Multiple analysis of the effects of morphological traits on body mass in different geographical populations of Schizothorax biddulphi (Postprint)

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Abstract

To investigate the effects of morphological traits on the body mass of *Schizothorax biddulphi*, body mass and 11 morphological traits were measured in a total of 136 fish samples collected from four geographical populations (Kezile River, Yarkant River, Hotan River, and Qiemo River) in the Tarim River system. The relationship between morphological traits and body mass was studied based on correlation analysis, multiple regression analysis, path analysis, and grey relational analysis.

The results showed that the coefficient of variation for body mass (0.270–0.586) was significantly higher than that of other morphological traits, indicating high potential for selective breeding. Path analysis revealed that body depth (X_3) and body width (X_{11}) in the Yarkant River population; body length (X_2) and body depth (X_3) in the Kezile River population; total length (X_1) and head length (X_4) in the Qiemo River population; and total length (X_1), body depth (X_3), snout length (X_5), and caudal peduncle depth (X_{10}) in the Hotan River population had significant direct effects on body mass ($P < 0.05$).

The coefficients of determination (R^2) of the equations constructed by multiple regression analysis were all higher than 0.90, indicating that the selected morphological traits were highly correlated with body mass and the fitting effect was good. Grey relational analysis showed that the average relational grade ranged from 0.59 to 0.87, and the morphological traits with higher relational grades to body mass included total length (X_1), eye diameter (X_6), interorbital width (X_7), and postorbital head length (X_8). In summary, total length (X_1) and body depth (X_3) are the key traits affecting the body mass of *Schizothorax biddulphi*. The research results provide a theoretical basis for the enhancement and conservation of *Schizothorax biddulphi* resources.

Full Text

Multiple Analysis of the Effects of Morphological Traits on Body Mass in Different Geographic Populations of *Schizothorax biddulphi*

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Abstract

To investigate the effects of morphological traits on the body mass of *Schizothorax biddulphi*, 14 morphological indicators and body mass were measured in 131 specimens collected from four locations within the Tarim River system. The relationships between these morphological traits and body mass were analyzed using correlation analysis, path analysis, and multiple regression analysis.

The results of the correlation analysis indicated that all 14 morphological traits exhibited highly significant positive correlations with body mass ($P < 0.01$). Path analysis revealed that four specific morphological traits—standard length (X_1), body width (X_4), head length (X_5), and caudal peduncle depth (X_{10})—exerted significant direct effects on body mass (Y). Among these, standard length (X_1) demonstrated the highest path coefficient (0.421), identifying it as the primary factor influencing body mass. This was followed by body width (X_4) with a path coefficient of 0.283. The cumulative determination coefficient (R^2) was found to be 0.942, suggesting that these four traits are the key morphological indicators affecting the body mass of *Schizothorax biddulphi*. Based on these findings, a multiple regression equation was established: $Y = -236.634 + 1.258X_1 + 4.144X_4 + 2.146X_5 + 4.904X_{10}$. The results of this study provide fundamental data for the germplasm resource evaluation, artificial breeding, and ecological conservation of *Schizothorax biddulphi*.

1. Introduction

The Tarim River is the largest inland river in China, with its main stem flowing along the northern edge of the Taklamakan Desert. *Schizothorax biddulphi* (Tarim schizothoracin), an endemic fish species primarily distributed in the Tarim River basin, holds significant ecological and economic value. However, since the end of the 20th century, its habitat has faced severe recession due to overfishing, invasive species, and hydraulic engineering projects that have blocked migratory pathways. Its distribution is now largely restricted to the upper reaches of the river systems.

Understanding the relationship between morphological characteristics and body

mass is crucial for fisheries management and selective breeding. Body mass is a vital indicator of fish health and growth rate, yet it is influenced by a complex interplay of morphological traits. Previous studies have shown that the contribution of specific traits to body mass can vary between geographic populations due to environmental pressures and genetic isolation. This study utilizes multiple statistical methods to quantify these relationships and provide a scientific basis for the sustainable utilization of *S. biddulphi* resources.

2. Materials and Methods

2.1 Sample Collection A total of 136 specimens were collected from four geographical populations: the Kizil River (41.82° N, 82.43° E), Yarkand River (38.68° N, 77.43° E), Hotan River (37.54° N, 80.16° E), and Qarqan River (38.58° N, 86.07° E). Samples were collected during the high-water period (August to October).

2.2 Morphological Measurements Body mass (Y) was weighed to a precision of 0.01 g. Eleven morphological traits were measured to a precision of 0.01 mm: total length (X_1), standard length (X_2), body depth (X_3), head length (X_4), snout length (X_5), eye diameter (X_6), interorbital distance (X_7), postorbital head length (X_8), caudal peduncle length (X_9), caudal peduncle depth (X_{10}), and body width (X_{11}).

2.3 Statistical Analysis Data were analyzed using Microsoft Excel 2021 and SPSS 27.0. The Shapiro-Wilk test was used to assess normality. Since body mass data was non-normally distributed, a natural logarithm transformation was applied. Pearson correlation analysis, multiple stepwise regression, and path analysis were performed to determine the direct and indirect effects of traits on body mass. Grey relational analysis was also employed to rank the importance of morphological traits.

3. Results and Analysis

3.1 Phenotypic Parameters and Normality The coefficient of variation (CV) for body mass (0.270–0.586) was significantly higher than that of other morphological traits, indicating substantial potential for selective breeding. After natural logarithm transformation, the Shapiro-Wilk test yielded $P > 0.05$ for all populations, confirming the data followed a normal distribution suitable for regression analysis.

3.2 Correlation and Path Analysis Correlation analysis showed that almost all morphological traits exhibited highly significant positive correlations with body mass ($P < 0.01$). Path analysis revealed population-specific key traits: - **Yarkand River**: Body height (X_3) and body width (X_{11}) had the most significant direct effects. - **Kizil River**: Body length (X_2) and body height (X_3) were the primary factors. - **Qarqan River**: Total length (X_1) and

Figure 1

Figure 1: Figure 1

head length (X_4) were retained in the model. - **Hotan River**: Total length (X_1), body height (X_3), snout length (X_5), and caudal peduncle depth (X_{10}) were the key indicators.

3.3 Regression Equations and Determination Coefficients Multiple regression equations were constructed for each population with $R^2 > 0.90$, indicating a robust fit: - **Kizil River**: $Y = e^{-2.308+0.034X_3+0.005X_2}$ - **Yarkand River**: $Y = e^{-1.121+0.062X_3+0.042X_{11}}$ - **Hotan River**: $Y = e^{-0.316+0.011X_1+0.023X_3+0.069X_{10}+0.05X_5}$ - **Qarqan River**: $Y = e^{-0.349+0.079X_4+0.007X_1}$

3.4 Grey Relational Analysis Grey relational analysis showed relational grades between 0.59 and 0.87. The traits most closely correlated with body mass across populations were total length (X_1), eye diameter (X_6), interorbital width (X_7), and postorbital head length (X_8).

4. Discussion and Conclusion

The study confirms that total length (X_1) and body height (X_3) are the most consistent morphological traits influencing the body mass of *Schizothorax biddulphi* across different geographic populations. The high coefficient of variation in body mass suggests significant potential for selective breeding.

The differences in key morphological traits between populations may be attributed to genetic background and environmental adaptations within the Tarim River basin. The established regression models provide a theoretical basis for the evaluation of germplasm resources and the selection of high-quality parental stocks for artificial reproduction and stock enhancement programs. By focusing on these key morphological indicators, conservationists can better monitor population health and improve the survival rates of released individuals.

Figures