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Algae functional group characteristics in reservoirs and lakes with different trophic levels in northwestern semi-humid and semi-arid regions in China

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ABSTRACT

In order to study the differences in algae species and their biomass in water bodies in a region, three reservoirs and two lakes at the center of Guanzhong Plain were chosen to identify algae functional groups, measure biomass, and assess water quality, from January 2013 to December 2014. The water bodies represented different trophic levels: one oligotrophic, three mesotrophic, and one eutrophic. Based on the Reynolds' functional groups, they had 10 groups in common—B, P, D, X1, M, MP, F, S1, J, and G, but the algae biomasses and proportions were different. In the oligotrophic reservoir, functional group B reached a peak biomass of 576×10^4 L^{-1}, which accounted for 31.27%. In the eutrophic lake, functional group D reached a peak biomass of 3227×10^4 L^{-1}, which accounted for only 13.38%. When samples collected from other water bodies with similar trophic levels were compared, we found differences in the algae species functional groups. The potential reasons for the differences in algae functional group characteristics in the different water bodies in the region were water temperature and nutritional states.

Introduction

Phytoplankton is essential for the functioning of our planet as it accounts for half of the Earth's primary production (Falkowski et al., 2003; Arrigo, 2005). Inland algae mostly grow in surface water bodies such as reservoirs and lakes. In recent years, several studies have been conducted on algae blooms in lakes and reservoirs (Leu et al., 2013; Liang et al., 2012; Cheng et al., 2014; Xu et al., 2013; Shen et al., 2011). As both reservoirs and lakes are often the primary water sources for cities, phytoplankton in these water bodies are gaining attention (Kerimoglu et al., 2014).

According to Reynolds (2006), a complex interplay of intrinsic and extrinsic drivers such as climate, resource availability, patterns of competition and predation, and dispersal regulate the composition and diversity of a phytoplankton community. They may also act as sensitivity indicators toward environmental pressures such as eutrophication (Kummerlin, 1998; Padisák and Reynolds, 1998). The growth state of algae in reservoirs and lakes can reflect the water quality (Michalak et al., 2013), meanwhile the water temperature and nutrient conditions also influence the differences in algae species and biomass (Cardinale, 2011). The Gleasonian line of reasoning assumes that individual species respond independently to the

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environment, and the community composition reflects the response of individual species to the environmental conditions (Izaguirre et al., 2012).

Algae taxonomy involves the study of the relationship between algae and their environment. Linnaean phylogenetic classification is the traditional classification method for algae. According to the evolutionary relationship between phytoplankton species, based on the cytochrome structure, photosynthetic pigment species, and storage substance, phytoplankton are divided into many species, belonging to different phyla and classes (South and Whittick, 2009). However, the environmental plasticity of phytoplankton (Reynolds et al., 2001) can be caused by physiological and ecological characteristics of the phytoplankton that are different in different habitats. Linnaean phylogenetic classification of plants is often based on the common phylogeny rather than polyphylogeny, recognizing commonly shared adaptive features (Reynolds et al., 2002). In fact, the functional mechanisms of biological communities may be better understood if species are pooled into groups of similar characteristics (Salmaso and Padisák, 2007). So far, 39 phytoplankton functional groups have been identified (Reynolds et al., 2002; Padisák et al., 2009). Two deductions can be made from the definition of functional groups: (1) a species belonging to a functionally well-adapted group of phytoplankton is likely to tolerate the constraining conditions of factor deficiency more successfully than individuals of a less adapted group, and (2) a habitat shown typically to be constrained by light, C or N or some other factor, is more likely to be populated by species with the appropriate functional properties (Reynolds et al., 2002). The functional groups (FGs) of phytoplankton were classified according to their preference for habitat and the response to changing environmental variables (Crossetti et al., 2013). The FGs were derived by summarizing the habitat of many algae to establish links between phytoplankton and their habitat. From the habitat differences, phytoplankton was divided further to reflect the ecological features of phytoplankton (Izaguirre et al., 2012). The concept of phytoplankton FGs can be applied in the understanding of phytoplankton succession in reservoirs (Xiao et al., 2011).

Many studies use FGs to discuss the driving factors of algae growth. A study carried out by Becker et al. (2009) in Faxinal Reservoir, a warm monomictic, meso-eutrophic reservoir in subtropical southern Brazil, analyzed the dynamics of phytoplankton FGs and defined the factors driving the growth of phytoplankton (Becker et al., 2009). In the Three Gorges Reservoir (TGR), which is the largest water conservancy and hydropower project reservoir in China (Huang et al., 2006). Wang et al. (2011) used FGs to classify phytoplankton and then analyzed the temporal variations of the FGs. Devercelli and O'Farrell (2013) studied phytoplankton structure along the main stem of the Lower Salado River (Argentina) and analyzed the relation between environmental variables and the influence exerted by the inflowing waters from the Paraná River. Stević et al. (2013) investigated a floodplain lake, which is a part of a natural floodplain along the Danube River, and analyzed the relationship between phytoplankton FGs and environmental factors. Borics et al. (2012) studied a shallow lake in the Carpathian Basin and compiled a large phytoplankton database for eutrophic shallow lakes, to study the dominance of algal FGs in the various sub-types of lakes and also the characteristics of the dominant diversity relationships. Most detailed studies have been conducted only for a reservoir or lake in a region, with no comparison between the algal FGs of different water body types in the same area. Further, only limited studies have compared water bodies with similar nutritional status in different regions. In order to analyze the effects of differences in nutrient content on the algae FGs and biomass in the same region, and discuss regional differences in the species of algae FGs, we studied algae characteristics in lakes and reservoirs with different trophic levels in the same area. We also looked at the differences in algae FGs in different regions with similar trophic levels. This allowed us to analyze the growth of algae functional group characteristics in different reservoirs and lakes and to predict the growth of the algae.

1. Methods

1.1. Study area

The study areas are located at the foot of the Qinling Mountains and the center of Guanzhong Plain, Xi'an city (107.40°–109.49°E; 33.42°–34.45°N), belonging to a warm temperate, semi-humid, continental monsoon climate. The average annual rainfall is 530 mm and falls mainly between July and September, accounting for more than 60% of the total annual rainfall. We selected three main reservoirs and two lakes in Xi'an City of Shaanxi Province, including the Jinpen Reservoir, Shibianyu Reservoir, Tangyu Reservoir, and Qujiang and Xingqing Lakes.

The three reservoirs are located at the north slope of Qinling Mountains and used for the downstream industry and residential water. The Qinling Mountains have two main flood seasons: spring and autumn. Because the winter snowfall is less in the Qinling Mountains, the rainfall in spring is the main driving force for the three reservoirs. The two lakes are elements of the landscape. The study area is shown in Fig. 1, and the basic information is shown in Table 1.

1.2. Sampling

Samples were collected monthly from January 2013 to December 2014 at three reservoirs and two lakes, and the samples were collected at a depth of 0.5 m below the surface. Some of the highest recorded densities of *Synechococcus* picoplankton come from shallow water (Izaguirre et al., 2001). Water samples were taken early in the month, and we chose to sample during periods with no rain and no wind or breeze. Temperature was measured *in situ* with a multi-parameter probe (HACH Hydrolab DS5). Phytoplankton samples were fixed with neutral Lugol's solution and the algae count was accomplished within two weeks.

1.3. Sample analysis

Phytoplankton counts and identification were performed using an ordinary light microscope (Utermöhl, 1958) at 400× magnification, and the counting error was estimated according to Venrick (1978). In all cases, we considered the individual algae as the unit (unicell, colony, coenobium, or filament), and

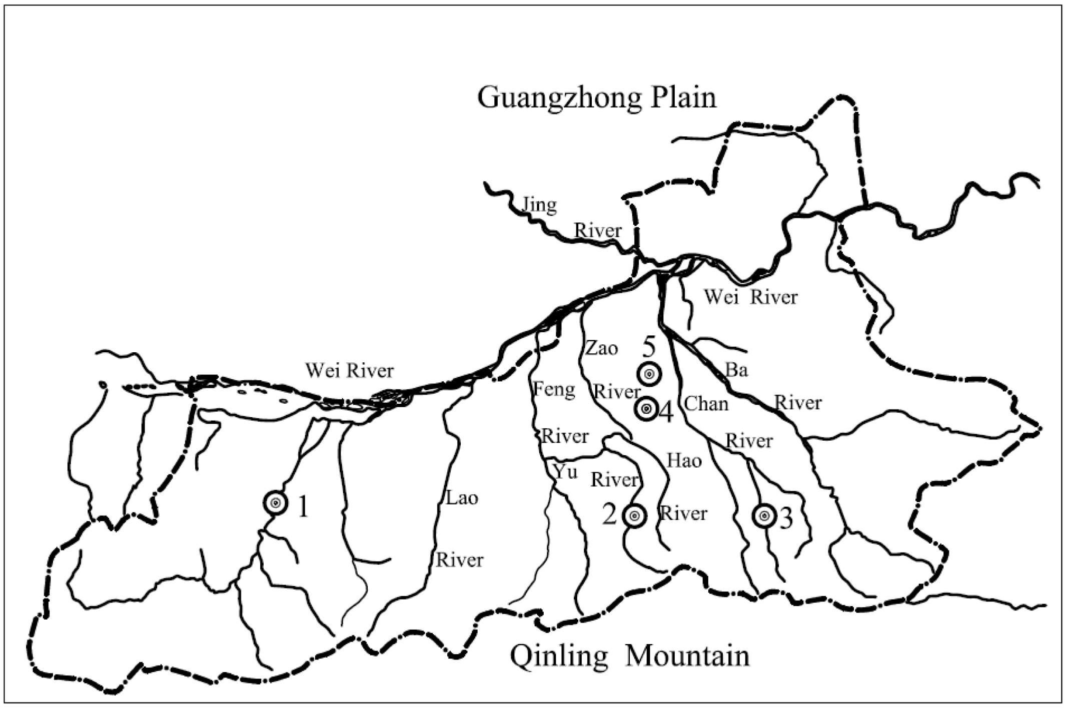

Fig. 1 – Location of the studied reservoirs and lakes in the north foot of Qinling Mountain, Shaanxi Province, China. (1) Jinpen reservoir;(2) Shibianyu reservoir; (3) Tangyu reservoir; (4) Qujiang lake; (5) Xingqing lake.

cell numbers were estimated per colony or filament. Biomass was estimated from biovolume, assuming unit specific gravity, calculating the number of algae per liter of water. All species recorded in the samples were classified into the FGs proposed in the classification of Reynolds et al. (2002) and Padisák et al. (2009). The biomass corresponding to each functional group was also calculated for the numerical analyses.

Nutrient analysis was carried out according to the Chinese national standards (SEPA, 2006). The nitrate (NO_3^--N) content was determined by ultraviolet spectrophotometry, ammonium (NH_4^+-N) content by Nessler's reagent spectrophotometry, total nitrogen (TN) by Potassium peroxodisulfate oxidation and ultraviolet spectrophotometry, total phosphorus (TP) content by Potassium peroxodisulfate dissolution-molybdenum-antimony spectrophotometry, and Chemical Oxygen Demand (COD) by the permanganate index - acid method. Chlorophyll-*a* (Chl-*a*) was extracted using ethanol and measured by spectrophotometry after filtering 500 mL samples through a 0.45 μm acetate fiber mesh (Moheimani et al., 2013). These measurements were completed within 24 hr of sampling.

1.4. Data analysis

Following the nutritional status classification from the Organization for Economic Cooperation and Development (OECD), we used the comprehensive trophic level index (TLI) formula:

$$T_{\sum} = \sum_{j=1}^{m} W_j TLI_j \tag{1}$$

where $T_{\sum}$ is the comprehensive trophic level index, W_j is the weight of the trophic level index of the *j*th parameter, and TLI_j is the trophic level index of the *j*th parameter.

Excel and Origin 8.0 were used for statistical data and the graphical analysis of the relationship between algal functional group characteristics and environmental factors. Data ordinations were performed using Canoco 4.5. Detrended correspondence analysis (DCA) for the species data was employed to decide whether linear or unimodal ordination methods should be applied. Redundancy analysis (RDA), which is a constrained

Table 1 – Basic information of reservoirs and lakes.

	Catchment area (km^2)	Multi-year average runoff (m^3)	Total capacity (m^3)	Elevation (m)	Distance from city (km)
Jinpen reservoir	1481	6.67×10^8	2.0×10^8	508	86
Shibianyu reservoir	132	0.95×10^8	2.8×10^7	710	35
Tangyu reservoir	80		4.48×10^6	744	50
Qujiang lake	3.77			443	
Xingqing lake	1.0			411	

linear ordination method, was applied to examine the relationships between the environmental variables and phytoplankton biomass.

2. Results

2.1. Reservoir and lake variables

The contrasting features of the studied reservoirs and lakes are shown in Table 2. The concentrations lower than the detection limit were set at 1/2 of the limit value (Dodds et al., 2006; Suplee et al., 2007). Water temperature in the region was related to the altitude and location of the reservoirs and lakes. The average temperature of the reservoirs is 2°C lower than that in the lakes. The three reservoirs are at higher altitudes than the lakes. The three reservoirs are far from the city, while the two lakes are in the center of the city, forming a heat island effect. These factors account for the temperature difference.

The highest NH_4^+-N and TP were observed in the lakes, and the higher Chl-*a* values of the lakes were one of the characteristics that distinguished them from the reservoirs. The three reservoirs, being far from the city, are less disturbed by human activity. The two lakes are municipal lakes, and have frequent human activity. Human activity may be responsible for the differences in the nutritional condition and the Chl-*a* values.

The OECD nutritional status classification from the studies conducted in this area allowed us to use 0–100 digital continuous grading in the trophic levels. The Jinpen Reservoir is an oligotrophic reservoir. Shibianyu and Tangyu Reservoirs and Qujiang Lake are three mesotrophic water bodies; Xingqing Lake is a eutrophic lake.

2.2. Phytoplankton genera and FGs

During the study period, we collected 9 genera of chlorophyta, 6 genera of diatoms, and 2 genera of cyanophyta in the three reservoirs. The two lakes had 7 genera of chlorophyta, 6 genera of diatoms, and a single genus of cyanophyta. The genera included *Oocystis*, *Chlorella*, *Diascenedesmus*, and *Schroederia* for chlorophyta. The diatoms included *Fragilaria*, *Melosira*, *Cyclotella*, *Synedra*, and *Navicula*. *Pediastrum* spp. were found in the lakes. Cyanophyta in the reservoirs included *Microcystis* and *Pseudanabeana* in the lakes. In this study, the FGs were those typical of turbulent and enriched systems (Table 3).

The species found were classified into 10 FGs: B, P, D, X1, M, MP, F, S1, J, and G. The algae functional group biomasses were different between reservoirs and lakes, especially regarding dominant FGs. The different FGs reached peak biomasses at different times. Functional group B reached a peak biomass of $1929.56 \times 10^4\ L^{-1}$ in August 2013 at Shibianyu Reservoir and May 2014 at Qujiang Lake. Functional group P reached a peak biomass of $1755.97 \times 10^4\ L^{-1}$ in October 2014 at Shibianyu Reservoir and $2915.72 \times 10^4\ L^{-1}$ in May 2013 at Xingqing Lake. The functional group X1 reached a peak biomass of $2915.72 \times 10^4\ L^{-1}$ in April 2013 at Xingqing Lake.

2.3. Phytoplankton temporal succession

The maximum distance between our sites did not exceed 150 km. The latitude and longitude have only narrow disparities, and the climate, including rainfall and light conditions, is similar. Similarity in location and climate created conditions for the presence of similar FGs, including B, P, D, X1, MP, J, S, and so on.

While similar FGs were found, the proportion in water bodies was different (Fig. 2). Among the selected reservoirs and lakes, high phytoplankton abundances and biomass appeared from April to September; low phytoplankton abundances and biomass appeared from October to March. Most algae in the reservoirs and lakes could be classified into 7 FGs (B, P, D, X1, MP, J, S1), which accounted for a high proportion of the total biomass (more than 99.0%). The Jinpen Reservoir had only four FGs, (B, P, D, X1) accounting for a high proportion of the total biomass (97.0%). Shibianyu Reservoir had three (B, P, D), occupying a total biomass of 98.3%. Tangyu Reservoir had five FGs, (B, P, D, X1, MP) accounting for 96.2% of total biomass. Qujiang Lake also had five (B, P, D, X1, J), reaching a total biomass of 97.2%. Four FGs (B, D, X1, S1) accounted for 97.6% of phytoplankton total biomass in Xingqing Lake.

The proportions of the dominant algae FGs varied in different water bodies. The total biomass of functional group B showed maximum values in spring and summer and minimum

Table 2 – Ranges of the main feature for three reservoirs and two lakes at the foot of north Qinling Mountain.

Environment variables	Jinpen reservoir		Shibianyu reservoir		Tangyu reservoir		Qujiang lake		Xingqing lake	
	Interval	Mean	Interval	Mean	Interval	Mean	Interval	Mean	Interval	Mean
Temp (°C)	6.0–24.6	15.7	6.5–26.4	15.6	2.3–27.6	15.9	4.2–30.1	17.4	6.0–31.6	17.6
NH_4-N (mg/L)	0.002–0.187	0.083	0.020–0.279	0.143	0.057–0.435	0.156	0.051–0.543	0.231	0.023–1.865	0.716
NO_3-N (mg/L)	0.862–2.337	1.194	1.003–4.786	2.777	1.010–6.101	2.907	0.700–1.839	1.157	0.204–2.960	1.941
TN (mg/L)	1.025–2.417	1.402	1.461–5.279	3.312	1.267–7.055	3.387	0.915–3.108	1.655	1.931–5.816	3.086
TP (mg/L)	0.005 [a]–0.043	0.013	0.005 [a]–0.075	0.030	0.005 [a]–0.085	0.030	0.010–0.099	0.038	0.020–0.158	0.073
Chl-*a* (μg/L)	0.194–10.479	1.966	1.395–12.555	5.325	0.698–11.300	3.193	4.185–29.925	11.886	26.156–87.365	42.414
COD (mg/L)	2.522–5.146	3.887	5.581–6.592	6.330	2.685–4.253	3.193	3.047–5.229	4.293	3.619–4.890	4.303
TLI		27.86		38.64		30.11		42.91		54.14

The TP limited value is 0.01 g/L.
TP: total phosphorus; TN: total nitrogen; Chl-*a*: Chlorophyll-*a*; COD: Chemical Oxygen Demand; TLI: trophic level index.
[a] The concentration of less than the detection limit were used 1/2 to the limited value.

Table 3 – Description of the characteristics of the main functional groups.

Code	Habitat	Representatives	Tolerances	Sensitivities
B	Vertically mixed, mesotrophic, small-medium lakes	*Cyclotella, stephanodiscus*	Light deficiency	pH rise, Si depletion
P	Eutrophic epilimnia	*Fragilaria, Melosira, Strurastrum*	Mild light and C deficiency	Stratification Si depletion
D	Shallow, enriched turbid waters, including rivers	*Synedra*	Flushing	Nutrient depletion
X1	Shallow mixed layers in enriched conditions	*Chlorella, Schroederia, Kirehneriella*	Stratification	Nutrient deficiency filter feeding
M	Dielly mixed layers of small eutrophic, low latitude lakes	*Microcystis*	High insolation	Flushing, low total light
MP	Frequently stirred up, inorganically turbid shallow lakes.	*Navicula*		
F	Clear epilimnia	*Oocystis*	Low nutrients high turbidity	CO_2 deficiency
S1	Turbid mixed layers	*Pseudanabeana*	Highly light deficient	Flushing
J	Shallow, enriched lakes ponds and rivers	*Scenedesmus, Pediastrum*		Settling into low light
G	Short, nutrient-rich water columns	*Eudorina*	High light	Nutrient deficiency

Code: Based on the Reynolds' functional group.

values in winter. Functional group B accounted for 45.6% of the total biomass in the Jinpen Reservoir and 41.3% in the Shibianyu Reservoir; however, the group B biomass in Shibianyu was more than in Jinpen. Group B accounted for 59.6% of the total biomass in the Tangyu Reservoir, 51.9% in Qujiang Lake, and only 3.06% in the Xingqing Lake. Group B is found mostly in mesotrophic and oligotrophic water bodies and less so in eutrophic ones. It dominated biomass in the mesotrophic water bodies.

Functional group P showed maximum values in the spring and summer, reaching up to 54.7% of the total biomass in the Shibinayu Reservoir. Functional group D showed maximum values in the spring and autumn, accounting for 32.38% of the total biomass in Qujiang Lake and 70.6% in Xingqing Lake. Functional group X1 accounted for 24.1% of the total biomass in Jinpen Reservoir, 15.9% in Tangyu Reservoir, and 21.5% in Xingqing Lake. FGs MP, J, and S1 biomasses were lower than others. MP was consistently identified in spring and winter and J and S1 in summer and autumn. The dominant algae FGs were B, P, D, X1, but there were differences in phytoplankton biomass and outbreak time. Based on these differences, the correlation between the environmental factors of water bodies and phytoplankton is analyzed and discussed.

2.4. Redundancy analyses of FGs of lakes and reservoirs

Redundancy analyses (RDA) were used to estimate the amount of variance in the biomass of the phytoplankton FGs (Reynolds et al., 2002) explained by the environmental variables. The Jinpen Reservoir's samples are found mostly in the III quadrant. Shibianyu's samples fall primarily in the II and III quadrants and Tangyu's samples in the I and III quadrants. However, the Qujiang Lakes samples are scattered and distributed in the I, III, and IV quadrants, while Xingqing's samples are found in the I and IV quadrants (Fig. 3a).

There were differences among the reservoirs and lakes. In the RDA, two axes accounted for 90.3% of the variance (axis 1: 73.9%, axis 2: 16.4%). The Monte Carlo test indicated that the environmental variables were significantly correlated with the first axis ($p = 0.011$) and the test of significance of all canonical axes was also significant ($p = 0.003$). The first axis was mainly correlated with water temperature, NH_4^+-N, and TP (intra-set correlation coefficients: 0.55, 0.44, and 0.73, respectively), and the second axis was mainly defined by TN, NO_3^--N, and TP (intra-set correlation coefficients: 0.74, 0.70, and 0.54). The FGs D, X1, MP, and J were positively correlated with axis 1, and the FGs D, S1, and P were positively correlated with axis 2. Fig. 3 shows the biplots (first two axes) of the reservoirs and lakes, which implied the FGs with respect to environmental variables.

We used multiple lineal regressions to create predictive models to explain FG classification and biomass from all the environmental variables determined during our study. The cause of algal bloom was nutrient-rich sediment (Ajioka and Swindle, 2013), and the results of these analyses indicated that the biomass of the phytoplankton FG P could be predicted from the environmental variables. The FGs J, X1, and MP were strongly linked to water temperature. Water temperature is one of the key factors for algae growth (Jia et al., 2013; Lewandowska et al., 2012; Tirok and Gaedke, 2007; Wu et al., 2010; Fu et al., 2008). The FG D was significantly affected by NH_4^+-N and TP. For FG P, TN and NO_3^--N are in the same quadrant (Salmaso et al., 2012; Bo et al., 2011). This indicated that a positive relationship existed between seasonal development of the more abundant and eutrophic-sensitive algal groups and the concurrent effect of trophic status (Table 3, Fig. 3).

3. Discussion

There are some water bodies, located in different regions, that have similar algae FGs and dominant algae FGs. Regarding nutritional status, water bodies need to be classified and then analyzed to determine the regions' characteristics.

3.1. Algae FG characteristics in oligotrophic water bodies in different regions

The biomasses of algae FGs in an oligotrophic nutrition state (reservoirs) are relatively small. In Stević et al. (2013), 189 phytoplankton taxa from Lake Sakadasˇ (45°36′N, 18°48′E) were

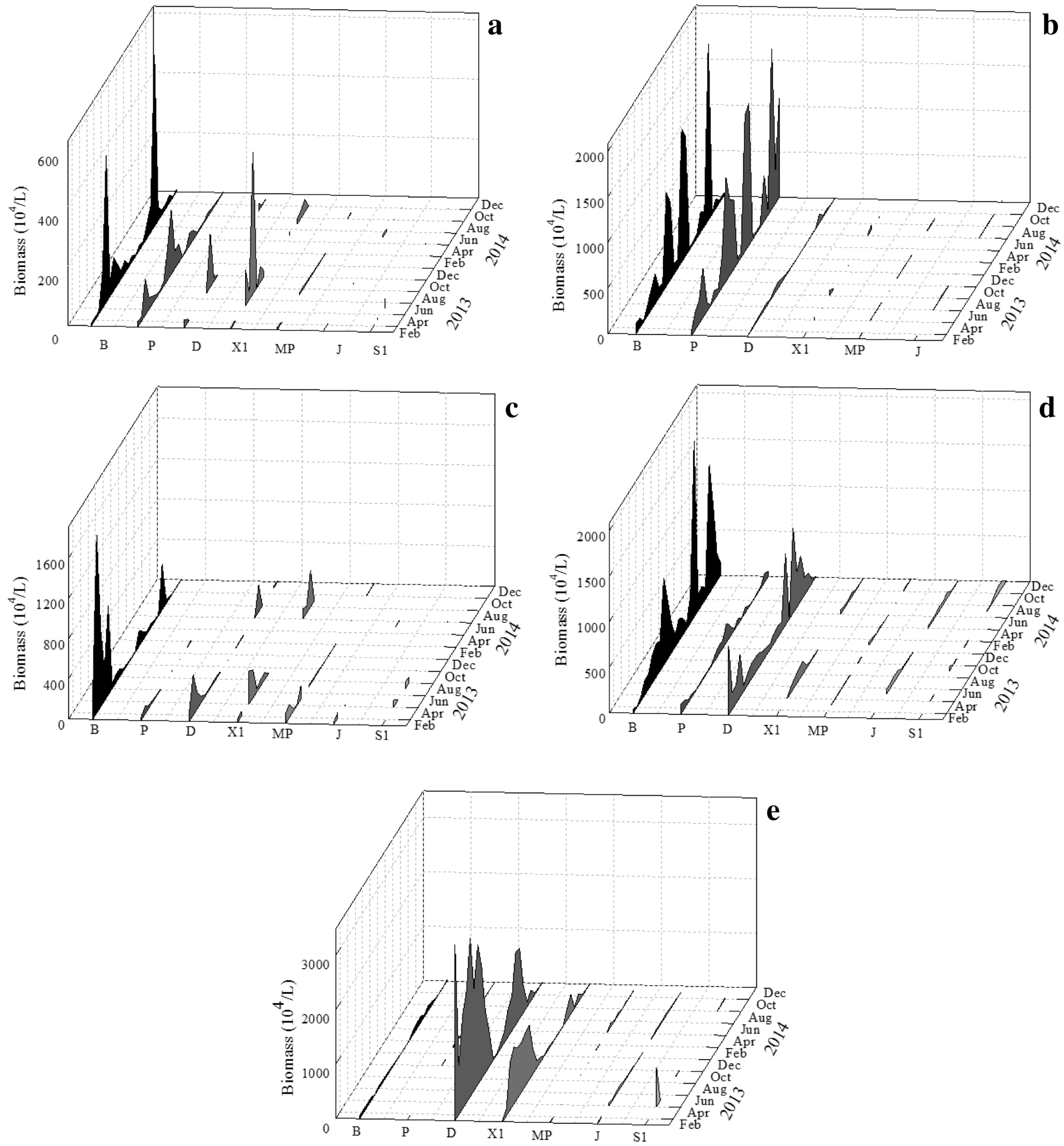

Fig. 2 – Biomass of phytoplankton functional groups (ten million/L) in the reservoirs and lakes. (a Jinpen reservoir, b Shibianyu reservoir, c Tangyu reservoir, d Qujiang lake, e Xingqing lake.).

identified and sorted into 20 FGs. The flooding and mixed periods in the lake were favorable to the development of diatoms belonging to the B, C, D, and P FGs (Stević et al., 2013). The trophic state in Sakadasˇ Lake is similar to the Jinpen Reservoir, and they have 10 FGs (B, P, D, X1, M, MP, F, S1, J, G) in common. In comparing the two water bodies whose latitudes are not far apart and have similar trophic levels, there is little difference in algae FGs.

3.2. *Algae FG characteristics in mesotrophic water bodies in different regions*

There were some differences in the FGs of algae in different regions of the mesotrophic nutritional status. Becker et al. (2009) found 88 algal species, which were distributed across 9 major taxonomic categories in 17 FGs in Faxinal Reservoir (29°05′00″S, 51°03′30″W). The H1, F, and C phytoplankton FGs were the most important in terms of biomass (Becker et al., 2009). The trophic level of Faxinal Reservoir is the same as that of Shibianyu and Tangyu Reservoirs and Qujiang Lake, but their algae FGs differed significantly. The study by Becker et al. (2009) was carried out in a warm monomictic, meso-eutrophic reservoir in southern Brazil, located in a subtropical region with a temperate climate. Our study area is a warm temperate, semi-humid, continental monsoon climate, and the two water bodies are located at different latitudes. This indicates that the differences in algae FGs were caused by climatic conditions and latitude.

The Lower Salado River, studied in Devercelli and O’Farrell (2013), receives urban and rural sewage waters, as well as rainfall excess from the surrounding settlements. Also, cattle are raised in its alluvial valley. Despite this, 289 taxa were

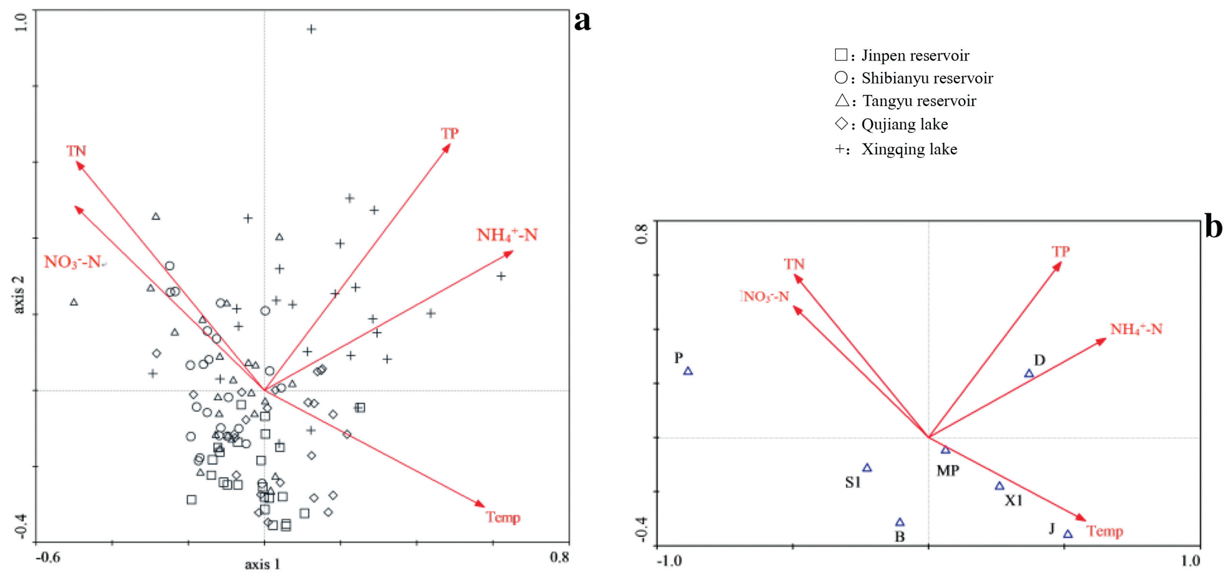

Fig. 3 – Biplots of the Redundancy analysis based on the biomass of the functional groups proposed. (a) Ordination of the samples and environmental variables. (b) Functional groups and environmental variables.

identified in the Salado River, 200 in Bedetti Lake and 162 in the El Vado Stream, and separated into 16 FGs (C, X1, X2, LO, D, W1, W2, S_N, K, F, B, E, Y, P, H1, S1) (Devercelli and O'Farrell, 2013). The main FGs (C, D, F, LO, X1, X2, W1, W2) presented significantly high density and biovolume in the Salado River, and X2 and X1 were high in the lake (Devercelli and O'Farrell, 2013). The water environment and trophic levels in the Lower Salado River are similar to Tangyu Reservoir, and they share 5 FGs (B, P, D, X1, S1).

The Lower Salado River latitude is similar to that of the Tangyu Reservoir. The Tangyu Reservoir water quality is affected by the surrounding resident life, as it collects the wastewater from the village upstream. The Lower Salado River has some FGs in common with the Tangyu Reservoir, likely because the water environment and latitudes are similar.

3.3. *Algae FG characteristics in eutrophic water bodies in different regions*

The Borics et al. (2012) study in shallow eutrophic lakes showed 16 groups to be dominant (B, D, E, H1, J, L_O, M, MP, SN, U, W0, W1, WS, X1, X2, Y), with a dominance of D, U, E, W1 and X1. X2 was exceptionally rare, and six FGs (H1, SN, M, WS, J, Lo) were capable of developing dominant assemblages (Borics et al., 2012). The Xingqing Lake is eutrophic, hosting 10 FGs, with four FGs (B, D, X1, S1) constituting a high proportion of the total biomass (97.6%). Borics et al. (2012) studied water bodies located in the Carpathian Basin, which has a latitude similar to that of Xingqing Lake; this may explain the similarity in the algae FGs.

In water bodies in different regions where the trophic levels are similar, but the latitude gaps are large, the algae FGs are different. Water bodies in different regions where the trophic levels and latitude are similar share some similarity in FGs, especially the dominant algae FGs.

4. Conclusions

By analyzing the results of 5 different water bodies in a region, we observed 10 similar FGs: B, P, D, X1, M, MP, F, S1, J, and G; but the algae biomasses and the proportions were different. This shows the variation in algae FGs among lakes and reservoirs and indicates the potential effects of environmental pressures, including water temperature and nutritional condition.

The results of this work, regarding the biomass and species in the algae FGs in different regions, would suggest that trophic levels and water temperature are the two major reasons for the presence of particular algae FGs. The trophic levels determine the biomass of algae; this deserves further detailed study. The FGs could be predicted based on the tropic level of the water body.

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