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Short Communication

Growth pattern variability in invasive non-indigenous mosquitofish *Gambusia holbrooki* (Girard, 1859) from southern Caspian basin, Iran

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Abstract: The study was conducted to determine the allometry variability of mosquitofish based on 10987 specimens collected from 11 localities in the southern Caspian Sea basin in summer 2021. The estimated b-values range from 2.414 for males from the coastal lagoon of Gorgan Bay to 3.911 for the population from the Sorkhroud River. In the basin, the overall mean of the b coefficient was 3.190±0.413. The growth patterns of most considered groups were positive allometric. The form factor $a_{3.0}$ indicated that body shapes were different between the areas.

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Introduction

The Eastern Mosquitofish, *Gambusia holbrooki*, is native to south-eastern America but now, during translocation, has extensive global distribution. This species was introduced to Iran in the 20th century (1922-1930) as part of a mosquito control program. Because of the tolerance to large changes in ecological conditions and the ability to reproduce rapidly, this species seriously threatens native fishes and aquatic fauna in Iran (Radkhah and Eagderi, 2015, 2023).

One of the key factors to the successful conservation of aquatic biodiversity is understanding life history fundamentals, especially the growth parameters of those invasive species. Among biometric relations in fishes, knowledge of the growth model (i.e., weight-length relationships) is useful for comparing life history and morphological features between fish species or fish populations in different habitats and/or regions (Goncalves et al., 1997). Therefore, data on their functional LWR is important for the interpretation of growth models and for estimating the relative condition factor. In light of this hypothesis, the present contribution describes detailed growth models of Mosquitofish from the southern Caspian basin, Iran.

Materials and Methods

Sampling was performed in 11 regions in the southern Caspian basin, including Golestan Province, southeast of the Caspian Sea: Gomishan lagoon, Golestan Dam Lake, Voshmgir Dam Lake, coastal lagoon of Gorgan Bay, Almagol wetland and Alakoli reservoir; and Mazanderan Province: southern Caspian Sea: Babol River, Shazdehroud stream, Sorkhroud River, Garmroud stream and Talarposht reservoir. The fish were collected using a net, similar to a small beach-seine, with a mesh size of 2 mm during the summer of 2021. The collected specimens were immediately preserved in a 10% formaldehyde solution and transferred to the laboratory.

The estimation of the W-L relationship (WLR) was done by the adjustment of an exponential curve to the data: $W=aL^b$, where W = the total weight (g), L = the total length (cm), a = the intercept (initial growth coefficient or condition factor) and b = the slope (growth coefficient, i.e., fish relative growth rate). The associated degree between variables (W and L) was calculated by the determination coefficient (r^2), and

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Descriptive statistics and estimated parameters of weight-length relationship for *Gambusia holbrooki* (Girard, 1859) from the southern Caspian basin (Mazandaran and Golestan provinces, northern Iran)

Location	Sex	N	Total length (mm) Min-Max. (Mean±SD)	Total weight (g) Min-Max. (Mean±SD)	a	b (confidence interval)	r^2
Gomishan Lagoon (Golestan Province)	Male	148	20-33 (25.7±0.25)	0.129-0.350 (0.22±0.06)	0.018	2.6364 (2.362-2.911)	0.71
	Female	1113	18-58 (34.1±0.68)	0.680-3.830 (0.71±0.47)	0.012	3.186 (3.117-3.256)	0.88
	Total	1261	18-58 (33.1±0.70)	0.129-3.830 (0.65±0.47)	0.011	3.243 (3.182-3.306)	0.89
Golestan Dam Lake (Golestan Province)	Male	201	21-37 (28.0±0.29)	0.156-0.500 (0.27±0.09)	0.013	2.859 (2.669-3.049)	0.81
	Female	1415	15-58 (34.0±0.75)	0.045-3.146 (0.69±0.48)	0.009	3.386 (3.340-3.420)	0.95
	Total	1616	15-58 (33.2±0.73)	0.045-3.146 (0.64±0.47)	0.008	3.421 (3.378-3.455)	0.95
Coastal lagoon of Gorgan Bay (Golestan Province)	Male	320	20-35 (26.0±0.22)	0.100-0.480 (0.23±0.05)	0.022	2.414 (2.206-2.624)	0.62
	Female	1135	15-59 (33.6±0.78)	0.057-3.261 (0.68±0.52)	0.010	3.231 (3.171-3.292)	0.91
	Total	1455	15-59 (31.9±0.77)	0.057-3.261 (0.57±0.49)	0.010	3.236 (3.185-3.287)	0.91
Almagol Wetland (Golestan Province)	Male	321	19-34 (26.3±0.27)	0.079-0.285 (0.20±0.06)	0.015	2.859 (2.720-2.999)	0.92
	Female	1281	13-58 (33.1±0.85)	0.018-3.397 (0.55±0.70)	0.007	3.422 (3.367-3.477)	0.94
	Total	1602	13-58 (30.3±0.80)	0.018-3.397 (0.48±0.64)	0.007	3.446 (3.397-3.496)	0.97
Alakoli Reservoir (Golestan Province)	Male	275	17-34 (24.7±0.70)	0.083-0.401 (0.20±0.29)	0.014	2.858 (2.668-3.049)	0.84
	Female	1132	13-56 (31.5±0.64)	0.048-2.520 (0.52±0.33)	0.016	2.929 (2.874-2.985)	0.92
	Total	1407	13-56 (30.1±0.64)	0.048-2.520 (0.46±0.32)	0.013	3.056 (3.006-3.107)	0.92
Voshmgir Dam Lake (Golestan Province)	Male	261	18-31 (25.0±0.24)	0.079-0.326 (0.22±0.06)	0.016	2.793 (2.657-2.930)	0.86
	Female	899	15-48 (30.9±0.69)	0.069-2.153 (0.56±0.40)	0.014	3.077 (3.024-3.131)	0.93
	Total	1160	15-48 (29.6±0.67)	0.079-2.153 (0.49±0.39)	0.013	3.154 (3.107-3.202)	0.96
Babolroud River (Mazanderan Province)	Male	249	20-32 (26.4±0.27)	0.060-0.350 (0.16±0.06)	0.004	3.658 (3.489-3.826)	0.88
	Female	250	39-58 (44.9±0.35)	0.530-2.090 (1.19±0.24)	0.017	2.551 (2.168-2.958)	0.68
	Total	499	20-58 (35.7±0.98)	0.060-2.090 (0.67±0.54)	0.004	3.790 (3.742-3.838)	0.98
Sorkhroud River (Mazanderan Province)	Male	247	20-32 (24.1±0.19)	0.040-0.350 (0.12±0.05)	0.005	3.549 (3.234-3.864)	0.67
	Female	246	22-56 (37.8±0.63)	0.191-3.162 (0.86±0.53)	0.011	3.201 (3.110-3.292)	0.95
	Total	493	20-56 (39.4±0.83)	0.042-3.160 (0.49±0.52)	0.004	3.937 (3.871-4.003)	0.96
Shazdehroud Stream (Mazanderan Province)	Male	250	19-31 (23.1±0.20)	0.041-0.301 (0.11±0.04)	0.005	3.482 (3.162-3.802)	0.65
	Female	250	24-44 (29.5±0.34)	0.121-1.090 (0.32±0.13)	0.013	2.926 (2.766-3.087)	0.84
	Total	500	19-44 (26.3±0.43)	0.042-1.091 (0.21±0.15)	0.003	3.911 (3.663-4.245)	0.89
Garmroud Stream, Haraz river drainage (Mazanderan Province)	Male	249	19-36 (25.2±0.25)	0.051-0.510 (0.14±0.05)	0.014	2.965 (2.670-3.261)	0.61
	Female	250	31-57 (44.4±0.38)	0.380-2.140 (1.06±0.23)	0.022	2.551 (2.151-2.832)	0.69
	Total	499	19-57 (34.9±1.02)	0.051-2.141 (0.60±0.49)	0.006	3.480 (3.419-3.548)	0.96
Talarposht Reservoir (Mazanderan Province)	Male	248	18-32 (23.3±0.22)	0.040-0.291 (0.10±0.04)	0.005	3.448 (3.160-3.736)	0.69

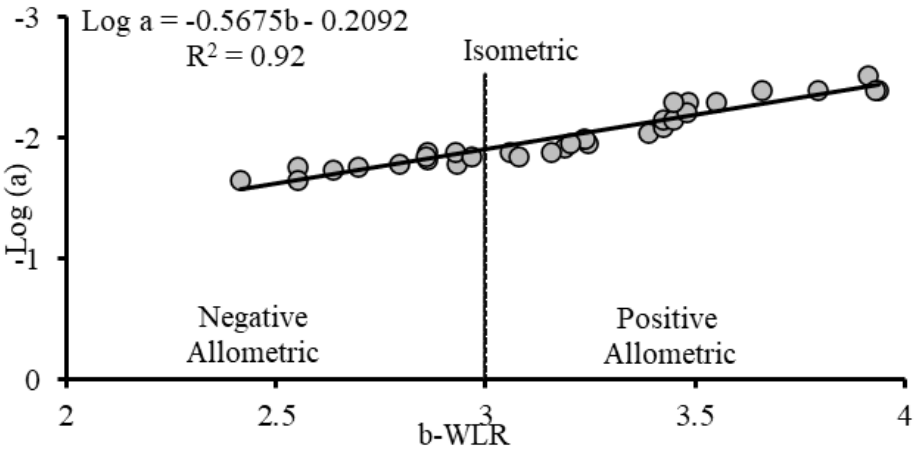

Figure 1. Plot of log a over b for 5 weight–length relationships of *Gambusia holbrooki* in southern Caspian basin, Iran.

Table 2. Parameters of the length-weight relationship of *Gambusia holbrooki* from different regions

Area	sex	b	a	Reference
Segura River basin (tributaries), Spain	Sexes combined	3.370	0.008	Andreu-Soler et al. (2006)
Segura River basin (main watercourse), Spain	Sexes combined	3.590	0.005	Andreu-Soler et al. (2006)
Segura River basin (reservoir), Spain	Sexes combined	3.810	0.004	Andreu-Soler et al. (2006)
Büyükçekmece Dam, Marmara, Turkey	Sexes combined	3.420	0.009	Tarkan et al. (2006)
Ömerli Dam, Marmara, Turkey	Sexes combined	3.490	0.006	Tarkan et al. (2006)
Dinor River Kermanshah	female	3.492	0.06	Sedaghat and Hoseini (2012)
Dinor River Kermanshah	male	2.871	0.05	Sedaghat and Hoseini (2012)
Central Iran	Sexes combined	3.048	0.011	Esmaeli and Ebrahimi (2006)
Tajan River- northern Iran	Female	3.231	0.008	Patimar et al. (2011)
Tajan River- northern Iran	male	2.442	0.015	Patimar et al. (2011)

the statistical significance level of r^2 and 95% confidence limits of the parameters b were estimated (Santos et al., 2002; Lai and Helser, 2004). To determine whether the body shape is significantly different between given species, the form factor ($a_{3.0}$) was calculated according to Froese (2006): $a_{3.0}= 10^{loga-s(b-3)}$ where a and b are the coefficient of LWR's and s is the regression slope of loga vs b.

Results

For this study, 10987 collected specimens from 11 localities in the southern Caspian Sea basin were used to estimate the LWRs. The LWR results are shown in Table 1, along with the coefficient of determination (r^2) and the fish size characteristics. The WLR parameters in Table 1 may be considered an adequate representation of the relationship between the length and weight of the species.

All regressions were highly significant. Estimated b-values are within the range from 2.414 for males from the coastal lagoon of Gorgan Bay to the population (sexes combined) from Sorkhroud River (3.937). Additionally, significant differences were found between males and females in all areas. The overall mean of the b coefficient was 3.190±0.413. Figure 1 shows the relationship of log a with the coefficient value of WLR (b) of the species. The growth patterns of most groups were positive allometric. The form factor $a_{3.0}$ (Fig. 2) indicated that body shape was different between the studied

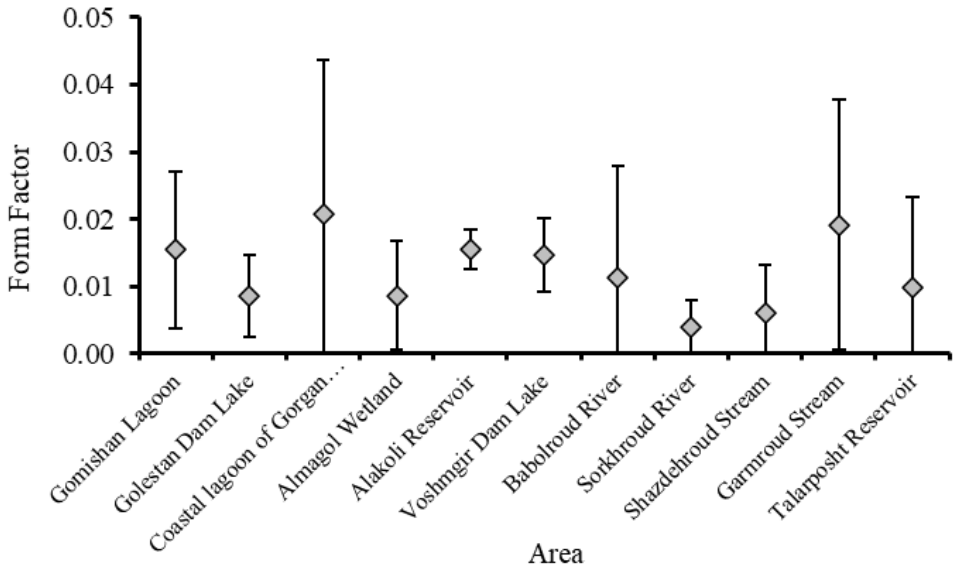

Figure 2. Distribution of form factor a3.0 by body shape for *Gambusia holbrooki* in southern Caspian basin, Iran.

populations.

Discussions

Our results showed that WLRs changed significantly between the studied populations even though the intercept (condition factor) is not very sensitive to small changes in condition (Suthers, 1998). In terms of growth pattern, in this work, 64% of the groups presented positive allometric growth, i.e. b>3 represents fish (64% of considered groups) that become more rotund as length increases, and 36% of groups become less rotund as length increases.

The differences between the b-coefficient in the studied populations reflect a change in their body form, which is probably an effect of different environmental conditions influencing local selective conditions on the fish. The variations could be attributable to species responses to different habitats, a functional adaptation. This variation reveals that those data involve different coefficients of allometry, indicating a presence of modification and instability of the coefficient. The effects of locality and sex for this species were considered for differences in b-value as species responded to different habitats and sexual dimorphism, whereby the species had significantly different LWRs by location and sex.

The coefficient values estimated in the studied populations differ from those found in the Tajan River (one of the southern Caspian rivers) (Patimar et al., 2011). Furthermore, the values in the studied south Caspian basin populations are different from those found in central and western Iran (Esmaeli and Ebrahimi, 2006; Sedaghat and Hoseini, 2012), Turkey (Tarkan et al., 2006) and Spain (Andreu-Soler et al., 2006) (Table 2). This demonstrates that interpopulation variation in the growth model in the Mosquitofish could be at least partly attributed to provenance.

Conclusion

The different b exponent of the *G. holbrooki* species could be a useful indicator for determining the importance of growth variability in exotic invasive species. Therefore, the hypothesis of an allometric pattern common to Mosquitofish must be accepted. Because allometric patterns can differ significantly even between closely related species populations, life history determination of the species, which requires a pattern of growth common to the populations under consideration, should not be applied without prior examination of the variation between populations.

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