Response of Fish Trophic Niche to Water Level Regulation of the Three Gorges Reservoir in its Backwater Bay Using a Stable Isotope Approach

Rongjing Huang 1, Xuemei Zhan 2, Xin Tao 2 and Bin Li 2*

1 Xinyang Agriculture and Forestry University College of Fisheries, Xinyang 464000, Henan, China.
2 Key Laboratory of Sichuan Province for Fishes Conservation and Utilization in the Upper Reaches of the Yangtze River, School of Life Sciences, Neijiang Normal University, Neijiang, Sichuan, 641100, China
*Email: happyhrj@163.com

Abstract. To date, our ability to speculate how species interactions will change temporally and spatially in response to WLR still inadequate, especially within large river-reservoir ecosystems. Fish communities in backwater bay of the Xiaojiang River of the TGR (Three Gorges Reservoir) were studied in 2010 and 2016 using a stable isotope approach to explore variations in fish trophic niches associated WLR. We found that fish assemblages tended to have broader trophic diversity spaces in LBAs (large backwater areas) at a water depth of 175 m, suggesting that the assimilation of food resources might come from a greater diversity of habitats or prey items with distinct isotopic signatures. Many among-fish species trophic niches tended to overlap and have broader ranges in LBAs compared to SBAs (small backwater areas) at a water depth of 145 m, which indicated that the processes of impounding at 175 m can provide more similar food resources for different fish species. Our findings highlight that WLR dynamics are typical characteristics of the backwater bay of the Xiaojiang River aquatic ecosystems caused by the operations of the TGR, which has significant ecological effects on the fish trophic structure within this community. Understanding the pattern of changes in fish trophic niche associated with WLR will be meaningful for fishery resources management of the other tributaries in the TGR.

1. Introduction
Hydropower dams have been built to satisfy the accelerated demands for water resources and energy following explosive climate vary and population growth worldwide [1]. Although hydropower dams supply high public utility, they can negatively influence river ecosystems [2]. Some experts have suggested that two different types of dam operations (run-of-the-river dams and storage dams) result in different ecological effects [3]. The size classification and operation of dams are key factors that determine their effects; hence, it is crucial to consider these cases separately. Stream-reservoir turnover times of run-of-the-river dams do not have regulation and range from a few hours to many weeks [3]. On the other hand, the water level regulation (henceforth referred to as WLR) of large river-reservoirs for dams (large storage) is connected to the homogenization of flow regimes with changing annual variation [4]. Anyhow, thus far the effect of WLR on key ecosystem processes and trophic interactions of different organisms is not well-understood [5].

Trophic niche theory is an important tool for explaining patterns of assemblage and community
structure, and it also could be used to understand the effects of WLR on aquatic communities. A fish’s trophic niche is the evolutionary result of their physiological, morphological and behavioral adaptation to the inhabitable environment [6]. Therefore, at a broader community scale, trophic niche could help to delineate trophic interactions and distinguish between different habitats and available resources in an aquatic ecosystem [7]. Studying variation in trophic niches of species within a community is also good for wild resource conservation because that changes is often associated with the stability of ecosystem functions [8]. Additionally, aquatic environments usually include substantial regular variability and/or a complex mosaic of habitat types. Therefore, an improved understanding of how trophic niches change for different aquatic organisms within food webs might contribute to the development of management strategies to protect biodiversity and ecosystem services [9]. Many ecologists have developed new technologies and renewed interest in this concept in recent years, which allows us to employ stable isotope method to quantify trophic niche metrics [10].

Stable carbon ($\delta^{13}$C) and nitrogen ($\delta^{15}$N) isotope composition are extensively used to study trophic structure and represent the ecological niches occupied by species [11]. The carbon isotope ($\delta^{13}$C) varies little between trophic levels but exhibits substantial variation among primary producers [12-13], so it is often used to identify the resource base [14-15]. In contrast, the nitrogen isotope ($\delta^{15}$N) is a powerful tool for estimating the trophic positions of organisms due to it exhibiting a gradual enrichment from one trophic level to another [16]. Recently, several studies have introduced a series of community-wide metrics to gain more quantitative information from stable isotope data at the species and community levels [17-18].

The TGR (Three Gorges Reservoir) is the largest river-reservoir in China. The TGR performs large-scale seasonal operations for diversity purposes. Tributaries of the TGR are among the most ecologically sensitive areas that respond to various in reservoir operation [19-20]. The Xiaojiang River, which is the largest tributary of the TGR, is located north of the TGR. Therefore, in the Xiaojiang River-reservoir continuum, the reservoir operation of the TGR forms two distinct backwater areas (see investigative sites), a large backwater area (175 m) and a small backwater area (145 m). In this study we used $\delta^{13}$C and $\delta^{15}$N values, Layman metrics and Bayesian statistical approaches to explore changes in the fish communities and WLR in the backwater of the Xiaojiang River. We hypothesized that the annual processes of impounding at a water level of 175 m supplies additional basal food resources for fish species across a greater diversity of habitats, thus increasing both the total available niche range for individual species and the trophic diversity spaces for the entire fish assemblage.

2. Materials and Methods

2.1. Study Area

The Xiaojiang River is one of the largest tributaries in the TGR (Figure 1). In 2006, the first impoundment of the TGR to a water level of 145 m resulted in a backwater bay of approximately 45 km$^2$ in the Xiaojiang River, from Yunyang to Yanglu [21]. When the water level reaches 175 m in the TGR, the backwater bay of the Xiaojiang River extends to Kaixian County. The backwater bay of the Xiaojiang River is about 65 km long at 175 m (Figure 1). The water level of the TGR remains at a high level (175 m) from October to April. By contrast, the TGR has a low water level (145 m) from May to September. The Xiaojiang River has a similar rhythm of WLR with the TGR, and nearly the full range of inundation (145–175 m). Therefore, in the Xiaojiang River different sizes of backwater areas are formed, including a small backwater area (SBA, water level at 145 m) and a large backwater area (LBA, water level at 175 m), following the operation of the WLR (145 m to 175 m) in the TGR.
Figure 1. Map of the TGR and the Xiaojiang River. We selected five sampling sites in the large backwater area (LBA): (1) Kaixian and (2) Yanglu (3) Quma, (4) Gaoyang and (5) Huangshi. In the small backwater area (SBA), three sampling sites ((3), (4) and (5)) were selected.

Yanglu is located about at the boundary between the LBA and the SBA in the Xiaojiang River. Figure 1. Five sampling sites were selected Figure 1. The location of these sites from downstream to upstream are as follows: Huangshi town, Gaoyang and Quma town were the SBA sampling sites and Huangshi town, Gaoyang, Quma town, Yanglu town and Kaixian County were the LBA sampling sites.

2.2. Sample Collection
To investigate changes in fish trophic niche that occurred due to WLR in the backwater bay of the Xiaojiang River we established two study areas in the backwater bay of the TGA. The first sampling site was within the SBA at the low water level (July, 145 m) and the other was within the LBA at the high water level (December, 175 m) in 2010 and 2016, respectively.

The Xiaojiang River fish community has a relatively high diversity and varies with the WLR of the TGR. Fish were sampled in the SBAs (three sites) and in the LBAs (five sites) with the help of professional fishermen from local cooperatives Figure 1. The number of species during four sampling occasions were 14, 16, 15, 15, respectively, and 7 species fishes of which appeared in each sampling occasion to five families of fishes. For all fish specimens, we removed a skinless, dorsal muscle samples were frozen separately in aluminum foil for later analysis [22]. Particulate organic matter (POM) samples, periphyton samples, snails, crustaceans and green leaves of macrophytes, were taken at each site in both 2010 and 2016. The collection and processing of all samples were completed with reference to literature [23].

2.3. Stable Isotope Analysis
In the laboratory, after completing the material preparations, all samples were sent for isotopic analysis at the Laboratory of Isotope Analysis in the Chinese Academy of Forestry (Beijing).

\[
\delta X (\%) = \left[ \frac{R_{\text{sample}}}{R_{\text{standard}}} - 1 \right] \times 1000
\]

In equation (1), \(R\) is \(^{13}\text{C}/^{12}\text{C}\) or \(^{15}\text{N}/^{14}\text{N}\), and \(X\) is \(^{13}\text{C}\) or \(^{15}\text{N}\).

Trophic position (TP) was calculated [24][13]:

\[
\text{TP}_{\text{consumer}} = \left( \delta^{15}\text{N}_{\text{consumer}} - \delta^{15}\text{N}_{\text{Pomacea canaliculata}} \right) / \text{TEF} + 2
\]

In equation (2), the TEF is the trophic enrichment factor.
In equation (1): The δ^{15}N_{consumer} represents the δ^{15}N value of the tested consumer, and 3.4‰ (TEF) is the assumed enrichment in δ^{15}N between successive TPs, which has been identified as an average trophic nitrogen fractionation for aquatic consumers [14][24][25]. The average δ^{15}N values for P. canaliculata was chosen to serve as the food web baseline values, and trophic level 2 was consequently attributed to these consumers, based on previous studies [26][27].

3. Data Analysis
Student’s t tests were conducted to determine differences in δ^{13}C and δ^{15}N for each sample in the SBA and the LBA of the Xiaojiang River in 2010 and 2016. Standard bi-plots of stable carbon and nitrogen values were generated. The six quantitative population metrics [17] and a Bayesian framework [28] were used to compare the fish trophic niches between the SBA and the LBA using the Stable Isotope Bayesian Ellipse package in R. The Layman indexes were calculated in R (software version 3.4) including CR, NR, TA, CD, MNND and SDNND [17].

The Standard Isotope Bayesian Ellipse in R can be used to quantify the trophic niches based on standard ellipse areas (SEA and SEAc) of the organism communities. SEA is a proxy of the richness and evenness of resources consumed by the population [17][29]. In this study, we used the SIBER to quantify the trophic niches of the common fish species including Carassius auratus, Cyprinus carpio, Hemniculter tchangi, Erythroculter mongolicus, Saurogobio dabryi, Pelteobagrus nitilus and Pelteobagrus vachelle in the backwater bay (the LBA and the SBA) of the Xiaojiang River at different sampling occasions. Moreover, for each fish species, we calculated an average degree of the overlap value with other species to identify whether they shared isotopic niche space within the food web.

4. Results
A total of 274 samples were isotopically analyzed, including 167 fish samples and 107 samples from potential food sources (basal food sources and benthic macroinvertebrates). The number of species during four sampling occasions were 14, 16, 15, 15, respectively, and made up 27 species belonging to five families of fishes. The δ^{13}C and δ^{15}N values of the basal resources (δ^{13}C: t = 0.811, P = 0.422; δ^{15}N: t = -1.12, P = 0.247) and macroinvertebrates (δ^{13}C: t = -0.315, P = 0.755; δ^{15}N: t = 1.16, P = 0.258) were not significantly different between the LBA and the SBA in 2010, but there was a significant difference for fish species (δ^{13}C: t = -3.95, P < 0.001; δ^{15}N: t = 4.59, P < 0.001). In 2016, the δ^{15}N values (t = 3.01, P < 0.05) of the basal resources showed an obvious difference between the LBA and the SBA, whereas for the other samples δ^{13}C (basal resources: t = 0.824, P = 0.415; macroinvertebrates: t = -0.227, P = 0.056; fish: t = -0.66, P = 0.507) and δ^{15}N (macroinvertebrates: t = -0.194, P = 0.85; fish: t = -0.818, P = 0.416) were not significantly different. However, significant differences were found between the δ^{13}C and δ^{15}N values of all samples including the basal resources (δ^{13}C: t = -3.63, P < 0.001), macroinvertebrates (δ^{13}C: t = 2.302, P < 0.05; δ^{15}N: t = -1.83, P < 0.05) and fish (δ^{13}C: t = 4.04, P < 0.001; δ^{15}N: t = -5.50, P < 0.001), with the exception of the δ^{15}C values (δ^{13}C: t = 0.08, P = 0.936) for the basal resources, in the backwater bay of the Xiaojiang River both in 2010 and 2016. Among all fish species and individuals, δ^{13}C values ranged over 5‰ in the SBA (from -26.80‰ to -21.13‰) and increased broadly in the LBA (from -29.26‰ to 14.67‰) in 2010 (Figure 2 a, b). In addition, δ^{15}N values showed a smaller range among fish samples, with values from 9.28‰ to 18.69‰ in the SBA and decreasing to a range of 4.77‰ to 13.51‰ in the LBA (Figure 2 a, b). In contrast to 2010, a large range of temporal variation in all fish samples’ stable isotope ratios (an increase in δ^{13}C by 6.09‰ and in δ^{15}N by 3.38‰) was found from the SBA to the LBA in 2016 (Figure 2 c, d).

The trophic positions of all consumers were characterized by δ^{15}N values in this study (Table 1). Based on the assumption of a δ^{15}N trophic enrichment of 3.4‰ per TP, we calculated the trophic positions of all consumers collected in the SBA and the LBA in both 2010 and 2016 (Table 1; Figure 2). Three trophic levels were observed in the food webs, excluding the LBA (2016), which contained four trophic levels. However, pairwise comparisons indicated non-significant differences in the mean trophic levels between the LBA and the SBA in 2010 (t = 0.073, P = 0.942) and 2016 (t = -1.187, P =
0.24). In addition, there were also no obvious variations in the trophic levels ($t = -0.825$, $P = 0.412$) between 2010 and 2016.
Figure 2. Bi-plot δ¹³C and δ¹⁵N values of tissues from primary production sourced, mollusc and fishes collected from the backwater of Xiaojiang River within the Three Gorge Reservoir, at different water level stages (a = SBA, 7. 2010; b = LBA, 12. 2010; c = SBA, 7. 2016; d = LBA, 12. 2016).

Particulate organic matter POM; periphytic algae Perip; *Alternanthera philoxeroides* A.phil;
Polygonum hydropiper P.drop; Lemma minor L.mino; Eichhornia crassipes E.cras; Xanthium sibiricum X.sibi; Setaria faberii S.fabe; Cynodon dactylon C.dact; Pomacea canaliculata P.cana; Bellamya aeruginosa B.aeru; Anodonta woodiana A.wood; Limnoperna lacustris L.lacu; Leander modestus L.mode; Macrobrachium nipponensis M.mipp; Parabotia fasciata P.fasc; Ctenopharyngodon idellus C.idel; Elopichthys bambusa E.bamb; Squaliobarbus curriculus S.curr; Carassius auratus C.aura; Cyprinus (Cyprinus) carpio C.carp; Procypris rabaudi P.raba; Spinibarbus sinensis S.sine; Hypophthalmichthys molitrix H.moli; Aristichthys nobilis A.nobi; Hemniculter tchangi H.tcha; Erythroculter ilishaeformis E.ilis; Pseudobrama simoni P.sim; Erythroculter dabryi E.dabr; Megalobrama amblycephala M.ambl; Saurogobio dabryi S.dabr; Hemibarbus marculatus H.macr; Coreius heterodon C.hete; Squalulus argentatus S.arge; Silurus asotus S.asot; Pelteobagrus nitilus P.niti; Pelteobagrus vachelle P.vach; Hemibagrus macropterus H.macro; Siniperca kneri S.kner; Coilia brachygnathus C.brac; Hemiramphus karumeus H.kuru
Figure 3. SIBER output δ13C and δ15N bi-plot of the common species common consumers including I (P.nitilus and P.vachelle), II (C.auratus and C.carpio) and III (E.mongolicus, S.dabryi and H.tchangi). Standard ellipse present the calculated isotopic feeding niche widths of each species at different water levels stages.

The trophic niche metrics (Layman metrics) for fish communities varied between the sampled periods in this study (Figure 4). The LBA (2016) showed the largest value of Layman metrics for fish communities (Figure 4, d). By contrast, the lowest value of Layman metrics was observed in the SBA (2010) (Figure 4, a). In total, an increased tendency in Layman metrics was seen from a water level of
145 m (SBA) to 175 m (LBA) in 2010 and 2016, suggesting higher total fish species, more abundant food resources, greater trophic diversity and a lower even distribution of trophic niches in the LBA compared with those in the SBA. The standard ellipses (SEA) based on the isotope ratios of the common fish communities visually differed in size, shape and position in the $\delta^{13}$C vs $\delta^{15}$N bi-plot space (Figure 3). The fish assemblages with the smaller SEAc values (consequently lower isotopic niche) occurred in the SBA (2010) at the low water level, followed by the LBA (2010) at the high water level, which showed the larger SEAc values (Table 1). However, this pattern of changes in SEAc values (Table 1) was not observed between the SBA and the LBA in 2016. Furthermore, when comparing the degrees of overlap for the common fish species’ food sources within fish communities between different water levels both in 2010 and 2016, we found a greater mean overlap ratio of fish species ($E. mongolicus$ was excluded because it had no obvious change at different water levels) in the LBA relative to the SBA (Table 2).

Table 1. Total area (TA) and SEA probability, standard ellipse areas with small sample corrections (SEAc) for the selected 7 species common consumers calculated using SIBER.

| Sampling times | index | $P. nitilus$ | $P. vachelle$ | $H. tchangi$ | $C. auratus$ | $C. carpio$ | $E. mongolicus$ | $S. dabryi$ |
|---------------|-------|-------------|--------------|-------------|-------------|-------------|---------------|------------|
| 7.2010 (145 m) | TA    | 0.43        | 0.13         | 0.05        | 0.43        | 5.43        | 3.43          | 0.17       |
|               | SEA   | 0.77        | 0.24         | 0.09        | 0.79        | 9.86        | 2.79          | 0.32       |
|               | SEAc  | 1.57        | 0.48         | 0.18        | 1.57        | 19.72       | 3.73          | 0.63       |
| 12.2010 (175 m)| TA    | 3.45        | 1.61         | 5.32        | 12.44       | 4.22        | 0.17          | 1.22       |
|               | SEA   | 6.27        | 2.92         | 3.74        | 10.15       | 4.09        | 0.32          | 1.7        |
|               | SEAc  | 12.53       | 5.84         | 4.68        | 12.69       | 5.11        | 0.63          | 2.55       |
| 7.2016 (145 m)| TA    | 1.71        | 0.01         | 0.18        | 0.19        | 1.47        | 0.86          | 0.01       |
|               | SEA   | 3.09        | 0.16         | 1.48        | 0.35        | 2.67        | 1.57          | 0.02       |
|               | SEAc  | 6.18        | 0.03         | 2.97        | 0.71        | 5.34        | 3.13          | 0.04       |
| 7.2016 (175 m)| TA    | 0.85        | 0.23         | 0.09        | 0.34        | 0.11        | 0.16          | 1.56       |
|               | SEA   | 1.54        | 0.42         | 0.15        | 0.62        | 0.19        | 0.29          | 2.84       |
|               | SEAc  | 3.07        | 0.84         | 0.31        | 1.25        | 0.38        | 0.58          | 5.67       |

Table 2. The mean overlap of each species standard Bayesian ellipsoid with other species ellipsoids using carbon and nitrogen data in two-dimensional space during the different sampling occasions.

| Species            | C-N overlap (%)                        |
|--------------------|----------------------------------------|
|                    | 145 m. 2010 | 175 m. 2010 | 145 m. 2016 | 175 m. 2016 |
| $C. auratus$       | 12.69 ± 0.32 | 16.29 ± 0.30 | 12.07 ± 0.14 | 18.59 ± 0.11 |
| $C. carpio$        | 2.27 ± 0.02  | 2.13 ± 0.02  | 1.88 ± 0.01  | 2.00 ± 0.01  |
| $E. mongolicus$    | 1.23 ± 0.03  | 1.38 ± 0.01  | 1.02 ± 0.05  | 2.13 ± 0.31  |
| $S. dabryi$        | 10.50 ± 0.23 | 13.08 ± 0.22 | 7.92 ± 0.11  | 13.19 ± 0.08 |
| $H. tchangi$       | 12.99 ± 0.35 | 16.89 ± 0.33 | 12.19 ± 0.16 | 19.01 ± 0.13 |
| $P. vachelle$      | 11.95 ± 0.27 | 14.95 ± 0.25 | 9.17 ± 0.12  | 15.26 ± 0.09 |
| $P. nitilus$       | 12.51 ± 0.35 | 16.44 ± 0.33 | 11.64 ± 0.16 | 19.00 ± 0.13 |

5. Discussion
Changes in WLR influence both the physical characteristics of the rivers and the trophic structure of fish communities [30]. The types of resources available to the aquatic community were also discrepant at different water levels (145 m and 175 m). Our study further explored these variations and elucidated
the complex species habitat and resource associations both within- and among-species trophic niches of fishes in the LBA and the SBA in 2010 and 2016. These changes in the carbon and nitrogen isotopic signature ranges of all consumers were reflected in the isotopically expanded or contracted prey base, which could originate from accessing prey of different habitats with distinct isotopic signatures or utilizing more diverse prey items [10]. However, a narrower or wider trophic niche space reflects shifts in available resources in response to environmental drivers [31]. Generally, compared to the SBA, we found a higher trophic diversity space in the LBA in both 2010 and 2016 (Figure 4), suggesting that the same species and individuals prefer to expand their resource base through utilizing a wider variety of habitats and/or consuming a broader range of prey items. Furthermore, many among-species (all common fish species with other species) trophic niches tend to overlap more at a water level of 175 m in the LBA, which indicated that the WLR of the TGA (from 145 m to 175 m) provided an increase in species utilization of similar resources and/or habitats within the fish community.

To further explore the variations in trophic position of all consumers between the LBA and the SBA in the backwater bay of the Xiaojiang River, we used common snails (P. canalicularata) collected at each sampled time as the baseline values to evaluate trophic levels [24] (Post, 2002). Many fish species’ trophic niche overlap increased in the LBA compared with those collected in the SBA in both 2010 and 2016 (Table 2). Post (2002) suggested that the isotopic value of consumers is closely related to temporal and spatial variation in the isotopic signatures of food resources, which could affect the position occupied by consumers within the community. Nevertheless, all fish species’ mean trophic positions did not significantly changed at different the water levels, as indicated by their mean trophic positions. In addition, the trophic positions of all fish had no obvious difference between 2010 and 2016. It is possible that many fishes have adapted to the complex aquatic environment of the WLR in the backwater bay of the Xiaojiang River because the first impoundment to 145 m occurred in the TGA in 2006 [21]. This could exhibit a dynamic relationship between the consumers’ trophic structure and their aquatic environments in the backwater bay of the Xiaojiang River [31].

Figure 4. Fish assemblage δ13C and δ15N niche space based on the convex hull during different water levels (a = SBA, 7. 2010, b = LBA, 12. 2010, c = SBA, 7. 2016, d = LBA, 12. 2016).
Thus far, several studies have emphasized that consumers prefer greater diversity of novel food sources and habitats after impounding in river ecosystems due to the importance of terrestrial nutrient matter from the laterals of the river [32][33]. In the LBA, it is likely that more abundant food sources might occur at a water level of 175 m because a large amount of terrestrial organic plant matter was annually submerged laterally in the backwater bay of the Xiaojiang River [34-35]. A relatively higher primary production was observed in the LBA, especially in 2010 [36], which is in line with its high fishery output after impounding of the TGA in 2010 [37]. Furthermore, some documents underline the importance of terrestrial resources in aquatic food webs, especially after inundation within a large river ecosystem [38-40]. Therefore, the high fishery output corroborates that allochthonous resources (e.g. *Cynodon dactylon* and *Setaria faberii*), which originated from submerged habitats at the high water level, are important in maintaining fish productivity in the LBA. Consistent with the above findings, the total range in δ¹³C values among all our samples in the LBA (-29.26‰ to -14.68‰ and -30.36‰ to -13.51‰ in 2010 and 2016, respectively) were greater than the ranges for fishes in the SBA (-26.80 to -21.13‰ and -30.72‰ to -19.95‰ in 2010 and 2016, respectively) within this aquatic ecosystem. Such an increase in among- and within-species carbon isotopic ranges in the LBA at a water level of 175 m could be associated with reduced competitive interactions among species because of greater resource availability due to the process of impounding [41]. Although fish communities and macroinvertebrates could characterize specific habitats [42], the range in δ¹³C values of the specimens indicated that fish might consume a greater diversity of prey items or forage in different habitat patches in the LBA. Li et al. (2011) and Ye et al. (2017) reported that a higher diversity of fish species was found in the LBA compared with those collected in the SBA within the backwater bay of the Xiaojiang River. In the present study, we collected more fish species in the LBA (175 m) than in the SBA (145 m). Consequently, we inferred that a mosaic of habitats might be more important to support the diversity of fish species in the backwater of the Xiaojiang River.

These variations in trophic diversity for fish species could be reflected in the differences in resource exploitation between the SBA and the LBA, both in 2010 and 2016. The trophic structures of the fish assemblages were completely different, and the processes of impounding appeared to exert more influence on the structure of the aquatic communities. In the LBA (in both 2010 and 2016) there was a higher variety of species to incorporate the supplied carbon, which might have led to a larger isotopic niche being occupied by the fish community, and consequently a larger trophic diversity and lower trophic redundancy in contrast to the SBA. In addition, ellipsoid overlap and the relative contribution of δ¹³C and δ¹⁵N tracers (values) varied between species. Moreover, we used all the tracer data of common fish species to explain their niche widths and overlaps with other species within this aquatic ecosystem. For example, *C. auratus* and *P. nitilus* had a large degree of trophic niche overlap with other species in the different water levels, suggesting that these species have a broader trophic niche to utilize common resources and habitats with multitudinous fishes in the community, which agrees with previous results of stomach content analyses on broad omnivores [43][44]. In contrast, *E. mongolicus* had a low trophic niche overlap with other species across time periods, suggesting that it owned a narrow trophic niche within the community, consistent with its classification as a carnivore [45]. Although the interactions of the different fish species in the backwater bay of the Xiaojiang River is further complicated due to the influence of the other factors (e.g., biogeochemistry, seasonal variations and human activities) on stable isotope values, understanding the relationships in trophic niche overlap among fish species could provide a solid foundation for further research on fish species’ interactions within this region [31].

6. Conclusion

The findings of the present study contribute to our understanding of the relationships between the trophic niches of the fish community and the WLR caused by the operations of the TGR in the backwater bay of the Xiaojiang River. We found that fish species within the community tended to have broader trophic niche spaces in the LBA, which reflected utilization of food resources from either a
wider range of isotopically distinct prey items or a greater diversity of habitats. Furthermore, many among-species trophic niches also tended to overlap and ranged more broadly in the LBA compared to the SBA. Our study highlights that the WLR dynamic is a typical characteristic in the backwater bay of the Xiaojiang River aquatic ecosystems, which has significant ecological effects on the fish trophic structure within the community. Understanding the pattern of changes in fish trophic niche associated with WLR in the TGR can provide implications for fishery resource management of the other tributaries (e.g., the Meixi River and the Daning River) in the TGR, and can help managers develop science-based plans on how to preserve the biodiversity of fish species. However, this study only showed short-term responses of fish trophic niches to WLR in this area affected by the TGR. It will be more important to continue to monitor fish species assemblages on a longer basis to assess the changes in fish trophic niches associated with WLR.

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