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*Original Research*

# An Interpretation of Diatom Community for Environmental Record in 5-65 cm of Cebong Lake Sediment

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**Abstract**

Cebong Lake is one of several lakes in Indonesia located in Sembungan Village and formed by volcanic activities from the Dieng plateau, Wonosobo. Cebong Lake is heavily used by local communities for irrigation, tourism, and the local community's needs. Water usage will have an impact on lake productivity and fish production. This study aims to determine the environmental changes in Cebong Lake that may have occurred in the past by analyzing the structure community of diatom that composes vertically using 5-65 cm samples sediment of Cebong Lake (interval 5 cm, 13 samples). Methods used for sample treatment include: preparation, digestion, identification of diatom, and enumeration. The result obtained are analyzed using the relative abundance and ecosystem indices. The result found 171 species of diatom belonging to 41 genera, total diatom abundance is 702.975 ind.gr, Diversity index value (H') ranges between 3.10-3.80, Evenness index value (E) ranges between 0.42-0.70, Dominance index value (D) ranges between 0.03-0.09. Based on Bray-Curtis analysis, Cebong Lake is divided into 2 zones, namely: zone 1 (40-65 cm layers) describes as oligo-mesotrophic waters, and zone 2 (5-35 cm layer) describes as meso-eutrophic waters.

**Keywords**: diatom, water quality, diversity, cebong lake, trophic status

## Introduction

Diatom (Bacillariophyta) are single-celled organisms (unicellular algae) with microscopic sizes (10-200 micros) and can be found in many environments containing water [1]. Diatoms can live solitary or colonized in some species, occupying waters in two main ecological niches: benthos and plankton. The benthic diatom has abilities to be attached, stalked, or motile, while the planktonic diatoms are drifting in a water body [2].

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Diatoms have a distinctive structure of silica walls and ornamentation that characterizes each diatom species, this structure is the most important feature referring to the correct identification and taxonomy [1]. The hard silica walls that enclose diatoms are formed from pectin and are commonly called frustules [3], allow them to be well preserved in sediments for long periods of time [4].

Paleoreconstruction is an activity in recreating conditions that existed in the past, based on the remains of organisms that are stored and well deposited in sediment layers [5]. In order to grow and develop, diatom has their own preferenced habitat, when diatoms are abundant under certain conditions and died, their skeletons (silica cell wall) will settle in the sediment, the changes in diatom assemblages found in a sedimentary layer will reflect environmental conditions when they are deposited [6].

In the Java region, freshwater has more stress due to the dense population, leading to an unbalanced water supply and demand, with agriculture, being on the top source of demanding surface water [7]. Cebong Lake is one of the lakes that support the surrounding area and local community for daily utilization, located in Sembungan Village, the highest village in Central Java [8]. Cebong Lake is one of several lakes that lies within the Dieng plateau, formed by volcanic activities on Prau Mountain [9]. Cebong water supply comes from rain. Cebong Lake used to have an area of 18 hectares, but now it is only 12 hectares, surrounded by potato plantations, residential areas, a camping area on the lakeside, and a Sikunir Hill tourism spot [10].

Continuous pollution pressure leads to further degradation of ecological conditions in the lake ecosystem, with the existence of regime changes (trophic transition of lakes from oligotrophic to eutrophic). It is important to identify ecological information for further use in lake management [11]. Trophic and climatic changes may impact diatom assemblage composition [12]. While diatom sensitiveness to environmental changes, their valves are well preserved in sediments, fossil diatom assemblage reflects seasonal fluctuations in sedimentation [6, 13]. Environmental variables such as lake-water pH, phosphorus content, and climatic variables are linked to diatom patterns [13]. This study aims to interpret  the abundance of preserved diatom communities in sediment to determine environmental changes in Cebong Lake that occurred in the past.

## Methods

The study area of Cebong Lake are coordinated at 7°14’10.2”S 109°55’12.1”E, sediment core was collected from one site in the corridor of Cebong Lake, with coordinate 7°14’11.0”S 109°55’16.5”E (Fig. 1). Cebong Lake is located in the administrative region of Dieng, Wonosobo, Central Java. Wonosobo and Banjarnegara

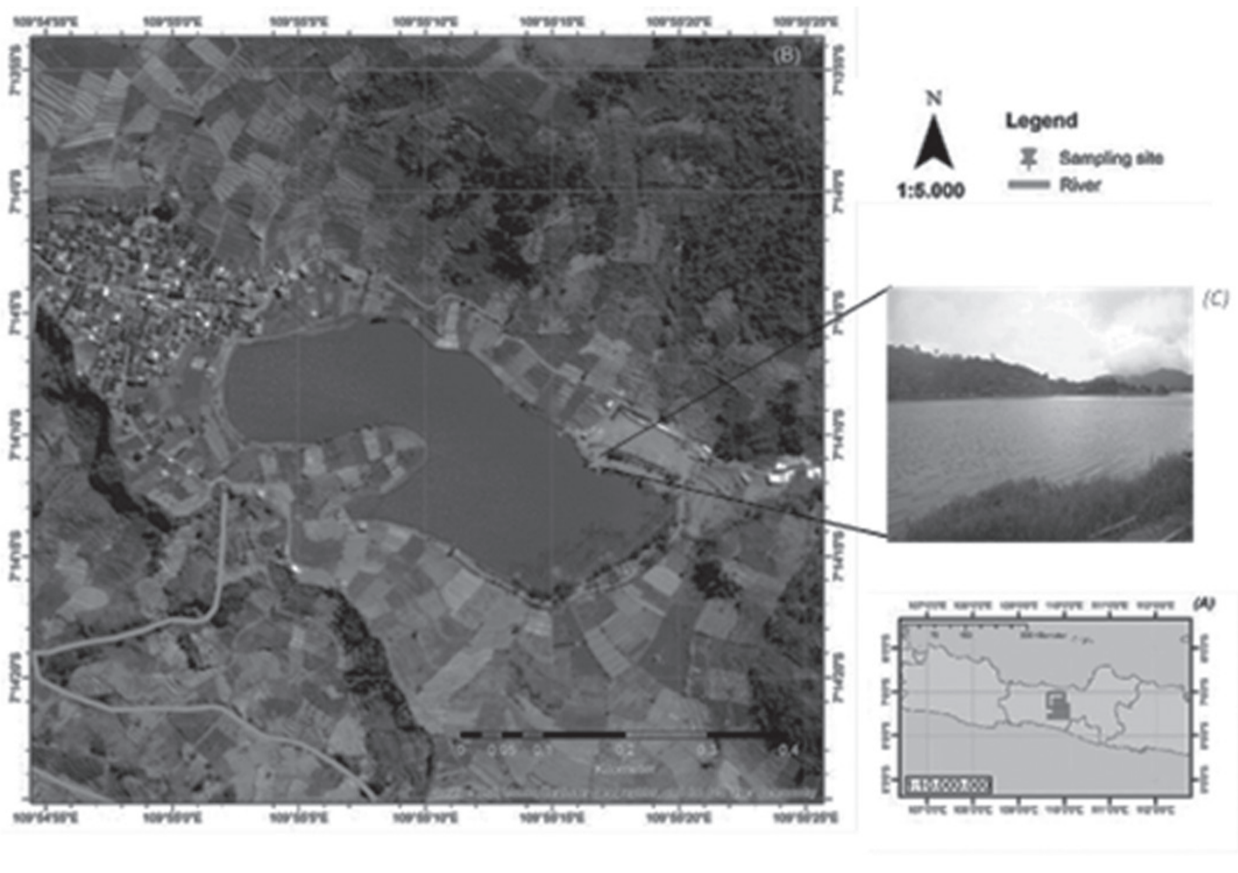



Fig. 1. Map of study site, (A) Java Island, (B) Cebong Lake area, Dieng, (C) sampling site.

are two of six administrative region that included in priority areas. Precisely, Cebong Lake is located in the Sembungan Village, surrounded by planting field such as caricas and potatoes. Cebong Lake serves as a water reservoir for local people throughout the year, during the dry season, the lake's water will drops due to water pumping, while during the rainy season, erosion enriches the lake, generating changes in water composition [8].

Sediment was collected from one location using Russian corer (Fig. 1). Sediments were taken to a depth of 65 cm in consideration of sediment condition (soft-textured), land use, and research conducted in [14] that showed the distribution of bottom sediment and drift sediment are distributed throughout the Cebong Lake area. The sediment samples were sliced every 1 cm. However, the sediment that is used in this study is selected per 5 cm (interval), with the total samples used being 13 sediments. For diatom analysis, the sediments were digested in methods [1] heated using HCL 10% and $H_2O_2$ 10% for 2 hours at >800ºC, washing is repeated throughout and after the stage. Samples were prepared and mounted using Naphrax on a microscopic slide. Diatoms were observed using a light microscope under 1000x magnification, each slide is counted up to a minimum of 400 diatom valves. Identification was done by matching the species morphology and habitat with identification books [15-16]. Validation and accepted names were checked on Algaebase.org [17].

### Data Analysis

The ecological indices calculated are Diversity, Evenness, and Dominance. Shannon Wiener diversity index (H') formula as follows [18]:

$$H' = -\sum_{i=1}^{s} pi \, \ln pi$$

Where H' = Shannon Wiener species diversity index, Ni = Number of individuals of type i, N = total number of individuals of all species. The Evenness index is used to determine community balance. the Evenness index formula is [19]:

$$e = \frac{H'}{\ln S}$$

where e = evenness index (values between 0-1), H' = species diversity, In = natural logarithm, S = number of taxa. Dominance Index (C) was used to determine the dominance species in the community, calculated by formula [20]:

$$C = \sum_{i=1}^{s} (\frac{ni}{N})^2$$

Where ni = number of the individuals per species; N = total number of individuals per species.

Diatoms were counted and tabulated using Ms. Excel. To determine structure community, species were input to C2 software for diagram and statistical analysis. Division of zones in stratigraphy were made using Bray-Curtis similarity on PAST software.

## Results and Discussion

Observations of diatom species in the sediment (5-65 cm) samples found 171 diatom species belonging to 41 genera and 28 families. A total of 13 families had an abundance above 1% considered as common diatom, including: Achnanthidiaceae (20 species), Staurosiraceae (11 species), Bacillariaceae (17 species), Fragilariaceae (7 species), Naviculales incertae sedis (3 species), Aulacoseiraceae (8 species), Cymbellaceae (8 species), Gomphonemataceae (18 species), Naviculaceae (9 species), Melosiraceae (3 species), Stephanodiscaceae (1 species), Pinnulariaceae (14 species), Eunotiaceae (16 species). While Families with abundance below 1% considered as rare diatom including: Stauroneidaceae (7 species), Amphipleuraceae (4 species), Ulnariaceae (2 species), Diploneidaceae (2 species), Sellaphoraceae (4 species), Brachysiraceae (2 species), Radialiplicataceae (1 species), Diadesmidaceae (2 species), Rhopalodiaceae (3 species), Cocconeidaceae (2 species), Neidiaceae (2 species), Triceratiaceae (1 species), Tabellariaceae, (2 species) Surirellaceae (2 species), Anomoeoneidaceae (1 species). The percentages of family and genus abundance are presented in Fig. 2.

Genus with high diversity were found in *Achnanthidium* taxa for 18 species and contributed on structure community in Cebong Lake for 24.36% of the overall total abundance. *Eunotia* is the second highest diversity taxa with 16 species but low on abundance, while *staurosirella* taxa is the second most abundance species with 10.28% of the overall total abundance. Relative abundance percentage data were used to interpret the structure community of diatom by eliminating diatom species that had a relative abundance below 1% (species that are considered rare) [21]. The relative abundance of Cebong Lake diatoms above 2% are composed by 32 diatom species (most frequently found) from the highest value shown in Fig. 3.

*Staurosirella pinnata* is the highest abundance (6.83%) found in all sediment depth (0-65 cm) with highest abundance value in layer 40 cm. *S. pinnata* is an alpine diatom commonly found in a high altitude lakes, this species indicate a high conductivity [22]. The second most abundace is *Achnanthidium* sp 2 with 5% value, in this study, *Achnanthidium* taxa has two species unidentified due to the small appearance. In some publication *Achnanthidium* were mentioned as difficult to identify due to small morphology with

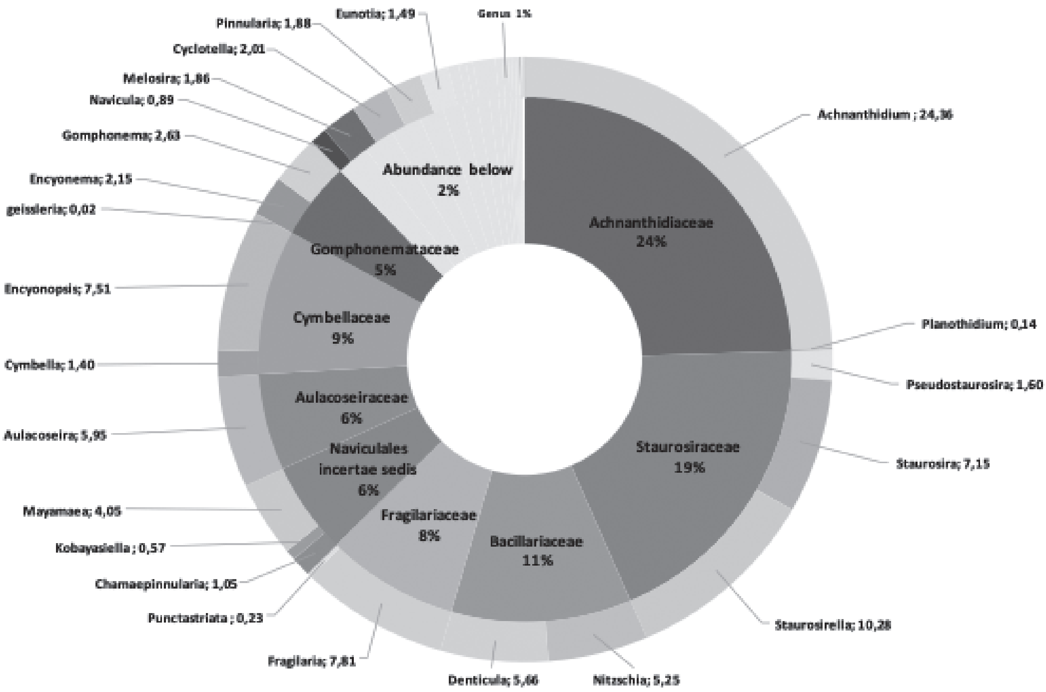



Fig. 2. Diatom families and genus composition.

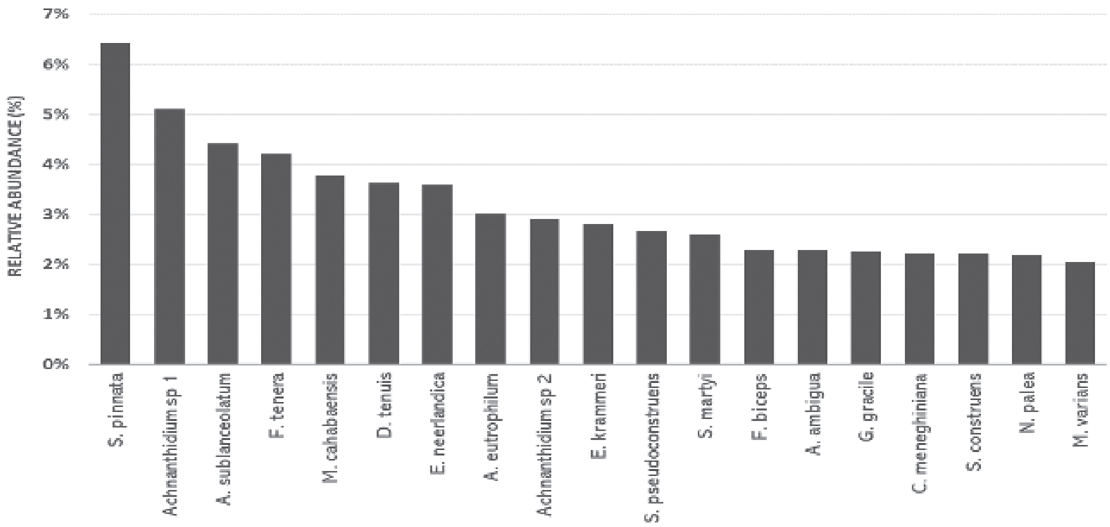



Fig. 3. Diatom composition, relative abundance above 2%.

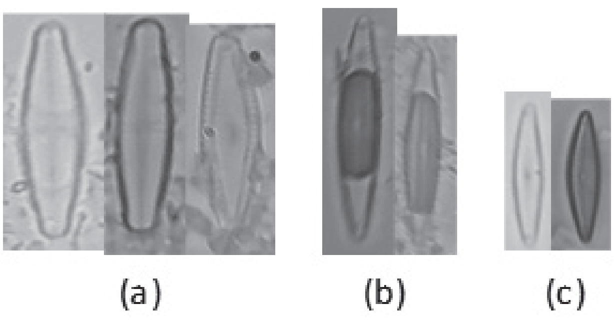



Fig. 4. *Achnanthidium* spesies, a) *A. minutissimum*, b) *Achnanthidium* sp 1, c) *Achnanthidium* sp 2.

a lot of similarities, molecular methods are required, thus many of its species are categorized as *Achnanthidium minutissimum* complex [23]. In this study, unidentified taxa were retrieved from *Achnanthidium minutissimum* complex and given a code (number). *Achnanthidium* sp 1 and *Achnanthidium* sp 2 were categorized as Achnanthidium taxa due to their features, *Achnanthidium* has a linear-lanceolate to lanceolate-elliptic valves, cell length less than 30 μm with width less than 5 μm, morphological differences can be seen in Fig. 4 [24].

### Ecological Indices

The total diatom overall are 702.975 individual.gr, with species value ranging from 125-15.000 individual/gr. Species Diversity, Evenness and Dominance were counted, the result of three indices are varies. Diversity index (H) diatom ranging from 3.10-3.80, highest diversity index value in layer 30 cm with 71 species (Fig. 5). Value of Diversity index with H'>3 indicates high diversity and community stability [25]. Evenness value were ranging from 0.70-0.43, the highest value was shown in layer 25 cm (Fig. 5). Criteria for Evenness index with a value of 0.40>E>0.60 were categorized for quite evenly distributed species, dominance existence, species opportunities to grow are not equal, while Evenness index with a value 0.60>1 were categorized equal for distribution of each species and chances to grow. Dominance index in Cebong lake ranging from 0.03-0.09. Dominance index with a value 0<D<0.5 were categorized as lower dominance until no dominance showed (Fig. 5). Layer 40 cm has a highest dominance value (0.09) with the lowest diversity (3.10), Evenness (0.43), in this layer, family of Staurosiraceae is the most abundant diatom, *Staurosirella pinnata* is the most abundant species with 15.000 individual/gr. On average Cebong Lake shows great values of Diversity and Evenness with low Dominance value.

### Environmental Variables Record from Diatom Composition

Analysis of diatom similarity in each layer were processed using PAST software, the results of sedimentary layers based on stratigraphic Bray-Curtis analysis using taxa similarity divided into two zones with each zone as follows: zone 1 (40-65 cm) and zone 2 (5-35 cm). A very significant difference is seen in those two zones which separated the upper layer (zone 2) and the lower layer (zone 1), shown in Fig. 6.

The CCA analysis conducted in [8], there is a positive correlation between environmental quality parameters and the abundance of diatoms in Cebong Lake (the position of species with environmental variables shows a connection) [8]. Thus, the use and changes in the diatom community preserved in biostratigraphy indicate environmental changes.

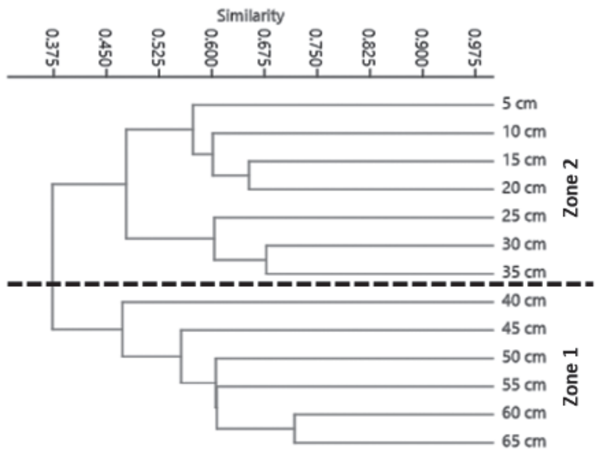
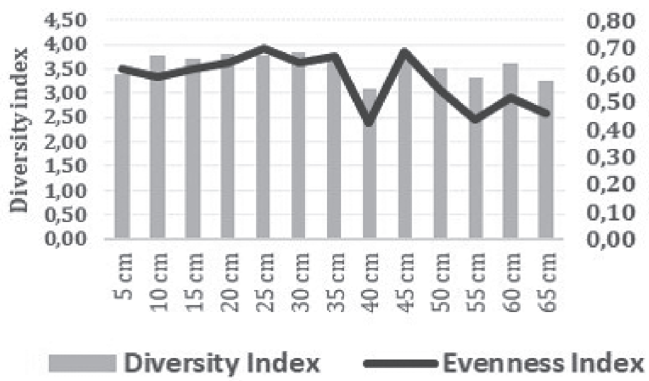



Fig. 6. Bray-Curtis similarity clustering result in PAST software.

*Zone 1*

Zone 1 (the lower layer) consisting of layers at a depth of 40-65 cm, has an average diversity index of 3.43 with an average of 62 taxa found. Based on the criteria of the diversity index value, the diversity index of zone 1 has a high diversity and stable biota community. In zone 1, the results of the index calculation show a dominance value (0.05). In Bray-Curtis similarity result, this zone were clustered into four groups as follows; group A1 (60-65 cm), group B1 (50-55 cm), C1 (45 cm), D1 (40 cm). In group 1A (60-65 cm) diatoms with high abundance are the Achnanthidiaceae family, with the following composition: *Achnanthidium* sp 1, *Achnanthidium sublanceolatum, Achnanthidium indistinctum, Achnanthidium* sp 2, *Denticula tenuis, Fragilaria tenera, Fragilaria synegrotesca, Staurosira construens, Aulacoseira tenela, Encyonopsis neerlandica*. In this group, the environmental variables that may be indicated by abundant species are follows; *A. sublanceolatum, A. tenela, S. construens, F. tenera, Fragilaria synegrotesca*



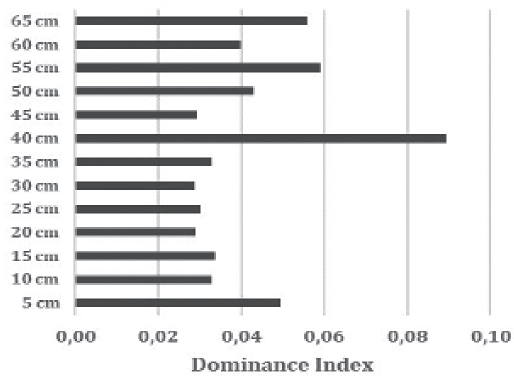




Fig. 5. Diversity, Evenness, and Dominance indices result.

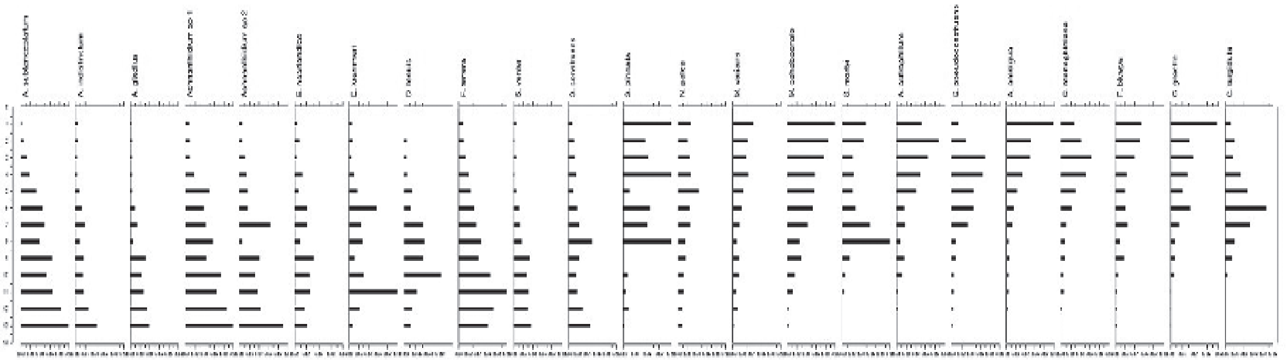


Fig. 7. Trend of diatom composition on each layer.

are indicated an oligotrophic water, while *E. neerlandica* indicated oligo- β-mesosaprobic. A slightly alkaline pH indicated by *D. tenuis, S. construens, A. sublanceolatum, A. indistinctum*, a neutrophilic pH indicated by *F. tenera*. Low-medium conductivity indicated by *A. indistinctum, A. sublanceolatum* [26-28].

In Group B1 (50-55 cm) diatoms with high abundance, namely; *Fragilaria tenera, Encyonopsis krammeri, Achnanthidium* sp 1, *Denticula tenuis, Encyonopsis neerlandica, Achnanthidium minutissimum, Staurosira construens, Achnanthidium sublanceolatum,. E. neerlandica* and *E. krammeri* indicated a mestrophic and an oligo- β-mesosaprobic water. A slightly alkaline pH indicated by *D. tenuis, S. construens, A. sublanceolatum*. a neutrophilic pH indicated by *F. tenera and E. neerlandica* [26-30]. In group C1 (45 cm) the abundant diatoms consist of; *Achnanthidium sublanceolatum, E. neerlandica, Achnanthidium* sp 1, *Denticula tenuis, Mayamaea cahabaensis, Fragilaria tenera, Staurosira construens, Achnanthidium* sp 2, *Staurosirella pinnata, Achnanthidium indistinctum. S. pinnata, E. neerlandica, S. construens, M. cahabaensis* indicated a β-mesosaprobic water. A slightly alkaline pH indicated by *D. tenuis, S. construens, A. sublanceolatum*. a neutrophilic pH indicated by *F. tenera* and *E. neerlandica* [26-29, 31].

In group D1 (40 cm) the abundant diatoms consisted of; *Staurosirella pinnata, Staurosira martyi, Stauorisa venter, Achnanthidium* sp 1, *Denticula tenuis, Staurosira construens, Fragilaria tenera, Achnanthidium sublanceolatum*. Abundance of *S. pinnata*, *S. martyi, S. venter* indicated a mesotrophic water. A neutrophilic-slightly alkaline pH indicated by *S. martyi, S. venter, S. construens, F. tenera, A. sublanceolatum* [8, 26, 32-33]. In general, zone 1 (40-65 cm) has a water pH ranging between netral-slightly alkaline water, the lower the layer depth, the higher the conductivity of the water, marked by the emergence of *S. pinnata* in the 40-45 cm layer [8].

*Zone 2*

Zone 2 (the upper layer) consisting of layers at a depth of 5-35 cm, this zone has an average diversity index of 3.64 with an average of 63 taxa found. Based on the criteria of the diversity index value, the diversity index of zone 2 has a high diversity and stable biota community. In zone 2, the results of the index calculation shows a dominance value (0.03). In Bray-Curtis similarity result this zone clustered into four groups as follows; group A2 (25-35 cm), group B2 (15-20 cm), C2 (10 cm), D1 (5 cm).

In group A2 (25-35 cm) the abundant diatoms consisted of; *Staurosirella pinnata, Mayamaea cahabaensis, Achnanthidium* sp 1, *Staurosira pseudoconstruens, Staurosirella martyi, Nitzschia palea, Cymbella turgidula, Achnanthidium eutrophilum*. Mesotrophic water indicated by *S. pinnata, M. cahabaensis, Achnanthidium* sp 1, *S. martyi*. Eutrophic water indicated by *M. cahabaensis*. Medium-high conductivity indicated by *S. pseudoconstruens*, *S. pinnata. C. turgidula* and *N. palea* indicated a medium-high pollutan in water. Alkaline pH indicated by *S. pseudoconstruens* and *N. palea* while A neutrophilic-slightly alkaline pH indicated by *S. pinnata, S. martyi* [31-32, 34-35]. In group B2 (15-20 cm) the abundant diatoms consisted of; *Staurosirella pinnata, Staurosira pseudoconstruens, Mayamaea cahabaensis, Cyclotella meneghiniana, Achnanthidium eutrophilum, Aulacoseria ambigua, Gomphonema gracile, Fragilaria biceps*. Mesotrophic water indicated by *S. pinnata, A. ambigua, F. biceps, M. cahabaensis*. Eutrophic water indicated by *C. meneghiniana, A. eutrophilum, G. gracile, F. biceps.* A neutrophilic-slightly alkaline pH indicated by *A. ambigua, S. pinnata*. Alkaline pH indicated by *C. meneghiniana, S. pseudoconstruens, G. gracile*. Medium-high conductivity indicated by *S. pseudoconstruens, S. pinnata, A eutrophilum, G. gracile* [32, 37-40].

At group C2 (10 cm) abundant diatoms consist of; *Achnanthidium eutrophilum, Mayamaea cahabaensis, Staurosirella pinnata, Aulacoseria ambigua, Fragilaria biceps, Staurosirella martyi, Cyclotella meneghiniana, Melosira varians*. Eutrophic water indicated by *C. meneghiniana, A. eutrophilum, F. biceps, M. varians.* Mesotrophic water indicated by *S. pinnata, F.biceps.* A neutrophilic-slightly alkaline pH indicated by *A. ambigua, S. pinnata, S. martyi* [8, 31-32, 37-40]. In group D2 (5 cm) abundant diatoms consist of; *Staurosirella* *pinnata, Mayamaea cahabaensis, Aulacoseria ambigua, Gomphonema gracile, Achnanthidium eutrophilum, Fragilaria biceps, Staurosirella martyi, Melosira varians, Cyclotella meneghiniana*. Eutrophic water indicated by *G. gracile, M. varians, C. meneghiniana, A. eutrophilum, F.biceps*. Mesotrophic water indicated by *S. pinnata, F.biceps, A. ambigua*. A neutrophilic-slightly alkaline pH indicated by *A. ambigua, S. pinnata, S. martyi*. Medium-high conductivity indicated by *S. pinnata, A eutrophilum, G. gracile* [8, 31-32, 37-40]. The trend of diatom abundance can be seen in the Fig. 7.

In general, Cebong lake has a high value of diversity and Evenness, with low value of dominance, the abundance of diatoms is very high, environmental changes recorded using diatom community data shows that Cebong Lake experienced a shift in trophic status, zone 1 has a trophic status ranging from oligotrophic-mesotrophic water, trophic status begins to shift from oligotrophic to mesotrophic characterized by reduced oligotrophic indicator species (*F.tenera, F. synegrotesca, S. contruens, Achnanthidium* sp.) replaced with an abundance of *S. pinnata* and *S. venter* [8, 33]. While zone 2 (5-25 cm) has a neutrophilic-alkaline pH with medium-high conductivity, meso-eutrophic water [31-32, 34-35, 37-40]. In this zone, mesotrophic condition starts at group A2-B2, the eutrophic water starts at layer C2-D2 indicated by a decrease in abundant of oligo-mesotrophic diatom and an upward trend of eutrophic species such as *G. gracile, F. biceps* and *A. eutrophilum* [37-40]. A significant difference between two zones were visible. The unidentified *Achnanthidum* species is likely an oligotrophic-mesotrophic species, characterized by decreasing taxa abundance as the layer approaches the surface.

There is no evidence supporting this research in which years this layer consist of, as no dating sediment were conducted. But, research approach in [5] consisting dating sediment in Warna Lake which is still in the same complex as Cebong lake in Dieng area stated that 0-15 cm of their layer estimated for 1980-2013, with 0-9 cm estimated for 2003-2013 years, it can be estimated in Cebong Lake for 0-65 cm layers are still consist of 1980-2020. This research showing a trophic changes recorded within those layers, by analyzing diatom dominant in community in each layer.

## Conclusions

Cebong lake has 171 diatoms identified belonging to 41 genera, indices calculation shows a high value of Diversity and Evenness, with low value of Dominance. Cebong Lake experienced a shift in trophic status, according to the trend of abundant diatom, the lower sediment (40-65 cm) recorded oligotrophic-mesotrophic water indicated by *F.tenera, F. synegrotesca, S. contruens, Achnanthidium* sp , while the upper layer (5-35 cm) recorded a meso-eutrophic water indicated by *G. gracile, F. biceps* and *A. eutrophilum*.

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## Conflict of Interest

The authors declare no conflict of interest.

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