

[Research]

## Variations in fish body and scale shape among *Aphanius dispar* (Cyprinodontidae) populations: insights from a geometric morphometric analysis

A. Khosravi, M. Shaker Golmakan, A. Teimori\*

Department of Biology, Faculty of Sciences, Shahid Bahonar University of Kerman, Kerman, Iran.

\* Corresponding author's E-mail: a.teimori@uk.ac.ir

(Received: Sep. 06. 2016 Accepted: Feb. 25. 2017)

### ABSTRACT

Phenotypic variations in fish body and scale shape were investigated among the three populations of *Aphanius dispar* (Rüppell, 1829) in Southern Iran through the use of landmark-based geometric morphometric analyses. This species is widely distributed in the region, and therefore, considerable morphological variations exist among the geographically allopatric populations. Based on the Principle Component Analysis (PCA), variation in body shape of the females is prominently related to the dorsal fin region, while in the males it is related to the dorsal fin and caudal peduncle. Moreover, the shape variations in the scales are obviously linked to the tip of anterior portion of the scales, and the left and right boundaries between anterior and posterior regions of the scales. The lateral sides of the fish scales in site I are concave, while they are laterally convex in sites II and III. The observed variation seen in the fish body shape and scales among the three studied sites are probably caused by the different ecological conditions of their habitats particularly variation in water flow.

**Key words:** Tooth-carps, Adaptation, Habitat changes, Water flow.

### INTRODUCTION

Generally, many geographical barriers to gene flow exist for the freshwater and brackish water fishes and, therefore, most species and populations have opportunity to show natural variation (Marcil *et al.* 2006). As a consequence, fishes in these environments are often assumed to be more genetically heterogeneous than for example marine fishes. For that reason, the freshwater and brackish water fishes are suitable candidates to study environmental-based variation and also genetic divergence in species and populations levels (e.g. Hendry & Stearns 2004).

One of the general characteristics of non-marine environments particularly freshwater resources is their geographic fragmentation in either long distance or short isolation. Fishes that exploit different resources in terms of food, space, and habitat tend to evolve

different morphologies, reflecting adaptation to these ecological differences (Alexander 1974; Marcil *et al.* 2006).

This is probably linked to phenotypic plasticity, which arises when the same genotype produces different phenotypes in different environments (Hutchings *et al.* 2004). The common tooth-carp, *Aphanius dispar* (Rüppell 1829) is a cyprinodontid, inhabited brackish and freshwater environments in often desert regions (Wildekamp 1993).

More especially, its principal habitats are coastal lagoons, but can inhabit inland waters and hot sulfuric springs (Wildekamp 1993; Teimori *et al.* 2012a-b). *A. dispar* shows a high tolerance to ecological changes, so that some populations occupied the man-made environments such as canals, ponds and streams within the cities in Southern Iran. In addition, owing to its high tolerance to

ecological changes, it shows wide distribution ranges, with considerable morphological variations (Wildekampe 1993; Teimori *et al.* 2012a-b). Therefore, the intraspecific morphological variation in *A. dispar* is documented to be linked to genetic isolation (in phylogenetic term) owing to geographic isolation (Teimori *et al.* 2012a-b). Moreover, the members of the genus *Aphanius* are known for their well-known color pattern, which made them being always potential candidate to be trans-located between and within different drainage systems. If this would happen in the case of *A. dispar* populations, then it can be another reason rather than genetic divergence for the observed morphological variation among allopatric populations. In our recent investigation on this taxon, we collected three populations in Southern Iran with considerable morphological variability. The collected specimens belong to a single population inhabiting a natural river (site I), and two populations inhabiting man-made environments (sites II - III). In this study, these three newly - collected populations were

investigated through the use of landmark-based geometric morphometric analyses to infer the pattern of phenotypic variations in fish body and scale shapes. This would be important, since body shape gives an idea to the different adaptations developed by the fish in a particular environment, and also for stock assessment of fish populations.

## MATERIALS AND METHODS

### Taxon sampling

A total of 104 adult individuals (SL > 25mm) belonging to three populations of *A. dispar* were collected from three natural and man-made environments in Southern Iran including a man-made canal within Bandarabbas City, capital of Hormuzgan Province (site I in Fig. 1), Shur brackish water River, a natural environment (site II in Fig. 1), and a man-made pool within Kahnuj City in Kerman Province (site III in Fig. 1).

Sample sizes, names and geographic coordinates of the sampling sites along with some ecological parameters of the habitats are listed in Table 1.

**Table 1.** Sampling sites, geographic coordinates and ecological parameters of the habitats.

Site no.	Site name	Habitat	Water T°C	Salinity (ppt)	Oxygen (ppm)	pH
I	Bandarabbas	Man-made canal	33.5	11.74	8.28	6.48
II	Shur River	Natural river	30.1	37.6	8.13	5.36
III	Kahnuj	Man-made pool	22.2	3.70	8.60	5.07

### Data collection

Landmark data were obtained from fish body and scales photographs taken with a Dino-Lite digital microscope AM-423X ver.2.0 connected to the stereomicroscope (Olympus SZ40). The dorsal sides of body shape of specimens were photographed. Millimeter paper was included in the images to allow the acquisition of a scaling factor afterwards.

### Digitizing shape information

The digitized information of the fish body shape and scales for each individual was analyzed using a landmark-based method (Rohlf & Marcus 1993). The coordinates of the landmarks for fish body shape of each individual were acquired from a dorsal (left

side) image of the fish, and for the scales acquired from anterior part using the tpsDig2 software (Rohlf 2005).

### Body shape landmarks

According to Park *et al.* (2013), the numbers of 11 homologous landmarks for the shape bodies of both males and females were selected and defined as follow (Fig. 2A):

Landmark 1 (LM1): anterior tip of upper jaw

Landmark 2 (LM2): left-rear notch of skull immediately lateral to dorsal midline

Landmark 3 (LM3): anterior base of the first ray of dorsal fin

Landmark 4 (LM4): posterior base of dorsal fin

Landmark 5 (LM5): dorsal base of caudal fin membrane

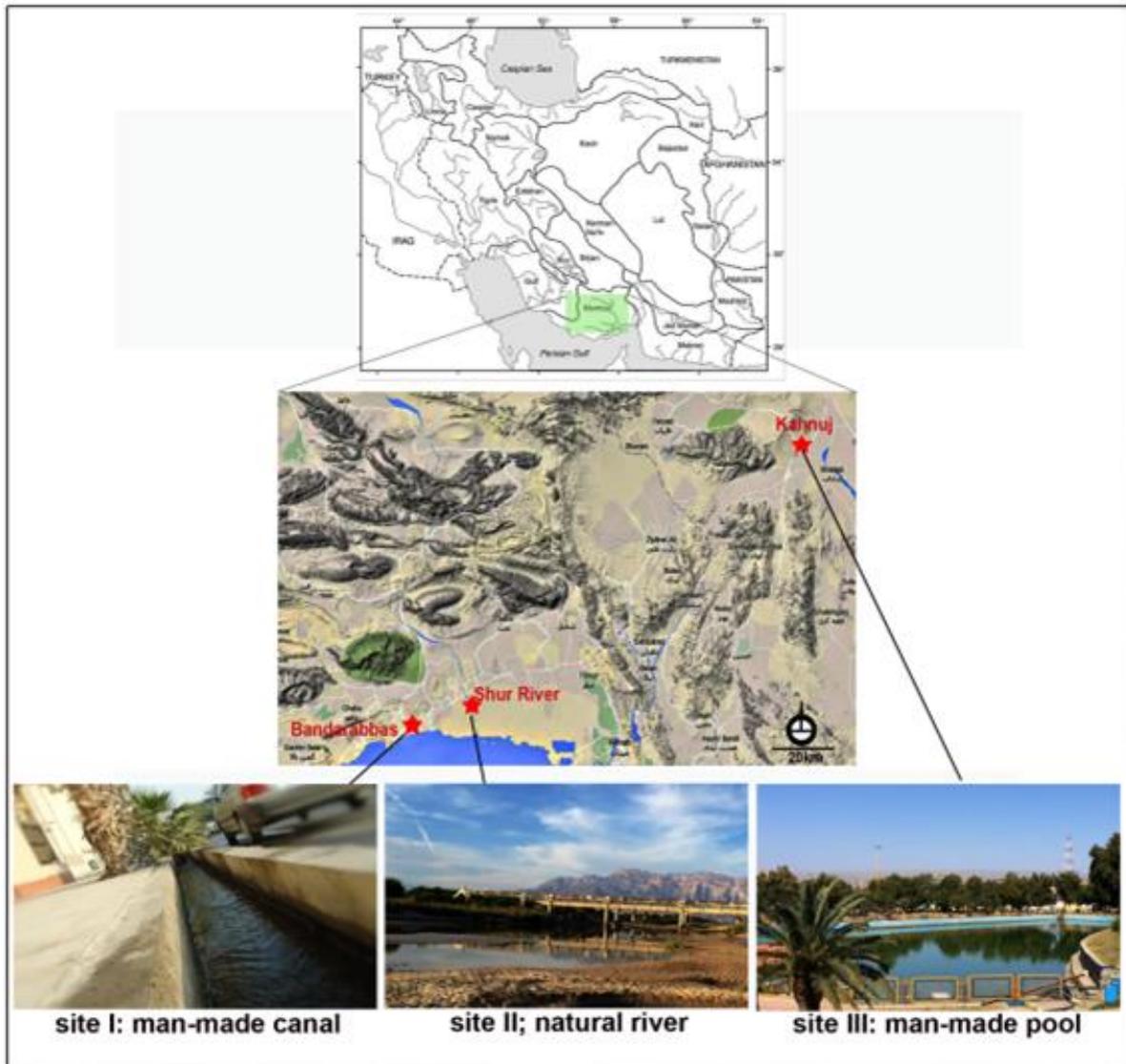
Landmark 6 (LM6): posterior-most tip of caudal peduncle at lateral midline

Landmark 7 (LM7): ventral base of caudal fin membrane

Landmark 8 (LM8): posterior base of anal fin

Landmark 9 (LM9): anterior base of the first ray of anal fin  
Landmark 10 (LM10): the most ventral opening of operculum

Landmark 11 (LM11): posterior edge of angular (lower jaw) bone



**Fig. 1.** Geographic overview and details of sampling sites in Southern Iran. Site I is a man-made canal in Bandarabbas City, site II is Shur brackish water River, and site III is a man-made pool in Kahnuj City.

#### Scale landmarks

According to Ibanez *et al.* (2007) and Requieron *et al.* (2012), the number of seven homologous landmarks for the scales of both males and females were selected and defined as follow (Fig. 2B):

Landmark 1 (LM1): the left lateral tip of the anterior portion of scale

Landmark 2 (LM2): the center of the anterior edge of scale

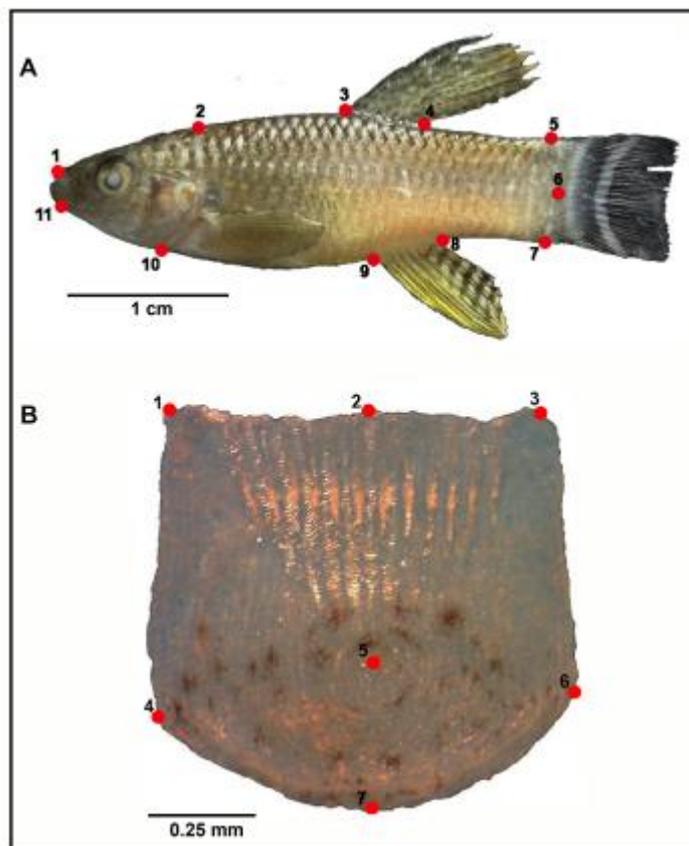
Landmark 3 (LM3): the right lateral tip of anterior portion of scale

Landmark 4 (LM4): the left boundary between anterior area with circuli and posterior area

Landmark 5 (LM5): the focus of scale

Landmark 6 (LM6): the right boundary between anterior area with circuli and posterior area

Landmark 7 (LM7): the tip of posterior portion of scale.



**Fig. 2.** Arrangement of the landmarks on fish body and scale. (A) Lateral image of the fish specimen with 11 digitized landmarks, and (B) scale with seven digitized landmarks.

### Geometric morphometric

A Generalized Procrustes Analysis (GPA) is used in order to remove disparities and rotation (Rohlf & Slice 1990) and to overlay the configurations of the landmarks in all fish specimens and scales to a common coordinate system, and to generate a set of shape variables (Gower 1975; Rohlf & Slice 1990). The multivariate analyses as Principal Component Analysis (PCA) and Canonical Variable Analysis (CVA) were used in Morpho J ver. 1.05c (Klingenberg 2011) to show possible separation of the shape variation. The visualization of shape changes, which is explained by the Canonical Variates (CV) was carried out using Morpho J ver. 1.05c (Klingenberg 2011), by generating deformed outline drawings with the average shape as a reference to analyze the data. The pairwise testing for detecting possible sexual

dimorphism and also differences between groups was tested by Discriminant Function Analysis (DFA) using Morpho J ver. 1.05c (Klingenberg 2011). Since DFA showed no sexual dimorphism in the scales shape ( $p > 0.0001$ ), therefore, the further analyses on scales were applied for both sexes together. However, because of the well-known sexual dimorphism seen in external parts of almost all the *Aphanius* species, analyses on fish body were applied separately for the males and females.

To evaluate the overall pattern of morphometric relationships between the three studied populations, a UPGMA cluster analysis was performed on the matrix of shape distances (Euclidean Distances) using PAST (PALaeontological STATistics, version 1.81 (Hammer *et al.* 2001). Moreover, Mahalanobis distance ( $p$  value  $< 0.0001$ ) was applied to

show the significance of means shape between the compared populations.

The effects of size on variation in shapes of the fish specimens and their scales (i.e., between populations allometry) were tested separately by multivariate regression analysis (Monteiro, 1999) of Procrustes coordinates-Pco on their size using Centroid size-Cs.

The multivariate regression analyses were performed by Morpho J ver. 1.05c (Klingenberg 2011).

## RESULTS

Discriminant Function Analysis shows difference between three studied populations and between sexes. However, there are some minimal overlap regarding to scale shape between sites I vs. III and II vs. III (Fig. 3A, C).

### Body shape in females

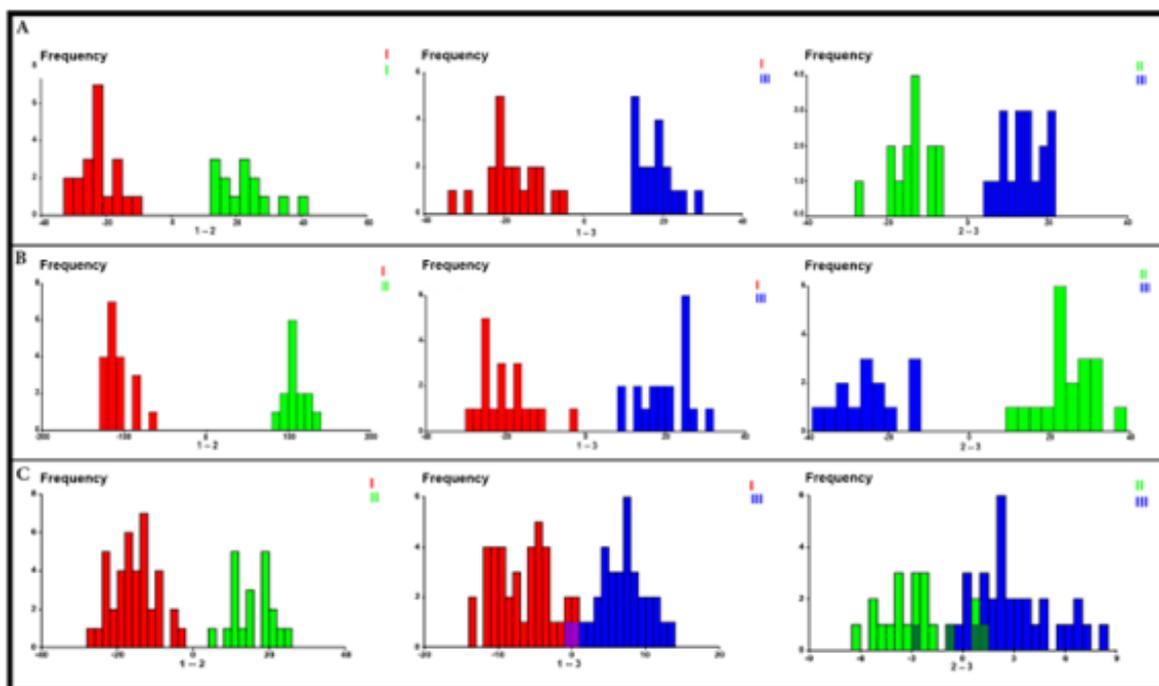
The PCA performed on lateral body shape of the females provides two principal components (PCs), which accounted for over 50% of the total variance. Morphological variation explained by PC1 is approximately

35% of the total variance, which is prominently related to the anterior tip of upper jaw (LM1), left-rear notch of the skull immediately lateral to the dorsal midline (LM2), anterior base of the first ray of the dorsal fin (LM3), posterior base of the dorsal fin (LM4) and the posterior edge of angular bone in lower jaw (LM11).

The CVA reveals that the first two CVs include 63.73% and 36.27% of the total shape variation respectively (Fig. 4A).

Shape changes associated with CV1 and CV2 are mainly due to the change in length of the body (in relation to original shape), anterior base of the first ray of dorsal fin (LM3), posterior base of dorsal fin (LM4), dorsal and ventral bases of caudal fin membrane (LMs5, LM7) and posterior and anterior bases of anal fin (LMs 8, 9) (Fig. 4A).

Regressing the independent contrast of shape onto the independent contrast of centroid size in body shape of the females for 3.01% of the variation in shape, and there is a statistically insignificant trend ( $P = 0.151$ ) (Fig. 5A).

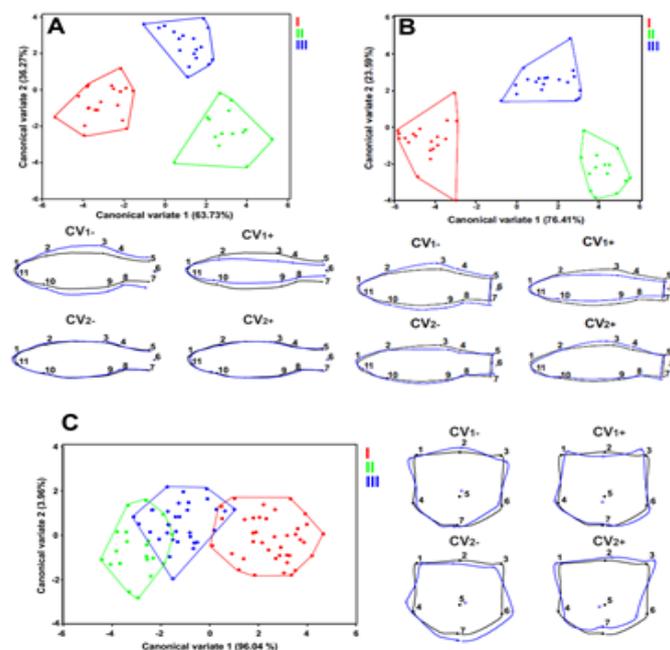


**Fig. 3.** Discriminant Function Analysis (DFA) on shape variables of the studied populations based on (A) lateral body shape in females, (B) lateral body shape in males and (C) scale shape.

### Body shape in males

The PCA performed on lateral body shape of the males provides two principal components (PCs), which accounted for more than 40% of the total variance. Morphological variation explained by PC1 is approximately 31% of the total variance, which is prominently related to the anterior tip of upper jaw (LM1), anterior

base of the first ray in dorsal fin (LM3), posterior base of dorsal fin (LM4), posterior-most tip of caudal peduncle at the lateral midline (LM6), ventral base of caudal fin (LM7), anterior base of the first ray in anal fin (LM9), and posterior edge of angular bone in lower jaw (LM11).



**Fig. 4.** Canonical Variable Analysis (CVA) scatter plot (axes 1 and 2) on shape variables of the studied populations based on (A) lateral body shape in females, (B) lateral body shape in males and (C) scale shape.

The CVA of body shape reveals that the first two CVs include 76.41% and 23.59% of the total shape variation respectively (Fig. 4B). Shape changes associated with CV1 are mainly due to the change in relative length of body, ventral base of caudal fin (LM 7), posterior base of anal fin (LM 8), and anterior base of the first ray in anal fin (LM 9).

The shape changes associated with CV2 are mainly due to the change in anterior base of first fin ray of dorsal fin (LM 9) and posterior-most tip of caudal peduncle at the lateral midline (LM 6) (Fig. 4B).

Regressing the independent contrast of shape onto the independent contrast of centroid size in body shape of the males for 5.65% of the variation in shape, and there is a statistically insignificant trend ( $P=0.006$ ) (Fig. 5B).

### Scale shape variation

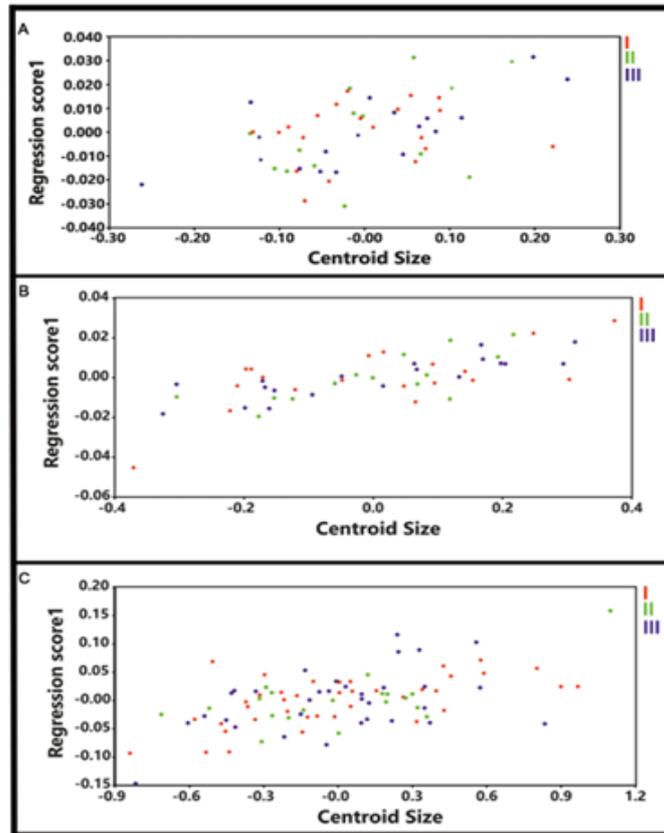
The PCA performed on shape of the scales provides two principal components (PCs), which accounted for more than 60% of total variance (plot not shown).

Morphological variation explained by PC1 is 48.8% of variance, which is mainly related to the left and right lateral tips of anterior portion of scale (LMs 1,3), the left and right boundary between the anterior area with circuli and posterior region (LMs 4,6).

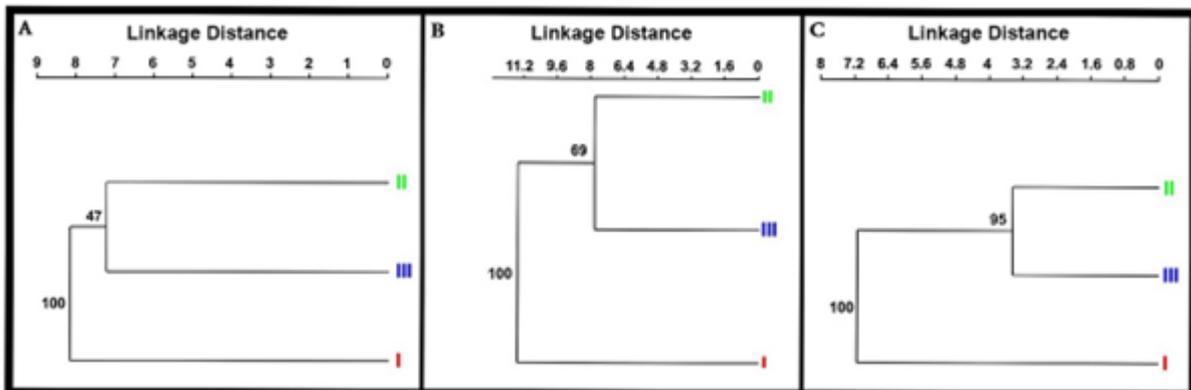
The CVA analysis reveals that the first two CVs include 96.04%, and 3.96% of the total shape variation respectively (Fig. 4.C). Shape changes associated with CV1 are mainly related to change in the left and right lateral tips of anterior portion of scale (LMs 1,3), and focus of scale (LM5) while, the shape changes associated with CV2 are mainly related to all

the landmarks with the exception of LM 1 and LM 5 (Fig. 4C). Regressing the independent contrast of shape onto the independent contrast of centroid size in scales for 5.12% of the variation in shape, and there is a statistically insignificant trend ( $P = 0.045$ ) (Fig. 5C). UPGMA dendrogram with 10000 replicates based on the data set of shape

information from the lateral body shape in females (Fig. 6A), lateral body shape in males (Fig. 6B) and the scale shape (Fig. 6C) show the same pattern on phenotypic relationships. In three dendrograms, populations from sites II and III are sister, and these together are sister to site I.



**Fig. 5.** Bivariate graphs derived from the multivariate regressions performed from the Procrustes coordinates (Pco) against the Log-transformed centroid size (Log-Cs). (A) Lateral body shape in females, (B) lateral body shape in males, and (C) scale shape.



**Fig. 6.** Dendrogram obtained from the UPGMA data set shape information from of the (A) lateral body shape in females, (B) lateral body shape in males, and (C) scale shape. The dendrogram used Euclidean distances between group means (branch bootstrap support shown as percentage at the nodes, 10000 replicates).

As results, there are significant differences in the shape of fish body and scales among the males and females of three studied populations. Both the males and females in site I have wider snout as well as wider and bigger anal and dorsal fins. Moreover, the caudal peduncle depth and maximum body depth are higher in site I. The individuals from site I can also be discriminate by considering changes in scale shape as their scales have two concave sides, and the distance between focus and the most posterior part of the scale is shorter than the two others. The scales in sites II and III are laterally convex.

## DISCUSSION

Generally, morphological variation seen in the nature may be the result of phenotypic plasticity, local adaptation, ecological character displacement, genetic divergence or the interaction of any of these processes (Nicieza 1995). In the species level, morphological differences among the species are often discussed as genetic divergent as results of competition and ecological preferences, so that different species exploiting different resources (e.g. Ehlinger & Wilson 1988; Dynes *et al.* 1999). However, among-population differences are often considered to be the result of adaptation to local environmental conditions (e.g. Meyer 1989; Mittelbach *et al.* 1992). As results and in large concept, variation in morphology resulted either from environmental effects on phenotypic characters or by counteracting genetic differences between populations (Marcil *et al.* 2006).

Evaluation and interpretation of the phenotypic variation among the isolated population as well as the pattern of these variations has always been a great and difficult subject in the evolutionary biology. It is particularly true in the case of geographically widespread species where taxonomy of the populations could not be easily solved as the studied taxon here.

In nature, temperature and water flow vary considerably along streams and are very important in influencing the structure and

morphological characteristics of fish communities. Even within streams, the range of temperatures can vary from one part of the stream to the next. This variation in conditions eventually results in the adaptation of different species (also populations) to a given range of temperatures and water flow conditions (Mckenzie *et al.* 2013).

The three studied populations inhabit ecologically different environments. Some ecological parameters of three environments are listed as follow; site I (EC=9450 us/cm, Ca=117.3 ppm, NH<sub>4</sub>=2.97 ppm, NO<sub>3</sub>=9.30 ppm); site II (Ec=35000 us/cm, Ca=272.1 ppm, NH<sub>4</sub>=1.55 ppm, NO<sub>3</sub>=0.0 ppm); site III (EC=3560 us/cm, Ca=264.4 ppm, NH<sub>4</sub>=very low and could not be analyzed, NO<sub>3</sub>=3.65 ppm). Noteworthy, in site I (man-made canal in Bandarabbas City), bed is rocky without any aquatic vegetation; water is clean with high flow. In wild site II (natural salty river), bed contains rubble and in site 3 (man-made pool in Kahnuj City), bed is rocky covered by green alga, and no water flow in the pool. In site II, EC is almost three times of the two man-made habitats (sites I and III).

In site I, individuals have wider and bigger anal and dorsal fins. The further change in this site is related to the scales of the fishes, in which they could be characterized by having scales with clearly concave sides.

In addition, variation in water flow is assumed to affect the body shape and swimming behavior of the fishes (Langerhans 2008). In the studied fishes, body depth showed differences among the individuals of three populations. Changes in body depth could affect the overall fusiform shape (spindle-like shape) of the fish; therefore, it may change the hydrodynamic power and swimming ability of the fish specimens (Riddell *et al.* 1981).

All these changes in shape and size of the body and scales are probably linked to the ecological conditions of the studied habitats and can be considered as ecomorphological variation (Sfakianakis *et al.* 2011). For example, the wider and bigger anal and dorsal fins in

site I is probably caused by the high water flow in this habitat. Langerhans & Reznick. (2010) reviewed the effects of variation in water flow patterns on body shape, and the predictability of body shape being associated with specific environmental conditions. They hypothesized that increasing water flow regimes may lead to increases in fin area.

We concluded that variation seen in body shape and scales among the three studied populations are caused more likely by the different ecological conditions of the habitats particularly water flow.

#### ACKNOWLEDGMENT

This work was supported financially by Shahid Bahonar University of Kerman and was approved by the Ethics Committee of Biology Department (ECBD-SBUK 02081395).

#### REFERENCES

- Alexander, RMcN 1974, Functional design in fishes. Hutchinson University Library, London, 160 p.
- Dynes, J, Magnan, P, Bernatchez, L & Rodríguez, MA 1999, Genetic and morphological variation between two forms of lacustrine brook charr. *Journal of Fish Biology*, 54: 955–972.
- Ehlinger, EJ & Wilson, DS 1988, Complex foraging polymorphism in bluegill sunfish. *Proceedings of the National Academy of Sciences of the United States of America*, 85: 1878–1882.
- Gower, JC, 1975 Generalized Procrustes analysis. *Psychometrika*, 40: 33–51.
- Hammer, Ø, Harper, DAT & Ryan, PD 2001, PAleontological STatistics software package for education and data analysis. *Palaeontologia Electronica*, 4: 1–9.
- Hendry, AP & Stearns, SC 2004, Evolution illuminated: salmon and their relatives. Oxford University Press, Oxford, 520 p.
- Hutchings, JA 2004, Norms of reaction and phenotypic plasticity in salmonid life histories. In Hendry, AP & Stearns SC (eds.), Evolution illuminated; salmon and their relatives. Oxford University Press, New York, 154–174.
- Ibañez, AL, Cowx, IG & O'Higgins, P 2007, Geometric morphometric analysis of fish scales for identifying genera, species, and local populations within the Mugilidae. *Canadian Journal of Fisheries and Aquatic Sciences*, 64: 1091–1100.
- Klingenberg, CP 2011, MorphoJ: an integrated software package for geometric morphometrics. *Molecular Ecology Resources*, 11: 353–357.
- Langerhans, R 2008, Predictability of phenotypic differentiation across flow regimes in fishes. *Integrative and Comparative Biology*, 48: 750–768.
- Langerhans, RB, & Reznick, DN 2010, Ecology and evolution of swimming performance in fishes: predicting evolution with biomechanics. In Domenici, P & Kapoor, BG (eds.), Fish locomotion: an etho-ecological perspective. Science Publishers, Enfield, 200–248.
- Marcil, J, Swain, DP & Hutchings, JA 2006, Genetic and environmental components of phenotypic variation in body shape among populations of Atlantic cod (*Gadus morhua* L.). *Biological Journal of the Linnean Society*, 88: 351–365.
- Martinez, PA, Berbel-Filho, WM & Jacobina, UP 2013, Is formalin fixation and ethanol preservation able to influence in geometric morphometric analysis? Fishes as a case study. *Zoomorphology*, 132: 87–93.
- Mckenzie, DJ, Estivales, G, Svendsen, JC, Steffensen, JF & Agnèse, JF 2013, Local adaptation to altitude underlies divergent thermal physiology in tropical killifishes of the genus *Aphyosemion*. *PLoS ONE*, 8: e54345.
- Mittelbach, GG, Osenberg, CW & Wainwright, PC 1992, Variation in resource abundance affects diet and feeding morphology in the pumpkinseed sunfish (*Lepomis gibbosus*). *Oecologia*, 90: 8–13.
- Monteiro, LR 1999, Multivariate regression models and geometric morphometrics: the

- search for causal factors in the analysis of shape. *Systematic Biology*, 48: 192–199.
- Nicieza, AG 1995, Morphological variation between geographically disjunct populations of Atlantic salmon: The effects of ontogeny and habitat shift. *Functional Ecology*, 9: 448–456.
- Park, PJ, Aguirre, WE, Spikes, DA & Miyazaki, JM 2013, Landmark-Based Geometric Morphometrics: What fish shapes can tell us about fish evolution? *Proceedings of the Association for Biology Laboratory Education*, 34: 361–371.
- Requieron, EA, Torres, MAJ & Demayo, CG 2012, Applications of relative warp analysis in describing of scale shape morphology between sexes of the snakehead fish *Channa striata*. *International Journal of Biological, Ecological and Environmental Sciences*, 1: 2277–4394.
- Riddell, BE, Leggett, WC & Saunders, RL 1981, Evidence of adaptive polygenic variation between two populations of Atlantic Salmon (*Salmo salar*) native to tributaries of the S. W. Miramichi River, N.B. *Canadian Journal of Fisheries and Aquatic Sciences*, 38: 321–333.
- Rohlf, FJ & Slice, D 1990, Extensions of the Procrustes method for the optimal superimposition of landmarks. *Systematic Biology*, 39: 40–59.
- Rohlf, FJ 2005, TpsDig, digitize landmarks and outlines, v. 2.05. Available online: <http://www.life.bio.sunysb.edu/morph> (accessed August 18, 2016).
- Rohlf, FJ, & Marcus, LF 1993, A revolution morphometrics. *Trends in Ecology and Evolution*, 8: 129–132.
- Sfakianakis, DG, Leris I & Kentouri M 2011, Effect of developmental temperature on swimming performance of zebrafish (*Danio rerio*) juveniles. *Environmental Biology of Fishes*, 90: 421–427
- Teimori, A, Schulz-Mirbach, T, Esmaeili, HR & Reichenbacher B, 2012a, Geographical differentiation of *Aphanius dispar* (Teleostei: Cyprinodontidae) from Southern Iran. *Journal of Zoological Systematics and Evolutionary Research*, 50: 251–337.
- Teimori, A, Jawad, JLA, Al-Kharusi, LH, Al-Mamry, JM & Reichenbacher, B 2012b, Late Pleistocene to Holocene diversification and historical zoogeography of the Arabian killifish (*Aphanius dispar*) inferred from otolith morphology. *Scientia Marina*, 76: 637–645.
- Wildekamp, RH 1993, A world of killies. Atlas of the oviparous cyprinodontiform fishes of the world. The genera *Adamas*, *Adinia*, *Aphanius*, *Aphyoplatys* and *Aphyosemion*. *American Killifish Association*, Indiana. 311p.

## گوناگونی های ریختی بدن ماهی و شکل فلس میان جمعیت های کپورماهی دندان دار معمولی *Aphanius dispar* (Cyprinodontidae) بر اساس آنالیز ژئومتریک – مورفومتریک

الف. خسروی، م. شاکر گل‌مکان، الف. تیموری\*

گروه زیست شناسی، دانشکده علوم، دانشگاه شهید باهنر کرمان، کرمان، ایران

(تاریخ دریافت: ۹۵/۰۶/۱۶ تاریخ پذیرش: ۹۵/۱۲/۰۷)

### چکیده

گوناگونی های ریختی بدن ماهی و شکل فلس در بین سه جمعیت از کپورماهی دندان دار معمولی *Aphanius dispar* (Rüppell, 1829) در جنوب ایران از طریق آنالیز ژئومتریک – مورفومتریک مورد مطالعه قرار گرفت. این گونه پراکنش وسیعی در این ناحیه دارد، و بنابراین گوناگونی های ریختی قابل توجهی در بین جمعیت های آلپتريک آن دیده می شود. بر اساس آنالیز تجزیه به مولفه های اصلی (PCA)، گوناگونی های ریختی بدن ماهی در جنس ماده بیشتر مربوط به ناحیه باله پشتی است، در حالیکه در جنس ماده اغلب مربوط به نواحی باله پشتی و ساقه دم است. علاوه بر این، گوناگونی ها در فلس بیشتر مربوط به جلویی ترین ناحیه قدامی فلس و مرز بین قسمت جلویی و پشتی فلس در هر دو سمت چپ و راست فلس می باشد. قسمت های جانبی فلس در ایستگاه I مقعر بوده، در حالیکه در ایستگاههای II و III محدب است. گوناگونی های ریختی مشاهده شده در بدن ماهی و شکل فلس بین سه جمعیت مطالعه شده از کپورماهی دندان دار معمولی احتمالاً بخاطر شرایط اکولوژیکی متفاوت زیستگاههای آنها بویژه گوناگونی در جریان آب می باشد.

\*مؤلف مسئول