in terms of species. The average cell density on Hon Lao islet was 11,347 ± 4,149 cells/liter (mean ± SE) in the dry season and 3,355 ± 2,601 cells/liter in the rainy season, respectively. The dominant species that contributed to the studied area were different in both seasons, such as *Oscillatoria princeps, O. limosa, Lyngbya martensiana, Anabaena inaequalis*, *Botryococcus braunii*, *Ulnaria ulna, Gomphonema parvulum, Fragilaria* sp., *Iconella tenera*, and *Phacus orbicularis* from the dry season, and species of *Oscillatoria* sp., *Spirogyra ionia, Radiococcus polycoccus, Fragilaria* sp., *Eunotia pectinalis, E. minor,* and *Navicula cryptocephala* from the rainy season. Analysis of the Bray-Curtis similarity index showed that phytoplankton composition differed between monitoring sites.

Keywords: Biodiversity, diversity index, Cu Lao Cham biosphere reserve, Hon Lao islet, phytoplankton.

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Introduction

In aquatic ecosystems, phytoplankton serve as the primary producers and are the first link in the food chain, supplying energy and nutrients to other organisms [1, 2]. The species composition, abundance, and distribution of phytoplankton directly influence the distribution of aquatic organisms through the food web and largely determine the primary productivity of the entire water body [3, 4]. In sustainable ecosystems, species diversity is generally high, with multiple phytoplankton species coexisting while the abundance of each species remains relatively low. Conversely, in impacted or eutrophic ecosystems, species diversity decreases, and environmental conditions favor only a few dominant species, resulting in the numerical dominance of certain taxa [5]. Databases on phytoplankton species composition provide critical information for assessing biological productivity, ecosystem health, and the potential for biodiversity in a given area.

The UNESCO recognized Cu Lao Cham World Biosphere Reserve on May 26, 2009. The reserve covers approximately 371 km², including the core zone (the Cu Lao Cham marine protected area), the buffer zone (the Thu Bon estuary), and the transition zone (Hoi An ancient town) [6]. he water surface area of Cu Lao Cham is 5,175 hectares, including about 311 hectares of coral reefs, 500 hectares of seagrass beds, and various valuable marine species, all of which contribute to the high biodiversity of the Cu Lao Cham Marine Protected Area [7, 8]. The Cham Islands consist of eight islets arranged closely in an arc, including Hon Lao (the largest), Hon Kho Me, Hon Kho Con, Hon Tai, Hon Dai, Hon La, Hon Mo, and Hon Ong.

Studies on phytoplankton in Cham Island have been reported in documents such as the independent state-level project of the Institute of Geography (2020) [9], entitled "Scientific evidence to harmonize the relationship between biodiversity conservation and sustainable livelihoods and socio-economic development in Cu Lao Cham - Hoi An biosphere reserve." However, these data have not been officially published. Moreover, the only published research on the phytoplankton of the Cham Islands was conducted by Huynh et al. (2019) [10] and was limited to the lower Thu Bon River and the coastal waters of Cu Lao Cham. To date, no study has been conducted on freshwater phytoplankton in Hon Lao islet. Therefore, the results of this study will provide essential baseline data on phytoplankton in the area, which are crucial for evaluating ecosystem health, primary productivity, and biodiversity management.

Materials and methods

Study area

Ten sampling sites were allocated at streams, water culverts, and lakes on Hon Lao islet, Quang Nam province. Phytoplankton samples were collected during the dry season (June) and the rainy season (December) in 2021; however, two sites (CLC-07 and CLC-10) were not sampled during the rainy season due to their disappearance. The sampling sites are shown in Figure 1.

Sample collection

Phytoplankton samples were collected using the method described by Edward and David (2010) [11]. Qualitative samples of phytoplankton were collected from surface waters by a plankton net (mesh size 25 µm). For streams and water culverts, water was passed through the net for 3–5 minutes. For lakes, the net was towed slowly at approximately 0.3 m/s, and this procedure was repeated four times at each site.

Quantitative samples of phytoplankton were collected by filtering 30 L of water through the plankton net (using a bucket to get water and pour it into the net). The collected samples were stored in 250 mL plastic jars and fixed with 5% formaldehyde in the field.

Data analysis

Phytoplankton species were observed at 200-1000X magnification by using an Olympus BX41 microscope. Species identification was based on morphology such as Desikachary (1959) [12], Shirota (1966) [13], Weber (1971) [14], Yamagishi & Akiyama (1987) [15], Duong (1996) [16], Duong

& Vo (1997) [17], Nguyen (2003) [18], Wehr & Sheath (2003) [19], Burchard (2014) [20]. A Sedgewick–Rafter counting chamber was used to determine phytoplankton cell density, and counting was performed following the method of Edward and David (2010) [11]. The phytoplankton taxon was arranged according to AlgaeBase's taxonomy system (Guiry and Guiry, 2021) [21].

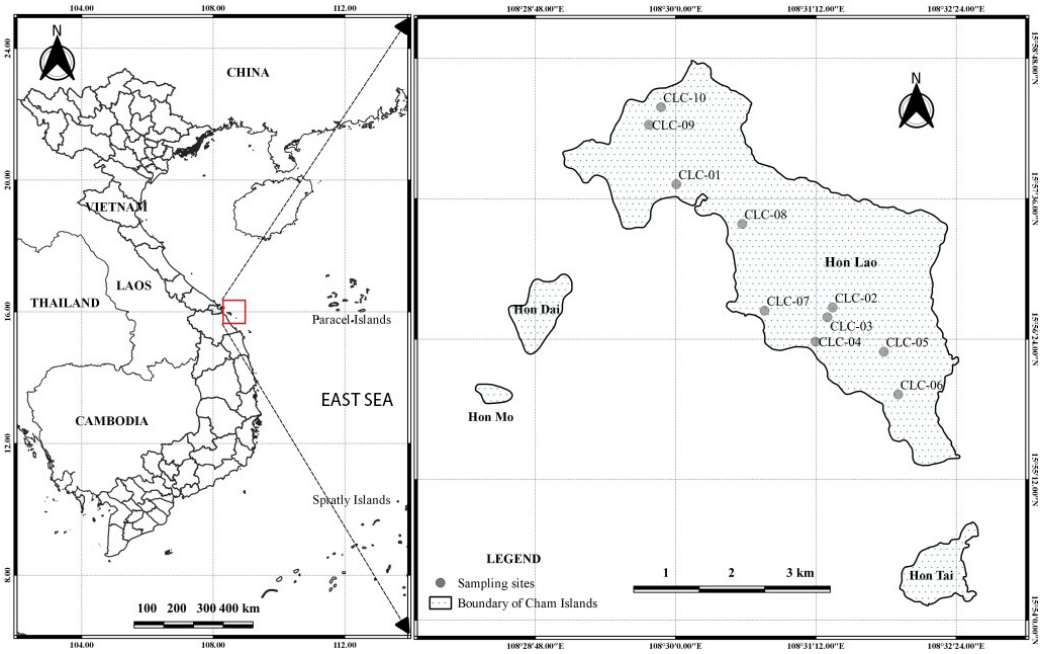

Figure 1. Map of collected samples on Hon Lao islet

The Bray-Curtis index is used to determine the similarity of species composition among survey sites. This index is calculated by Primer V6 software [22].

Bray-Curtis index (1957) [23]:

$$BC_{ij} = 1 - \frac{2C_{ij}}{S_i + S_j}$$

where in: C_{ij}: the sum of similar species between samples *i* and *j*; S_i and S_j: the total number of species in samples *i* and *j*, respectively.

Results

Structure of phytoplankton composition

A total of 126 phytoplankton species from Hon Lao islet have been recorded, belonging to 62 genera, 43 families, 27 orders, 11 classes, and 6 divisions: Cyanobacteria, Ochrophyta, Bacillariophyta, Chlorophyta, Euglenophyta, and Dinophyta. Among the phytoplankton groups, Chlorophyta and Bacillariophyta were dominant in species number (Table 1).

Table 1. Structure of phytoplankton species composition in Hon Lao islet

No.	Phylum	Class	Order	Family	Genus	Species	Percentage %
1	Cyanobacteria	1	3	5	8	14	11.1
2	Ochrophyta	2	2	2	2	2	1.6
3	Bacillariophyta	3	13	16	20	44	34.9
4	Chlorophyta	3	7	16	25	47	37.3
5	Euglenophyta	1	1	2	4	16	12.7
6	Dinophyta	1	1	2	3	3	2.4
Total		11	27	43	62	126	100

In the study area, the Chlorophyta group exhibited greater species diversity than all other phytoplankton groups. The genera *Closterium* and *Cosmarium* had the highest number of species (9 species each), followed by *Staurastrum* (4 species) and *Spirogyra* (3 species). Among the Bacillariophyta, the genera *Pinnularia* (9 species), *Surirella* (*Iconella*) (7 species), *Eunotia* (5 species), and *Nitzschia* (4 species) were the most diverse. For the Euglenophyta group, the genera *Euglena* (6 species), *Phacus* (5 species), and *Trachelomona*s (4 species) were the most diverse. Within Cyanobacteria, only the genus *Oscillatoria* displayed dominance in species (6 species). The remaining algal groups were represented by only one or two species per genus (Fig. 2, Table 2).

The number of phytoplankton species ranged from 10 to 47 in the dry season and from 9 to 36 in the rainy season. The species composition within each phytoplankton group varied between the two seasons (Fig. 3).

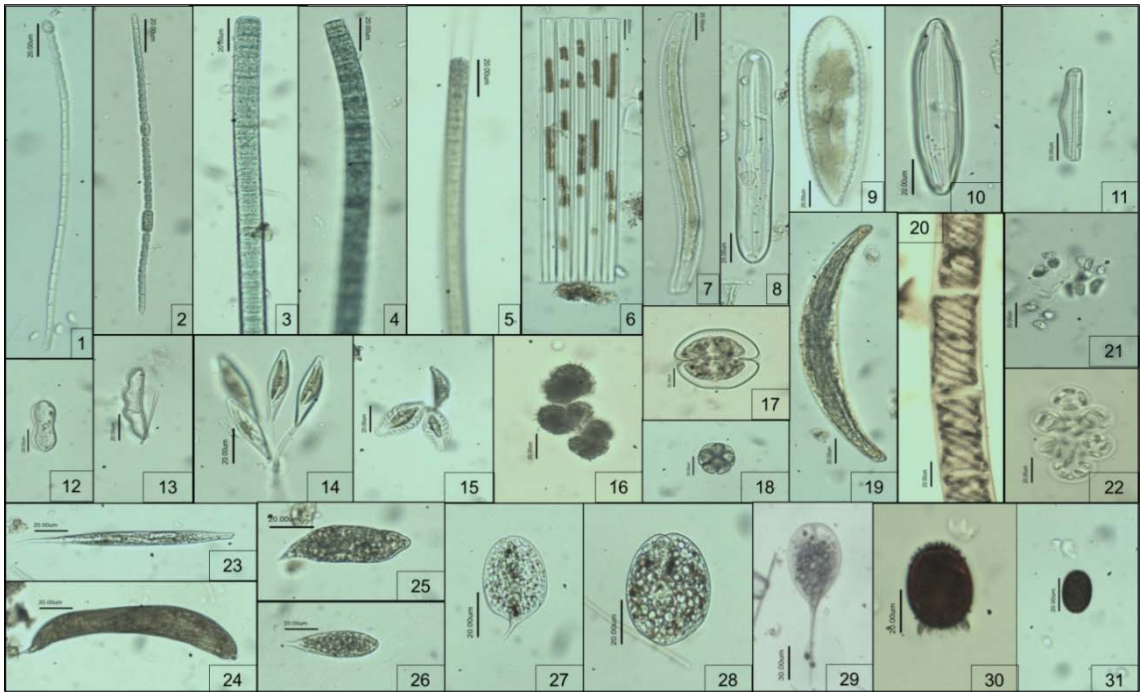

Figure 2. Some of the common phytoplankton species observed in this study. Legend: 1. *Cylindrospermum stagnale*, 2. *Anabaena inaequalis*, 3. *Oscillatoria limosa*, 4. *O. princeps*,5. *Lyngbya martensiana* (Cyanobacteria); 6. *Ulnaria ulna*, 7. *Nitzschia flexa*, 8. *Pinnularia major*, 9. *Surirella robusta*, 10. *Neidium ampliatum*, 11. *Epithemia gibba*, 12. *Tryblionella coarctata*, 13. *Eunotia zygodon*, 14. *Gomphonema parvulum*, 15. *Rhopalodia gibberula* (Bacillariophyta); 16. *Botryococcus braunii*, 17. *Cosmarium obsoletum*, 18. *Pandorina morum*, 19. *Closterium nematodes*, 20. *Spirogyra ionia*, 21. *Dimorphococcus lunatus*, 22. *Nephrocytium agardhianum* (Chlorophyta); 23. *Euglena acus*, 24. *E. spirogyra*, 25. *E. viridis*, 26. *E. gracilis*, 27. *Phacus orbicularis*, 28. *P. lefevrei*, 29. *P. longicauda*, 30. *Trachelomonas armata*, 31. *T. hispida* (Euglenophyta)

Table 2. List of phytoplankton species on Hoa Lao islet

Phylum	Class	Order	Family	Species	Dry season	Rainy season
Cyanobacteria	Cyanophyceae	Nostocales	Aphanizomenonaceae	*Anabaena inaequalis*	+	
				Cylindrospermum stagnale	+	
				Cylindrospermum trichotospermum	+	

Phylum	Class	Order	Family	Species	Dry season	Rainy season
				Dolichospermum affine	+	
		Chroococcales	Chroococcaceae	*Chroococcus turgidus*	+	
			Gomphosphaeriaceae	*Gomphosphaeria aponina*	+	
		Oscillatoriales	Oscillatoriaceae	*Lyngbya martensiana*	+	
				Oscillatoria acuta	+	
				Oscillatoria limosa	+	
				Oscillatoria princeps	+	
				Oscillatoria proboscidea	+	
				Oscillatoria sp.	+	+
				Oscillatoria tenuis	+	
			Gomontiellaceae	*Komvophoron schmidlei*	+	
Ochrophyta	Xanthophyceae	Mischococcales	Sciadiaceae	*Centritractus belonophorus*		+
	Chrysophyceae	Chromulinales	Dinobryaceae	*Dinobryon sertularia*		+
Bacillariophyta	Bacillariophyceae	Mastogloiales	Achnanthaceae	*Achnanthes brevipes*	+	+
		Naviculales	Naviculaceae	*Navicula cryptocephala*	+	+
			Neidiaceae	*Neidium affine*	+	
				Neidium ampliatum	+	
			Pinnulariaceae	*Pinnularia episcopalis*	+	+
				Pinnularia interrupta	+	+
				Pinnularia graciloides	+	+
				Pinnularia legumen	+	+
				Pinnularia major	+	+
				Pinnularia microstauron	+	
				Pinnularia nobilis	+	+
				Pinnularia viridiformis	+	+
				Pinnularia viridis	+	+
			Stauroneidaceae	*Craticula cuspidata*	+	+
				Stauroneis acuta	+	+
				Stauroneis anceps		+
		Rhopalodiales	Rhopalodiaceae	*Epithemia gibba*	+	
				Rhopalodia gibberula	+	
		Bacillariales	Bacillariaceae	*Nitzschia flexa*	+	+
				Nitzschia linearis	+	
				Nitzschia navicularis		+
				Nitzschia sigmoidea		+
				Tryblionella coarctata	+	
		Eunotiales	Eunotiaceae	*Eunotia zygodon*	+	
				Eunotia didyma	+	+
				Eunotia minor		+
				Eunotia rabenhorstiana		+
				Eunotia pectinalis		+
		Fragilariales	Fragilariaceae	*Fragilaria* sp.	+	+
		Surirellales	Surirellaceae	*Iconella capronii*	+	+
				Iconella nervosa	+	+
				Iconella tenera	+	+
				Surirella elegans	+	+
				Surirella elegantula f. *cuneata*	+	+
				Surirella robusta	+	+
				Surirella splendida	+	+
		Cymbellales	Gomphonemataceae	*Gomphonema gracile*	+	+
				Gomphonema parvulum	+	+
		Licmophorales	Ulnariaceae	*Ulnaria ulna*	+	+
	Coscinodiscophyceae	Stephanopyxales	Hydroseraceae	*Hydrosera triquetra*	+	+
		Melosirales	Melosiraceae	*Melosira varians*	+	+
				Melosira moniliformis	+	
		Rhizosoleniales	Rhizosoleniaceae	*Urosolenia longiseta*		+
	Mediophyceae	Stephanodiscales	Stephanodiscaceae	*Cyclotella meneghiniana*		+
Chlorophyta	Trebouxiophyceae	Trebouxiales	Botryococcaceae	*Botryococcus braunii*	+	

Phylum	Class	Order	Family	Species	Dry season	Rainy season
		Chlorellales	Chlorellaceae	*Closteriopsis longissima*		+
				Mucidosphaerium pulchellum		+
			Oocystaceae	*Nephrocytium agardhianum*	+	
				Oocystis borgei		+
	Chlorophyceae	Chlamydomonadales	Palmellopsidaceae	*Asterococcus limneticus*		+
			Volvocaceae	*Pandorina morum*	+	
		Sphaeropleales	Selenastraceae	*Kirchneriella obesa*	+	+
			Hydrodictyaceae	*Tetraedron gracile*	+	+
			Scenedesmaceae	*Coelastrum microporum*		+
				Scenedesmus acuminatus	+	
				Scenedesmus quadricauda		+
				Dimorphococcus lunatus	+	
			Radiococcaceae	*Radiococcus polycoccus*		+
			Schizochlamydaceae	*Planktosphaeria gelatinosa*		+
		Oedogoniales	Oedogoniaceae	*Oedogonium* sp.	+	+
	Zygnematophyceae	Desmidiales	Closteriaceae	*Closterium acerosum*	+	+
				Closterium gracile	+	
				Closterium kuetzingii	+	+
				Closterium lunula	+	+
				Closterium macilentum	+	
				Closterium moniliferum	+	+
				Closterium nematodes	+	+
				Closterium pseudodianae		+
				Closterium venus	+	
			Desmidiaceae	*Cosmarium askenasyi*		+
				Cosmarium botrytis	+	
				Cosmarium contractum		+
				Cosmarium connatum	+	+
				Cosmarium obsoletum	+	+
				Cosmarium speciosum	+	
				Cosmarium lundellii	+	
				Cosmarium variolatum	+	+
				Cosmarium vexatum	+	
				Euastrum ansatum	+	
				Pleurotaenium trabecula	+	+
				Staurastrum gracile		+
				Staurastrum trissacanthum		+
				Staurastrum dickiei		+
				Staurastrum dejectum		+
			Gonatozygaceae	*Gonatozygon monotaenium*	+	
		Zygnematales	Mesotaeniaceae	*Cylindrocystis brebissonii*	+	+
			Zygnemataceae	*Mougeotia scalaris*	+	
				Netrium digitus		+
				Spirogyra ionia	+	+
				Spirogyra protecta	+	
				Spirogyra sp.	+	
Euglenophyta	Euglenophyceae	Euglenida	Euglenidae	*Euglena acus*	+	
				Euglena deses	+	
				Euglena gracilis	+	+
				Euglena spirogyra	+	
				Euglena oxyuris	+	
				Euglena viridis	+	
				Trachelomonas armata	+	
				Trachelomonas hispida	+	
				Trachelomonas cylindracea	+	
				Trachelomonas volvocina	+	
			Phacidae	*Lepocinclis salina*		+
				Phacus acuminatus	+	

Phylum	Class	Order	Family	Species	Dry season	Rainy season
				Phacus lefevrei	+	
				Phacus longicauda	+	
				Phacus orbicularis	+	
				Phacus tortus		+
Dinophyta	Dinophyceae	Peridiniales	Peridiniaceae	*Peridinium gatunense*	+	+
			Peridiniopsidaceae	*Parvodinium inconspicuum*	+	+
				Peridiniopsis cunningtonii		+
				Total species	97	74

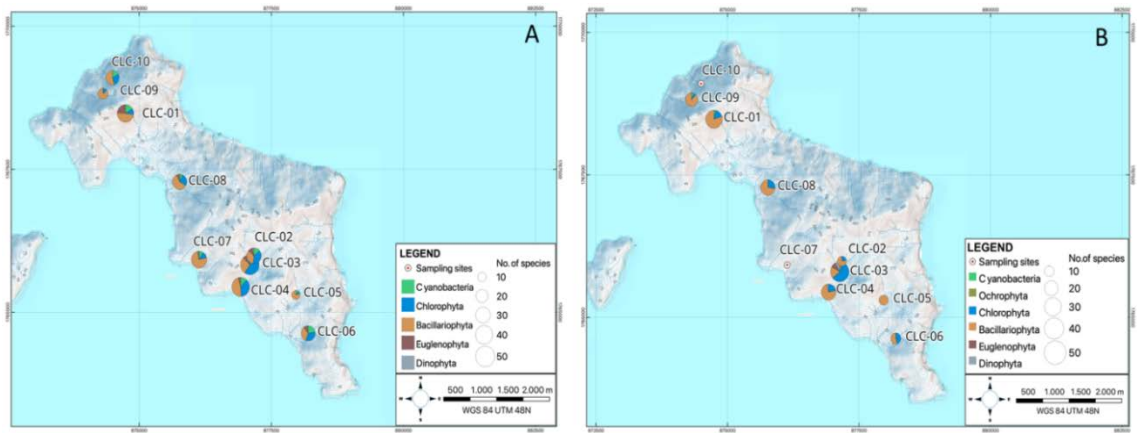

Figure 3. The spatial distribution of phytoplankton groups in dry season (A) and rainy season (B)

Density and dominant species

The variations in phytoplankton density at the sampling sites across the two seasons are shown in Figure 4. The average phytoplankton density was 11,347 ± 4,149 cells/L in the dry season and 3,355 ± 2,601 cells/L in the rainy season. Chlorophyta played a dominant role in the cell density structure during the dry season, whereas Bacillariophyta was the main contributor in the rainy season.

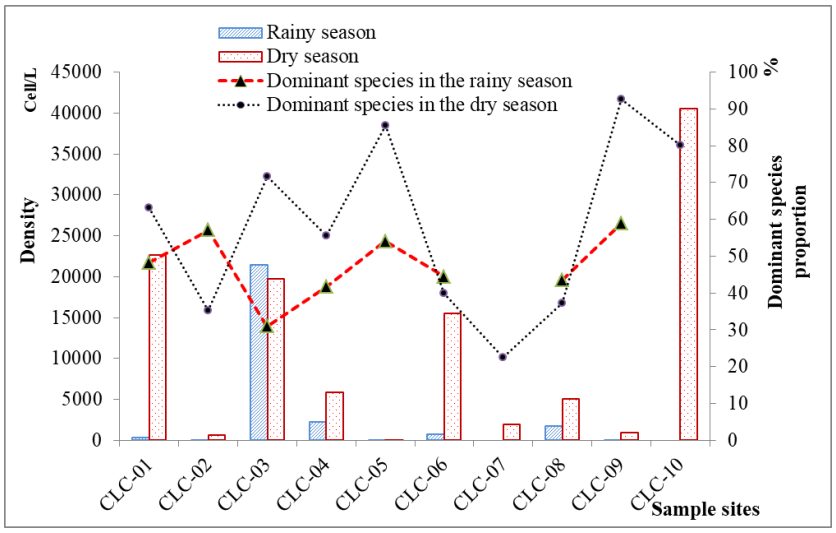

Figure 4. Seasonal variations in cell density and dominant species proportion at the sampling sites

At the 10 sampling sites on Hon Lao Islet, dominant species in the dry season included *Oscillatoria princeps*, *Lyngbya martensiana*, *Oscillatoria limosa*, *Anabaena inaequalis* (Cyanobacteria); *Botryococcus braunii* (Chlorophyta); *Ulnaria ulna*, *Gomphonema parvulum*, *Fragilaria* sp., *Iconella tenera* (Bacillariophyta); and *Phacus orbicularis* (Euglenophyta). The proportion of dominant species ranged from 22.5% to 92.6%, with the highest value at site CLC-09 and the lowest at site CLC-07. During the rainy season, the dominant species were *Fragilaria* sp., *Eunotia pectinalis*, *Eunotia minor*, *Navicula cryptocephala* (Bacillariophyta); *Spirogyra ionia*, *Radiococcus polycoccus* (Chlorophyta); and *Oscillatoria* sp. (Cyanobacteria), accounting for 30.9% to 58.9% of total density. The highest proportion occurred at site CLC-09, whereas the lowest was observed at site CLC-03.

Bray-Curtis index

Analysis of non-metric multidimensional scaling (MDS) in Primer V6 showed that phytoplankton species composition differed among the monitoring sites. The similarity index was low. It ranged from 2.1 to 38.5% in the dry season and between 2.1 and 48.3% in the rainy season (Fig. 5). The multidimensional graph also indicated the sampling sites were widely dispersed and less distributed in clusters.

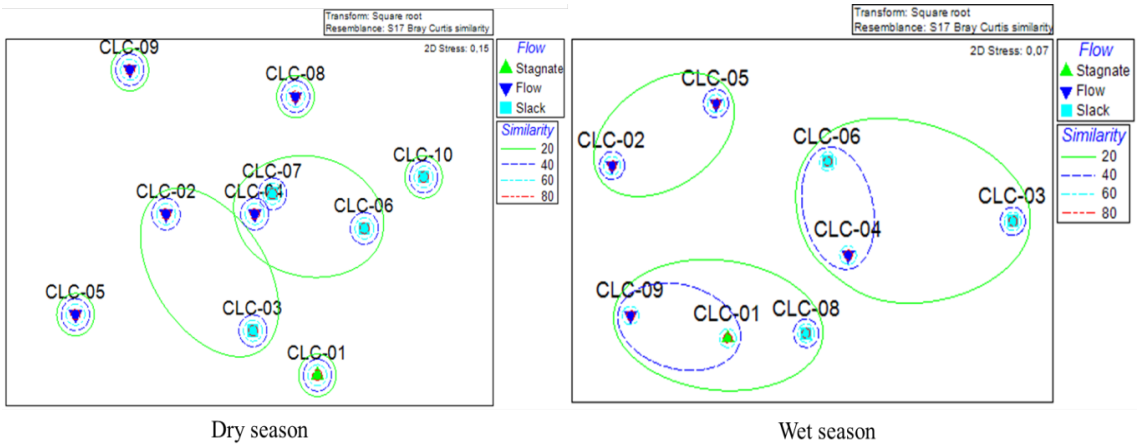

Figure 5. MDS-2D graph showing similarity of phytoplankton species composition (Bray-Curtis) among survey locations in both seasons

Discussion

In the Cham Islands, Huynh et al. (2019) [10] conducted a phytoplankton survey in the lower Thu Bon River, the transition zone, and the coastal area of Cu Lao Cham, reporting 233 species in the dry season and 193 species in the rainy season. These species were classified into the Bacillariophyceae, Coscinodiscophyceae, Mediophyceae, Dinophyceae, Cyanophyceae, Conjugatophyceae, and others. However, their study focused on estuarine and coastal areas, whereas the present study was conducted in the freshwater areas of Hon Lao Islet. Therefore, our study contributes to the checklist of phytoplankton species in the Cu Lao Cham Biosphere Reserve. The variation in phytoplankton species composition between the two seasons showed a significant decrease, from 97 taxa in the dry season to 74 taxa in the rainy season. This can be explained by the fact that streams on the island have fast-flowing water during the rainy season, which limits the growth of phytoplankton adapted to stagnant water (mainly cyanobacteria and euglenoids). Moreover, the reduction of sampling at a few points (CLC-07, CLC-10) during the rainy season also affected the observed species composition.

From the checklist presented in Table 2, green algae were identified as the most diverse group. The order Desmidiales was particularly dominant, comprising 25 species and

representing 53.2% of all recorded green algal taxa. Within this group, the genera *Closterium* and *Cosmarium* were the most species-rich, each contributing nine species. These patterns suggest that the environmental conditions on Hon Lao Islet are highly conducive to the development of Desmidiales. According to Nguyen (2003) [18], members of this order typically inhabit nutrient-poor waters with slightly acidic pH. Consistent with this, our survey revealed that Desmidiales were mainly distributed in stream habitats on the islet. In addition to the green algae, our study also recorded several cyanobacterial species, including *Anabaena inaequalis, Dolichospermum affine, Cylindrospermum stagnale, Cylindrospermum trichotospermum*, and *Oscillatoria* spp., together with euglenoid taxa such as *Euglena* spp. and *Phacus* spp. These taxa were primarily found in lakes and culverts. Previous studies by Truong et al. (2017) [24], M. Radwan et al. (2018) [25], and Sultana et al. (2024) [26] have shown that these species serve as reliable indicators of eutrophic conditions and polluted aquatic environments.

Comparisons with other freshwater bodies that share similar geographic conditions indicate that Hon Lao Islet supports a higher phytoplankton richness. Hon Lao harbored 126 species, whereas Bay Sanh, Nhan Co, and Cau Tu lakes in Dak Lak Province contained 98, 100, and 75 species, respectively [27]. Likewise, Xuan Huong and Dankia lakes in Lam Dong Province supported 75 and 104 species, respectively [28, 29], and Bien Ho Lake in Gia Lai Province recorded 98 species [30]. Although species numbers varied among sites, the dominant taxa consistently belonged to Bacillariophyta, Chlorophyta, Euglenophyta, and Cyanobacteria. A broader comparison with studies from islands elsewhere in the world further highlights the relatively high diversity on Hon Lao Islet. Only 41 species were reported from James Ross Island in Antarctica [31], 46 species from a volcanic lake on Deception Island in the South Shetland Islands [32], and 36 species from St. Martin's Island in Bangladesh [33]. These comparisons collectively suggest that the phytoplankton community of Hon Lao Islet is exceptionally diverse relative to other regional and global island freshwater systems.

MDS ordination revealed clear differences in phytoplankton community structure among the sampling sites. During the dry season, sites were widely dispersed across the MDS plot, corresponding to low Bray–Curtis similarity values and indicating strong spatial heterogeneity in environmental conditions among freshwater bodies. In contrast, during the rainy season, the sites tended to cluster more closely, likely due to increased water mixing and homogenization of hydrological conditions, which resulted in higher similarity among communities. Nevertheless, similarity values in both seasons remained relatively low (2.1–48.3%), suggesting a highly fragmented freshwater ecosystem in which each waterbody supports distinct assemblages of phytoplankton. Such differentiation may be driven by variations in hydrological and physicochemical conditions, water sources, nutrient inputs, and the island's topographic characteristics. These findings underscore the sensitivity of phytoplankton communities to fine-scale environmental gradients and highlight their utility as effective indicators of spatial environmental variation on islands.

Conclusion

The freshwater phytoplankton community on Hon Lao Islet exhibited a relatively high level of diversity, with 126 species belonging to six algal phyla recorded. Among these, green algae and diatoms were the most species-rich groups. Both species richness and phytoplankton density exhibited seasonal variation, with higher values observed during the dry season compared to the rainy season. Differences in community structure among the sampling sites were also more pronounced during the dry season, as indicated by lower similarity indices. This study represents the first investigation of freshwater phytoplankton on an island in central Vietnam. Consequently, the findings provide important scientific insights and contribute valuable data to the understanding of island biodiversity in the region.

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