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ORIGINAL ARTICLE

Comparative morphometrics of two populations of giant river catfish (*Mystus seenghala*) from the Indus river system

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Abstract

Giant river catfish (*Mystus seenghala*) from the Beas river were compared with a population in the Sutlej river of the Indus river system using 28 morphometric characters. Discriminant analyses and a univariate ANOVA were used to explore these data. Allometric transformation of each measurement was done to eliminate correlations with size. The stepwise discriminant analysis retained nine variables that significantly discriminated the Beas samples from the Sutlej samples. Using these variables, 91.2% (original) and 89.0% (cross validated) of fish were classified into their correct samples. Misclassification was higher for the Sutlej samples (12.5%) than for the Beas samples (6.3%). The results of the discriminant analyses showed that variability in the Beas samples was more homogeneous and provided a more characteristic picture of the group than the Sutlej samples. The univariate ANOVA revealed significant differences between the means of the two populations for 12 of the 28 transformed morphometric measurements.

Key words: Beas, India, morphometry, *Mystus seenghala*, stock identification.

INTRODUCTION

The giant river catfish (*Mystus seenghala*; also known as *Aorichthys seenghala* and *Sperata seenghala)* is one of the most common species of fish from the family Bagridae found in South Asia. This species is distributed throughout India, Pakistan, Bangladesh, Afghanistan and Nepal (Talwar & Jhingran 1991; Jayaram 2002). It is easily recognized by its broad, spatulate snout with smooth upper surface, brownish-gray back, silvery flanks and belly and a dark well-defined spot on the adipose dorsal fin. It is mainly a riverine fish, although it also inhabits a few other freshwater habitats (Talwar & Jhingran 1991). *Mystus seenghala* is a very important commercial species, contributing substantially to the total inland fish production in South Asia. It is the most preferred fish species for eating in the north and north-western states of India because of its tasty flesh and the low number of intramuscular bones. It is a popular species of catfish to capture because it fetches a higher price than carp (Tripathi 1996).

Catfish are in great demand in the Indian domestic markets; however, catfish aquaculture has not yet been developed in India. *Mystus seenghala* has not yet been explored for its aquaculture potential (Tripathi 1996). The entire demand for this fish in the domestic market is met through capture from river bodies; thus, the effective management of wild stocks is critical. Scientifically sound management of fish resources depends on basic knowledge of the biology of the species, including information on population structure. This type of information is useful for the development of management strategies that will conserve the biodiversity associated with different

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species, sub-species, stocks and races (Turan *et al.* 2005). Thus, detailed knowledge on the population structure of *M. seenghala* is needed for sound management and successful commercial fishing of this species.

Morphometric analyses have been very useful for separating species, populations and races in the past and have been widely used for the identification of different fish stocks (Turan *et al.* 2004, 2005). Such morphometric studies of fish populations are very important for understanding the interactive effect of environment, selection and heredity on the body shapes and sizes within a species (Cadrin 2000). Several studies on the comparative morphometrics of different fish populations have been conducted (Nakamura 2003; Turan *et al*. 2005; Ibanez-Aguirre *et al.* 2006). Animals with the same morphometric characteristics are often assumed to constitute a stock; this idea has been used widely in fishery stock differentiation studies (Avsar 1994).

Given the growing importance of *M. seenghala,* detailed morphometric studies on this species are required and provide an important first step in what will surely become an inland fishery. Previous studies have dealt predominantly with systematics and distribution (Talwar & Jhingran 1991; Jayaram 2002). Therefore, the present study aimed to determine the morphometric differences in giant river catfish from the river Beas compared with catfish from the river Sutlej. The objective of the present study was to use statistical techniques to analyze and compare the size-free shape of different geographical populations of giant river catfish in the two rivers of the Indus river system to elucidate morphometric variations in this species. Morphometric variations between stocks can provide a basis for stock structure and might be useful for studying short-term, environmentally induced variation, for example, in fisheries management (Begg *et al.* 1999).

MATERIALS AND METHODS

Morphometric data

A total of 136 giant river catfish were investigated from the Sutlej and Beas rivers of the Indus river system in India (Fig. 1). All fish samples were collected from commercial catches at selected sites. Fifty-six fish samples were collected from the Harike wetland (river Sutlej) located near Amritsar (31°13' N, 75°12' E) and 80 fish samples

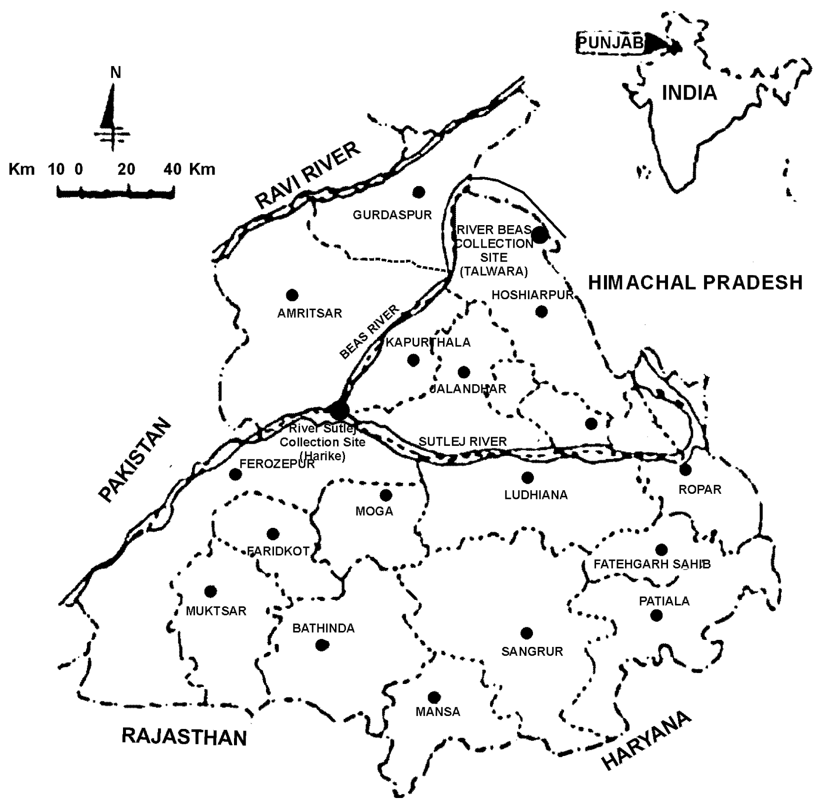

Figure 1 Map showing the two giant river catfish collection sites in the Indus river system in India.

Table 1 Mean values for 28 morphometric measurements of giant river catfish at two sampling locations in the Beas and Sutlej rivers and ANOVA results between the samples

Characters	River Sutlej Mean (Variance)	River Beas Mean (Variance)	Wilks' Lambda	*F*	*P*-value
TL	62.05 (4.74)	62.23 (6.70)	0.999	0.165	0.685
CFL	13.08 (4.58)	13.22 (6.24)	0.999	0.110	0.740
CPL	7.23 (1.35)	6.85 (0.43)	0.959	5.755	0.018*
ADFL	7.57 (1.30)	6.91 (0.44)	0.881	18.017	0.000***
DDAF	8.93 (1.31)	9.47 (0.73)	0.930	10.080	0.002**
DDCF	22.83 (2.30)	22.72 (1.50)	0.998	0.245	0.621
DFB	6.62 (0.35)	6.31 (0.26)	0.930	10.064	0.002**
DFL	10.19 (1.67)	11.03 (0.48)	0.849	23.897	0.000***
PDD	20.89 (0.64)	20.87 (3.96)	1.000	0.007	0.933
DODF	6.60 (0.99)	6.43 (0.32)	0.988	1.658	0.200
AFL	6.67 (0.46)	6.18 (0.46)	0.889	16.730	0.000***
AFB	4.84 (0.23)	4.74 (0.28)	0.991	1.213	0.273
PAD	37.58 (1.66)	38.50 (2.70)	0.916	12.224	0.001**
DVAF	10.57 (0.63)	10.35 (0.47)	0.979	2.942	0.089
VFL	6.27 (0.27)	6.45 (0.30)	0.974	3.615	0.059
PVD	26.82 (1.24)	27.77 (3.08)	0.913	12.791	0.000***
DPVF	14.32 (2.16)	14.22 (0.48)	0.998	0.265	0.607
PFL	7.67 (0.54)	7.55 (0.50)	0.993	0.935	0.335
PSL	6.69 (0.45)	6.60 (0.46)	0.996	0.475	0.492
PPD	12.11 (0.78)	12.75 (1.05)	0.903	14.329	0.000***
MNBW	3.80 (1.05)	3.73 (0.12)	0.998	0.277	0.600
MXBW	10.05 (4.71)	8.68 (0.46)	0.827	27.943	0.000***
HL	12.44 (0.83)	12.65 (0.36)	0.979	2.818	0.096
HD	4.94 (0.48)	5.44 (0.27)	0.854	22.964	0.000***
SNL	3.72 (0.18)	3.68 (0.09)	0.996	0.539	0.464
POD	4.85 (0.15)	4.88 (0.11)	0.999	0.176	0.676
ED	1.11 (0.05)	1.20 (0.03)	0.959	5.765	0.018*
ID	3.95 (0.13)	3.93 (0.10)	1.000	0.061	0.805

$^*P < 0.05$; $^{**}P < 0.01$; $^{***}P < 0.001$. The morphometric characteristics are defined in Fig. 2.

were collected from Maharana Pratapsagar lake of Pong dam (river Beas) located near Talwara town (31°57' N, 75°53' E). Both sites are among the largest fishing locations for giant river catfish on these two rivers. Fresh samples of *M. seenghala* were measured for 29 different morphometric characters (Fig. 2) selected according to the criteria given by Jayaram (2002) and Turan *et al.* (2005). Linear measurements were made to the nearest 0.1 cm, except for maximum body width (MXBW), minimum body width (MNBW), head length (HL), head depth (HD), snout length (SNL), interorbital distance (ID), post-orbital distance (POD), eye diameter (ED) and the distance between the occipital process and the dorsal fin (DODF), which were measured to the nearest 0.01 mm.

Data analysis

Morphological variations should be attributable to body shape differences and should not relate to the relative size of the fish to avoid misinterpretation of the results (Strauss 1985). Several univariate and multivariate techniques can

Table 2 Standardised canonical discriminant function coefficients of the different morphological variables that discriminated the two populations

Morphometric characteristics	Canonical score
MXBW	–0.750
DFL	0.727
DPVF	0.608
HD	0.436
DFB	–0.412
DDAF	0.365
AFL	–0.364
DDCF	–0.319
ADFL	–0.253

Scores are ordered by the absolute value of the canonical scores, with the largest value first. The morphometric characteristics are defined in Fig. 2.

Table 3 Pooled within-group correlations between the discriminating variables and the standardized canonical discriminant functions

Characters	Function 1
MXBW	–0.365*
DFL	0.338*
HD	0.331*
ED	0.294*
ADFL	–0.293*
AFL	–0.283*
PPD	0.229*
DDAF	0.219
DFB	–0.219
CPL	–0.208
DVAF	–0.190
PVD	0.120
DODF	–0.113
MNBW	–0.108
PFL	0.093
AFB	0.087
SNL	–0.087
POD	0.080
PAD	0.076
HL	0.070
PSL	0.068
CFL	–0.056
TL	–0.052
PDD	0.040
DPVF	–0.036
DDCF	–0.034
VFL	–0.020
ID	0.000

Variables are ordered by the absolute size of the correlation within function. *Largest correlation between each variable and discriminant function. The morphometric characteristics are defined in Fig. 2.

be used to remove the effect of size (e.g. regression analysis, allometric methods, multiple-group principal component analysis). The allometric method adequately achieves size and shape separation and reasonably meets statistical assumptions (Reist 1985). The data were subjected to an allometric transformation as suggested by Elliot *et al.* (1995) to eliminate size correlations:

$$M_{adj} = M\,(L_S / L_O)^b$$

where M is the original measurement, M_{adj} is the size-adjusted measurement, L_O is the standard length (SL) of the fish, and L_S is the overall mean of the SL for all fish from all samples in each analysis. Parameter b was estimated for each character from the observed data as the slope of the regression of log M on log L_O, using all fish combined for both sites. The transformed data were checked for efficiency by testing the significance of the correlation between the transformed variables and SL. Standard length was excluded from the final analysis.

The transformed data were submitted to discriminant analysis to examine any phenotypic differences between the two populations. As the discriminant analysis requires a reduced set of characters, a stepwise procedure was used to reduce the number of variables. A cross-validation test was carried out to assess the ability of the phenotypes to discriminate between the populations. In cross validation, one individual is removed from the original matrix and a discriminant analysis is carried out with the remaining observations, which is then used to classify the omitted individuals. The percentage of correctly and incorrectly classified fish forms the basis for differentiation among samples. The percentage of correctly classified individuals gives a measure of the morphological distinctness of the samples. The number of misclassified individuals indicates the degree of intermingling between the populations (Turan *et al*. 2005). In addition, a univariate ANOVA was used to test the significance of morphometric

Table 4 Number and percentage of individuals classified using discriminant analysis for each group (rivers Sutlej and Beas) from the original matrix and from the cross-validation procedure

Matrix	Observed group	Predicted group		Total membership
		Sutlej	Beas	
Original Count	Sutlej	49	7	56
	Beas	5	75	80
%	Sutle	87.5	**12.5**	100.0
	Beas	**6.3**	93.8	100.0
Cross validated Count	Sutlej	48	8	56
	Beas	7	73	80
%	Sutlej	85.7	**14.3**	100.0
	Beas	**8.8**	91.3	100.0

Percentage of errors for each classification are shown in bold underlined text.

differences among the two populations. All statistical analyses were carried out using SPSS (Version 10; SPSS Inc. 1999).

RESULTS

After the allometric transformation, none of the 28 morphometric measurements gave a significant correlation with SL, which indicates that the allometric formula effectively removed size effects from the data. A univariate ANOVA revealed that 12 of the 28 morphometric measurements were significantly different among samples to varying degrees (Table 1). The samples from the river Sutlej displayed a higher MXBW with longer adipose, anal and dorsal fins and an elongated caudal peduncle, whereas the samples from the river Beas exhibited a higher HD and dorsal fin length with a larger ED and a longer distance between the dorsal and adipose fins. In addition to this, the prepectoral, prepelvic and preanal distances of the river Beas samples were comparatively longer than the river Sutlej samples.

The stepwise discriminant analysis retained nine variables (Table 2) that significantly discriminated the Beas samples from the Sutlej samples. Pooled within-group correlations between the discriminating variables and discriminant function (DF) also revealed that anterior body measurements such as MXBW, dorsal fin length (DFL), HD, ED, prepectoral distance (PPD), adipose fin length (ADFL) and anal fin length (AFL) predominantly contributed to the DF (Table 3), indicating that these characters are the most important in distinguishing the two populations. In the classification results of the discriminant analyses (Table 4) we found that the percentage of correctly classified fish in both groups was high, 87.5% and 93.8% in the rivers Sutlej and Beas, respectively. At the same time, the frequency of overlap between the two groups was low, 12.5% of Sutlej samples and 6.3% of Beas samples, which indicates morphological distinctness of both populations.

DISCUSSION

We revealed significant differences in morphometrics between two populations of giant river catfish in the Indus river system. However, both populations had similar average lengths. An allometric transformation was used to avoid size effects (the correlation matrix showed both positive and negative values) and clearly shows that there are differences between the populations. The average size of both of the populations was very similar, and this might reflect the use of similar fishing gear at both collection sites because both collections were made from commercial catches. There is a clear morphological distinction between certain characters in both populations. It is often difficult to explain the causes of morphological differences between populations (Cadrin 2000). These differences may be genetically related differences or they might be associated with phenotypic plasticity in response to different

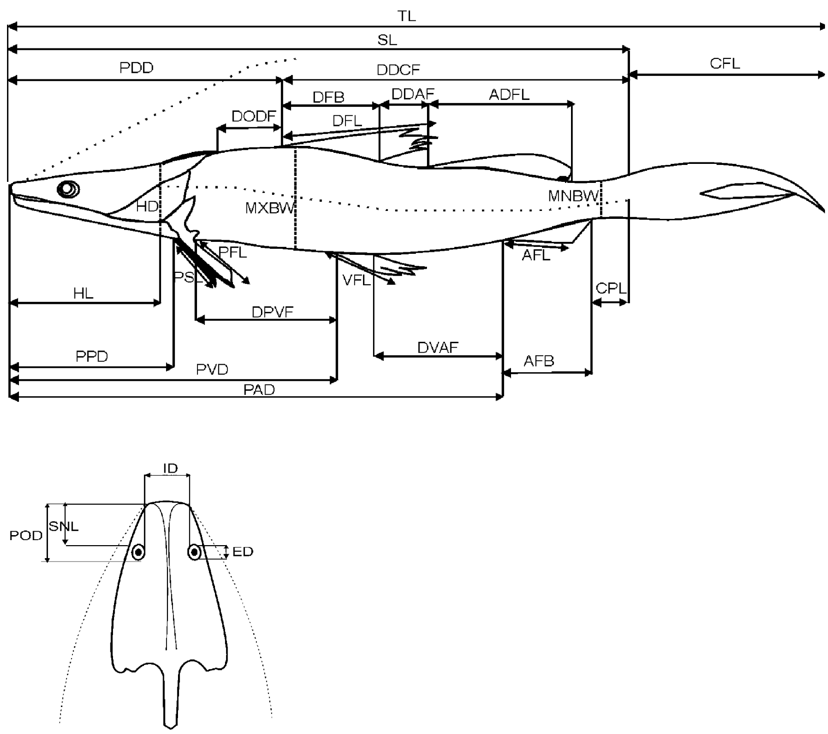

Figure 2 Schematic illustration of the 29 morphometric measurements taken on *Mystus seenghala* specimens. TL, total length; SL, standard length; CFL, caudal fin length; CPL, caudal peduncle length; ADFL, adipose fin length; DDAF, distance between the dorsal and adipose fins; DDCF, distance between dorsal and caudal fin; DFB, dorsal fin base; DFL, dorsal fin length; PDD, predorsal distance; DODF, distance between occipital process and dorsal fin; AFL, anal fin length; AFB, anal fin base; PAD, preanal distance; DVAF, distance between the ventral and anal fins; VFL, ventral fin length; PVD, preventral distance; DPVF, distance between the pectoral and ventral fins; PFL, pectoral fin length; PSL, pectoral spine length; PPD, prepectoral distance; MNBW, minimum body width; MXBW, maximum body width; HD, head depth; HL, head length; SNL, snout length; POD, postorbital distance; ED, eye diameter; ID, interorbital distance.

environmental factors in each area (Murta 2000). Thus, morphological variation can reflect genetic differences between stock and/or environmental differences between localities. Significant differences between the two populations were found using caudal peduncle length (CPL), MXBW, ED, HD, ADFL, distance between the dorsal and adipose fins (DDAF), dorsal fin base (DFB), DFL, AFL, preanal distance (PAD), preventral distance (PVD) and PPD (Table 1). Comparatively longer prepectoral, prepelvic and preanal distances in the river Beas samples reveal a comparatively elongated anterior region, despite the fact that the average size of fish from both populations is the same. These differences might be attributed to differential environmental factors prevailing in the two rivers. Bhardwaj (2005) classified Sutlej as a grossly polluted river and Beas as a relatively clean river. Features distinguishing river Beas water from river Sutlej water at the sampling sites include low temperature, specific conductivity, biological oxygen demand (BOD), bicarbonate, phosphate, silicate and organic carbon, and high dissolved oxygen content and faster water currents. The addition of industrial wastes in large quantities to upstream sites of the river Sutlej (particularly from the industrialized cities of Ludhiana and Jalandhar) might be responsible for the increased alkalinity and BOD at the Harike site (Dhillon & Kaur 1996). Morphometric comparisons of African catfish, *Clarias gariepinus*, in different river systems in Turkey revealed significant divergence (Turan *et al*. 2005). Similarly, both morphological and genetic methods have been used to characterize different populations of *Clarias gariepinus* and *Clarias anguillaris* (Agnese *et al*. 1997). Thus, the possibility exists that the observed morphological variations in the present study might be because of genetic differences among the populations. Correlation between genetic variation and morphological variation has been confirmed in natural populations (Poulet *et al*. 2004) and both have been widely used to make assessments of population differentiation (Buth & Crabtree 1982; Agnese *et al*. 1997; Ibanez *et al.* 2006). Genetic differentiations were observed among different populations of yellow catfish, (*Mystus nemurus*) from Thailand (Leesa-Nga *et al*. 2000). Significant genetic diversity was observed among two different populations of Korean catfish, (*Silurus asotus*) (Yoon & Kim 2001). In Malaysian river catfish, (*Mystus nemurus*) genetic variation was observed among different rivers and tributaries of Malaysia (Chong *et al.* 2000). In the present study, the genetic basis of morphometric differences is not explored. However, the application of molecular markers would be a very useful method (Agnese *et al.* 1997; Delling *et al.* 2000; Poulet *et al.* 2004) for confirming the observed phenotypic differences among different geographical regions and for facilitating the development of management strategies and future exploitation of this species for intensive aquaculture plans.

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