Effects of water ecological environment on benthic algae in a water source reservoir

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Abstract. Several benthic plants and animals live in lakes and reservoirs. Benthic algae, mostly diatoms, can reflect the quality of the water environment. The indicative function of water quality by diatom community and basic principle of diatoms in-dex method was described. This paper investigates the benthic algal community in a water reservoir basin, in flood season (July) and non-flood season (November) respectively. A total of 129 species of benthic diatoms were collected in flood season (July) and non-flood season (November). By analyzing the generic index of Trophic Diatom Index (TDI), Index of Biological Diatom (IBD) and Specific Pollution Sensitivity Index (IPS) the status of aquatic ecological environment in this reservoir was evaluated, which indicates that the water quality of reservoir area is better.

1. Introduction

Sediments in lakes and reservoirs are not only the source of various pollutants, but also the "homeland" of various benthic organisms such as aquatic insects, mollusks, oligocosms and crustaceans [1]. Benthic organism is the collective term for all living things in sediment, including animals, plants and microorganisms. Benthic algae (mainly diatoms) are widely distributed, and their ecological research is also more in-depth (REFs). Studies have shown that diatoms are more sensitive than protozoa and macrobenthic invertebrates to organic pollutants. Algae, such as Aulacoseira alpigea, Nitzschiacommunis and Stephanodiscus parvus prefer to live in nutrient-rich bodies of water, which can indicate the eutrophication status of the body of water. Diatomamoniliformis, living in bodies of low total phosphorus concentration, can indicate poorly nutrient waters. Cembella amphicephla and Synedra acus Kutz. is sensitive to contaminants and is the indicator of clean water. Cyclotellabodanica Eul. is a common diatom species in acidified water. Diatoms as a test material, the test results more accurate and more predictable, the main advantages are as follows [2]: 1) Benthic algae gcannot evade the harmful effects of pollution by migration; 2) Species in benthic algae biomes are generally richer than other communities, with over 100 different algae in a few square centimeters of sediment; also different algae having different environmental tolerances and preferences; 3) benthic algae have a relatively short life cycle, can produce rapid response to environmental changes, and their changes in community structure can directly reflect the current environmental conditions; 4) Samples are easy to handle and manage, and the management and storage of benthic algae forms take up only a small volume. Benthic algae are used to monitor the ecological health of lakes, rivers and other bodies.
because of their sensitivity to environmental effects [3]. In recent years, many countries have established a series of benthic algae (diatoms) indices for detecting different environmental problems, including: Specific Pollution Sensitivity Index (IPS), Generic Diatom Index (IDG), Trophic Diatom Index (TDI), Descy Index (DESCY) [4]. This project is to study the community structure and the existing stock of benthic diatoms in reservoirs, which could be a good reference value to understand the status of watershed nutrition status, primary productivity and pollution of water bodies.

2. Materials and methods

2.1. Overview of the research area
Tangpu Reservoir is in the eastern low-relief hilly area of Zhe Jiang Province. It is a typical channel reservoir, with normal impounded water level of 32.05 m, total capacity of $2.35 \times 10^8$ m$^3$, surface area of 14 km$^2$ and designed daily water supply capacity of 1,000,000 tons.

2.2. Layout of sampling sites and collection of samples
In order to understand the distribution of benthic organisms in the sediments of Tangpu Reservoir, we set up sampling points respectively in the reservoir and in inbound river. Benthic algae are collected, and the species composition of the algae analyzed.

Algae, especially diatom community, are very sensitive to changes of temperature, pH value, conductivity, nutrient concentration and their distribution in sediments is generally patchy [5]. It has a wide range of application value in discriminating water pollution degree and evaluating water eutrophication [6,7]. In order to compare the distribution of benthic algae in different waters in the reservoir area, 15 sampling points were set up in the rivers and tributaries, the upstream wetlands and the main reservoir area, as shown in figure 1. Two sampling points were in Bei Xi Stream (BX1, BX2), 2 sampling points were in Nan Xi Stream (NX1, NX2), 2 sampling points were in rivers (SJX, WHX), 2 sampling points were in wetland (SD1, SD2), 1 sampling point is in Wang Tan town (WT), 6 sampling points are in the reservoir (DAS, TT, KZX, SJX1, WHX1, QSK). Benthic samples were collected separately in the flood season and non-flood season. Specific sampling points as shown below.

![Figure 1. Zoobenthos sampling points.](image-url)

Samples were taken at three different locations near each sampling point using a Peterson screener, and after being washed by a nylon mesh having a pore size of 0.95 mm and 0.45 mm, the residue left in the mesh was taken back to the laboratory. Algae in optical microscopy (Olympus BX51, 1000X), visual field method for counting, counting not less than 500 per piece, and record the corresponding
visual field number. Calculate twice for each sample, and finally take the average of two times. The difference between the calculated result and the average value of the control two pieces was within 15%, and the average value thereof was regarded as a valid result. Algae were identified using China's Freshwater Algae [8].

2.3. Analyzing method
Water environmental conditions have a significant impact on the composition of diatoms. Pollutants in water not only affect individual algae, such as cell structure, morphology, biochemical and physiological processes, but also affect the community structure of algae, such as population size, community composition and function [9]. The change of water physical and chemical properties will limit the growth of some algae and even destroy them, which will accelerate the growth and proliferation of other species and become the dominant species [10]. Therefore, the disappearance or multiplication of one species of algae corresponds to a change in one aspect of environmental conditions.

Therefore, it is possible to indicate the environmental state of the water body by observing the change of diatom community composition [11]. Diatoms index method proposed by Descy in 1979, currently used in a variety of diatoms index: Generic Index of diatom assemblage (GI), Trophic Diatom Index (TDI) and Index of Biological Diatom (IBD). These are mostly based on classical equations proposed by Zelinka and Marvan [12,13]:

\[
\text{Index} = \frac{\sum_{j=1}^{n} a_j s_j v_j}{\sum_{j=1}^{n} a_j v_j}
\]

Where: \(a_j\) is the abundance of species \(j\) in the sample; \(v_j\) is the indicated value of species \(j\), \(s_j\) is the pollution sensitivity of species \(j\), \(s_j\) varies from 1 to 3, 3 means species \(j\) is sensitive to eutrophication, 1 means species \(j\) is not sensitive to eutrophication.

Benthic algal dominance refers to the extent to which benthic algae predominate in the population. The formula is:

\[
Y = \frac{Ni \times fi}{N}
\]

Where: \(N\) represents the total number of individuals of all species in each sampling point, \(Ni\) represents the total number of individuals \(i\), \(fi\) represents the frequency of occurrence of the species at each sampling point. The dominance of \(Y \geq 0.02\) indicates that the species is the dominant species in the community.

TDI is mainly used to evaluate the eutrophication of freshwater environment, the greater the value of water quality worse. In addition to TDI range of 0-100, IBD index is converted to 0-20 range of values [14], as shown in table 1. The lower the TDI value, the lower the degree of eutrophication. The higher the value, the more the eutrophication tends to occur. The lower the IBD value, the higher the contamination at the sampling point. The ratings of the two indexes are as follows:

| Evaluation    | Colour | TDI  | IPS  | IBD  |
|---------------|--------|------|------|------|
| Very good     | Blue   | 1<35 | 20>17| 17<19|
| Good          | Green  | 35<50| 17>15| 13<17|
| Middle        | Yellow | 50<60| 15>12| 9<13 |
| Poor          | Orange | 60<75| 12>8 | 5<9  |
| Very poor     | Red    | 75<100| 8>1  | <5   |
3. Results and discussions

3.1. Species composition of benthic algae
In the project area, benthic diatoms were collected twice in flood season (July) and non-flood season (November) respectively. A total of 129 species of benthic diatoms were collected in flood season (July) and non-flood season (November). There are 19 genera and 68 species in the reservoir area and 105 genera and 21 genera in the rain-collecting area. Among them, 33 species of Navicularia, 17 species of Rhodophyceae and 11 species of Campylobacter were collected as shown in table 2.

Table 2. Diatom species composition of different zone of Tang Pu reservoir.

| Zone             | Genus | Species | Genus | Species | Genus | Species |
|------------------|-------|---------|-------|---------|-------|---------|
| Up reaches       | 17    | 75      | 19    | 76      | 21    | 105     |
| Reservoir area   | 11    | 39      | 17    | 51      | 19    | 68      |
| The whole basin  | 19    | 86      | 22    | 90      | 25    | 129     |

Ninety-nine species of 86 species of algae were collected during the flood season and 22 species of 90 species of algae were collected during the non-flood season (table 3). There was no significant difference in the number of algae species in different sampling points in the reservoir area. Among them, the lowest algae species number was found in sampling sites of WHX in flood season, and the highest number of species in SJX sampling sites was 31 species with an average of 21 species in non-flood season.

Table 3. Diatom species composition of different time of Tang Pu reservoir.

| Month         | Up reaches | Reservoir area | Total |
|---------------|------------|----------------|-------|
|               | July       | Nov.           | Total |
| Achmanthes    | 8          | 7              | 8     |
| Navicula      | 23         | 23             | 29    |
| Nitzschia     | 14         | 7              | 15    |
| Cymbella      | 6          | 7              | 10    |
| Gomphonema    | 4          | 6              | 10    |
| Fragilaria sp | 6          | 6              | 12    |
| Others        | 14         | 20             | 28    |

Figure 2. The dominance of dominant species in benthic algae basin-wide.
There were significant differences in algae species in the upper reaches of the river, 2-38 species, with an average of 25 species. The dominance of the dominant species in the sampling samples of the whole basin was 23.76% of *Achnanthes subhudsonit* and 8.83% of *Achnanthes subsessilis*; the average relative abundance was also 5.16% of *Gomphonema clevei*, *Encyonema simile* 4.63%, *Navicula minima* 3.16%, *Fragilaria bidens* 2.22%, *Nitzschia amphibian* 2.20% (figure 2), *Achnanthes minutaissima* 1.78%, *Navicula notha* 1.65%, *Cymbella turgidula* 1.16%, *Navicula subminuscula* 0.81%. The main advantage of the sample in the reservoir area is *Achnanthidium catenatum* 53.47%. The dominance of the main dominant species in the upper reaches of the river is *Achnanthes subhudsonit* 15.33%, *Nitzschia palea* 7.67%, *Encyonema simile* 8.67%.

3.2. Diatoms density
The flood season and non-flood season diatoms density changes are between 0.25-6.74×10^10 ind./m²; the average density of 1.92×10^10 ind./m² (figure 3). In flood season, the average density of algae is 1.83×10^10 ind./m². In non-flood season, the average density of algae is 2.02×10^10 ind./m². The lowest value appears in the flood of WHX. The total density of algae between the river and reservoir area is relatively large, with an average of 2.18×10^10 ind./m² in the reservoir and an average of 1.17×10^10 ind./m² in the upper reaches.

![Figure 3. The diatom density of each sample.](image)

According to figure 3, the density of benthic algae in each sampling point is greater than that in the upper reaches in the flood season; in the non-flood season, the density of algae in the upper reaches is greater than that in the reservoir. This is due to the frequent changes of river water volume in flood season, great impact on benthic algae in the river channel, affecting the growth of algae [15]. However, the water level in reservoirs is deep, the flow rate is slow, the impact of runoff is small, the sediment environment is stable and the runoff will bring a large amount Nutrients for the growth of algae to create the conditions [16]. As a result, the density of algae in the reservoir area is greater than that in non-flood season in flood season. In non-flood season, the water volume of the river changed little and did not change frequently, and the sediments were in a stable environment. Compared with the reservoir area, the river sediments have high oxygen content and can be exposed to sunlight. The growth environment is superior to the sediments in the reservoir area, so a large number of algae begin to grow and multiply, and the density of algae increases accordingly [17]. The correlation analysis between the physical and chemical indexes of the reservoir was carried out. The results shows that the parameters related to chlorophyll a ranged from high to low according to the correlation absolute value: phytoplankton density > silicate > transparency >TP> CODMn>TOC>pH (r=0.358); The parameters related to phytoplankton density ranged from high to low according to the correlation absolute value: silicate >CODMn>chl >pH>TOC> transparency > ammonia nitrogen>TP>water temperature>DO (r=0.371). Phytoplankton density and water chlorophyll content, which characterize algal bloom biomass, not only have good correlation with their response variables, such as transparency, pH, CODMn, DO, but also have a high correlation with their driving variables, such as TP, silicate,
specific to each species, the density of Achnanthes is between 0.01-4.30×10^10 ind./m², the density of Cymbella is between 0-0.50×10^10 ind./m², the density of Fragilaria sp is between 0-0.38×10^10 ind./m², the density of Gomphonema is between 0.02-1.55×10^10 ind./m², the density of Navicula is between 0.02-1.25×10^10 ind./m², the density of Nitzschia is between 0.02-1.43×10^10 ind./m². The maximum is 7.25×10^10 ind./m² appears at WHX1; The minimum value is 0.40×10^10 ind./m² appears at NX2. Comparing the percentage of each genus in each sampling point in the reservoir area and the upper reaches, we can see that the main algae in the reservoir area are Achnanthes, accounting for 21.88% -73.60%, with an average of 50.92%; while the river channel is mainly Nitzschia, accounting for 2.35% -49.6%, with an average of 17.06% as shown in figure 4.

![Figure 4. Composition and Distribution of of each genus richness.](image)

It can be seen from the composition of the algae in each sampling point that sampling points at different positions have different proportions of algae. From the upper reaches of the river to the reservoir area, the abundance of Navicula algae gradually decreased and the abundance of Achnanthes increased gradually. This is mainly due to the different habits of the two species of algae and their adaptation to the sediment environment. Navicula has a narrow shape, like to live in high-velocity water [18]. Therefore, in the upper reaches of the river, the distribution of Navicula is broader and higher in abundance.

### 3.3. TDI index

The TDI value of the reservoir area is between 8.5-51.2 and the average is 33.12, which indicates that the water quality of reservoir area is better, as shown in figure 5. The TDI values of the sampling points in the upper reaches is between 18.1-92.5, with an average of 60.76, slightly larger than 60. This shows poor water quality of the river at up reaches.

Judging from the spatial distribution, the TDI index of each sampling point in the upper reaches of the river is generally higher than that in the reservoir area. From the time distribution, the TDI index of this sampling point in non-flood season is higher than that of the flood season. This shows that downstream from the river, along the water quality of nutrition has gradually increased. Along the way, the river flows through a large number of villagers gathering area, as well as a large number of farmland. The river receives a large number of point source pollution and agricultural non-point source pollution, resulting in poor water quality in the lower reaches. Therefore, the TDI index of river sediments is high [19]. The water in the reservoir is vast with abundant water and various types of nutrients have enough time to migrate and transform. Therefore, the pollutant content in the water body is reduced, and the water quality is better than the water quality of the river.
In addition, due to the rapid exchange of water bodies in rivers and reservoirs in flood season, the temperature is high (flood season is in summer and autumn) and all kinds of aquatic animals and plants grow rapidly. A large amount of pollutants in the water body will be utilized. Therefore, TDI Index is less than in the non-flood season.

The TDI Index indicates that the nutritional status of the reservoir area is in good condition [20]. In the upper reaches of the reservoir area, only the sampling points of the wetland outlet is good, other half of the sampling points being poor and very poor, which shows that the eutrophication of river water bodies in the upper reaches of the reservoir area is rather serious and poses a potential threat to the water quality of the reservoir.

3.4. **IPS index**

The value of IPS is between 1 and 20. The greater the value of IPS indicates the better the water quality. The IPS values of various sampling points in Tangpu Reservoir Area ranged from 12.8 to 19.4. The minimum IPS value of each sampling point in the upstream river channel was 2.8 and the maximum was 17.5 as shown in figure 6.

Similar to the TDI index, the IPS indices at each sampling point indicate that the water quality of the reservoir area is better than that of the river course, and also indicates that the water quality of the flood season is better than that of the non-flood season. IPS can indicate the pollution of organic matter, heavy metals and other substances in the water body. The results show that the water quality in the reservoir area is obviously superior to that in the upper reaches. All sampling points in the reservoir area are at a "good" level. Water quality in the NX1 and SD2 are better, and NX2 and BX1
appear more serious pollution, while the remaining samples are slightly polluted.

3.5. IBD index
The value of IBD is between 1 and 20. The greater the value of IPS indicates the better the water quality. The IBD values of various sampling points in Tangpu Reservoir Area ranged from 15.5 to 18.9, which indicated that the overall water quality of the reservoir area was good. The IBD values of various sampling points in the rain catchment area ranged from 5.8 to 19.2 with an average of 14.7 and the water quality was slightly worse as shown in figure 7.

Figures 7. IBD Index in each sampling point.

3.6. Discussions
Different natural geographical environment results in different types of community ecology. The composition of benthic diatoms, in rivers and lakes, can reflect the change of geography spatial pattern. Studies shown that the main factors influencing the distribution of benthic diatoms in light sediments were hydrochemical properties, sediment properties, water flow rate, illumination conditions and food chain [21]. So the heterogeneity of geospatial has an important influence on the distribution of diatoms.

From the river upstream to the reservoir area, experienced different geological formations and topography, water quality conditions are also different, the distribution of sediment also has its own characteristics, which led to different sampling points benthic diatom dominant species different [22].

The main algae in the source of the river are Achnanthes subhudson (15.33%), which is widely distributed in poorly nutrient waters [23]. This type of diatoms narrow body, low biomass and fast growth rate, is like the life of the water flow rate larger environment. This is in line with the natural geographical conditions of the upper reaches of the upper reaches of the river. This shows that the upstream river water quality is better. Affected by people’s activity, the more pollutants are accepted by the water bodies and the quality of the water is deteriorating. The distribution of benthic diatoms is also affected [24].

4. Conclusion
In the project area, benthic diatoms were collected twice in flood season (July) and non-flood season (November) respectively. A total of 129 species of benthic diatoms were collected in flood season (July) and non-flood season (November). The largest species is the Navicularia species. The dominance of the dominant species in the whole basin of the Reservoir was Achnanthes subhudson. The dominance value is 23.76%. The TDI value of the reservoir area is between 8.5-51.2 and the average is 33.12, which indicates that the water quality of reservoir area is better.

Due to the larger reservoir area, there is a big space difference. The upper reaches are mountainous areas and the lower reaches are reservoir areas. The differences in ecological environment space lead
to significant differences in the composition of benthic plants (algae) at different sampling sites. By establishing the benthic algae biological index, the ecological environment and the water quality of the reservoir can be monitored and evaluated from the biological point of view, which is of great reference significance for the daily monitoring of water quality and water resources management in Tangpu Reservoir.

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