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# Water Level Fluctuation Rather than Eutrophication Induced the Extinction of Submerged Plants in Guizhou's Caohai Lake: Implications for Lake Management

**Fusheng Chao, Xin Jiang, Xin Wang, Bin Lu, Jiahui Liu and Pinhua Xia ***

Key Laboratory for Information System of Mountainous Areas and Protection of Ecological Environment of Guizhou Province, Guizhou Normal University, Guiyang 550001, China; cfs1632564152@163.com (F.C.); jiangxin@gznu.edu.cn (X.J.); 21010160522@gznu.edu.cn (X.W.); 18385713683@163.com (B.L.); h1052228049@163.com (J.L.)

* Correspondence: pinhuaxia@gznu.edu.cn; Tel.: +86-13984870860

**Abstract:** The intensifying global decline in submerged aquatic lake plants is commonly attributed to lake eutrophication, while other drivers such as water levels are seldom considered. This study focused on the sudden extinction of the submerged plants in Caohai Lake, Guizhou, and employed long-term data and a whole-lake water level manipulation experiment to explore the impacts of nutrients and water level changes on the decline in submerged plants. The results indicated that over the past 40 years, the total nitrogen and ammonia nitrogen in the water did not change significantly, while the total phosphorus showed a significant decreasing trend. In recent years, however, the water level rose. The biomass of submerged plants continuously increased until a sudden large-scale extinction occurred in 2021; chlorophyll a also significantly increased. It is speculated that the large-scale extinction of the submerged plants was caused by water level fluctuations rather than eutrophication. After the restoration of the natural hydrological regime of low water levels in winter and spring and high levels in summer and autumn, the submerged plants gradually recovered, with the biomass increasing to 922.6 g/m$^2$ in 2023. The structural equation modeling indicated that the water depth and bottom light availability were the main drivers for the changes in the submerged plants. However, in lake protection and management, more attention is often paid to controlling nutrients, while other influencing factors are neglected. These findings confirm the importance of water levels in the decline in and restoration of submerged plants in shallow lakes, suggesting a focus on water level management in lake protection and aquatic vegetation restoration.

**Keywords:** submerged plants; water level fluctuations; nutrients; chlorophyll a; eutrophication

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**Citation:** Chao, F.; Jiang, X.; Wang, X.; Lu, B.; Liu, J.; Xia, P. Water Level Fluctuation Rather than Eutrophication Induced the Extinction of Submerged Plants in Guizhou's Caohai Lake: Implications for Lake Management. *Water* **2024**, *16*, 772. https://doi.org/10.3390/w16050772

Academic Editor: Reynaldo Patiño

Received: 11 February 2024
Revised: 27 February 2024
Accepted: 2 March 2024
Published: 5 March 2024



## 1. Introduction

Submerged plants as primary producers in shallow lakes play a crucial role in forming the food chain of aquatic ecosystems [1]. These plants provide food and habitat for plankton and herbivorous fish and secrete allelochemicals, significantly contributing to the structure and function of shallow aquatic ecosystems. Additionally, submerged plants improve water quality by absorbing nutrients in the water, reducing nutrient levels, and stabilizing bottom sediments, thereby maintaining the water clarity in lakes [2–4]. However, dramatic changes in submerged plants in global lakes have been observed over the past century, with the decline rate increasing from 13.5 ± 16.9%/year (1900–1980) to 33.6 ± 59.8%/year (post-2000) [5]. The reduction in submerged plants has triggered a shift in lake ecosystems from a macrophyte-dominated state to a phytoplankton-dominated state. This shift has led to significant changes in the composition and the dominant species of aquatic plant communities, including a sharp reduction in the biomass and diversity, resulting in catastrophic shifts that greatly diminish the ecosystem services of lakes [6–8].

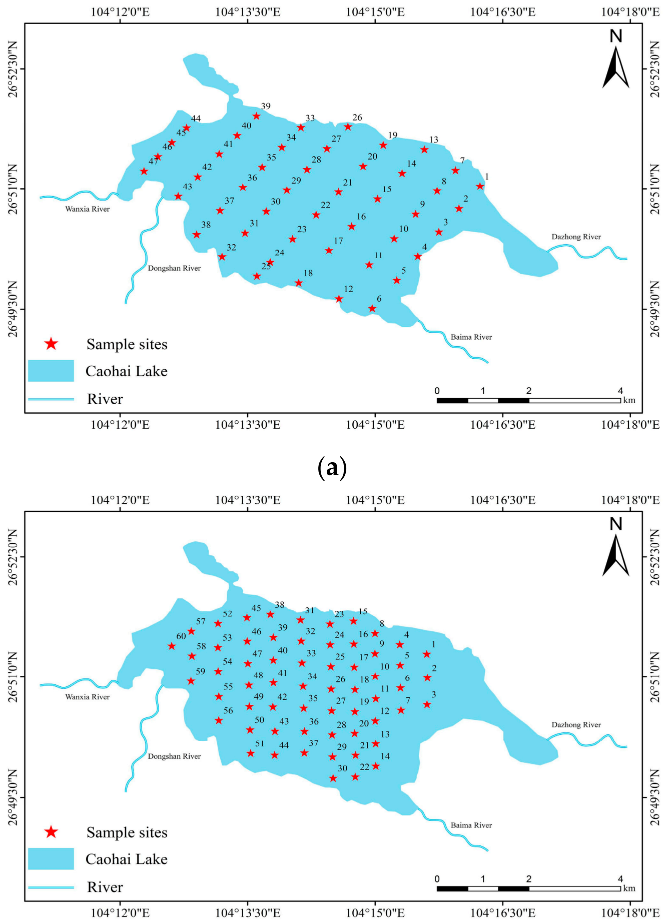
Numerous factors drive the decline in submerged plants in lakes, including nutrients, water levels, aquaculture, global climate change, and species invasion [5,9]. Increased nutrient loading leads to the proliferation of planktonic and epiphytic algae, causing the decline in submerged plants through shading [10]. The decline in the submerged plants in many lakes is attributed to increased nutrient loads, and it is generally believed that the eutrophication-induced decline in submerged plants is a slow process [11–14]. However, the extinction of submerged plants in many lakes is often sudden and difficult to attribute to eutrophication alone. Moreover, the drivers of the decline in submerged plants are often confounded when multiple anthropogenic and natural disturbances occur simultaneously in space and time [15]. Recently, the impacts of other factors have been gaining attention. For example, Su et al. found that the impact of climate change and fish stocking on the degradation of submerged plants in subtropical lakes in China is greater than that of nutrient loading [16]; the invasion of Asian carp has led to a sharp decline in the biomass and coverage of submerged plants in North American lakes [17]; and hydrological conditions, a fundamental attribute of lake ecosystems, determine the biomass, distribution, and species structure of submerged plants, which have a more direct impact on the ecology and function of lakes [4,18]. Water level changes affect the substrate, nutrients, light, water, and gas, leading to changes in the surface or root microbes of submerged plants and thereby affecting their growth [19,20]. Water level changes have been demonstrated to be an important reason for the extinction of aquatic vegetation in lakes such as Taihu Lake and Chaohu Lake [19,21]. Using structural equation modeling (SEM) in Taihu Lake and Datong Lake, Yang et al. and Chao et al. confirmed that the SD/WD and the water level were the primary drivers controlling the community composition of the submerged plants and triggered changes in the state of the lake ecosystem [22,23]. Thus, the decline in submerged plants is not only due to eutrophication but is also closely related to other factors. However, previous studies often overlooked the impact of other factors such as water level fluctuations, which may be an important reason why many submerged lake plants still struggle to recover. Therefore, the impact of multiple factors should be considered comprehensively when exploring the degradation and restoration of lake aquatic vegetation.

Caohai Lake, a typical clear-water, macrophyte-dominated lake, has recently witnessed a sudden, extensive extinction of submerged plants, and opinions vary as to the causes of this phenomenon. In this study, 40-year-long observational data were collected on the nutrients, water levels, and submerged and planktonic plants (chlorophyll a), and a water level manipulation experiment was conducted. This study aimed to achieve the following: (1) reveal the long-term characteristics and correlations of Caohai Lake's nutrients, water levels, and submerged and planktonic plants (chlorophyll a); (2) verify the effectiveness of water level manipulation in facilitating the restoration of submerged plants; and (3) discuss the role and significance of water level manipulation in lake management and aquatic vegetation restoration.

## 2. Materials and Methods

Caohai Lake, located in the karst region of southwest China, near the west side of Weining County in Guizhou Province (104°12′–104°18′ E, 26°49′–26°53′ N), is a typical karst shallow lake. Its catchment area is 19.8 km$^2$ during the dry season and 26.0 km$^2$ during the rainy season. With a water storage capacity of $3.9 \times 10^7$ m$^3$ [24], this basin is characterized by a subtropical monsoon climate with an average annual temperature of 10.6 °C and an annual rainfall of 1000 mm, with the rainfall mainly concentrated in summer, making this basin one of the least rainy areas in Guizhou [25]. The lake's primary water source is rainfall, followed by groundwater [26]. The lake was once home to a variety of aquatic plants, with a coverage exceeding 80%; emergent plants are mainly distributed in the eastern region, while other areas are dominated by submerged plants [27].

In September 2021 (n = 47), August 2022 (n = 47), and August 2023 (n = 60), field sampling activities were conducted, as shown in Figure 1. Data on environmental (nutrients, water depth, and Secchi depth) and submerged plants for the years 1983, 2005, and 2016 were sourced from the Report on the Comprehensive Scientific Survey in the Caohai National Nature Reserve of Guizhou [28].




(**a**)

(**b**)

**Figure 1.** Sampling sites in Caohai Lake. (**a**): For the years 2021 and 2022; and (**b**): for the year 2023.

Water samples were collected at each site, and the physicochemical indicators were measured in situ, followed by plant sampling. Before the plant sampling, a 40 cm high and 15 cm diameter water sampler was used to collect water samples at a depth of about 0.5 m at each site, while ensuring that the sediment remained undisturbed. The measured physical parameters included the dissolved oxygen (DO), pH, electrical conductivity (EC), total dissolved solids (TDS), Secchi depth (SD), water depth (WD), and bottom light availability (Ts, which is defined as the ratio of SD/WD). Furthermore, the water level differed from the WD. The water level refers to the height from the water surface to a baseline, with China using the Yellow Sea baseline as the unified elevation reference. A portable water quality analyzer (HQ30d, Hach, Loveland, CO, USA) was used to measure the DO, pH, EC, oxidation reduction potential (ORP), and TDS. A black and white Secchi disc was used to measure the transparency, and a scaled ruler was used to measure the WD at each sampling site. The water samples were analyzed in the laboratory using the standard methods prescribed by SEPA [29], including the total phosphorus (TP), total nitrogen (TN), ammonia nitrogen ($NH_3$-N), and chlorophyll a (Chl a). Data from the literature related to Chl a was available only from 2010 onwards. The submerged plants were collected using a long-handled rake with pointed teeth perpendicular to the handle, rinsed with lake water, and identified by species. The wet weight of the submerged plants was recorded as biomass. All plants were collected within a 1 $m^2$ area.

A whole-lake water level manipulation experiment was conducted by dredging the downstream water channels and removing the dams to ensure an unobstructed outflow, restoring the natural hydrological regime characterized by low water levels in winter and spring and high water levels in summer and autumn.

Due to the non-homogeneity and non-normality of the data. The non-parametric Kruskal–Wallis test [30] was used to determine the differences in the water parameters and submerged plant characteristics across different years. We used multiple regressions to identify the most important environmental variables, which explain the biomass and coverage of submerged plants in the lake [31]. The significance of the regression and correlation analysis was $p < 0.05$. To further visually understand the connections between the submerged plants and the water parameters (WD, SD, SD/WD, Chl a, TN, $NH_3$-N, and TP), structural equation modeling (SEM) was employed for path analysis. The model fit was evaluated using parameters such as the chi-square (CHISQ), $p$-value ($p > 0.05$), goodness-of-fit (GFI > 0.90), comparative fit index (CFI > 0.95), and standardized root mean square residual (SRMR < 0.08). The SEM was conducted using the 'lavaan' package in R. In the ArcGIS 10.8 environment, a vector map of the Caohai Lake basin was created by using ArcMap 10.8 software to incorporate the digital contour map of the lake as a base and to integrate the GPS coordinates recorded during the sampling process. The figures were created using Origin 2023 software.

## 3. Results

### 3.1. Changes in Nutrients and the Water Level

The variations in the TN, TP, and $NH_3$-N for the years 1983, 2005, 2016, and 2021–2023 are depicted in Figure 2. From 1983 to 2016, there were no significant changes in the TN and $NH_3$-N, while the TP significantly decreased. The average concentration of the TP peaked in 1983 at 0.451 mg/L, then showed a declining trend, eventually falling below the regime shift threshold (0.08–0.12 mg/L) [32]. No significant differences were observed in the TP levels for the years 2016 (0.066 mg/L), 2021 (0.044 mg/L), 2022 (0.065 mg/L), and 2023 (0.048 mg/L). Compared to 1983, the average concentration of the TN in 2005 decreased from 0.894 mg/L to 0.540 mg/L. A significant increase in the TN was observed in 2021 ($p < 0.05$), with an average concentration of 1.235 mg/L, slightly higher than previous years. The TN levels in 2022 and 2023 were significantly lower than in 2021, averaging 1.014 mg/L and 0.989 mg/L, respectively. From 1983 to 2016, the average concentration of $NH_3$-N was around 0.3 mg/L. The $NH_3$-N level was highest in 2021 (0.69 mg/L), about double that of previous years, then significantly decreased to 0.314 mg/L in 2022 and increased again in 2023 (0.541 mg/L).

The water level fluctuations in Caohai Lake from 2012 to 2023 are shown in Figure 3. The lowest water levels occurred in 2012 and 2013, with an average level of 2171.35 m. Since 2014, the water level of Caohai Lake has exhibited a rising trend. The average water level from 2014 to 2021 was 2172.09 m, an increase of 0.74 m compared to the previous two years. The water level in 2022 ranged from 2171.52 to 2171.76 m, with an average of 2171.63 m, and in 2023 the water level ranged from 2171.22 to 2171.58 m, with an average of 2171.43 m. The average SD was 0.919 m in 2016, and it dropped to 0.659 m in 2021, 0.553 m in 2022, and 0.74 m in 2023. Due to the increase in the average water level and WD, the Ts (SD/WD) decreased from 0.821 in 2016 to 0.48 in 2021. As water levels and WD decreased, the Ts increased to 0.53 in 2022 and 0.632 in 2023 (Figure 3b). The Ts was the most important parameter accounting for the changes in the submerged plant coverage during the study period.

### 3.2. Spatiotemporal Variations in the Submerged Plants

As shown by the data from the scientific surveys in 1983, 2005, and 2016, and investigations from 2021–2023, the biomass of the submerged plant communities doubled from 1983 to 2016. In the lake's eastern part (near the upstream town), where water nutrient levels are relatively higher, the submerged plant biomass consistently increased, reaching the highest levels among all parts of the lake. Conversely, the biomass initially decreased and then increased in the central and western parts of the lake, with the deepest parts in the center showing the lowest biomass.

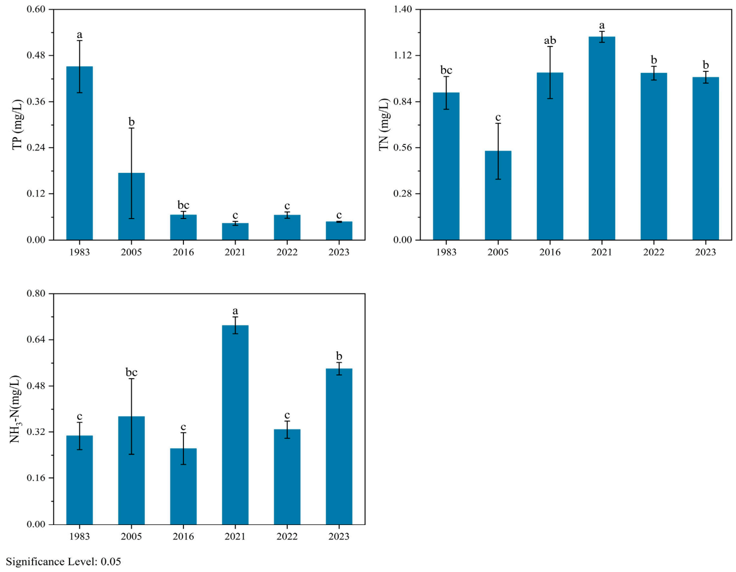
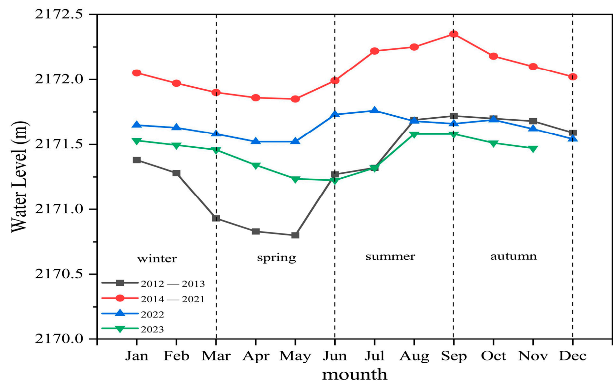



**Figure 2.** Changes in total nitrogen (TN), total phosphorus (TP), and ammonia nitrogen ($NH_3$-N) in Caohai Lake (mean ± SE). The different letters (a, b, c) represent significant differences in the means based on the Kruskal–Wallis test ($p < 0.05$).

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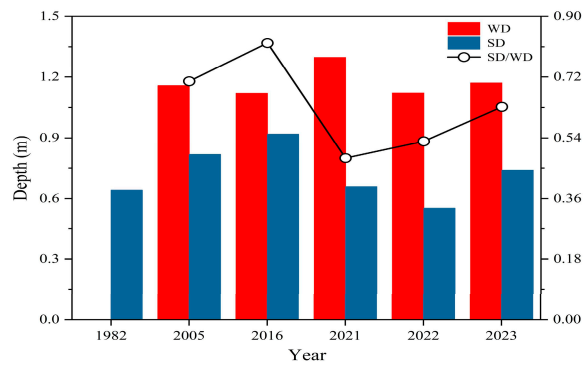


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**Figure 3.** (**a**): Annual and seasonal variations in water level; and (**b**): changes in bottom light availability (water depth (WD), Secchi depth (SD), and SD/WD).

Since 2016, emergent vegetation first exhibited decline and extinction, followed by a sporadic decrease in *Myriophyllum verticillatum* in 2019. In 2020, local conservation patrol officers in Caohai reported a darkening and muddying of the central water body, with a localized extinction of submerged plants over an area of about 3.7 km$^2$. There were significant interannual variations in the submerged plant biomass in Caohai Lake, especially deviating in 2021 (see the distribution of the biomass in the lake in 2021, 2022, and 2023 in Figure S1). By 2021, a massive extinction of submerged plants occurred throughout the lake, with the biomass reducing from 4094.7 g/m$^2$ in 2016 to 125.7 g/m$^2$ in 2021 and the submerged plant biomass ranging from 0 to 1337.4 g/m$^2$ and being mainly distributed in the southwestern part of the Caohai Lake. In 2022, the effective restoration of submerged plants was achieved by dredging the outlet, lowering the water level, and restoring the natural hydrological regime by increasing the biomass to 383.2 g/m$^2$ and ensuring the submerged plant biomass ranged from 0 to 1823 g/m$^2$ and the biomass was highest in the eastern part of the lake. In 2023, a more marked increase in the submerged plant biomass was observed, where the submerged plant biomass ranged from 0 to 2590.7 g/m$^2$, with the biomass in the eastern part of the lake being the highest and the spread heading towards the center, with an average biomass of 922.6 g/m$^2$ across the lake, 3.6 times that of 2021 (Table 1).

**Table 1.** Temporal variations of the biomass of submerged plants in the Caohai Lake (g/m$^2$).

| Section | 1983 | 2005 | 2016 | 2021 | 2022 | 2023 |
|---|---|---|---|---|---|---|
| East of Caohai | 1141.6 | 2980.6 | 5456 | 241.5 | 668.4 | 1475.7 |
| Middle of Caohai | 1195.0 | 826.8 | 2552.9 | 141.4 | 138.7 | 595.6 |
| West of Caohai | 1821.6 | 1012.1 | 4275.1 | 377.4 | 269.1 | 611.7 |
| Mean | 1386.07 | 1606.3 | 4094.7 | 255.1 | 383.2 | 922.6 |

### *3.3. Characteristics of Chl a Variation*

Chl a, an important component of phytoplankton, serves as a crucial indicator for the existing quantity of phytoplankton [33,34]. The data from 2010 to 2020, prior to the extinction of the submerged plants, indicated that the Chl a concentration was consistently low, averaging 7.764 mg/m$^3$ [35–40]. However, following the decline in the submerged plants in 2021, the concentration of the Chl a significantly increased to an average of 25.236 mg/m$^3$ [41], approximately three times that of previous years. With the lowering of the water level and WD and the increase in the submerged plants, the Chl a significantly decreased in 2023 to 17.252 mg/m$^3$ (Figure 4).

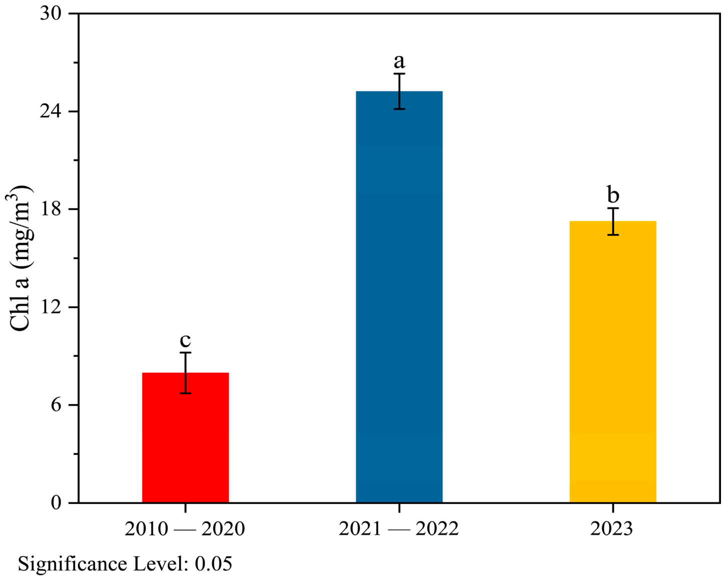



**Figure 4.** Changes in chlorophyll a concentration in Caohai Lake over recent years (2010–2023) (mean ± SE). The different letters represent significant differences in the means based on the Kruskal–Wallis test ($p < 0.05$).

*3.4. Relationship between Chl a, the Water Parameters, and the Submerged Plants*

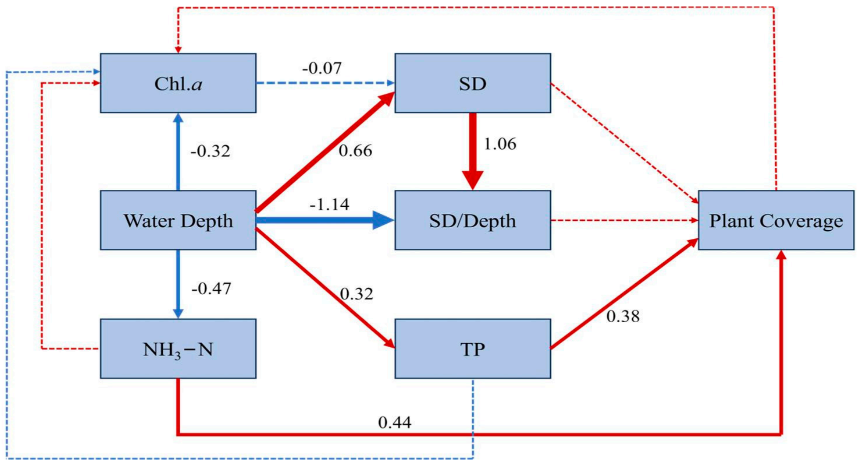
Multiple linear regression analyses were conducted with TN, TP, $NH_3$-N, Chl a, WD and SD as independent variables and coverage and biomass as dependent variables. The TP (β = −0.184, $p$ = 0.017), Chl a (β = −1.680, $p$ < 0.001), and WD (β = −0.455, $p$ < 0.001) were important for predicting the biomass. The independent variable explains 53.1% of the change in biomass (Table 2a). The TP (β = −0.278, $p$ < 0.001), Chl a (β = −0.475, $p$ < 0.001), and WD (β = −0.319, $p$ < 0.001) were important for predicting the biomass. The independent variable explains 64.5% of the change in coverage (Table 2b).

**Table 2.** Interpretation rate of environmental variables to coverage (a) and biomass (b) of submerged plants in model of multiple regression analysis.

| | | | (a) | | | |
|---|---|---|---|---|---|---|
| | B | *β* | t | *p* | *F* | $R^2_{adj}$ |
| TN | 8.796 | 0.082 | 1.179 | 0.241 | 20.983 *** | 0.531 |
| TP | −496.817 | −0.184 | −2.432 | 0.017 | | |
| $NH_3$-N | −11.719 | −0.068 | −0.965 | 0.337 | | |
| Chl a | −1.680 | −0.365 | −4.584 | <0.001 | | |
| WD | −31.552 | −0.455 | −4.821 | <0.001 | | |
| SD | 8.697 | 0.058 | 0.636 | 0.526 | | |
| | | | (b) | | | |
| b | B | *β* | t | *p* | *F* | $R^2_{adj}$ |
| TN | 0.128 | 0.042 | 0.695 | 0.489 | 33.151 *** | 0.645 |
| TP | −21.280 | −0.278 | −4.219 | <0.001 | | |
| $NH_3$-N | 0.018 | 0.004 | 0.059 | 0.953 | | |
| Chl a | −0.062 | −0.475 | −6.854 | <0.001 | | |
| WD | −0.628 | −0.319 | −3.855 | <0.001 | | |
| SD | 0.085 | 0.020 | 0.252 | 0.802 | | |

Note: The results of the analysis using multiple linear regression showed that the regression equation was significant, (a): F = 20.983, $p$ < 0.001; and (b) F = 33.151, $p$ < 0.001. *** $p$ < 0.001

The SEM provided insights into the direct and indirect effects of the water parameters on the submerged plant coverage recorded during the investigation period. Specifically, during the first year of Caohai Lake's restoration (2022), the plant coverage was positively influenced by the $NH_3$-N and TP, with the WD having a significant indirect impact on the plant coverage, and the Chl a being negatively influenced by the WD (Figure 5a). In the second year of the restoration (2023), the SD increased with WD, positively affecting the plant coverage, while the SD/WD increased with a decreasing WD, positively impacting the plant coverage. Thus, the WD had a negative impact on the plant coverage through its negative impact on the SD/WD. The Chl a and TP were negatively affected by the submerged plant coverage (Figure 5b).

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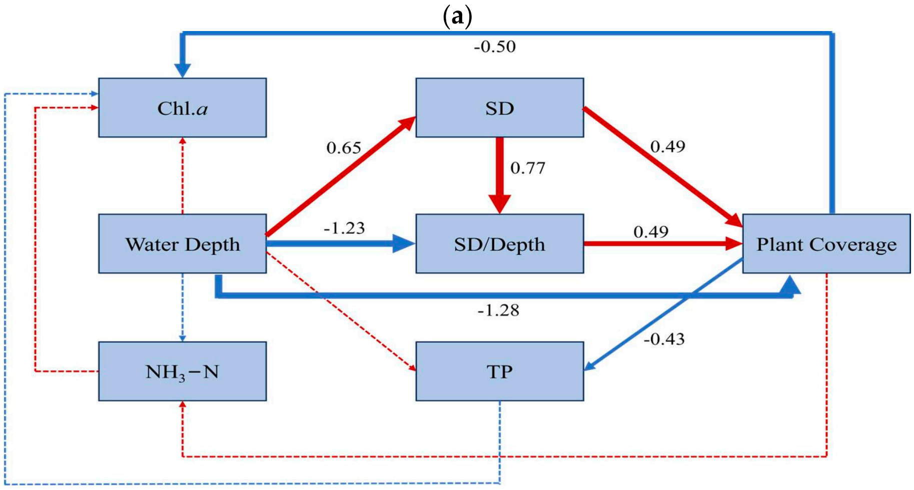


(**b**)

**Figure 5.** Piecewise structural equation model (SEM) exploring the relationships between WD, SD, SD/WD, Chl a, $NH_3$-N, TP, and plant coverage. (**a**) The relationship between the variables during the first year (2022) of restoration in the entire lake. CHISQ = 11.388, $p = 0.077$, GFI = 0.995, CFI = 0.969, and SRMR = 0.067; (**b**) The relationship between the variables during the second year (2023) of restoration in the entire lake. CHISQ = 12.442, $p = 0.087$, GFI = 0.998, CFI = 0.976, and SRMR = 0.058. Solid and dashed arrows indicate significant ($p < 0.05$) and nonsignificant ($p > 0.05$) relationships, respectively. The red and blue lines represent positive and negative pathways, respectively. The arrow thickness is proportional to the strength of the relationship. The number above each arrow is the normalized path coefficient.

## 4. Discussion

### *4.1. Relationship Between the Water Parameters and Submerged Plants*

The present findings clearly indicate that, while there was no increase in nutrients in Caohai Lake, the water levels fluctuated and remained high from 2014 to 2021 (Figure 3a). The growth of the submerged plants in the lake was strongly influenced by the water level and light availability. In Caohai, the biomass and coverage area of the submerged plants were negatively correlated with the WD (Figure 5). The regime shift theory suggests that fluctuations in water levels can alter the growth environment of submerged plants, thereby affecting their community succession [6]. During periods of water level fluctuation, plants experience environmental disturbances such as rapid and drastic changes in DO, carbon dioxide concentrations, and light availability, potentially limiting their gas exchange and photosynthesis [42,43]. The biomass and coverage area of submerged plants tend to decrease with an increasing WD [44]. Extreme water levels can trigger a transition between algae-dominated turbid states and macrophyte-dominated clear states [45]. Prolonged high water levels can hinder the growth and reproduction of submerged plants. The extensive extinction of the submerged plants in Caohai Lake in 2021 was likely due to increased water levels in the spring (compared to 2014–2021 and 2022–2023) (Figure 3). High water levels in the spring can cause the water body to become turbid [46]. Plants require ample light during the spring germination period, while the increase in water level and decrease in Ts lead to reduced bottom light, ultimately preventing plant survival [47–49]. In this study, by lowering the water level and restoring the natural hydrological regime characterized by low levels in winter and spring and high levels in summer and autumn, the degradation of aquatic plants in Caohai Lake was significantly controlled, and the restoration of submerged plants was rapidly achieved, even under higher nutrient concentrations.

Eutrophication is usually regarded as an important factor in the degradation of submerged plants in freshwater ecosystems; however, its effects on Caohai Lake are limited. In 1983, the TP concentration had a mean value of 0.451mg/L, which decreased to 0.174mg/L in 2005. Though the TP concentration was well above the threshold at which a regime shift occurs, the submerged plants had a high biomass (Table 1). And according to the correlation analysis, the coverage area and biomass of the restored submerged plants in the lake were positively correlated with the $NH_3$-N and TP (Figure 5a). Similar phenomena were observed in other lakes. In the 1950s, when Chaohu Lake was already eutrophic and water blooms occurred every year, the submerged plant coverage areas were high (25%) [19]. The TN concentration in Taihu Lake is higher than that in Chaohu Lake, but the macrophyte coverage is approximately 20% [50]. According to Jeppesen et al., submerged plants were also found in lakes with an average TP concentration of approximately 0.7 mg/L [51]. This finding indicates that certain submerged plants can survive under eutrophic conditions, with a range of concentrations promoting their growth. In conditions of high levels of nutrients, lower water levels are required to sustain submerged plants [52,53]. Nutrients played a catalytic role in the recovery of submerged plants in Caohai Lake, ruling out eutrophication as the cause of the submerged plant recession.

There is a complex interaction between submerged plants and the aquatic environment [23]. When abundant, submerged plants can improve the water quality by absorbing or degrading pollutants in the water and adsorbing particles to inhibit the suspension of sediments and thus the release of endogenous nutrients. Submerged plants also have an advantage in nutrient uptake, thus alleviating water eutrophication and inhibiting the proliferation of phytoplankton, in addition to suppressing algal growth through allelopathy [54–57]. Before 2021, with the abundance of submerged plants in Caohai Lake, phytoplankton were not dominant in the macrophyte-dominated clear-water ecosystem, which maintained a low Chl a concentration and thus clear water. After 2021, the average Chl a concentration was more than three times that of the previous years, mainly due to the decline in submerged vegetation. The decline in submerged vegetation also led to an increased water flow and turbulence under wind and wave disturbances, which promoted sediment resuspension and material transfer, thereby reducing the sedimentation rate of suspended particles and increasing light attenuation in the water, while significantly increasing the lake's endogenous nutrient load and providing more nutrients for phytoplankton proliferation [58]. In addition, the inhibitory effect of the submerged vegetation on the phytoplankton was significantly weakened [59], enabling the easy proliferation of the lake phytoplankton under suitable summer temperatures. After the decline in submerged plants in 2021, the concentration of Chl a significantly increased; after the restoration of submerged plants in 2023, their coverage negatively impacted the Chl a concentration, which significantly decreased (Figures 4 and 5b). Therefore, the phytoplankton dominance in the lake and the associated water quality deterioration are more likely a result, rather than a cause, of the extinction of submerged plants.

### *4.2. Importance of Water Level Manipulation to the Restoration of Submerged Plants in Lakes*

Restoring submerged plants is key to rehabilitating eutrophic waters and maintaining the health of aquatic ecosystems, with the water level being a crucial factor affecting the successful colonization and survival of submerged plants in shallow lakes [60]. When restoring aquatic lake vegetation, an effective measure is to manipulate water levels based on plant growth needs, which involves maintaining appropriate water levels to ensure proper WD and transparency ratios, thereby ensuring an environment conducive to the germination and growth of submerged plants. In China, water level manipulation for restoring aquatic vegetation has been applied. A previous experiment in Wuli Lake revealed that lowering water levels could create favorable conditions for submerged vegetation restoration [61]. Li et al. conducted a water level manipulation experiment by first lowering water levels, then introducing aquatic plants (especially submerged plants), and subsequently gradually increasing water levels based on the survival rate and growth of the aquatic plants, which significantly enhanced the coverage and diversity of the aquatic plants in Wuli Lake [62]. In a large subtropical lake in Florida, USA, Havens lowered the water level by 2 m, relieving the pressure of many years of high water levels; approximately two months after the water level was reduced, *Chara* became dominant in the submerged plant community, and, six months later, vascular taxa (*Hydrilla and Potamogeton*) became the dominant species; and the authors concluded that the biomass of submerged plants in the water body was negatively correlated with the WD, with a correlation coefficient of $-1.69$ [44]. In the Netherlands, to promote the development of vegetation in emergent lake wetlands, water level manipulation measures are implemented that involve increasing water level fluctuations and lowering water levels in summer. These measures have promoted vegetation germination and growth, leading to increased biodiversity. As shown above, water level manipulation significantly impacts the reconstruction, restoration, and succession of submerged vegetation, and, therefore, the management of lake water level fluctuations should be emphasized in lake management and restoration practices.

## 5. Conclusions

This work used Caohai Lake in Guizhou as a case study and utilized long-term monitoring data and a whole-lake water level manipulation experiment to explore the relationship between nutrients, water levels, and submerged plants, emphasizing the importance of water level manipulation in lake management and aquatic vegetation restoration. The nitrogen and phosphorus nutrients in Caohai Lake did not increase over the last 40 years, and the TP showed a decreasing trend, while significant changes occurred in water level fluctuations. The submerged plant biomass had been increasing until a sudden extensive extinction in 2021. This indicated that water level fluctuations, rather than nutrients, triggered the decline in submerged plants in Caohai Lake. Comprehensive water level manipulation was performed, which restored the natural hydrological regime characterized by low water levels in winter and spring and high levels in summer and autumn, leading to the rapid restoration of the submerged plants. This confirms the importance of water level manipulation in the restoration of aquatic lake plants. Therefore, water level fluctuations have a crucial impact on the restoration, reconstruction, and succession of submerged vegetation, highlighting the need for the enhanced management of lake water levels in lake protection and restoration practices.

**Supplementary Materials:** The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/w16050772/s1, Figure S1: Distribution of the submerged plant biomass during the years 2021, 2022 and 2023 for Caohai Lake.

**Author Contributions:** F.C.: data curation, formal analysis, and writing—original draft. X.W., B.L., and J.L.: investigations. P.X.: writing—review and funding acquisition. X.J.: writing—review and editing. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research was funded by the Guizhou Provincial Key Technology R&D Program (No. 2023216) and the National Natural Science Foundation of China (32360288).

**Data Availability Statement:** The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

**Conflicts of Interest:** The authors declare no conflicts of interest.

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