

Length-weight and length-length relationships of an established exotic *Gambusia holbrooki* population, from the Anzali Lagoon in the southern Caspian Sea basin

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Abstract. This study describes the length-weight (LWR) and length-length (LLR) relationships for 254 specimens of *Gambusia holbrooki* from the Anzali Lagoon, in the southern Caspian Sea basin. Total length (TL), standard length (SL) and weight were determined. Specimens were collected occasionally in summer 2020 by hand net. The maximum total length and weight of the studied population were 5.6 cm and 3.5 g, respectively. The length-weight parameter b for this species was 3.02, with a high regression coefficient ($r^2 > 0.95$). The LLR was highly significant ($r^2 > 0.99$).

Key Words: exotic fish, Guilan province, livebearer, Poeciliidae, population structure.

Introduction. The Caspian Sea basin belongs to the Ponto-Caspian biogeographical region, encompassing the basins of the Black, Azov, Caspian, and Aral Seas (Coad 2020). The native fish fauna of the Caspian Sea basin consists of an estimated 162 fish species, 100 of them being endemic species or subspecies (Economidis et al 2004; Vasil'eva et al 2015), which are threatened due to the increasing number of exotic species in recent years (Mousavi-Sabet 2018).

The family Poeciliidae includes live-bearing fishes of small size (<200 mm length), having diverse morphology and coloration, with distribution in the freshwater and brackish environments of the eastern United States, South America, and Africa, including Madagascar (Moyle 2002; Nelson 2006). A myriad of poeciliids have been widely and deliberately introduced worldwide for mosquito control (Winfield & Hollingworth 1999), or for the aquarium trade (Crossman & Cudmore 1999) due to their short generation time, colorfulness, hardiness, and readiness to breed in captivity (Moyle 2002). One of the exotic species introduced almost in the entire Iran is the mosquitofish, *Gambusia holbrooki* (Esmaeili et al 2010; Mousavi-Sabet & Eagderi 2014; Jouladeh-Roudbar et al 2015; Mousavi-Sabet 2018). Introduction of the fish into Iranian water bodies dates back a long time, but it was most prominent in the 1920s, when it was introduced to combat malaria spread (Esmaeili et al 2010; Jouladeh-Roudbar et al 2015; Radkhah et al 2016). However, other poeciliids were later introduced into the country due to ornamental fish trade (Mousavi-Sabet & Eagderi 2014; Mousavi-Sabet & Eagderi 2016; Mousavi-Sabet 2018), as these are popular fish species for hobbyists and interesting models for researchers in the country (Faghani-Langroudi et al 2014a; Moshayedi et al 2015a; Moshayedi et al 2015b).

A few research papers have dealt with biological characteristics of exotic species including length-weight (LWR) and length-length (LLR) relationships in Iran. Therefore,

the biology of these nonnatives is barely known in the country. Information on LWR of fishes are a useful tool for biologists for assessing fisheries and their proper management due to providing the estimation of biomass from length observations (Mousavi-Sabet et al 2016a; Heidari et al 2018; Alavi-Yeganeh et al 2018). Fish LWRs are useful for converting length observations into weight estimates to provide some measure of biomass (Froese 1998; Froese 2006; Mousavi-Sabet et al 2015; Mousavi-Sabet et al 2016b). This information is necessary for fisheries management in the area, as well as for estimation of the biomass of the fish species (Froese 2006; Mousavi-Sabet et al 2016c). The LLRs are used to convert length measurements from one length-type into another (Froese 1998, 2006; Faghani-Langroudi et al 2014b; Mousavi-Sabet et al 2016d). The general biology including LWR and LLR for exotic/invasive fish species in Iranian inland waters is barely known (Mousavi-Sabet et al 2013a; Mousavi-Sabet et al 2013b; Heidari et al 2018). The specific objectives of this study were to determine LWR and LLRs of the established exotic *Gambusia holbrooki* from the Anzali Lagoon, in the southern Caspian Sea basin, north of Iran.

Material and Method. Sampling was carried out by hand net (mesh size: 2 mm) during occasional sampling in the summer of 2020, from the Anzali Lagoon, in the southern Caspian Sea basin, north of Iran (37°27'53.91"N, 49°20'26.23"E) (Figure 1). The collected specimens were preserved in 10% formalin after being anesthetized with 1% clove solution and transferred to laboratory for further processing. Total (TL) and standard (SL) lengths (± 1.0 mm) and body weight (W) (± 0.1 g) were recorded for each fish. LWRs were calculated using the formula $W = aL^b$, where W is the total weight (g), L is the TL (cm), and a and b are regression coefficients (Ricker 1973). For LWR with $r^2 < 0.95$, the regression was repeated after removing outliers (Froese 2006). Additionally, 95% confidence limits (CL) of a and b were estimated. The model fit to the data was measured by the coefficients of the Pearson r-squared (r^2) test. Outliers observed in the log-log plots of all species were excluded from the regression. The parameters a and b were estimated by linear regression: $\log(W) = \log(a) + b \log(L)$ (Froese 1998, 2006).

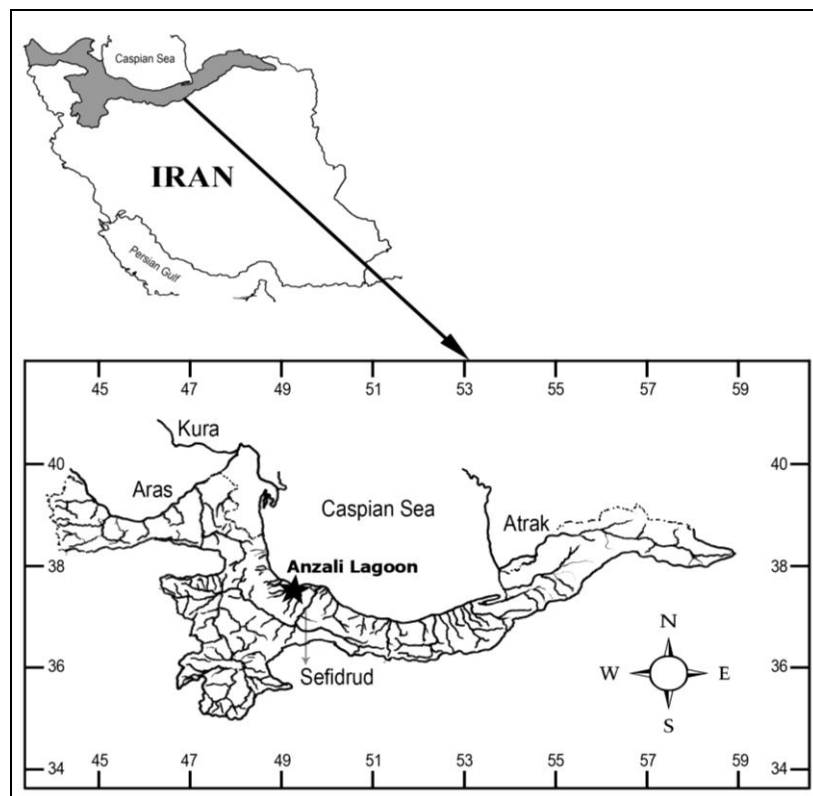


Figure 1. Map of the Iranian portion of the Caspian Sea basin; showing the important rivers system and the Anzali Lagoon (sampling site).

Results and Discussion. A total of 254 individuals (218 females and 36 males) of *G. holbrooki* were included in this LWR and LLR study. Sample descriptive statistics and estimated parameters of LWR are presented in Table 1. Sample size, TL, W, LWR with 95% confidence intervals of a and b with the respective confidence intervals, and the coefficient of correlation (r^2) are also presented. The value of parameter b was 3.02 with r^2 value 0.95. LLRs and the coefficient of determination r^2 are presented in Table 2. In this study, LLR was found to be highly correlated ($r^2 > 0.99$; $p < 0.02$).

Table 1
Descriptive statistics and parameters of length-weight relationships for *Gambusia holbrooki* determined from samples collected in the Anzali Lagoon, the Caspian Sea basin, Iran

Species	n	Length (cm)	Weight (g)	a	b	95% CL a	95% CL b	r^2
<i>G. holbrooki</i>	254	2.2-5.6	0.3-3.5	0.0006	3.02	0.0011-0.0198	2.94-3.59	0.95

Note: n - sample size; a - intercept; b - slope; CL - confidence limits; r^2 - coefficient of determination.

Table 2
Length-length relationship for *Gambusia holbrooki* determined from samples collected in the Anzali Lagoon, the Caspian Sea basin, Iran

Species	TL (cm)	SL (cm)	n	Equation	r^2
<i>G. holbrooki</i>	2.2-5.6	1.8-4.9	254	TL = 0.216+0.889SL	0.99

Note: TL - total length; SL - standard length; n - sample size; r^2 - coefficient of determination.

The parameter b of the studied species was 3.02. According to Bagenal & Tesch (1978), the range of b could be from 2 to 4, and $b=3$ in fish with isometric growth. This study is the first report on LWR and LLR for *G. holbrooki* from the Anzali Lagoon in the Caspian Sea basin and can serve as a baseline for future studies.

There are some differences in the functional regression b value in available data on LWR for *G. holbrooki* from different countries (Table 3).

Table 3
Length-weight relationships for different populations of *Gambusia holbrooki*

n	Sex	Length (cm) /Length type	a	b	r^2	Country	Reference
35	mixed	2.4-4.1 TL	0.0114	3.05	0.876	Iran	Esmaeili & Ebrahimi (2006)
50	mixed	2.3-3.7 TL	0.000008	3.09	0.96	Iran	Eagderi & Radkhah (2015)
25	mixed	1.6-3.1 TL	0.00001	2.99	0.98	Iran	Eagderi & Radkhah (2015)
43	mixed	2.6-5.5 TL	0.000007	3.76	0.96	Iran	Eagderi & Radkhah (2015)
119	mixed	2.4-5.8 TL	0.0008	3.05	0.85	Iran	Mousavi-Sabet & Salehi (2018)
2338	female	1.8-5.9 TL	0.007	3.27	0.966	Spain	Moreno-Valcárcel et al (2012)
1172	male	1.8-4.1 TL	0.007	3.12	0.887	Spain	Moreno-Valcárcel et al (2012)
119	unsexed	2.2-5.7 FL	0.0044	3.81	0.945	Spain	Andreu-Soler et al (2006)
57	unsexed	2-5.7 FL	0.00523	3.59	0.939	Spain	Andreu-Soler et al (2006)
60	unsexed	1.9-4.9 FL	0.00779	3.37	0.861	Spain	Andreu-Soler et al (2006)
19	unsexed	2-4.4 TL	0.0064	3.49	0.948	Turkey	Tarkan et al (2006)
15	unsexed	3.2-4.7 TL	0.0087	3.42	0.97	Turkey	Tarkan et al (2006)
6799	female	0.7-3.9 SL	0.0195	3.02	0.806	USA	Klassen et al (2014)
1181	male	0.9-3.1 SL	0.0145	3.22	0.809	USA	Klassen et al (2014)
18951	mixed	0.7-4.7 SL	0.0172	3.02	0.894	USA	Klassen et al (2014)
254	mixed	2.2-5.6	0.0006	3.02	0.95	Iran	Present study

Note: TL - total length; SL - standard length; FL - fork length; a - intercept; b - slope; r^2 - coefficient of determination.

It is well known that the functional regression b value represents the body form of fish (Ricker 1973; Kalayci et al 2007; Mousavi-Sabet et al 2014; Mousavi-Sabet et al 2017a; Mousavi-Sabet et al 2017b), and it is affected by a number of factors such as gonad maturity, sex, diet, stomach fullness, health, age, fishing time as well as the area and fishing vessels (Wootton 1998); however, these factors were not considered in the present study.

Conclusions. The present study presented basic information on LWR and LLR for an established population of the exotic *G. holbrooki* in Iran, which would be useful for fish biologists to control exotic species in the region. The narrow sample size or the length range possibly affected the b value of the study. Thus, differences in LWRs between this and other studies could be potentially attributed to the combination of one or more of the factors given above.

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Conflict of Interest. The authors declare that there is no conflict of interest.

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