

Appendix Supplementary data

Distance-decay relationship reveals both horizontal and vertical dispersal limitation and source – sink relationships of phytoplankton in a deep channel-type reservoir

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Appendix A Materials and methods

Shannon-Wiener Diversity Index (H') (Spellerberg and Fedor, 2003) is used to assess the diversity of a community, considering both the abundance and evenness of species. The formula is:

$$H' = - \sum_{i=1}^S P_i \cdot \ln P_i \quad (1)$$

where P_i is the relative abundance of the i -th species, and S is the total number of species. The relative abundance P_i is calculated as the ratio of the number of individuals of the i -th species to the total number of individuals in the community.

Pielou's evenness index (J) (Jost, 2010) measures the evenness of species abundances within a community. The formula is:

$$J = \frac{H'}{\ln S} \quad (2)$$

where H' is the Shannon-Wiener diversity index, and S is the total number of species. The index ranges from 0 to 1, with higher values indicating a more even distribution of species in the community.

Margalef's Species Richness Index (D) (Gamito, 2010) evaluates the species richness of a community. The formula is:

$$D = \frac{S-1}{\ln N} \quad (3)$$

where S is the total number of species, and N is the total number of individuals in the community. A higher value of D indicates greater species richness.

The calculation of phytoplankton community diversity indices a , k , and N followed the method described by Ye et al. (2024). In this study, the data were analyzed at the genus level. Firstly, the phytoplankton detected in each sample were sorted

according to their abundance from the smallest to the largest (serial number i starting from 0). The relative abundance proportion (P_i) of each taxon was calculated from the phytoplankton abundance ρ_i ($i \leq m$, m is the total number of phytoplankton genera in each sample) according to Eq. (4):

$$P_i = \frac{\rho_i}{\sum_{i=1}^m \rho_i} \quad (4)$$

According to the general formula of exponential function ($y = e^x$) based on natural numbers (e), the Eq. (5) in this study is obtained. For each sample, an exponential model was used to fit the serial number i (independent variable) and P_i (dependent variable) according to Eq. (5):

$$\bar{P}_i = a \times e^{ki} \quad (5)$$

where \bar{P}_i is the calculated relative abundance of taxon i , e is the mathematical constant, and both a and k are constants.

The Eq. (5) can be transformed into $\bar{P}_i = \bar{P}_0 \times e^{ki}$. If e^k is indicated as q , then the above equation can be re-written as $\bar{P}_i = \bar{P}_1 \times q^{i-1}$ ($i \geq 0$), which forms a geometric progression with the geometric ratio of q . The q can reflect the intensity of competition among taxon, with k as the competition coefficient.

When $i = 0$, $\bar{P}_0 = a$, which represented the relative abundance of taxon with ranking number of 0. It can be interpreted as the taxon with the smallest abundance when the specific taxon disappears from an ecosystem, and a is considered as the critical relative abundance of extinction.

Where i is the set of natural numbers, the exponential Eq. (5) can be converted into a geometric progression with prime a and common ratio e^k . The corresponding N could

be calculated according to the sum formula for the first n terms of the geometric progression, considering each community as 100 % of the sum of relative abundance of all phytoplankton taxa. The sum of the first N terms of the geometric progression can be calculated according to Eq. (6):

$$S_N = \frac{a_1(1 - e^{kN})}{1 - e^k} = 100\% \quad (6)$$

where S_N is the sum of the geometric progression, $a_1 = \overline{P}_0 \times e^k$, and N is the environmental taxa capacity. N can be solved by the above equation.

Appendix B Figure

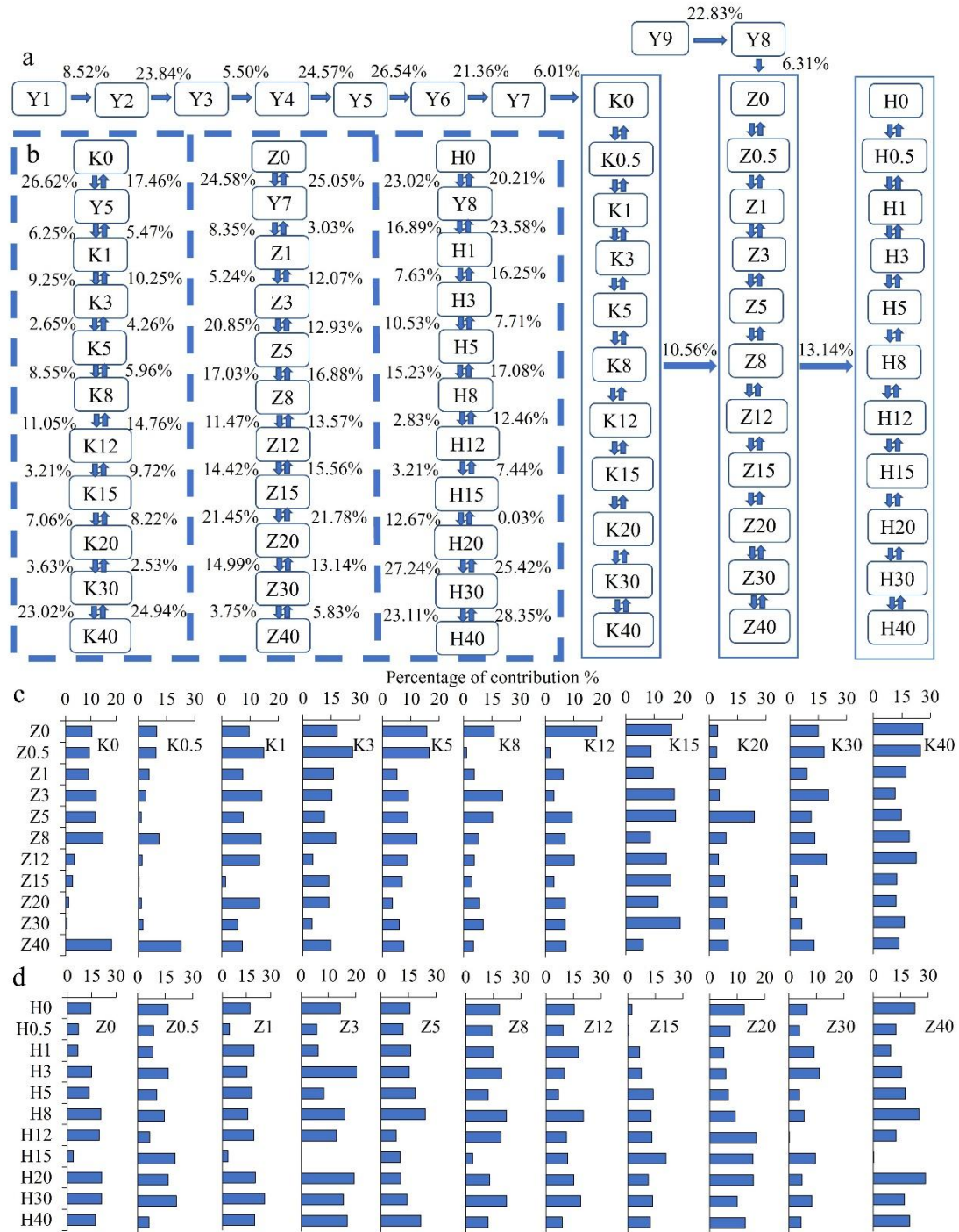


Fig. B1. Source–sink relationships among phytoplankton communities (February).

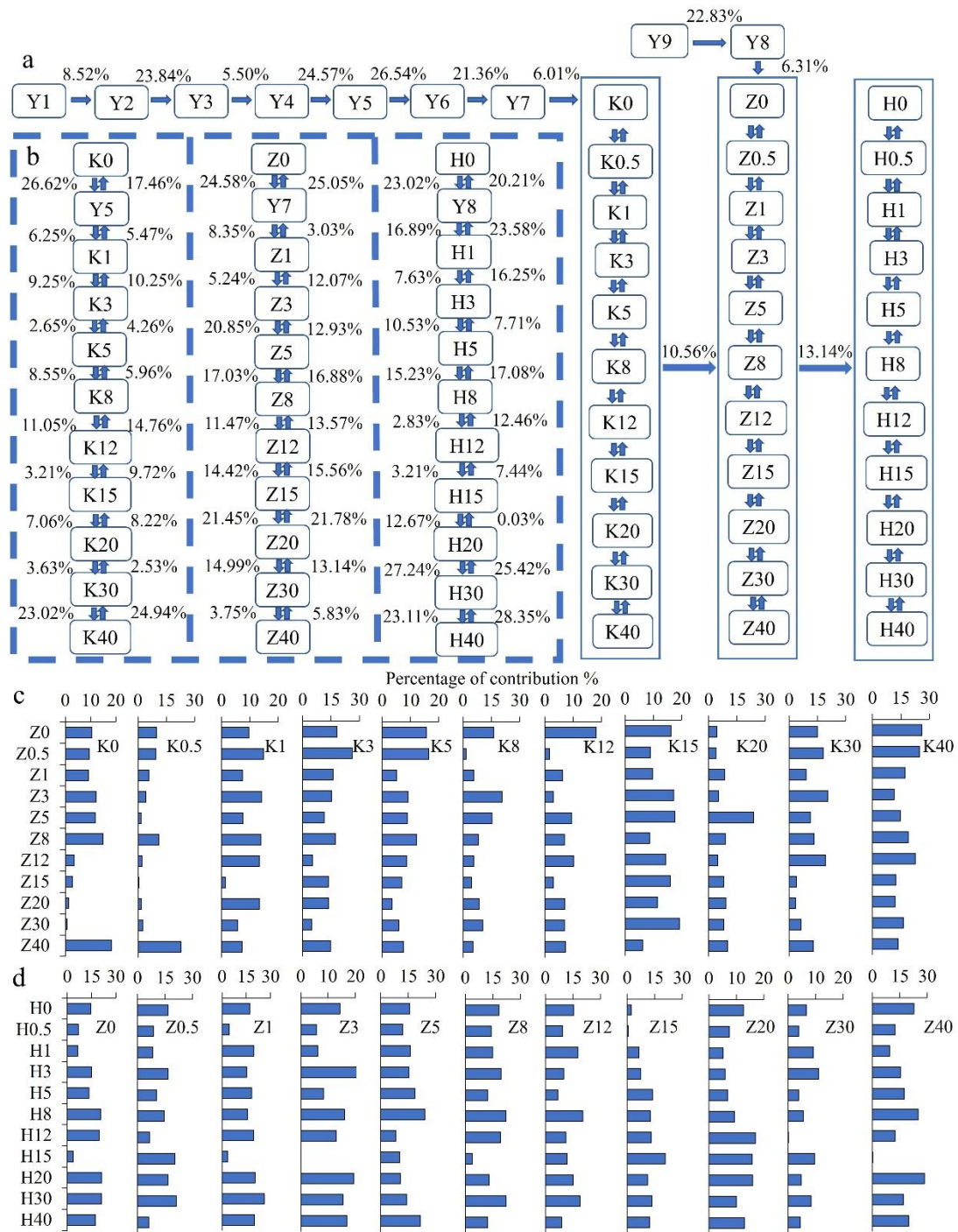


Fig. B2. Source–sink relationships among phytoplankton communities (March).

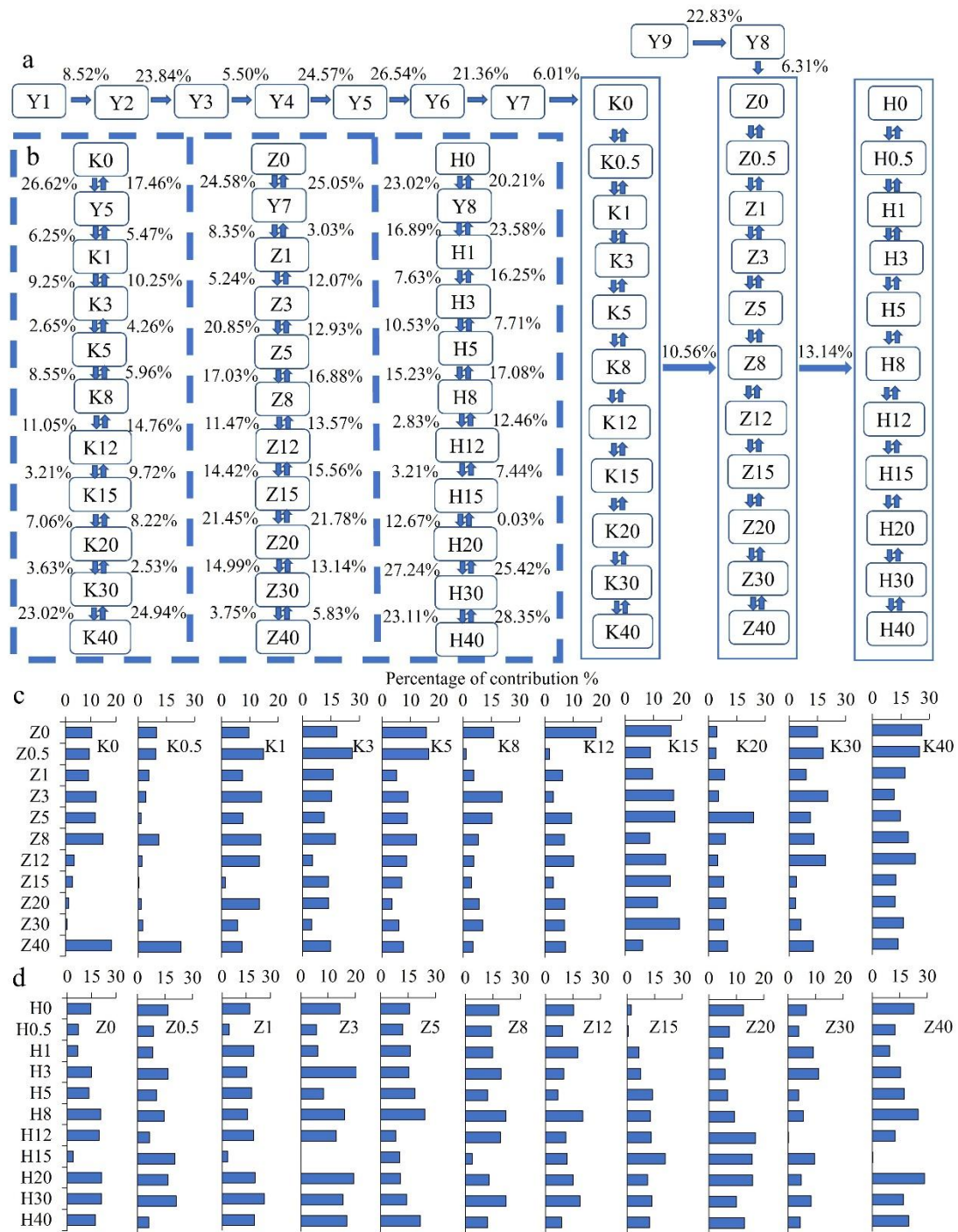


Fig. B3. Source–sink relationships among phytoplankton communities (August).

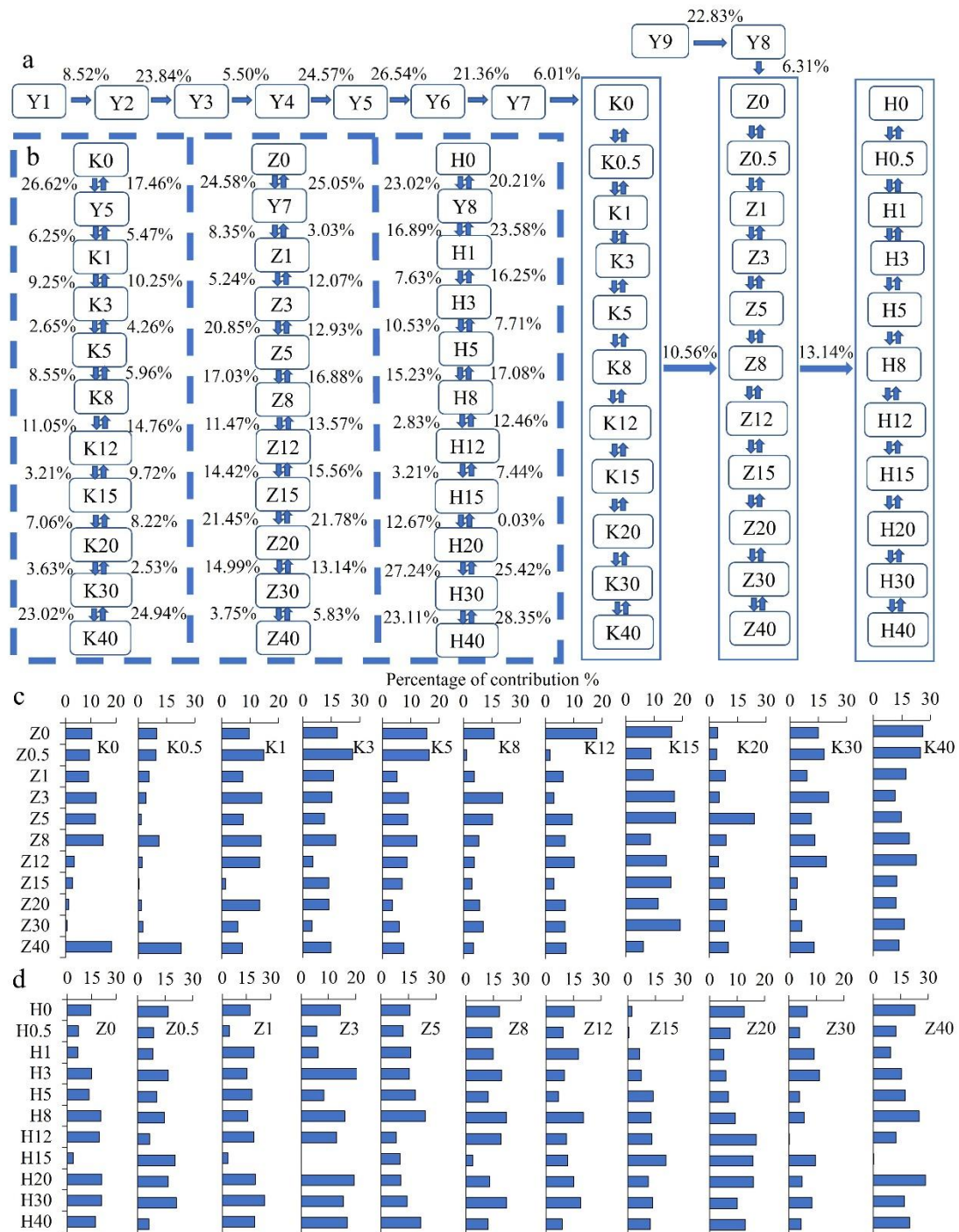


Fig. B4. Source–sink relationships among phytoplankton communities (October).

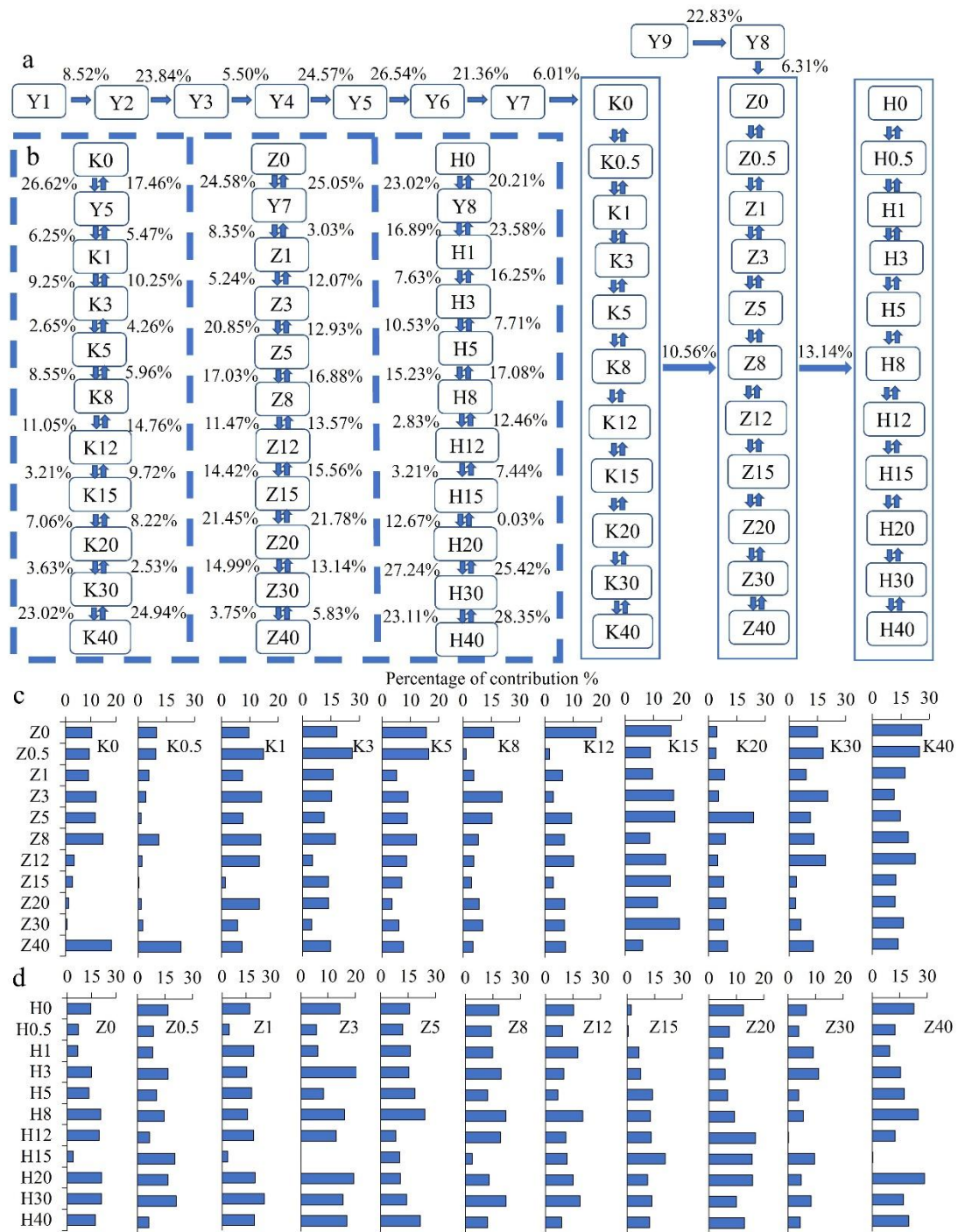


Fig. B5. Source–sink relationships among phytoplankton communities (November).

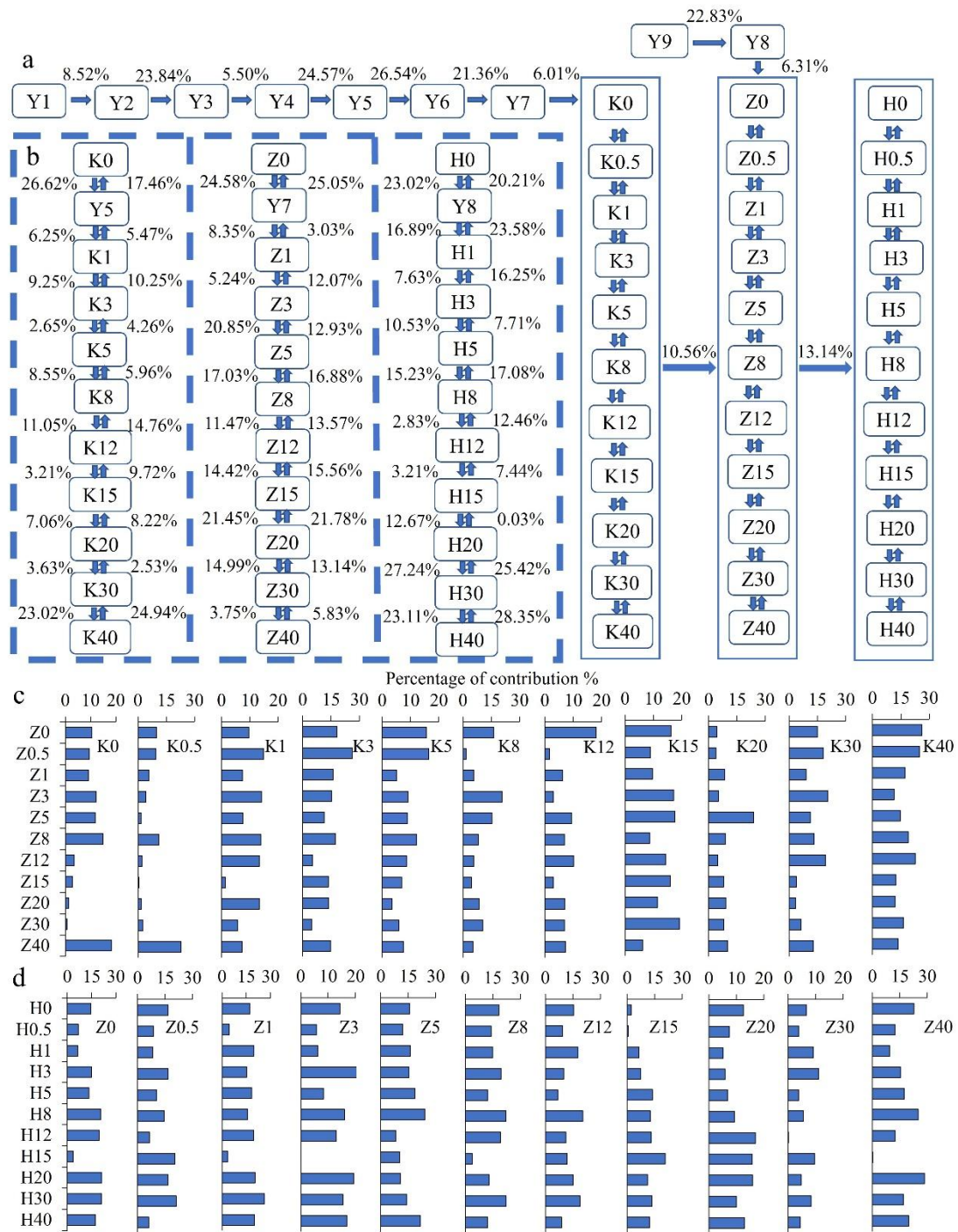


Fig. B6. Source–sink relationships among phytoplankton communities (December).

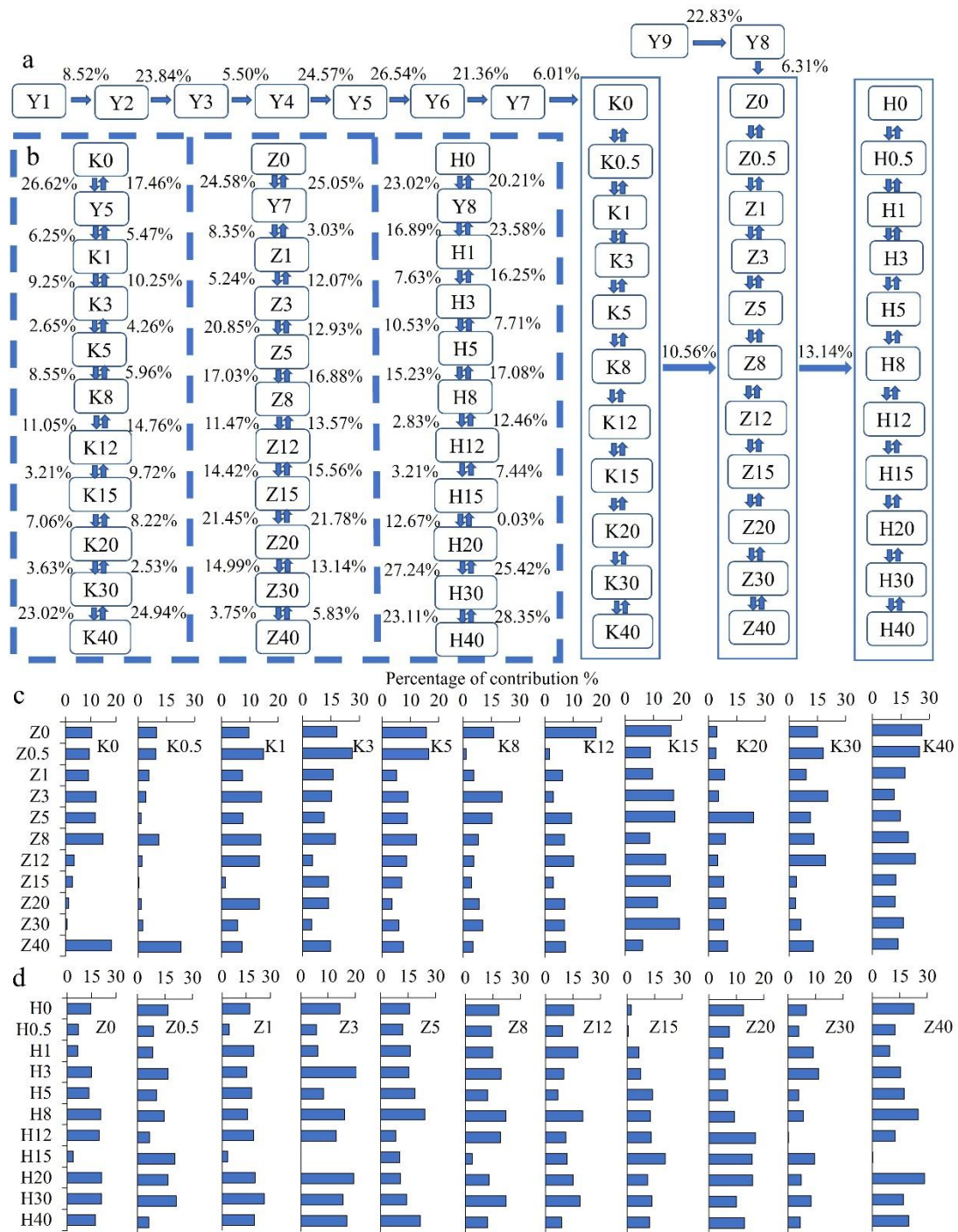


Fig. B7. Source–sink relationships among phytoplankton communities (January).

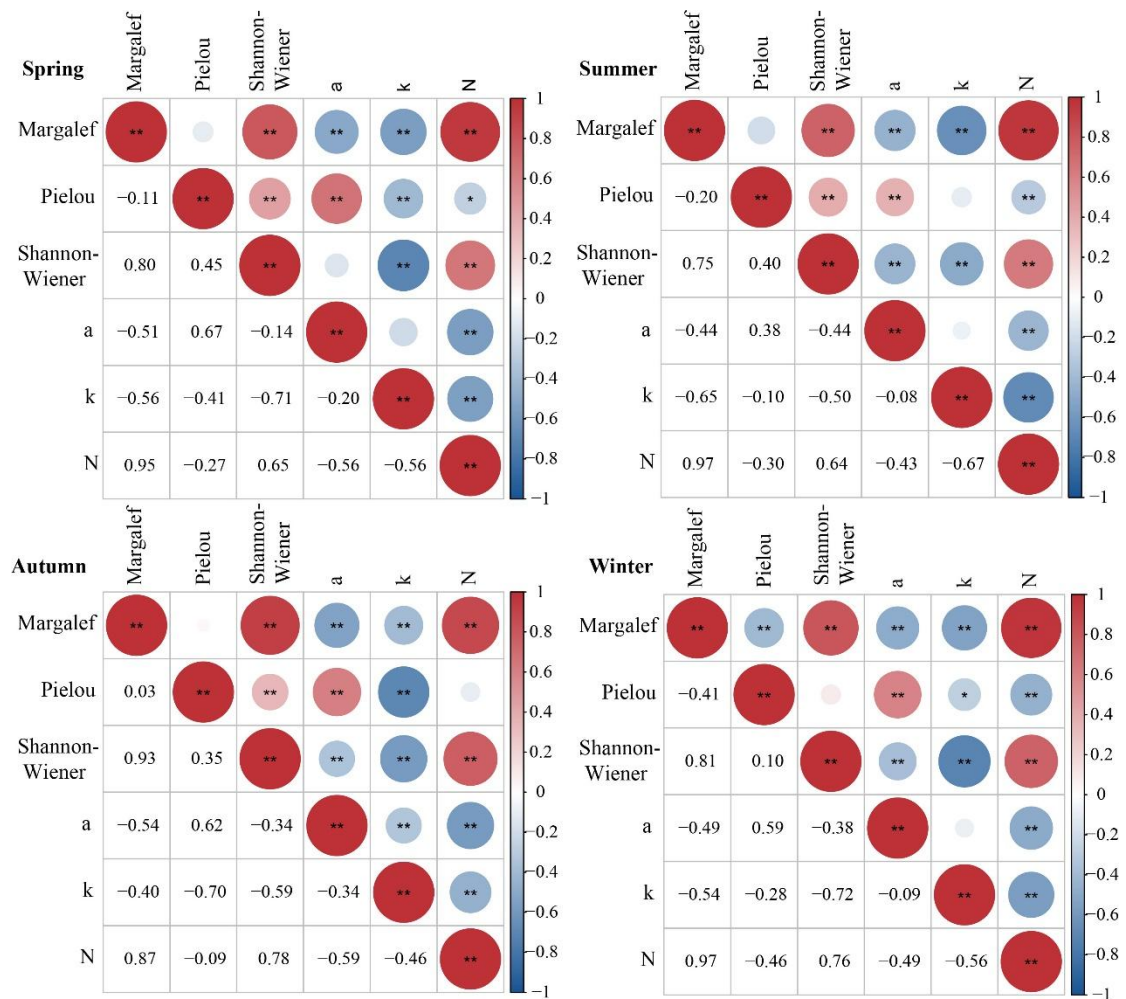


Fig. B8. Correlation heatmaps of phytoplankton community diversity indices across four seasons (spring, summer, autumn, and winter). * $P < 0.05$, ** $P < 0.01$.

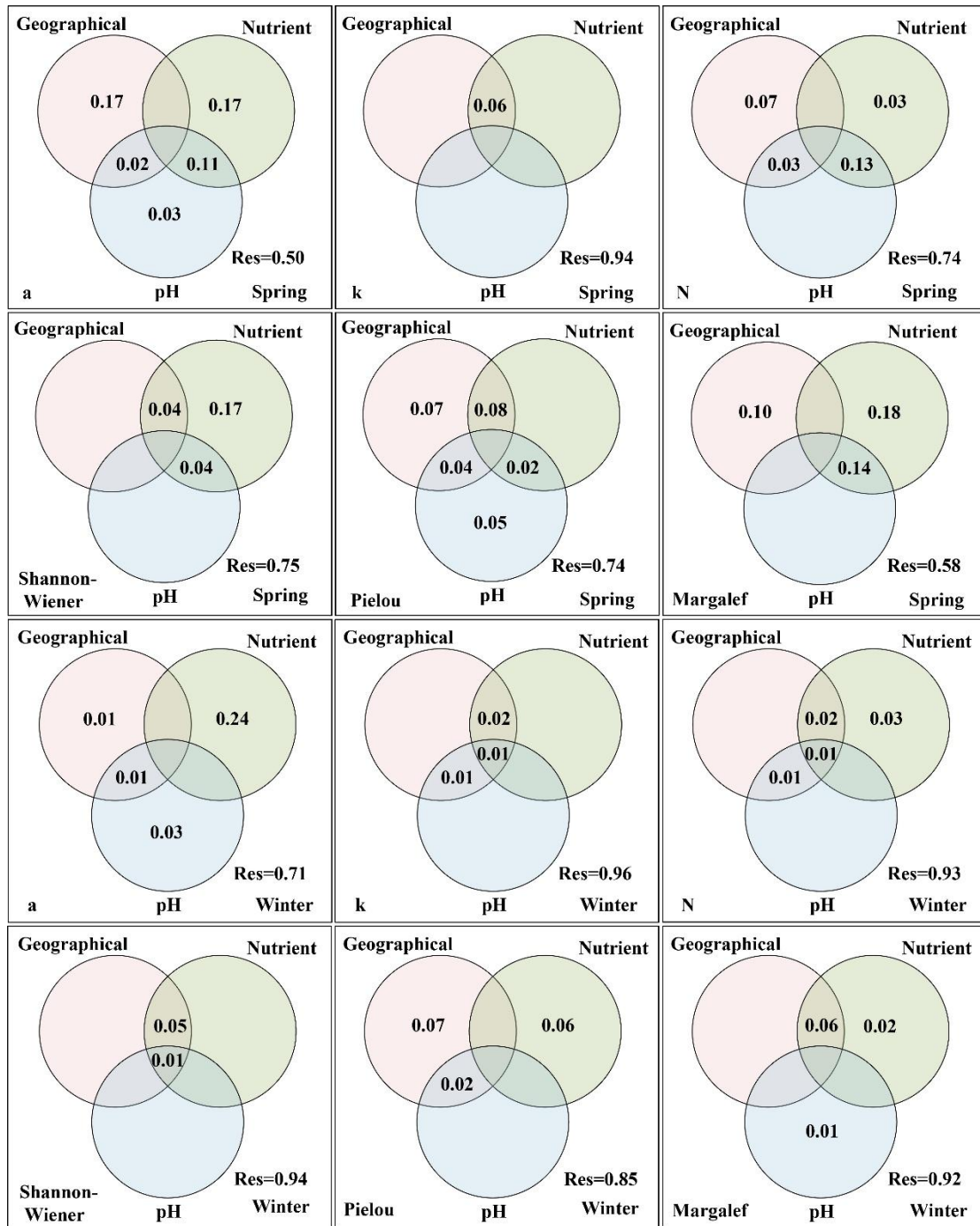


Fig. B9. Variance partitioning of phytoplankton diversity indices in spring and winter.