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PHYTOPLANKTON SPECIES IN SONG HINH HYDROPOWER RESERVOIR, PHU YEN PROVINCE, VIETNAM

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ABSTRACT

Research results in 5 survey periods (May 2023 - February 2024) have identified 141 species of phytoplankton belonging to 60 genera, 39 families, 25 orders, 11 classes and 7 different phyla in Song Hinh hydropower reservoir, Phu Yen province. In particular, the Charophyta phylum dominates in quantity with 51 species (accounting for 36.17% of the total number of species); Chlorophyta phylum with 37 species (accounting for 26.24% of the total number of species); Euglenophyta has 19 species (accounting for 13.48%), Bacillariophyta has 15 species (accounting for 10.64%), Cyanophyta has nine species (accounting for 6.38%), Dinophyta and Ochrophyta have a relatively low number of recorded species with from 4 to 6 species, (accounting for 2.84 - 4.26%, respectively). The number of species ranges from 72 - 97 species/site. The density of phytoplankton in the Song Hinh hydropower reservoir through surveys ranged from 2,209 to 553,344 cells/L. Seven toxic Cyanophyta species (*Microcystis aeruginosa*, *Microcystis botrys*, *Microcystis wesenbergii*, *Oscillatoria princeps*, *Lyngbya sp.*, *Oscillatoria sp.*, *Anabaena sp.*) have been recorded distributed at all sampling points with quite high density (>10^4 cells/L).

Keywords: *Phytoplankton species, Charophyta phylum, Chlorophyta phylum*

1. Introduction

Song Hinh hydropower reservoir is built on Hinh River, one of three major tributaries of Ba River, located in the west of Phu Yen province. Hinh River originates from Vong Phu mountain range, has a length of about 65.4km, the section running through Hinh River is 45km in the southwest - northeast direction, entering the Ba river at Duc Binh. The hydropower lake was officially constructed from som3 of water, and has important economic and environmental functions for the locality. region and surrounding areas [1]. The main task of the Song Hinh hydropower project is to generate electricity with a design capacity of 70MW, average electricity of 357 million KWh, connecting to the national grid to serve the economic needs of the people. Water after generating electricity (average 36.99m3/s) will supply water for industry, daily life and irrigation of 19,800 hectares of agriculture in the downstream area. Phytoplankton are the first primary producers in aquatic ecosystems; is the link through which energy and matter of the food web are formed, accumulated and transformed; They are present in almost all water bodies with many types, from single-celled forms to colonies in clusters, chains, and fibers; live floating or attached to substrates in the water and are very sensitive to environmental factors. Up to now, there has been no published research on the species composition and distribution characteristics of phytoplankton groups in Song Hinh hydropower reservoir, Phu Yen province. This article publishes the initial results of research on the composition of phytoplankton species in Song Hinh hydropower reservoir, Phu Yen province in order to contribute to building a scientific database and moving towards integrated management of biological resources. in the lake in a sustainable way.

2. Materials and Methods

2.1. Research sites

In this study, we researched phytoplankton composition in the Song Hinh hydropower reservoir, Phu Yen province. The research process follows 08 points (symbols from M1 - M8). Sampling points are selected so that representatives of the sampling area can be obtained and comply with the scientific and technical committee's basic investigation procedures and regulations, now the Ministry of Science and Technology issued in 1981.

Table 1. ***Point data collection in Song Hinh's Hydropower reservoir***

Sampling point	Sampling points		Altitude above sea level (m)
	Longitude	Latitude	
M1	12°51'00.7"	108°57'59.0"	213,39
M2	12°51'41.0"	108°57'43.2"	213,65
M3	12°52'08.6"	108°56'59.8"	212,29
M4	12°53'06.0"	108°56'48.9"	213,32
M5	12°53'53.2"	108°57'43.7"	211,00
M6	12°54'25.9"	108°58'29.9"	210,19
M7	12°55'07.7"	108°58'02.1"	209,78
M8	12°55'56.6"	108°57'45.4"	208,43

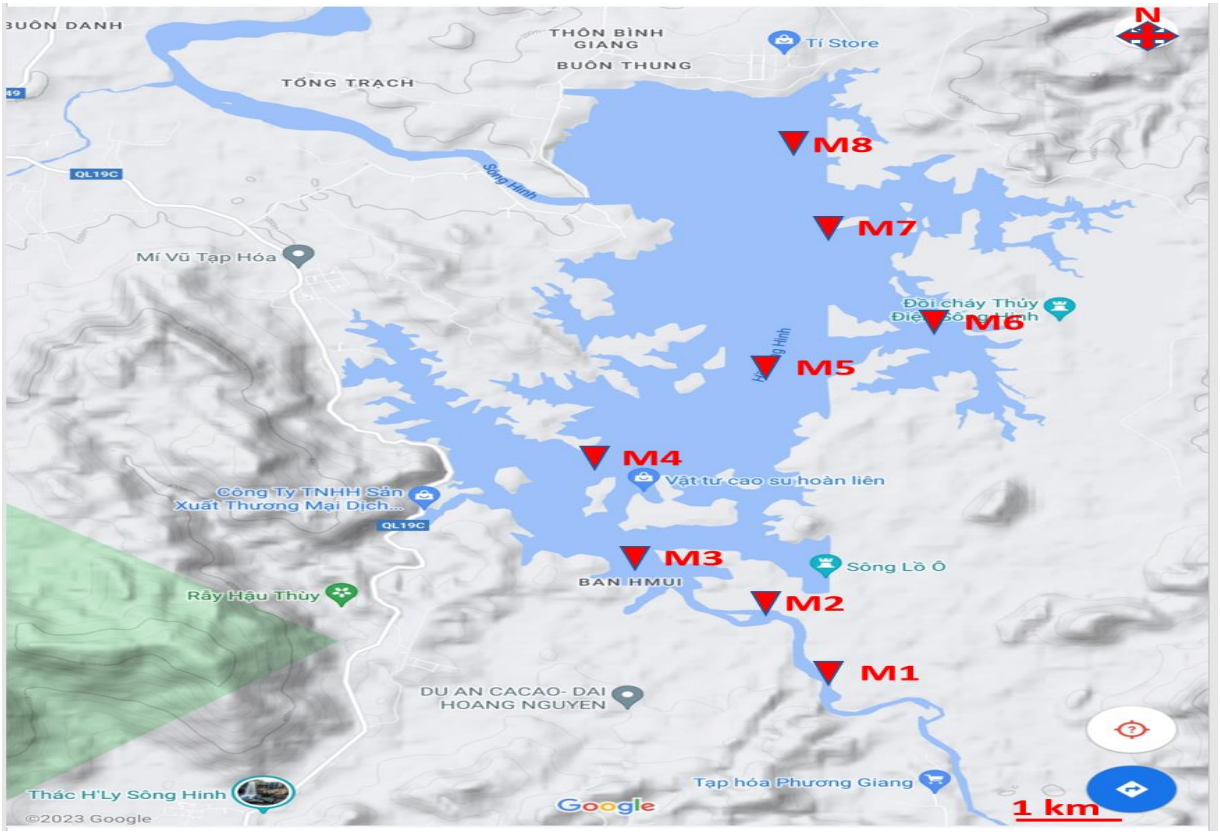

Figure 1. ***Sampling point on the Song Hinh hydropower reservoir*** *(Note: M1 → M8 (sample point))*

2.2. Samples and Data collection methods

Phytoplankton samples were collected and analysed according to the instructions of Baird et al. (2017) [2]. Samples were collected at 08 sampling points on Song Hinh hydropower reservoir in 05 times (May 2023, October 2023, November 2023, December 2023, February 2024). Qualitative samples were collected using phytoplankton net, with a mesh size of 25µm. The net was pulled about 50m long on the surface, with an average pulling speed of 0.5m/s. Quantitative samples were collected by filtering 60 Ls of water through a filter with a mesh size of 20µm. Specimens were fixed at the scene with 4% formalin. The collected samples are marked and noted, including the date and time of sample collection, symbol and location of sample collection on the label.

2.3. Analysis and laboratory methods

Samples can settle for 12 - 24 hours after being brought to the laboratory. Drain the water to a volume of 60 ml. Shake the sample well in the volume of water, suck with a straw 3 - 6 times, 1 ml each time and put it into the Sedgewick Rafter counting chamber; count each species until the number changes insignificantly. Determine the composition of phytoplankton species based on cell morphology and the characteristics of dissected appendages under a microscope with magnification from 100 - 1000 times to determine the species present in the sample. Qualitative samples are determined. Identify the species and record it in the sample analysis chart. Conduct classification based on morphological characteristics according to classification documents of domestic and foreign authors: Cornelius (1971) [3]; Desikachary (1959) [4]; Edmondson (1959) [5]; Nguyen Thi Thu Lien (2007) [6]; Shirota (1966) [7]; Stidolph et al (2012) [8]; Duong Duc Tien (1996) [9]; Duong Duc Tien and Vo Hanh (1997) [10]; Nguyen Van Tuyen (2003) [11].

2.4. Data analysis

- Diversity index (Shannon – Wienner, 1949):

$$H' = -\sum_{i=1}^{n} \frac{ni}{N} \log_2 \frac{ni}{N}$$

In which:

H': Mannon - Wienner diversity index;

ni: Total number of ith species

N: Total number of individuals at a research site

3. Results and discussions

3.1. Species and distributions

There were 141 phytoplankton species belonging to 60 genera, 39 families, 25 orders, 11 classes and 7 different phyla have been identified in Song Hinh hydropower reservoir, Phu Yen province. In particular, the Charophyta phylum dominates in quantity with 51 species (accounting for 36.17% of the total number of species); Chlorophyta phylum with 37 species (accounting for 26.24% of the total number of species); Euglenophyta has 19 species (accounting for 13.48%), Bacillariophyta has 15 species (accounting for 10.64%), Cyanophyta has 9 species (accounting for 6.38%); The phyla Dinophyta and Ochrophyta have several species ranging from 4 to 6 species, 2.84 - 4.26%, respectively, table 2.

Table 2. ***Composition of species of phytoplankton***

No.	Scientific name	Sampling points							
		M1	M2	M3	M4	M5	M6	M7	M8
	CYANOPHYTA								
	Cyanophyceae								
	Chroococcales								
(1)	**Microcystaceae**								
1	*Microcystis aeruginosa* (Kützing) Kützing, 1846	+	+	+	+	+	+	+	+
2	*Microcystis botrys* Teiling, 1942	+	+	+	+	+	+	+	+
3	*Microcystis wesenbergii* (Komárek) Komárek ex Komárek, 2006	+	+	+	+	+	+	+	+
	Oscillatoriales								
(2)	**Microcoleaceae**								
4	*Lyngbya* sp.		+		+				
(3)	**Oscillatoriaceae**								
5	*Oscillatoria princeps* Vaucher ex Gomont, 1892	+	+	+	+	+	+	+	+

6	*Oscillatoria* sp.	+	+	+	+	+	+	+	
	Nostocales								
(4)	**Nostocaceae**								
7	*Anabaena* sp.	+	+	+	+	+	+	+	+
(5)	**Rivulariaceae**								
8	*Rivularia planctonica* Elenkin, 1921	+	+		+	+		+	
	Synechococcales								
(6)	**Merismopediaceae**								
9	*Merismopedia glauca* (Ehrenberg) Kützing, 1845			+			+		
	OCHROPHYTA								
	Chrysophyceae								
	Chromulinales								
(7)	**Dinobryaceae**								
10	*Dinobryon bavaricum* Imhof, 1890	+	+	+	+	+	+	+	+
11	*Dinobryon sertularia* Ehrenberg, 1834	+	+	+	+	+	+	+	+
	Synurales								
(8)	**Mallomonadaceae**								
12	*Mallomonas* sp.	+	+	+	+	+	+	+	+
13	*Synura ahydropower reservoirsii* G.M.Smith, 1924	+	+	+	+	+	+	+	+
14	*Synura uvella* Ehrenberg, 1834	+	+	+	+	+	+	+	+
	Xanthophyceae								
	Mischococcales								
(9)	**Sciadiaceae**								
15	*Centritractus belonophorus* (Schmidle) Lemmermann, 1900		+	+	+	+	+	+	
	BACILLARIOPHYTA								
	Bacillariophyceae								
	Bacillariales								
(10)	**Bacillariaceae**								
16	*Nitzschia sigmoidea* (Nitzsch) W.Smith, 1853	+	+						
	Cymbellales								

(11)	**Cymbellaceae**								
17	*Cymbella tumida* (Brébisson) Van Heurck, 1880	+							
(12)	**Gomphonemataceae**								
18	*Gomphonema gracile* Ehrenberg, 1838		+						
	Eunotiales								
(13)	**Eunotiaceae**								
19	*Eunotia pectinalis* (Kützing) Rabenhorst, 1864	+							
	Licmophorales								
(14)	**Ulnariaceae**								
20	*Ulnaria ulna* (Nitzsch) Compère, 2001	+	+	+	+		+		
	Naviculales								
(15)	**Naviculaceae**								
21	*Gyrosigma acuminatum* (Kützing) Rabenhorst, 1853	+	+	+	+	+	+		
(16)	**Pinnulariaceae**								
22	*Pinnularia gentilis* (Donkin) Cleve, 1891		+			+			
23	*Pinnularia legumen* Ehrenberg, 1843	+							
24	*Pinnularia* sp.	+	+	+					
25	*Pinnularia* sp$_1$	+							
(17)	**Stauroneidaceae**								
26	*Stauroneis anceps* Ehrenberg, 1843		+						
	Surirellales								
(18)	**Surirellaceae**								
27	*Surirella elegans* Ehrenberg, 1843	+	+	+		+	+	+	+
28	*Surirella robusta* Ehrenberg, 1841	+	+	+	+	+	+	+	+
	Mediophyceae								
	Stephanodiscales								
(19)	**Stephanodiscaceae**								
29	*Cyclotella* sp.		+						
	Coscinodiscophytina								
	Coscinodiscophyceae								

	Aulacoseirales								
(20)	**Aulacoseiraceae**								
30	*Aulacoseira granulata* (Ehrenberg) Simonsen, 1979	+	+	+	+	+	+	+	+
	CHLOROPHYTA								
	Chlorophyceae								
	Chlamydomonadales								
(21)	**Chlamydomonadaceae**								
31	*Protococcus* sp.	+	+	+	+	+	+	+	+
(22)	**Goniaceae**								
32	*Gonium pectorale* O.F.Müller, 1773	+							
(23)	**Sphaerocystidaceae**								
33	*Sphaerocystis schroeteri* Chodat, 1897	+	+	+	+	+	+	+	+
(24)	**Volvocaceae**								
34	*Eudorina elegans* Ehrenberg, 1832	+	+	+	+	+	+	+	+
35	*Pandorina morum* (O.F.Müller) Bory, 1826	+	+	+	+	+			
	Sphaeropleales								
(25)	**Hydrodictyaceae**								
36	*Pediastrum boryanum* (Turpin) Meneghini, 1840	+	+						
37	*Pediastrum duplex* Meyen, 1829	+	+	+	+	+	+	+	+
38	*Pediastrum simplex* Meyen, 1829	+							
39	*Pediastrum tetras* (Ehrenberg) Ralfs, 1844	+	+	+	+	+	+		
40	*Tetraedron gracile* (Reinsch) Hansgirg, 1889	+	+	+	+	+	+	+	+
41	*Tetraëdron incus* (Teiling) G.M.Smith, 1926		+						
42	*Tetraëdron regulare* Kützing, 1845	+	+	+	+	+	+	+	+
43	*Tetraedron trigonum* (Nägeli) Hansgirg	+	+	+	+	+		+	
(26)	**Scenedesmaceae**								
44	*Coelastrum cambricum* W.Archer, 1868	+	+	+	+	+	+	+	+
45	*Coelastrum microsporum* Nägeli, 1849	+	+	+	+	+	+	+	+
46	*Dimorphococcus lunatus* A.Braun, 1855	+	+	+	+	+	+	+	+
47	*Scenedesmus acuminatus* (Lagerheim) Chodat, 1902	+	+	+					+

48	*Scenedesmus arcuatus* (Lemmermann) Lemmermann, 1899	+	+		+				
49	*Scenedesmus bicaudatus* Dedusenko, 1925	+							
50	*Scenedesmus bijugatus* Kützing, 1834	+	+						
51	*Scenedesmus denticulatus* Lagerheim, 1882						+		
52	*Scenedesmus obliquus* (Turpin) Kützing, 1833	+							
53	*Scenedesmus quadricauda* (Turpin) Brébisson, 1835	+	+	+	+	+	+	+	+
54	*Tetrallantos lagerheimii* Teiling, 1916					+			
(27)	**Selenastraceae**								
55	*Ankistrodesmus bibraianus* (Reinsch) Korshikov, 1953	+	+	+	+	+	+	+	+
56	*Ankistrodesmus fusiformis* Corda, 1838	+	+	+	+	+	+	+	+
57	*Ankistrodesmus spiralis* (W.B.Turner) Lemmermann, 1908	+	+			+		+	+
58	*Kirchneriella lunaris* (Kirchner) K.Möbius, 1894	+	+	+	+	+	+	+	+
59	*Kirchneriella obesa* (West) West & G.S.West, 1894	+							
60	*Quadrigula chodatii* (Tanner-Füllemann) G.M.Smith, 1920			+		+	+	+	+
	Trebouxiophyceae								
	Chlorellales								
(28)	**Chlorellaceae**								
61	*Actinastrum hantzschii* Lagerheim, 1882		+						
62	*Chlorella mucosa* Korshikov, 1953	+		+		+			
63	*Dictyosphaerium anomalum* Korshikov, 1953		+	+	+	+	+	+	+
64	*Dictyosphaerium pulchellum* H.C. Wood, 1873	+	+	+	+	+	+	+	+
(29)	**Nephrocytiaceae**								
65	*Nephrocytium agardhianum* Nägeli, 1849	+	+	+	+	+	+	+	+
(30)	**Oocystaceae**								
66	*Oocystis* sp.	+	+	+	+	+	+	+	+
	Trebouxiophyceae ordo *incertae sedis*								

(31)	**Trebouxiophyceae**								
67	*Crucigenia fenestrata* (Schmidle) Schmidle, 1900	+	+	+					
	CHAROPHYTA								
	Zygnematophyceae								
	Desmidiales								
(32)	**Closteriaceae**								
68	*Closterium acerosum* Ehrenberg ex Ralfs, 1848	+	+	+			+		
69	*Closterium cornu* Ehrenberg ex Ralfs, 1848		+	+	+	+	+	+	+
70	*Closterium gracile* Brébisson ex Ralfs, 1848	+	+	+	+	+	+	+	+
71	*Closterium kuetzingii* Brébisson, 1856	+	+	+	+	+	+	+	
72	*Closterium moniliferum* Ehrenberg ex Ralfs, 1848	+	+		+				
73	*Closterium* sp.		+						
74	*Closterium tumidum* L.N.Johnson, 1895	+	+		+				
(33)	**Desmidiaceae**								
75	*Cosmarium connatum* Brébisson ex Ralfs, 1848		+	+					
76	*Cosmarium contractum* Kirchner, 1878	+	+	+	+	+	+	+	+
77	*Cosmarium granatum* Brébisson ex Ralfs, 1848		+						
78	*Cosmarium lundellii* Delponte, 1877	+	+	+	+	+	+	+	+
79	*Cosmarium magnificum* Nordstedt, 1887			+	+	+	+		
80	*Cosmarium margaritatum* (P.Lundell) J.Roy & Bisset, 1886	+	+	+	+			+	
81	*Cosmarium obsoletum* (Hantzsch) Reinsch, 1867	+	+	+	+				
82	*Cosmarium obtusatum* (Schmidle) Schmidle, 1898	+	+	+	+	+	+	+	+
83	*Cosmarium ordinatum* (Børgesen) West & G.S.West, 1896		+		+				
84	*Cosmarium perfissum* G.S.West, 1909	+	+	+	+	+	+	+	+
85	*Cosmarium vitiosum* A.M.Scott & Grönblad, 1957	+	+	+	+	+	+	+	+
86	*Desmidium baileyi* (Ralfs) Nordstedt, 1880		+	+	+	+	+	+	+

87	*Desmidium suboccidentale* A.M.Scott & Prescott, 1958		+						
88	*Euastrum didelta* Ralfs, 1848		+						
89	*Euastrum* sp.				+	+			+
90	*Euastrum spinulosum* Delponte, 1876	+	+	+		+		+	
91	*Euastrum substellatum* Nordstedt, 1880		+						
92	*Micrasterias radians* W.B.Turner, 1893			+					
93	*Pleurotaenium ovatum* (Nordstedt) Nordstedt, 1877		+		+	+	+		
94	*Pleurotaenium trabecula* Nägeli, 1849	+							
95	*Spondylosium planum* (Wolle) West & G.S.West, 1912	+	+	+	+	+	+	+	+
96	*Staurastrum bigibbum* Skuja, 1949	+	+	+	+	+	+	+	+
97	*Staurastrum cyclacanthum* West & G.S.West, 1902	+	+	+	+	+	+	+	+
98	*Staurastrum gladiosum* W.B.Turner, 1885	+	+	+	+	+	+	+	
99	*Staurastrum gracile* Ralfs ex Ralfs, 1848	+	+	+	+	+	+	+	+
100	*Staurastrum limneticum* Schmidle, 1898	+	+	+	+	+	+	+	+
101	*Staurastrum margaritaceum* Meneghini ex Ralfs, 1848			+					
102	*Staurastrum megacanthum* P.Lundell, 1871	+	+	+	+	+	+	+	+
103	*Staurastrum natator* West, 1892	+	+	+	+	+	+	+	+
104	*Staurastrum ophiura* P.Lundell, 1871	+	+	+	+	+	+	+	+
105	*Staurastrum protectum* West & G.S.West, 1908	+		+		+	+		
106	*Staurastrum sexangulare* (Bulnheim) Rabenhorst, 1863	+	+	+	+	+	+	+	+
107	*Staurastrum* sp.	+	+	+	+	+	+	+	+
108	*Staurastrum* sp_1	+	+	+	+	+	+	+	+
109	*Staurastrum tauphorum* West & G.S.West, 1902	+	+	+	+	+	+	+	+
110	*Staurastrum tohopekaligense* Wolle, 1885	+	+	+	+	+	+	+	+
111	*Staurastrum vaasii* A.M.Scott & Prescott, 1961			+	+	+	+		
112	*Staurodesmus convergens* (Ehrenberg ex Ralfs) S.Lillieroth, 1950								+

113	*Staurodesmus corniculatus* (P.Lundell) Teiling, 1967	+	+	+	+	+	+	+	+
114	*Staurodesmus incus* (Hassal ex Ralfs) Teiling, 1967	+	+	+	+	+	+	+	+
115	*Staurodesmus octocornis* (Ehrenberg ex Ralfs) Stastny, Skaloud & Neustupa, 2013	+	+	+		+	+	+	+
116	*Xanthidium acanthophorum* Nordstedt, 1880								+
	Zygnematales								
(34)	**Mesotaeniaceae**								
117	*Netrium digitus* (Brébisson ex Ralfs) Itzigsohn & Rothe, 1856		+			+		+	
	Spirogyrales								
(35)	**Spirogyraceae**								
118	*Spirogyra* sp.	+	+		+	+		+	+
	EUGLENOPHYTA								
	Euglenophyceae								
	Euglenales								
(36)	**Euglenaceae**								
119	*Euglena acus* (O.F.Müller) Ehrenberg, 1830	+	+	+	+		+		
120	*Euglena ehrenbergii* Klebs, 1883			+	+	+	+	+	
121	*Euglena gracilis* G.A.Klebs, 1883	+	+	+	+				
122	*Euglena oxyuris* Schmarda, 1846	+	+	+	+	+	+	+	+
123	*Euglena polymorpha* P.A.Dangeard, 1902	+	+	+	+				
124	*Euglena tripteris* (Dujardin) G.A.Klebs, 1883	+	+	+	+	+			
125	*Strombomonas gibberosa* (Playfair) Deflandre, 1930	+							
126	*Strombomonas* sp.	+	+	+	+	+	+		
127	*Trachelomonas armata* (Ehrenberg) F.Stein, 1878	+	+	+	+	+	+	+	+
128	*Trachelomonas hispida* (Perty) F. Stein, 1926		+	+	+	+	+	+	+
129	*Trachelomonas lacustris* Dreżepolski, 1925	+	+			+	+		+
(37)	**Phacaceae**								
130	*Phacus acuminatus* Stokes, 1885	+	+	+	+	+	+	+	
131	*Phacus helikoides* Pochmann, 1942	+							

132	*Phacus longicauda* (Ehrenberg) Dujardin, 1841	+	+	+	+	+	+	+	+
133	*Phacus pleuronectes* (O.F.Müller) Nitzsch ex Dujardin, 1841	+	+		+				
134	*Phacus* sp.	+	+	+	+	+	+	+	+
135	*Phacus* sp_1	+							
136	*Phacus suecicus* Lemmermann, 1913			+					
137	*Phacus tortus* (Lemmermann) Skvortzov, 1928	+	+	+	+	+	+	+	+
	DINOPHYTA								
	Dinophyceae								
	Gonyaulacales								
(38)	**Ceratiaceae**								
138	*Ceratium hirundinella* (O.F.Müller) Dujardin, 1841	+	+	+	+	+	+	+	+
	Peridiniales								
(39)	**Peridiniaceae**								
139	*Glenodinium* sp.	+	+	+	+	+	+	+	+
140	*Peridinium* sp.	+	+	+	+	+	+	+	+
141	*Peridinium* sp_1	+	+	+	+	+	+	+	+
	Total	**107**	**113**	**97**	**92**	**91**	**84**	**78**	**72**

3.2. Species composition structures

In terms of classification by class: class Zygnematophyceae has the most abundant species, with 51 species belonging to 11 genera, 4 families, 3 orders; Next is the class Chlorophyceae with 30 species belonging to 14 genera, 7 families, 2 orders; Class Euglenophyceae has 19 species belonging to 4 genera, 2 families, 1 order; Class Bacillariophyceae has 13 species belonging to 9 genera, 9 families, and 6 orders. The least diverse classes are Xanthophyceae, Mediophyceae and Coscinodiscophyceae, with only 1 species belonging to 1 genus, 1 family and 1 order recorded. Cyanophyceae, Chrysophyceae, Trebouxiophyceae and Dinophyceae have several species from 4 to 9 species/class.

Table 3. *Composition of phytoplankton*

No.	Branch	Class	Flora	Family	Genus	Species	%
1	Cyanophyta	1	4	6	6	9	6.38
2	Ochrophyta	2	3	3	4	6	4.26
3	Bacillariophyta	3	8	11	11	15	10.64
4	Chlorophyta	2	4	11	20	37	26.24
5	Charophyta	1	3	4	12	51	36.17

No.	Branch	Class	Flora	Family	Genus	Species	%
6	Euglenophyta	1	1	2	4	19	13.48
7	Dinophyta	1	2	2	3	4	2.84
	Total	**11**	**25**	**39**	**60**	**141**	**100**

Regarding taxonomy by order: Desmidiales is the order with the number of species that dominates other orders with 49 species; Next is the Sphaeropleales order with 25 species, the Euglenales order with 19 species, the Naviculales and Chlorellales orders together with 6 species, and the Chlamydomonadales order with 5 species. The remaining orders only have 1 - 3 species. Regarding the classification level by family, most families have recorded from 1 - 8 genera, with different numbers of species in each genus: the most common is the genus Staurastrum (20 species); Cosmarium (11 species); Phacus (8 species), Scenedesmus, Closterium (7 species); Euglena (6 species). On the contrary, there are up to 35 genera with only 1 species recorded, including representative genera: Anabaena, Merismopedia, Lyngbya, Mallomonas, Centritractus, Cyclotella, Nitzschia, Tetrallantos, Eudorina, Pandorina, Crucigenia, Spondylosium, Ceratium. The families Chlorellaceae, Selenastraceae and Euglenaceae all have 3 genera/families recorded, but the number of species of each genus is low, ranging from 1 - 6 species. A few species, such as Microcystis aeruginosa, Dinobryon Sertularia, Gonium pectoral, Aulacoseira granulata, Pediastrum duplex, Tetraedron gracile, Cosmarium contracted, Nephrocytium agardhianum, Staurastrum big bum*, Ceratium hirundinella, Staurastrum tohopekaligense, Staurastrum gracile*, have a wide distribution. present at most sampling points across all surveys, but the density is not high, ranging from 1 - 248,400 cells/liter. Out of a total of 141 species of phytoplankton in Song Hinh hydropower reservoir, 7 species of Cyanophyta (*Microcystis aeruginosa, Microcystis botrys, Microcystis wesenbergii, Oscillatoria princeps, Lyngbya sp., Oscillatoria sp., Anabaena sp.*) have been identified as having potential produces toxins Antoxin, Saxitoxins, Microcystins. These species were recorded at all sampling points at quite high densities (>104 cells/L).

3.2. Distribution characteristic of phytoplankton compostion in Song Hinh hydropower reservoir

3.2.1. Time distribution

The species composition structure between survey periods had little change and was similar to the general species composition structure of the phytoplankton community in the Song Hinh hydropower reservoir. Chlorophyta and Charophyta always dominate in quantity compared to other, and they also have the most fluctuations in the number of species between surveys. Notably, the Dinophyta has a stable and unchanging number of species through 5 survey periods (all recorded 4 species/time). The highest number of species recorded was in the May 2023 survey (105 species), followed by October 2023 (94 species); The worst is the survey in December 2023 (75 species) and the surveys in November 2023 and February 2024, with the number of species recorded being 77 species/time and 78 species/time, respectively (Table 4).

Table 4. Species composition of phytoplankton

No.	Branch	May/2023		Oct./2023		Nov./2023		Dec./2023		Feb./2024	
		Species	%	Species	%	Species	%	Species	%	Species	%
1	Cyanophyta	7	6.67	7	7.45	6	7.79	5	6.67	6	7.69
2	Ochrophyta	3	2.86	3	3.19	5	6.49	5	6.67	5	6.41
3	Bacillariophyta	9	8.57	12	12.77	2	2.60	2	2.67	4	5.13
4	Chlorophyta	27	25.71	29	30.85	26	33.77	24	32.00	20	25.64

No.	Branch	May/2023		Oct./2023		Nov./2023		Dec./2023		Feb./2024	
		Species	%	Species	%	Species	%	Species	%	Species	%
5	Charophyta	37	35.24	34	36.17	26	33.77	24	32.00	31	39.74
6	Euglenophyta	18	17.14	5	5.32	8	10.39	11	14.67	8	10.26
7	Dinophyta	4	3.81	4	4.26	4	5.19	4	5.33	4	5.13
	Total	**105**	**100**	**94**	**100**	**77**	**100**	**75**	**100**	**78**	**100**

3.2. Distribution by spaces

According to space, the composition of phytoplankton species distributed inside the Song Hinh hydropower reservoir (from point M3 to point M8) is relatively stable and similar between sampling points, with a tendency to gradually decrease from upstream to downstream, the number of species at each survey site ranges from 72 - 97 species/sampling point; In the downstream area (from M1 to M2), there is a higher number of species in the lake bed, ranging from 107 - 113 species/site. The number of species recorded is highest at M2 (113 species) and lowest at M8 (72 species). The average number of species at each sampling point ranges from 48 - 55 species/sampling point, reaching the highest value at M2 and the lowest at M8 (table 5).

Table 5. *Number of phytoplankton species in Song Hinh hydropower reservoir*

Sampling point	May/2023	Oct./2023	Nov./2023	Dec./2023	Feb./2024	Average
M1	54	46	55	55	53	53
M2	59	55	56	55	51	55
M3	64	51	50	54	52	54
M4	60	46	46	47	50	50
M5	61	49	47	45	50	50
M6	62	53	45	46	56	52
M7	54	48	48	44	52	49
M8	50	45	51	48	48	48

3.3. Change by phytoplankton density

Table 1. *Phytoplankton density in* Song Hinh hydropower reservoir *by months in 2023 and 2024*

Sampling point	May/2023	Oct./2023	Nov./2023	Dec./2023	Feb./2024	Average
M1	10542	2209	15653	16154	320160	72944 ± 138312
M2	30597	3458	41826	38910	231222	69203 ± 91829
M3	359492	553344	35498	53806	88976	218223 ± 228795
M4	111276	472412	33300	34456	183492	166987 ± 181726
M5	148263	445596	15066	22244	122408	150715 ± 175120
M6	274720	291992	34190	23066	114342	147662 ± 128924
M7	262467	223872	28438	16712	226164	151531 ± 118784
M8	373452	212532	35648	25718	143478	158166 ± 143242

Average	196351 ± 141443	275677 ± 207193	29952 ± 9723	28883 ± 12822	178780 ± 77133

Results of analysis of the phytoplankton community in the Hinh River hydropower reservoir show that the density ranges from 2,209 - 553,344 cells/L, reaching the highest value at sampling point M3 and the lowest at sampling point M1 and the end of the year. October 2023. The average cell density recorded was highest during the October 2023 survey, with 275,677 ± 107,193 cells/L (ranging from 2,209 - 553,344 cells/L), but it tended to decrease sharply during the survey period. November 2023 and December 2023, respectively, reaching an average of 29,952 ± 9,723 cells/L (from 15,066 - 41,826 cells/L) and 28,883 ± 12,822 cells/L (16,254 - 53,806 cells/L); The average cell density recorded in the May 2023 and February 2024 surveys was relatively high, reaching an average of 196,351 ± 141,443 cells/L (10,542 - 373,452 cells/L) and 178,780 ± 77,133, respectively. cells/L (88,976 – 320,160 cells/L).

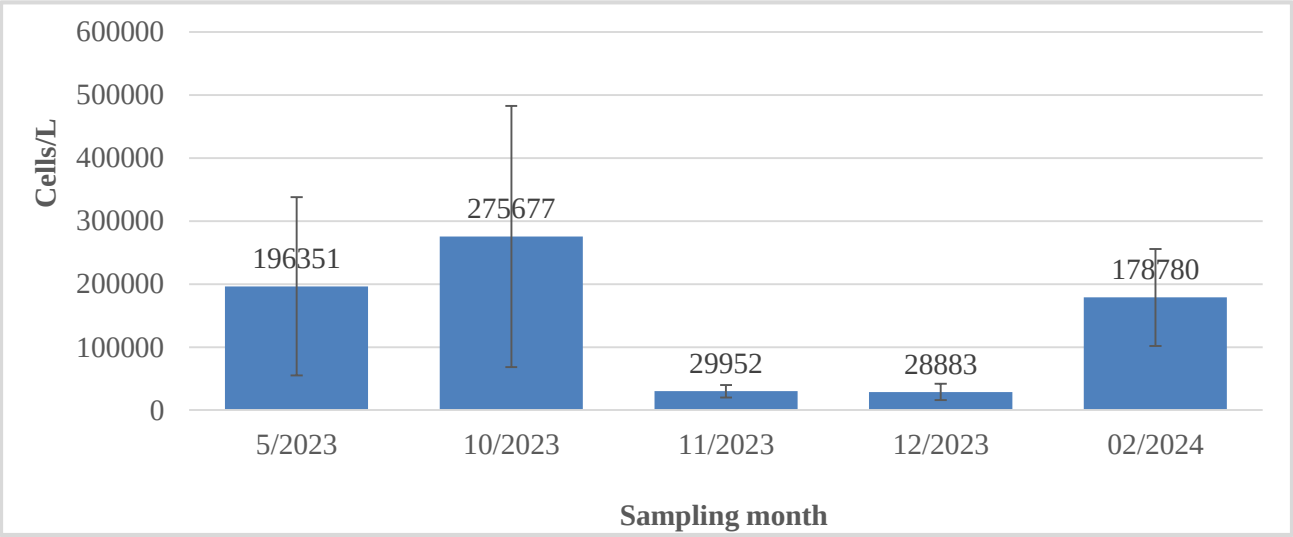

Figure 1. *Changes of phytoplankton density in Song Hinh hydropower reservoir by time*

3.3. Change by different places and spaces

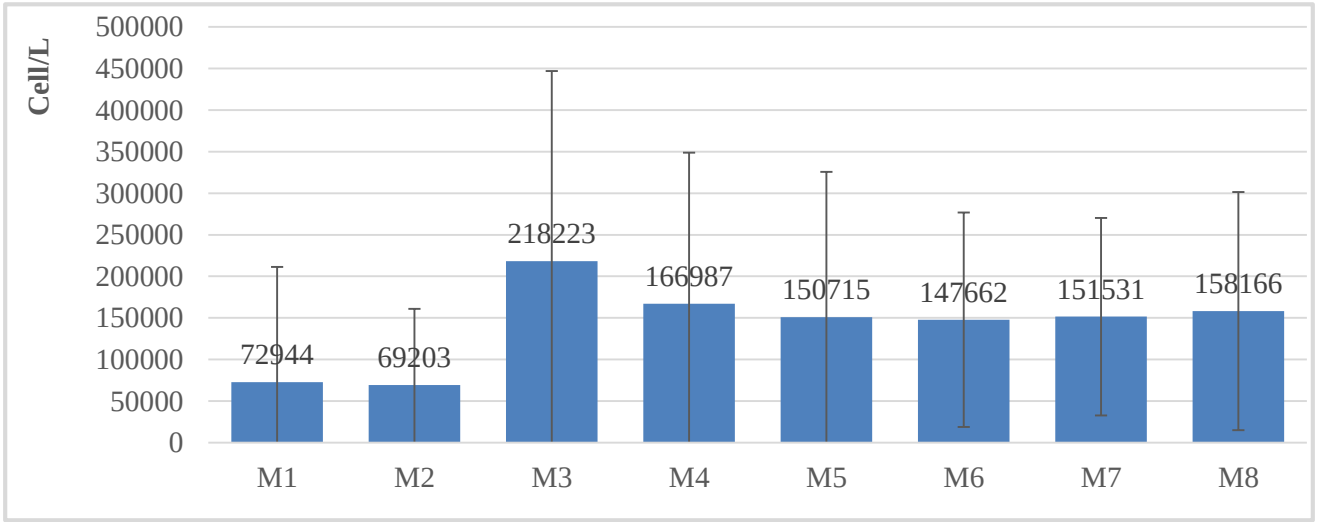

Figure 3. *Changes of the phytoplankton density by spaces*

The average cell density of phytoplankton in Song Hinh hydropower reservoir at each survey point ranged from 69,203 - 218,223 cells/L, reaching the highest value at point M3 (218,223 ± 228,795 cells/L) and the lowest value at point M2 (69,203 ± 91,829 cells/L). The cell density at sampling points

M4 to M8 was recorded as relatively high during the surveys, ranging from 147,662 to 166,987 cells/L on average. The density of phytoplankton in Song Hinh hydropower reservoir at sampling points during the study period fluctuated unclearly and unevenly across surveys; sampling points M3 to M8 had density. Through the surveys, it was pretty stable, all reaching over 10^4 cells/L. In the surveys in May 2023, October 2023 and February 2024, the density reached over 10^5 cells/L, while at sampling points M1 and M2, the density was relatively low (<10^4 cells/L) during October

3.4. Dominance phytoplankton species

The dominant phytoplankton species have the highest distribution density in the biological community at the sampling point. The development of dominant species in a biological community partly reflects the diversity and balance of the community and ecosystem in that area, expressed through the proportion of dominant species. Results of analysis of the phytoplankton community in Song Hinh hydropower reservoir during surveys in 2023 - 2024 show that the dominant species growing in the study area are mainly Cyanophyta, Bacillariophyta and Chlorophyta, with dominance levels ranging from 16.7 - 76.2%. Among them, Cyanobacteria species (*Microcystis aeruginosa, Anabaena sp*., *Oscillatoria princeps)* dominate others; they thrive in several cells and appear at most sample collection points over the years. Surveys in November 2023, December 2023 and February 2024 with dominance levels from 16.7 - 65.0%. Chlorophyta species (*Eudorina elegans, Protococcus sp., Pediastrum duplex*) dominated at all sampling points in the October 2023 survey, with dominance levels ranging from 21.7 - 76.2% and dominating scattered in surveys in November 2023 and February 2024 with dominance level from 27.2 - 47.6%. The species Bacillariophyta - *Melosira granulata* dominated all sampling points in the survey in May 2023 with a dominance level ranging from 38.2 - 69.1% (table 7).

Table 7. *Number, ratio and dominant species of phytoplankton*

Sampling point	Dominance	No.	Total (Cell/L)	Density (Cell/L)	(%)
		May./2023			
M1	*Melosira granulata*	54	10542	5060	48.0
M2	*Melosira granulata*	59	30597	11730	38.3
M3	*Melosira granulata*	64	359492	248400	69.1
M4	*Melosira granulata*	60	111276	56580	50.8
M5	*Melosira granulata*	61	148263	56700	38.2
M6	*Melosira granulata*	62	274720	115200	41.9
M7	*Melosira granulata*	54	262467	103950	39.6
M8	*Melosira granulata*	50	373452	187200	50.1
		Oct./2023			
M1	*Eudorina elegans*	46	2209	480	21.7
M2	*Pediastrum duplex*	55	3458	800	23.1
M3	*Protococcus* sp.	51	553344	403200	72.9
M4	*Protococcus* sp.	46	472412	360000	76.2
M5	*Protococcus* sp.	49	445596	331200	74.3
M6	*Protococcus* sp.	53	291992	198720	68.1
M7	*Protococcus* sp.	48	223872	128064	57.2

M8	*Protococcus* sp.	45	212532	61824	29.1
		Nov./2023			
M1	*Eudorina elegans*	55	15653	4256	27.2
M2	*Anabaena* sp.	56	41826	22080	52.8
M3	*Anabaena* sp.	50	35498	16560	46.7
M4	*Anabaena* sp.	46	33300	14490	43.5
M5	*Oscillatoria princeps*	47	15066	4000	26.5
M6	*Oscillatoria princeps*	45	34190	12600	36.9
M7	*Microcystis aeruginosa*	48	28438	7000	24.6
M8	*Anabaena* sp.	51	35648	5940	16.7
		Dec./2023			
M1	*Microcystis aeruginosa*	55	16154	3500	21.7
M2	*Anabaena* sp.	55	38910	25300	65.0
M3	*Anabaena* sp.	54	53806	19780	36.8
M4	*Anabaena* sp.	47	34456	14260	41.4
M5	*Anabaena* sp.	45	22244	11500	51.7
M6	*Anabaena* sp.	46	23066	6440	27.9
M7	*Anabaena* sp.	44	16712	3080	18.4
M8	*Anabaena* sp.	48	25718	6160	24.0
		Feb./2024			
M1	*Anabaena* sp.	53	320160	137700	43.0
M2	*Anabaena* sp.	51	231222	95220	41.2
M3	*Protococcus* sp.	52	88976	34496	38.8
M4	*Anabaena* sp.	50	183492	71760	39.1
M5	*Anabaena* sp.	50	122408	57960	47.3
M6	*Protococcus* sp.	56	114342	30912	27.0
M7	*Anabaena* sp.	52	226164	107640	47.6
M8	*Anabaena* sp.	48	143478	57960	40.4

3.5. The 'Shannon' species diversity index

Several indices of species diversity are used in the large amount of literature on biological diversity and ecological monitoring. A commonly used index is that referred to as 'Shannon's Index' or 'H'. The results for the phytoplankton of Hinh River hydropower reservoir, the recorded diversity index H' ranges from 1.53 - 3.98; reached the highest value at point M1 and the lowest value at point M4 in the October 2023. During the December 2023, the diversity index H' of phytoplankton was recorded as the highest, all sampling points had H'>3 (except point M2 with H=2.38); Next, the diversity index of phytoplankton at all sampling points during the period of November 2023 and February 2024

all had H'>2. The lowest of phytoplankton in the October 2023 had a low value of the diversity index, with 3/8 sampling points having H'<2. In the May 2023, 1/8 of the sampling points had H'<2. H'<2. In general, the diversity index H' of the phytoplankton of Hinh River hydropower reservoir at sampling points is quite high (H'>2), demonstrating the characteristics of the biological water environment according to phytoplankton are quite good.

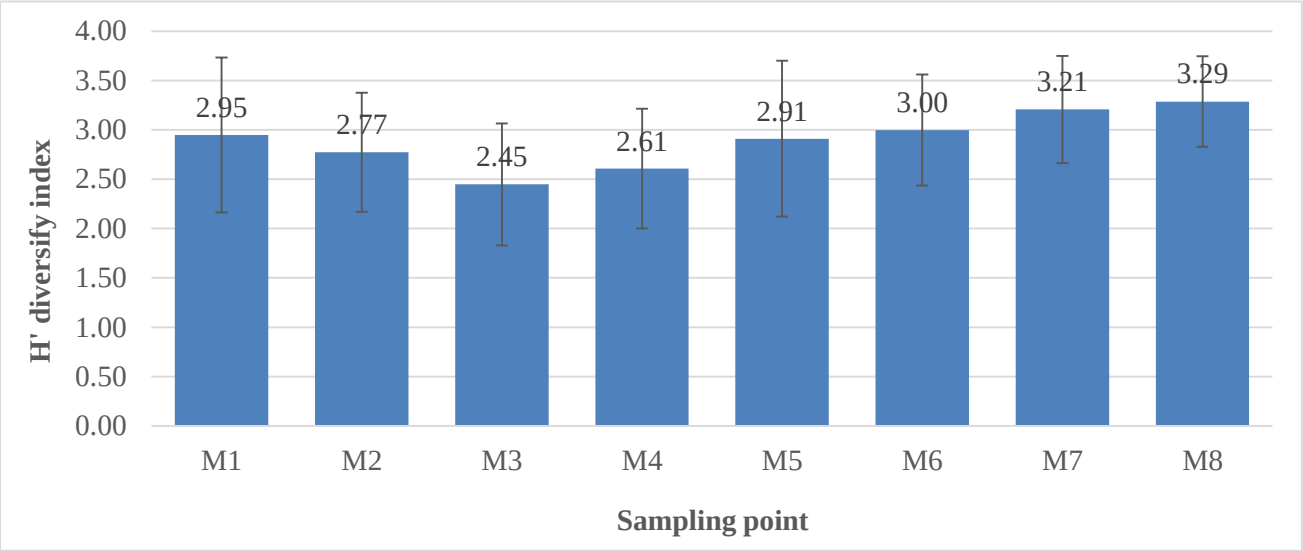

Figure 2. Average diversity index H' of phytoplankton at sampling points in Song Hinh hydropower reservoir

4. Conclusions

- There were 141 phytoplankton species belonging to 60 genera, 39 families, 25 orders, 11 classes and 7 different phyla identified in Song Hinh hydropower reservoir, Phu Yen province. In particular, the Charophyta phylum dominates in quantity with 51 species (accounting for 36.17% of the total number of species); Chlorophyta phylum with 37 species (accounting for 26.24% of the total number of species); Euglenophyta) has 19 species (accounting for 13.48%), Bacillariophyta has 15 species (accounting for 10.64%), Cyanophyta has 9 species (accounting for 6.38%), Dinophyta and Ochrophyta have a relatively low number of recorded species, reaching from 4 to 6 species, (accounting for 2.84 - 4.26%, respectively). Seven toxic species of Cyanophyta (*Microcystis aeruginosa, Microcystis botrys, Microcystis wesenbergii, Oscillatoria princeps, Lyngbya sp., Oscillatoria sp., Anabaena sp*.) have been recorded distributed at all sampling points with relatively high density (>10^4 cells/liter), these species have the ability to secrete toxins Antoxin, Saxitoxins, and Microcystins.

- The number of phytoplankton species distributed at sampling sites ranges from 72 - 97 species/sampling point. The density of phytoplankton in Song Hinh hydropower reservoir through surveys ranged from 2,209 - 553,344 cells/liter. The variation in species composition focuses mainly on the phyla of Bacillariophyta, Chlorophyta, Charophyta and Euglenophyta.

- The diversity index H' of phytoplankton reached a quite high value, most sampling points in the survey in May 2023, November 2023, December 2023 and February 2024 all had H'> 2; In contrast, in October 2023 had a diversity index at 3/8 sampling points H'<2.

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