Optimization of selective breeding through analysis of morphological traits in Chinese sea bass (*Lateolabrax maculatus*)

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ABSTRACT. Determining correlations between certain traits of economic importance constitutes an essential component of selective activities. In this study, our aim was to provide effective indicators for breeding programs of *Lateolabrax maculatus*, an important aquaculture species in China. We analyzed correlations between 20 morphometric traits and body weight, using correlation and path analyses. The results indicated that the correlations among all 21 traits were highly significant, with the highest correlation coefficient identified between total length and body weight. The path analysis indicated that total length (X_1), body width (X_5), distance from first dorsal fin origin to anal fin origin (X_{10}), snout length (X_{16}), eye diameter (X_{17}), eye cross (X_{18}), and slanting distance from snout tip to first dorsal fin origin (X_{19}) significantly affected body weight (Y) directly. The following multiple-regression equation was obtained using stepwise multiple-regression analysis: $Y = -472.108 + 1.065X_1 + 7.728X_5 + 1.973X_{10} - 7.024X_{16} - 4.400X_{17} - 3.338X_{18} + 2.138X_{19}$, with an adjusted multiple-correlation coefficient of 0.947. Body width had the largest determinant coefficient, as well as the highest positive direct correlation with body weight. At the same time, high indirect effects with six other morphometric traits on *L. maculatus* body weight, through body width, were identified. Hence, body width could be a key factor that efficiently indicates significant effects on body weight in *L. maculatus*.

Key words: *Lateolabrax maculatus*; Correlation analysis; Path analysis; Morphological traits; Body weight

INTRODUCTION

In many aquaculture-breeding programs, body weight is widely used as a direct indicator for selection and is considered an important economic factor for enhancing production. Given the fact that body weight of farmed species has been found to be highly correlated with various morphological traits (Pérez-Rostro and Ibarra, 2003; Trong et al., 2013), many statistical methods had been employed to develop a selection index. This has been done by exploring the relationships among particular morphological traits and estimating the contribution of each morphological trait on the trait of interest, in this case body weight. These methods include correlation analysis, path analysis, and regression analysis. To date, studies of phenotypic and genetic relationships among growth-related traits have been performed in many fish species, including *Oncorhynchus mykiss* (Kause et al., 2002), *Scophthalmus maximus* (Wang et al., 2010), *Pangasianodon hypophthalmus* (Sang et al., 2009), *Paralichthys olivaceus* (Tian et al., 2011), *Penaeus vannamei* (Pérez-Rostro and Ibarra, 2003), and *Salmo salar* (Haffray et al., 2012). For example, nine morphological traits (total length, head length, snout length, body width, head width, interorbital distance, body depth, head depth, and body weight) from juvenile *Polyodon spathula* were measured, among which total length was the most predominant variable to affect body weight (Yuan et al., 2012). Likewise, in *Micropterus salmoides*, nine morphometric traits (total length, standard length, body depth, body width, interorbital distance, head length, snout length, caudal peduncle length, and caudal peduncle depth) were analyzed, among these body width had the biggest impact on body weight (He et al., 2009). Because measurement of these traits, such as total length or body width, is considerably easier and faster to perform under field conditions than direct measurement of body weight (Harrison, 2001), these traits could be used in selection studies of aquatic organisms in breeding programs (Zhao et al., 2014).

Chinese sea bass, *Lateolabrax maculatus*, is a redescribed species (Yokogawa and Seki, 1995; Kim et al., 2001) that was recently distinguished from the Japanese sea bass, *L. japonicus*. It is widely distributed along the Chinese coast, reaching the borders with Vietnam and Korea (Yokogawa and Seki, 1995; Shao et al., 2009). Its high nutritional value has made it an important commercial species in China. Due to increasing market demands for *L. maculatus*, cage and pond-culturing of this species have been developed and have spread quickly in the east coast regions of China. However, recently, the amount of resources spent and germplasm degeneration are becoming bottleneck problems that limit further aquaculture development of *L. maculatus*. To improve aquaculture production of *L. maculatus*, a number of studies have been carried out investigating growth, feeding, and population structure in this species (Lee and Yang, 2002; Liu et al., 2006; Li et al., 2012; An et al., 2013, 2014; Wang et al., 2015a,b). Although the selection and rearing of breeders with high-productive properties are important tools to improve progeny quality in fish farming (Borrell et al., 2007), efficient breeding programs are currently lacking for *L. maculatus*.

In the present study, our aim was to understand the relationships among morphological traits, and to identify effective indicators that could be applied in selective breeding programs of *L. maculatus*. We used correlation and path analyses, to analyze the correlations between body weight and various morphometric traits. Furthermore, regression analysis was performed to construct a best-fit multiple-regression equation. These results could provide useful information that may be used to promote the selection activities in this species.

MATERIAL AND METHODS

Ethics statement

The frozen wild *L. maculatus* samples were collected from the southeast coastal area of China. Due to the scientific research purpose, no permissions were required for this species and sampling area. The sampling locations were not protected or privately owned, and the field sampling did not involve protected or endangered species.

Experimental animal sampling

A total of 87 wild individuals of *L. maculatus* were collected from three locations in the southeast coastal area of China, Qingdao (N = 42), Dongtou (N = 23), and Lieyu (N = 22), from March 2015 to September 2015. The body integrity of all frozen samples was investigated to ensure the measurement accuracy of all morpholometric traits and body weight.

Measurement of morphological traits

In total, 21 morphological traits were measured (shown in Figure 1).These included total length (X_1), body length (X_2), distance from the tip of lower jaw to anus (X_3), body height (X_4), body width (X_5), caudal peduncle height (X_6), caudal peduncle length (X_7), distance from snout tip to first dorsal fin origin (X_8), basal length of dorsal fin (X_9), distance from first dorsal fin origin to anal fin origin (X_{10}), distance from the tip of lower jaw to pelvic fin origin (X_{11}), basal length of anal fin (X_{12}), pectoral fin length (X_{13}), pelvic fin length (X_{14}), head length (X_{15}), snout length (X_{16}), eye diameter (X_{17}), eye cross (X_{18}), slanting distance from snout tip to first dorsal fin origin (X_{19}), distance from the tip of lower jaw to pectoral fin origin (X_{20}), and body weight (Y). The first 20 morphometric traits (X_{1-20}) were measured to cover most of the phenotypic characters of *L. maculatus* and to identify any differences among sampled individuals, as described by previous researchers (Harrison, 2001; Ruiz-Campos et al., 2003; Li et al., 2006; He et al., 2009; Liu et al., 2011). The measurements were performed using vernier calipers (accuracy: 0.02 mm) to the nearest 0.10 mm as illustrated in Figure 1.

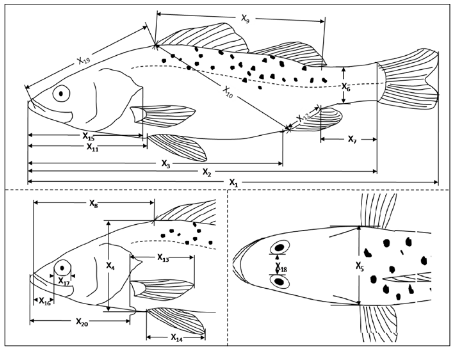

Figure 1. Measurement of the various morphological traits of *Lateolabrax maculatus*. X_1 = total length; X_2 = body length; X_3 = distance from the tip of lower jaw to anus; X_4 = body height; X_5 = body width; X_6 = caudal peduncle height; X_7 = caudal peduncle length; X_8 = distance from snout tip to first dorsal fin origin; X_9 = basal length of dorsal fin; X_{10} = distance from first dorsal fin origin to anal fin origin; X_{11} = distance from the tip of lower jaw to pelvic fin origin; X_{12} = basal length of anal fin; X_{13} = pectoral fin length; X_{14} = pelvic fin length; X_{15} = head length; X_{16} = snout length; X_{17} = eye diameter; X_{18} = eye cross; X_{19} = slanting distance from snout tip to first dorsal fin origin; X_{20} = distance from the tip of lower jaw to pectoral fin origin.

The body weight of *L. maculatus* was measured to the nearest 0.01 g with a digital electronic balance. As shown by a Kolmogorov-Smirnov test, the body weights of all 87 individuals conformed to the law of normal distribution, suggesting that there were no significant differences in body weight among the individuals from different sampling locations. Hence, the collected samples could be used in the following analysis as described by Du and Chen (2010). Because not all sampled individuals had reached sexual maturity, gender was not included in the subsequent analyses.

Data analysis

The mean value and standard deviation (SD) of all traits were calculated using SPSS 16.0. The coefficient of variation (CV) for each of the 20 recorded morphometric traits and body weight were estimated using the following formula:

$$CV = (SD / mean) \times 100\% \qquad \text{(Equation 1)}$$

The path analysis was carried out using SPSS 16.0, as described by Du and Chen (2010). The bivariate correlations among all morphological traits were then determined. A stepwise multiple regression analysis was used to identify which parameters significantly contributed to body weight. Parameters with $P < 0.01$ were subsequently included in the regression analysis as independent variables (Wada, 1986).

The multiple regression equation for body weight (Y) was calculated as follows:

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + ... + b_iX_i \qquad \text{(Equation 2)}$$

where *Y* is the dependent variable, *a* is the intercept, X_i are the independent variables, and b_i are the partial regression coefficients for X_i on Y. The determination (d_i) and co-determinant (d_{ij}) coefficients were calculated using the following formulae (described by Ma et al., 2013):

$$d_i = (P_{Y.Xi})^2 \quad \text{(Equation 3)}$$

$$d_{ij} = 2xr_{ij} \text{ x } P_{Y.Xi} \text{ x } P_{Y.Xj} \quad \text{(Equation 4)}$$

where d_i is the effect of a single trait X_i on Y; $P_{Y.Xi}$ is the path coefficient from X_i to Y; d_{ij} is the effect of traits X_i and X_j on Y; r_{ij} is the correlation coefficient between traits i and j; and $P_{Y.Xj}$ is the path coefficient from trait X_j to Y.

RESULTS

Descriptive statistics of morphological traits

The mean, SD, and CV for the 20 morphometric traits and body weight of *L. maculatus* are presented in Table 1. In the case of the morphometric traits, the CV for X_{18} (23.73%), X_{16} (19.59%), and X_{17} (18.24%) were the highest, whereas X_1 and X_{19} had the lowest CV (10.24%). The CV for body weight was 35.25%, which was higher than any of the morphometric traits.

Table 1. Descriptive statistics of morphological traits and body weight of *Lateolabrax maculatus* (N = 87).

Trait name	Abbreviation	Minimum	Maximum	Mean	SD	CV (%)
Total length	X_1	225.55	360.02	289.23	29.62	10.24
Body length	X_2	185.68	285.01	242.66	25.06	10.33
Distance from the tip of lower jaw to anus	X_3	127.00	216.87	159.28	16.88	10.60
Body height	X_4	48.81	87.65	65.96	8.10	12.29
Body width	X_5	23.14	43.19	32.32	5.25	16.24
Caudal peduncle height	X_6	18.00	33.92	23.59	3.72	15.77
Caudal peduncle length	X_7	30.29	61.00	46.72	6.42	13.74
Distance from snout tip to first dorsal fin origin	X_8	46.08	101.06	80.26	9.71	12.10
Basal length of dorsal fin	X_9	11.07	153.56	114.17	18.05	15.81
Distance from first dorsal fin origin to anal fin origin	X_{10}	84.72	134.34	110.45	11.99	10.86
Distance from the tip of lower jaw to pelvic fin origin	X_{11}	68.54	105.31	86.41	9.64	11.15
Basal length of anal fin	X_{12}	20.24	37.99	28.58	4.03	14.10
Pectoral fin length	X_{13}	25.00	56.76	40.52	6.50	16.04
Pelvic fin length	X_{14}	30.00	55.05	42.88	5.42	12.64
Head length	X_{15}	61.00	95.44	76.05	8.11	10.67
Snout length	X_{16}	12.16	27.55	16.69	3.27	19.59
Eye diameter	X_{17}	12.01	25.24	15.58	2.84	18.24
Eye cross	X_{18}	10.04	24.88	13.99	3.32	23.73
Slanting distance from snout tip to first dorsal fin origin	X_{19}	69.76	104.51	86.39	8.85	10.24
Distance from the tip of lower jaw to top of pectoral fin origin	X_{20}	59.21	92.56	74.47	8.00	10.74
Body weight	Y	111.50	442.30	255.88	90.20	35.25

For each trait, the name, abbreviation, minimum, maximum, mean, standard deviation (SD), and coefficient of variation (CV, %) are given. All measurements are reported in mm, except body weight which is reported in g.

Correlation coefficients among the morphological traits

The correlation coefficients among the 21 morphological traits (including the 20 morphometric traits and body weight) of *L. maculatus* are presented in Table 2. Significant correlations were detected in all comparisons among all measured traits. The highest correlation coefficient was found in the correlation between X_1 and X_2, with a value of 0.974, followed by the correlations between X_2 and X_{10} (0.957) and X_{11} and X_{20} (0.955). All 20 morphometric traits were found to correlate significantly with body weight, with the correlation coefficient ranging from 0.193 (between Y and X_{18}) to 0.933 (between Y and X_1).

Table 2. Phenotype correlation coefficients among the 20 morphometric traits and body weight of *Lateolabrax maculatus* (N = 87).

Trait	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}	X_{19}	X_{20}	Y
X_1	1	0.974	0.921	0.796	0.76	0.630	0.785	0.866	0.542	0.945	0.904	0.707	0.756	0.779	0.842	0.404	0.361	0.367	0.915	0.869	0.933
X_2		1	0.935	0.783	0.786	0.681	0.829	0.861	0.548	0.957	0.934	0.739	0.725	0.764	0.871	0.475	0.423	0.420	0.939	0.905	0.911
X_3			1	0.768	0.798	0.686	0.793	0.818	0.492	0.912	0.897	0.736	0.742	0.772	0.859	0.516	0.453	0.466	0.892	0.893	0.865
X_4				1	0.809	0.717	0.674	0.699	0.529	0.820	0.757	0.742	0.760	0.772	0.772	0.531	0.513	0.394	0.763	0.761	0.784
X_5					1	0.868	0.784	0.740	0.536	0.833	0.826	0.824	0.783	0.825	0.832	0.755	0.742	0.601	0.823	0.867	0.738
X_6						1	0.772	0.644	0.501	0.745	0.776	0.842	0.712	0.795	0.797	0.857	0.839	0.753	0.754	0.824	0.532
X_7							1	0.725	0.458	0.799	0.824	0.732	0.679	0.742	0.792	0.690	0.629	0.685	0.843	0.846	0.654
X_8								1	0.434	0.816	0.841	0.692	0.657	0.694	0.788	0.495	0.423	0.499	0.874	0.849	0.800
X_9									1	0.595	0.513	0.544	0.463	0.445	0.478	0.288*	0.322	0.137*	0.465	0.506	0.539
X_{10}										1	0.922	0.789	0.757	0.798	0.858	0.511	0.495	0.416	0.917	0.893	0.910
X_{11}											1	0.772	0.720	0.779	0.902	0.617	0.559	0.546	0.933	0.955	0.827
X_{12}												1	0.664	0.717	0.754	0.708	0.720	0.619	0.745	0.784	0.621
X_{13}													1	0.874	0.775	0.577	0.562	0.461	0.730	0.750	0.706
X_{14}														1	0.803	0.662	0.611	0.545	0.799	0.798	0.718
X_{15}															1	0.636	0.593	0.542	0.864	0.933	0.782
X_{16}																1	0.892	0.819	0.590	0.705	0.260
X_{17}																	1	0.726	0.521	0.620	0.244*
X_{18}																		1	0.558	0.615	0.193*
X_{19}																			1	0.915	0.849
X_{20}																				1	0.786
Y																					1

X_1 = total length; X_2 = body length; X_3 = distance from the tip of lower jaw to anus; X_4 = body height; X_5 = body width; X_6 = caudal peduncle height; X_7 = caudal peduncle length; X_8 = distance from snout tip to first dorsal fin origin; X_9 = basal length ofdorsal fin; X_{10} = distance from first dorsal fin origin to anal fin origin; X_{11} = distance from the tip of lower jaw to pelvic fin origin; X_{12} = basal length of anal fin; X_{13} = pectoral fin length; X_{14} = pelvic fin length; X_{15} = head length; X_{16} = snout length; X_{17} = eye diameter; X_{18} = eye cross; X_{19} = slanting distance from snout tip to first dorsal fin origin; X_{20} = distance from the tip of lower jaw to top of pectoral fin origin; Y = body weight. All correlations were significant at $P \leq 0.01$ except for those followed by an asterisk, which were significant at $P \leq 0.05$.

Path and determination coefficients

The direct and indirect effects of the different morphometric traits on body weight were evaluated using path correlation analysis. Of the 20 morphometric traits, seven traits (X_1, X_5, X_{10}, X_{16}, X_{17}, X_{18}, and X_{19}) showed significant direct effects on body weight (Table 3). The direct effects of these traits on body weight ranged from -0.123 (X_{18}) to 0.450 (X_5). Only the direct effect of X_5 was greater than the indirect effects on body weight. X_{10} had the largest indirect effect (0.331) on body weight through X_5.

Table 3. Direct and indirect effects of morphometric traits on body weight of *Lateolabrax maculatus* (N = 87).

Trait (X_i)	Related coefficient	Direct effect	Indirect effect (X_j)							
			Σ	X_1	X_5	X_{10}	X_{16}	X_{17}	X_{18}	X_{19}
X_1	0.933	0.350	0.583		0.342	0.248	-0.103	-0.050	-0.045	0.192
X_5	0.737	0.450	0.288	0.266		0.218	-0.193	-0.103	-0.074	0.173
X_{10}	0.910	0.262	0.648	0.331	0.375		-0.130	-0.069	-0.051	0.193
X_{16}	0.259	-0.255	0.514	0.141	0.340	0.134		-0.124	-0.101	0.124
X_{17}	0.244	-0.139	0.383	0.126	0.334	0.130	-0.227		-0.089	0.109
X_{18}	0.192	-0.123	0.315	0.128	0.270	0.109	-0.209	-0.101		0.117
X_{19}	0.849	0.210	0.639	0.320	0.370	0.240	-0.150	-0.072	-0.069	

The indirect effect of X_iX_j means the indirect effect of X_i on body weight through X_j. Σ means the total indirect effects of X_i on body weight. In this table, X_1 = total length; X_5 = body width; X_{10} = distance from first dorsal fin origin to anal fin origin; X_{16} = snout length; X_{17} = eye diameter; X_{18} = eye cross; X_{19} = slanting distance from snout tip to first dorsal fin origin.

The determination coefficients of the morphometric traits on body weigh are listed in Table 4. The determination coefficient of X_5 was the largest (0.203), whereas that of X_{18} was the lowest (0.015). The co-determinant coefficient of X_1 and X_5 on body weight was found to be the highest, with a value of 0.239. The sum of the determination coefficients X_1, X_5, X_{10}, X_{16}, X_{17}, X_{18}, and X_{19} on body weight was 0.953, indicating that these seven traits significantly affect the body weight of *L. maculatus*.

Table 4. Determinant coefficients of morphometric traits on body weight of *Lateolabrax maculatus* (N = 87).

Trait	X_j						
X_i	X_1	X_5	X_{10}	X_{16}	X_{17}	X_{18}	X_{19}
X_1	**0.123**	0.239	0.173	-0.072	-0.035	-0.032	0.135
X_5		**0.203**	0.196	-0.173	-0.093	-0.067	0.156
X_{10}			**0.069**	-0.068	-0.036	-0.027	0.101
X_{16}				**0.065**	0.063	0.051	-0.063
X_{17}					**0.019**	0.025	-0.030
X_{18}						**0.015**	-0.029
X_{19}							**0.044**

The co-determinant (d_{ij}) and determination (d_i) coefficients are shown on the off-diagonal and the diagonal (highlighted in bold), respectively. d_i is the effect of a single trait X_i on body weight and d_{ij} is the effect of traits X_i and X_j on body weight. X_1 = total length; X_5 = body width; X_{10} = distance from first dorsal fin origin to anal fin origin; X_{16} = snout length; X_{17} = eye diameter; X_{18} = eye cross; X_{19} = slanting distance from snout tip to first dorsal fin origin.

Construction of multiple-regression equation

The regression relationship between the morphometric traits and body weight of *L. maculatus* was estimated using a stepwise multiple-regression analysis, which can be used to identify the significance of partial regression coefficients by gradually removing nonsignificant parameters (Zhao et al., 2014). We found that the same seven traits as identified above (X_1, X_5, X_{10}, X_{16}, X_{17}, X_{18}, and X_{19}) showed significant relationships with body weight. The best-fit multiple-regression equation of body weight was: $Y = -472.108 + 1.065X_1 + 7.728X_5 + 1.973X_{10} - 7.024X_{16} - 4.400X_{17} - 3.338X_{18} + 2.138X_{19}$. The results of the analysis of variance on the multiple-regression equation are shown in Table 5. The P value of this equation was <0.01, indicating that the prediction of body weight, in relation to these morphometric traits, is reliable (Zhao et al., 2014). The adjusted multiple-correlation coefficient was 0.947, indicating that the above mentioned seven morphometric traits can be considered key factors affecting the body weight of *L. maculatus*. This is consistent with the results found for the determination coefficients.

Table 5. Analysis of variance of multiple-regression equation of *Lateolabrax maculatus* (N = 87).

Index	Sum of squares	d.f.	Mean square	F	P
Regression analysis	66,5501.369	7	95071.624	219.378	<0.001
Residual	34,236.169	79	433.369		
Total	699,737.537	86			

The adjusted multiple-correlation coefficient of this equation is 0.947.

DISCUSSION

Enhancing production is one of the main objectives in aquaculture. Therefore, body weight is often considered an important indicator for direct selection that is used in many aquaculture-breeding programs. However, due to the effects of genetic linkage, pleiotropy and environmental factors (Toro and Newkirk, 1990; Li et al., 2006; Fu et al., 2015), it has proven difficult to achieve satisfactory results in the selection programs when only taking body weight into account. However, body weight has been found to be highly correlated with many other morphological traits (Pérez-Rostro and Ibarra, 2003). In the present study, abundant variation was found in the 21 morphological traits of *L. maculatus*. A high CV was found for traits X_{18} (23.73%), X_{16} (19.59%), and X_{17} (18.24%), whereas X_1 and X_{19} had the lowest CV (10.24%). This high variation in morphological traits, which was consistent with the previously determined genetic diversity of *L. maculatus* (Shao et al., 2009; An et al., 2013, 2014; Han et al., 2015), could provide sufficient materials for economic performance selection in this species.

A correlation analysis indicated that all 20 morphometric traits were significantly correlated with body weight. Furthermore, the correlation coefficients of X_1, X_2, X_3, and X_{10} with body weight were all higher than 0.85. However, it has been well established that only using correlation coefficients between morphometric traits and body weight might not adequately explain all aspects of their relationships and an investigation of the causality of these relationships is necessary (Falconer and Mackay, 1996). To this end, we used a path analysis to estimate the contribution of each morphometric trait on body weight and to identify economically important traits for selective purposes. Our results revealed that, although the correlation coefficients of 13 morphometric traits (X_2, X_3, X_4, X_6, X_7, X_8, X_9, X_{11}, X_{12}, X_{13}, X_{14}, X_{15}, and X_{20}) on body weight were highly significant, their respective direct effects on body weight were not significant. Thus, these traits were sequentially deleted from a multiple-regression analysis of body weight. The remaining seven morphometric traits were used to construct a simplified multiple-regression equation: $Y = -472.108 + 1.06X_1 + 7.728X_5 + 1.973X_{10} - 7.024X_{16} - 4.400X_{17} - 3.338X_{18} + 2.138X_{19}$. The adjusted multiple-correlation coefficient of this equation was 0.947, which suggested that these traits (X_1, X_5, X_{10}, X_{16}, X_{17}, X_{18}, and X_{19}) could be considered main factors affecting the body weight of *L. maculatus*. This result is similar to those found in previous studies in other fish species (Zhang et al., 2008; Tong et al., 2007, 2011; Wang et al., 2014). By using path analysis, total length has been identified as a key factor that had the largest direct effect on body weight in *Hucho taimen* (Tong et al., 2011), *Pelteobagrus fulvidraco* (Wang et al., 2014), as well as in F_1 hybrids of *Cyprinus carpio* L. and *Cyprinus carpio haematopterus* (Tong et al., 2007). In *Ctenopharyngodon idella*, the traits with the strongest direct and indirect effects on body weight were body length and body width, respectively (Sun et al., 2015). These differences may in part be derived from the different body types of these species. In the present study, body width (X_5) had the highest positive direct correlation with body weight, whereas total length (X_1) mainly had an indirect effect. These results were similar to those found by He et al. (2009) in *Micropterus salmoides*, which is closely related to *L. maculatus*. It is worth noting that only the direct effect of X_5 was greater than any of the indirect effects on body weight. At the same time, high indirect effects on body weight of X_1, X_{10}, X_{16}, X_{17}, X_{18}, and X_{19} through X_5 were identified in this study. Hence, X_5 could be considered the most important morphometric trait, as indicated by the identified significant effects on *L. maculatus* body weight. In a previous study on *Sparusaurata*, broodstocks divided into two groups based on larval body width were analyzed to evaluate growth and carcass traits (Mazzeo et al., 2014). Their results showed that the specimens that had the largest body widths reached the largest sizes and performed better both in terms of general well-being and degree of nourishment. In combination with the findings from our own study, body width could be used as an effective morphometric indicator in breeding programs of *L. maculatus*.

In conclusion, the identified correlations among the 20 morphometric traits and body weight of *L. maculatus* were further tested using path and regression analyses in this study. Using these methods, seven morphometric traits (X_1, X_5, X_{10}, X_{16}, X_{17}, X_{18}, and X_{19}) were identified as having significant effects on body weight. A best-fit multiple-regression equation was constructed relating these seven morphometric traits to body weight. Body width was identified as a key trait affecting *L. maculatus* body weight. This knowledge will provide useful and valuable information for promoting the breeding programs of *L. maculatus* by identifying traits related to body weight and other important economic properties. It is worth mentioning that, due to the long sexual maturation cycle of this species, the gender of the fish was not considered in this study. Likewise, the genetic background of the identified correlations among the morphological traits was not discussed. These aspects should be highlighted in future studies.

Conflicts of interest

The authors declare no conflict of interest.

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