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Length–weight relationships of invasive mosquitofish (*Gambusia holbrooki* Girard, 1859) in 23 river basins of Turkey

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Abstract: *Gambusia holbrooki* Girard, 1859 has established very strong populations in freshwater resources in Turkey after being introduced into Amik Lake (Hatay/Antakya) at the beginning of the 1920s. In this study, it was aimed to determine the female:male ratios and length-weight relationships of *G. holbrooki* populations in Turkey, which are considered as a threat, especially for endemic species. *G. holbrooki* specimen were sampled at total of 66 locations, including 39 lentic and 27 lotic locations, between 2016 and 2017. The female:male ratio was 1:0.39 for all of the investigated localities. Length–weight relationships were investigated at 44 sampling locations for the females and 34 sampling locations for the males. The sampled specimens ranged between 12.7 and 57.2 mm in total length, and 0.03 and 2.88 g in total weight. The length-weight relationship of the female and male *G. holbrooki* specimens indicated mostly isometric growth, whereas the *b* values varied between 1.755 and 4.009, and 2.154 and 3.665 for the females and males, respectively, in terms of the sampling locations.

Key words: Anatolia, freshwater, fish, *b* value, growth parameters

1. Introduction

Turkey, like many other countries around the world, is prone to intense pressure from invasive alien fish species. Turkey comprises special geographic features that have created a high level of biodiversity richness, which makes it extremely fragile in terms of invasive species.

Gambusia holbrooki Girard, 1859 is a global member of the family Poeciliidae (a ovoviviparous topminnow), which is known as mosquitofish. The natural distribution area of this family is North America (Lloyd and Tomasov, 1985; Lloyd, 1987). Today the most well-known species in the family are *G. holbrooki* and *G. affinis*, of which there are currently very strong populations throughout the world. Invasions of these species into other ecosystems are now considered one of the major issues causing serious threats for the sustainability of species diversity (Copp et al., 2005a).

Mosquitofish have extremely high tolerance to different aquatic bodies and a wide habitat preference, and can thus adapt to very different environments (Pyke, 2005). They have strong adaptability to environmental variables; hence, they are able to live in different water quality classes. Lakes, ponds, lagoons, wells, and swamps are among their main habitats and they can live in at temperatures ranging from 4 to 42 °C (Pyke, 2005). They have an extensive salinity tolerance and can survive in waters with 23 ppt salinity (Alcaraz and García-Berthou, 2007). Moreover, they can tolerate extremely low levels of oxygen, and can even survive in polluted waters (Cech et al., 1985).

G. holbrooki was introduced into freshwater resources worldwide for the biological control of malaria at the beginning of the 1920s (Krumholz, 1948). It is a highly invasive species that has been observed in the inland waters of many geographic areas, and has shown many negative effects on ecosystems and native fish fauna (Milton and Arthington, 1983; Rupp, 1996; Howe et al., 1997; Hamer et al., 2002; Ling, 2004; Pyke, 2008; Buttermore et al., 2011). It was the first exotic species introduced into freshwater resources in Turkey (İnnal and Erk'akan, 2006).

Length–weight relationships (LWRs) are fundamental data for a wide range of research, such as presenting growth rates, determining age structures, and many other population parameters. LWRs have several execution areas in almost every type of fishery research. Moreover, these morphological data provide the opportunity to compare the histories and morphological structures of populations that live in different habitats (Moutopoulos and Stergiou, 2002). LWRs enable comparisons to be made between populations of the same species living in different habitats (Sangun et al., 2007). The relationship between the length

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and weight of fish is substantial for designation of the actual and prospective situation of a population (Petrakis and Stergiou, 1995).

G. holbrooki is one of the world's superior invaders[1]. It has a very large distribution in the inland waters of Turkey. In the literature, there are records of *Gambusia* in Balık Lake (Bafra), Gelemen State Hatchery Canals (Samsun), and Aras River State Hatchery Canals (Iğdır) (Kuru, 1975); Yuvarlakçay (Muğla) (Balık et al., 2005); Taflan River (Samsun) (Uğurlu and Polat, 2007); Afyonkarahisar water resources (Yeğen et al., 2007); Eğirdir Lake (Isparta) (Küçük et al., 2009); Apolyont Lake (Bursa) (Berber et al., 2011); Nizip River (Gaziantep) (Birecikligil and Çiçek, 2011); Kırkgöz water resources (Antalya) (Güçlü and Küçük, 2011); and Marmara Lake (Manisa) (İlhan and Sarı, 2015).

As far as is known, more studies of *G. holbrooki* populations, which are found dominantly in almost all natural freshwaters in Turkey, are necessary (Ekmekçi et al., 2013; Özuluğ et al., 2013). To date, the population structure of this species has not been compherensively documented. Although a century has passed since this species was first introduced into the freshwater resources in Turkey, there have been no scientific comperensive studies regarding their populations.

LWR data on *G. holbrooki* in freshwater resources in Turkey remain insufficient. *G. holbrooki* populations in other lakes in Turkey should be investigated in future. In particular, invasive species populations should be monitored regularly.

2. Materials and methods

2.1. Study area and sampling procedure

Sampling was performed in 6 different geographical regions in Turkey, comprising 23 river basins. Fish were sampled using a seine net (3-mm mesh size) and hand net (500-µm mesh size). *G. holbrooki* populations were found in 39 lentic and 27 lotic habitats. The sampling locations at which the *G. holbrooki* specimens were captured are given in Tables 1 and 2. Field study was conducted between April 2016 and November 2017. After sampling, the specimens were euthanized with high doses of phenoxyethanol (1 mL/L), and then preserved in formaldehyde (4%) until laboratory studies were conducted.

2.2. Data analyses

The sex ratio of the *G. holbrooki* population in Turkey was evaluated using the chi-square test (χ^2) (Zar, 1999). The total length (TL) of each *G. holbrooki* specimen was measured with a vernier caliper to the nearest 0.05 mm, and weighed with a digital scale to the nearest 0.01 g. As this species represents sexual dimorphism, male and female specimens were evaluated seperately. Regression analysis was used to determine the relationship between the total length and weight of the species. For the regression, the equation $W = aL^b$ was used (Ricker, 1973). Here, W is the total weight (g), L is the total length (cm), and a (intercept) and b (slope) are regression constants (Zar, 1999) The 95% confidence limits (CLs) of a and b were estimated. Before determination of the LWR equality, the correlation coefficient was calculated (Zar, 1999) and a correlation coefficient significance control test was applied. The t-test was used to determine the growth types for the female and male specimens according to their localities (Pajuelo and Lorenzo, 1998).

3. Results and discussion

3.1. Sex ratio

A total of 2545 *G. holbrooki* specimens were examined (n_{female} = 1833, n_{male} = 712), based on localities that had $n_{samples}$ >30 for the female:male (F:M) ratio (Table 3). The overall F:M ratio of the population was 1:0.39 (X^2_{total} = 659.63, $P < 0.05$), for all of the investigated samples. It was observed that the sex ratio followed a pattern, where the female specimens were dominant at almost all of the localities.

F:M ratios of *Gambusia* populations in different habitats are given in Table 4. According to these previous studies, the minimum F:M ratio was determined as 1:0.23 in Akgöl Lake (Öztürk and İkiz, 2003) and females were dominant in all of the studies, except one in the Rupite Thermal Springs (Zarev, 2012).

Two localities in the present study, Akgöl Lake and Acıgöl-Başmakçı WRs, had been investigated previously with regards to the F:M ratio. The sex ratio in the present study was almost similar (1:0.27) to that of the study (1:0.23) in Akgöl Lake (Öztürk and İkiz, 2003). However, that in the present study was quite different (1:1.36) than the results (1:0.57, 1:0.65, and 1:0.59) reported in 3 different Acıgöl-Başmakçı WRs. The main reason for the differences in these locations may have been related to the sampling size, as the narrow sample size of the present study may have possibly affected the F:M ratio.

The male sex ratios of the *G. holbrooki* populations in Rupite Termal Springs (1:1.11) (Zarev, 2012) and Seyhan Reservoir (1:0.95) (Ergüden, 2013) were higher than those at all of the localities in the present study, except in Acıgöl-Başmakçı WRs and Sünbaş River. The differences between the present study and the 2 other localities may have been caused by the annual range of temperature.

Nikolsky (1980) stated that the sex ratio in fish populations varied for each species, but could be accepted as 1:1. Differences between the sex ratios at different localities may have occurred as a result of the different

[1] ISSG (2013). Global Invasive Species Database (Invasive Species Specialist Group) [online]. Website http://www.iucngisd.org/gisd/100_worst.php [Accessed: 22 July 2016].

Table 1. Information about the lentic sampling localities.

No.	Locality	Region	River basin	Altitude (m)	Latitude	Longitude
G1	Belevi Lake	A	Küçük Menderes	2	38°01′12″	27°28′05″
G2	Kazan Lake	A	Küçük Menderes	3	37°59′12″	27˚16′30″
G2	Sazlıgöl Lake	A	Gediz	2	38°36′07″	26°54′41″
G4	Sülüklügöl Lake	A	Gediz	609	38°34′16″	27°30′00″
G5	Marmara Lake	A	Gediz	74	38°35′55″	27°59′55″
G6	Kırkgöz WRs	Me	Antalya	303	37°06′04″	30°35′10″
G7	Titreyengöl Lake	Me	Antalya	4	36°45′19″	31°27′15″
G8	Seyhan Reservoir	Me	Seyhan	57	37°02′56″	35°18′54″
G9	Mercimek Lake	Me	Ceyhan	25	37°03′26″	35°46′11″
G10	Eber Lake	CA	Akarçay	967	38°36′50″	31°07′41″
G11	Karamık Marsh	A	Akarçay	1007	38°25′40″	30°48′55″
G12	Işıklı Lake	A	Büyük Menderes	816	38°12′16″	29°52′13″
G13	Kocagöl Lake (Muğla)	A	Western Mediterranean	1	36°40′52″	28°49′56″
G14	Akgöl Lake	Me	Western Mediterranean	1	36°41′50″	29°02′08″
G15	Güllük Lagoon	A	Western Mediterranean	0	37°15′16″	27°37′37″
G16	Bafa Lake	A	Büyük Menderes	2	37°28′43″	27°31′23″
G17	Azap Lake	A	Büyük Menderes	3	37°35′19″	27°26′25″
G18	Barutçu Lake	A	Küçük Menderes	1	37°59′38″	27°19′23″
G19	Kocagöl Lake (İzmir)	A	Küçük Menderes	1	37°56′36″	27°19′49″
G20	Gebekirse Lake	A	Küçük Menderes	2	37°59′13″	27°18′07″
G21	Eğirdir Lake	Me	Antalya	917	38°04′47″	30°50′57″
G22	Beyşehir Lake	Me	Konya CB	1123	37°44′36″	31°26′25″
G23	Karakuyu Lake	A	Büyük Menderes	1006	38°03′54″	30°13′26″
G24	Acıgöl-Başmakçı WRs	Me	Burdur Lakes CB	838	37°48′03″	29°53′39″
G25	VRY Reservoir	A	Büyük Menderes	328	37°46′44″	29°07′27″
G26	Güllübağ Reservoir	A	Büyük Menderes	716	38°22′37″	29°02′53″
G27	Uluabat Lake	M	Susurluk	2	40°12′24″	28°27′22″
G28	İznik Lake	M	Marmara	83	40°24′54″	29°21′52″
G29	Gölbaşı Lake (Hatay)	Me	Asi	84	36°30′21″	36°29′47″
G30	Gölbaşı Lake (Adıyaman)	GDA	Ceyhan	883	37°47′40″	37°39′04″
G31	Güllapoğlu Reservoir	M	Meriç	51	41°38′19″	26°37′11″
G32	Mert Lake	M	Marmara	0	41°52′05″	27°58′37″
G33	Poyrazlar Lake	BS	Sakarya	25	40°50′03″	30°28′04″
G34	Sapanca Lake	M	Sakarya	30	40°41′36″	30°16′34″
G35	Efteni Lake	BS	Western Black Sea	118	40°45′15″	31°03′27″
G36	Mogan Lake	CA	Kızılırmak	975	39°46′09″	32°47′00″
G37	Bahçecik Reservoir	CA	Sakarya	894	39°25′17″	31°20′19″
G38	Dicle University Reservoir	GDA	Fırat	686	37°55′17″	40°17′33″
G39	Tahta Köprü Reservoir	GDA	Fırat	403	36°51′25″	36°41′24″

R: region, A: Aegean Region, Me: Mediterranean Region, CA: Central Anatolian Region, SE: Southeastern Region, M: Marmara Region, BS: Black Sea Region, CB: closed basin, WRs: water resources, VRY: Vali Recep Yazıcıoğlu.

Table 2. Information about the lotic sampling localities.

	Locality	Region	River basin	Altitude (m)	Latitude	Longitude
A1	Karpuz River	Me	Western Mediterranean	1	36°43′01″	31°33′09″
A2	Alara River	Me	Antalya	5	36°40′09″	31°39′27″
A3	Sultansuyu	Me	Eastern Mediterranean	3	36°02′31″	32°49′13″
A4	Akgöl Canal	Me	Eastern Mediterranean	2	36°19′16″	33°59′37″
A5	Berdan River	Me	Eastern Mediterranean	27	36°57′13″	34°53′36″
A6	Seyhan River	Me	Seyhan	1	36°45′03″	35°00′30″
A7	Karataş WRs	Me	Seyhan	2	36°35′34″	35°22′53″
A8	Akyatan Lagoon canal 1	Me	Seyhan	1	36°37′57″	35°19′12″
A9	Akyatan Lagoon canal 2	Me	Seyhan	1	36°36′04″	35°22′11″
A10	Sünbaş River	Me	Ceyhan	38	37°23′51″	35°55′11″
A11	Gölyazı Village WRs	CA	Konya CB	918	38°55′19″	33°12′00″
A12	Sarısu River	Me	Western Mediterranean	1	36°43′07″	28°42′43″
A13	Sarısu River 1	Me	Western Mediterranean	2	36°42′52″	28°42′24″
A14	Sarısu River 2	Me	Western Mediterranean	1	36°42′28″	28°42′37″
A15	Kocagöl Canal	A	Western Mediterranean	1	36°41′52″	28°49′04″
A16	Yuvarlakçay River	Me	Western Mediterranean	3	36°54′31″	28°41′50″
A17	Sarıçay River	A	Western Mediterranean	12	37°18′24″	27°42′43″
A18	Söke-Milas Ditch WRs	A	Büyük Menderes	4	37°34′23″	27°21′27″
A19	Pınarbaşı WRs	Me	Burdur Lakes CB	998	37°27′09″	30°03′29″
A20	Narlı River	A	Büyük Menderes	550	38°19′16″	29°06′15″
A21	Gediz River (old canal)	A	Gediz	1	38°36′58″	26°48′56″
A22	Miliç River	BS	Yeşilırmak	4	41°11′06″	37°01′47″
A23	Kızılırmak River	BS	Kızılırmak	1	41°39′49″	36°01′04″
A24	Bakırçay River	A	Northern Aegean	3	38°57′22″	27°00′39″
A25	Kocaçay River	M	Susurluk	17	40°09′44″	27°50′28″
A26	Tatarhüyük WRs	M	Meriç	30	41°33′06″	26°37′13″
A27	Gülbahçe River	A	Gediz	1	38°19′46″	26°39′06″

R: region, A: Aegean Region, Me: Mediterranean Region, CA: Central Anatolian Region, M: Marmara Region, BS: Black Sea Region, CB: closed basin, WRs: water resources.

sampling strategies used in the studies, differences in the sampling tools, microhabitat preferences of the species according to sex (for instance, *G. holbrooki* females and males have special preferences in their microhabitats), and changes in their microhabitat preferences at specific stages of life (for example, at the end of pregnancy, females prefer mostly pebblly areas) (Fernández-Delgado and Rossomanno, 1997).

3.2. Length–weight distributions

Based on the fishery-independent surveys, it was found that the total length of all of the specimens ranged between 12.7 and 57.2 mm. Females and males ranged between 16.7 and 57.2 mm, and 16.4 and 33.7 mm, respectively. According to the surveys, the highest mean total length of the females was found in Pınarbaşı WRs (57.2 ± 19 mm). The highest mean total length of the males was recorded in Güllük Lagoon (16.4 ± 3.0 mm). The total weight of the specimens ranged between 0.03 and 2.88 g for the females, and 0.05 and 0.41 g for the males.

3.3. Length–weight relationships

The LWR parameters were determined for localities where the individual number was sufficient for regression. A total of 1554 *G. holbrooki* specimens (n_{female} = 965, n_{male} = 589) were analyzed with regards to their LWR parameters. The sample size (n), estimated parameters of the LWRs (*a* and *b*), standard error of *b*, r, and $r_{(tcal)}$, growth types, and

Table 3. F:M ratio of the *G. holbrooki* populations in different habitats according to the present study.

Locality	F	M	F+M	F:M	χ^2	Result
Belevi Lake	38	21	59	1:0.55	4.92	P < 0.05
Sazlıgöl Lake	57	19	76	1:0.37	15.34	P < 0.05
Marmara Lake	41	22	63	1:0.54	5.73	P < 0.05
Titreyengöl Lake	88	30	118	1:0.34	28.51	P < 0.05
Mercimek Lake	35	19	54	1:0.54	4.74	P < 0.05
Işıklı Lake	572	104	676	1:0.18	324.00	P < 0.05
Akgöl Lake	45	12	57	1:0.27	19.11	P < 0.05
Azap Lake	40	11	51	1:0.28	16.49	P < 0.05
Barutçu Lake	38	28	66	1:0.74	1.52	P > 0.05
Acıgöl-Başmakçı WRs	14	19	33	1:1.36	0.76	P > 0.05
VRY Reservoir	60	37	97	1:0.62	5.45	P < 0.05
İznik Lake	65	5	70	1:0.08	51.43	P < 0.05
Güllapoğlu Lake	25	15	40	1:0.60	2.50	P > 0.05
Poyrazlar Lake	28	10	38	1:0.36	8.53	P < 0.05
Bahçecik Lake	43	10	53	1:0.23	20.55	P < 0.05
Karpuz River	34	12	46	1:0.35	10.52	P < 0.05
Alara River	103	94	197	1:0.91	0.41	P > 0.05
Seyhan River	61	30	91	1:0.49	10.56	P < 0.05
Akyatan Lagoon canal 1	53	3	56	1:0.06	44.64	P < 0.05
Sünbaş River	26	34	60	1:1.31	1.07	P > 0.05
Sarısu River 2	57	34	91	1:0.60	5.81	P < 0.05
Narlı River	28	19	47	1:0.68	1.72	P > 0.05
Gediz River	77	20	97	1:0.26	33.49	P < 0.05
Miliç River	87	32	119	1:0.37	25.42	P < 0.05
Kızılırmak River	23	5	28	1:0.22	11.57	P < 0.05
Kocagöl River	95	67	162	1:0.71	4.84	P < 0.05
Total	1833	712	2545	1:0.39	659.63	P < 0.05

t_{test} results are given in Tables 5 and 6, for the females and males, respectively.

Due to the sexual dimorphism, the LWR parameters were calculated separately for the female and male specimens. The *b* value varied between 1.755 and 4.009, and 2.154 and 3.665 for the females and males, respectively, in terms of location.

Comparison of the LWRs between the present study and other studies are shown in Table 7. The range of *b* parameters calculated at all of the localities in the current study showed similarity to those of other studies (Sedaghat and Hoseini, 2012; Ergüden, 2013; Eagderai and Radkhah, 2015).

The LWR parameters of *G. affinis* were evaluated in Marmara Lake (İlhan and Sarı, 2015) and Akgöl Lake (Öztürk and İkiz, 2004). In Marmara Lake, the *G. affinis* LWR parameters for all of the specimens were reported as $a = 0.0145$ and $b = 2.945$ (İlhan and Sarı, 2015). In this study, these values were determined as $a = 0.016$ and $b = 2.905$ for the females, and $a = 0.009$ and $b = 3.107$ for the males. According to the results of the t test, there was no difference between the studies (t_{cal}: 0.345; t_{cal}: 0.888, $P < 0.05$).

In the previous study in Akgöl Lake, the LWR parameters were determined as $b = 3.230$ for the females and $b = 3.006$ for the males (*a* value was given logarithmically in the previous study) (Öztürk and İkiz, 2004). In this study, the regression parameters were determined as $a = 0.013$ and $b = 3.126$ for the females, and $a = 0.014$ and $b = 2.719$ for the males, for the population in the same locality. As a

Table 4. F:M ratios of *Gambusia* sp. populations in different studies.

Locality	n	F (%)	M (%)	F:M
Akgöl Lake (Öztürk and İkiz, 2003)[a]	705	81.42	18.58	1:0.23
Dalaman Marshes (Öztürk and İkiz, 2004)[a]	682	71.55	28.45	1:0.40
Ortaca Marshes (Öztürk and İkiz, 2004)[a]	639	70.42	29.58	1:0.42
Seyhan Reservoir (Ergüden and Ergüden, 2008)[a]	224	61.60	38.40	1:0.62
Seyhan Reservoir (Ergüden, 2013)[b]	1582	51.20	48.80	1:0.95
Acıgöl-Başmakçı WRs (Sta. 1) (Yoğurtçuoğlu and Ekmekçi, 2017)[b]	508	63.38	31.62	1:0.57
Acıgöl-Başmakçı WRs (Sta. 2) (Yoğurtçuoğlu and Ekmekçi, 2017)[b]	212	60.37	39.63	1:0.65
Acıgöl-Başmakçı WRs (Sta. 3) (Yoğurtçuoğlu and Ekmekçi, 2017)[b]	214	62.61	37.39	1:0.59
Dolni Bogrov Lake, Bulgaria (Zarev 2012)[b]	213	69.48	30.52	1:0.44
Meriç River (Maritza River), Bulgaria (Zarev 2012)[b]	23	65.22	34.78	1:0.53
Ognyanovo Reservoir, Bulgaria (Zarev 2012)[b]	77	79.22	20.78	1:0.26
Pancharevo Reservoir, Bulgaria (Zarev 2012)[b]	564	67.90	32.10	1:0.47
Potamyata River, Bulgaria (Zarev 2012)[b]	59	76.27	23.73	1:0.31
Rupite Thermal Springs, Bulgaria (Zarev 2012)[b]	148	47.29	52.70	1:1.11
Tunca River, Bulgaria (Zarev 2012)[b]	183	60.65	39.34	1:0.65
Present study	2545	72.02	27.98	1:0.39

a: *G. affinis*, b: *G. holbrooki*, Sta: station, n: number of specimens.

result of the t-test, no difference was found between the studies (t_{cal}: 0.584; t_{cal}: 0.657, $P < 0.05$).

The LWR parameters (*a* and *b*) of a fish could be attributed to the degree of gonad maturity, sex, diet, area/season effects, sampling duration, etc. (Moutopoulos and Stergiou, 2002). It is well known that the *b* value 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). Therefore, the possible reasons for differences in the LWRs between other studies and this study may have been related to the combination of one or more factors given above.

Isometric growth was determined for the female specimens at the majority of the sampled localities. Negative allometric growth was determined for female specimens in Işıklı Lake, Eğirdir Lake, Dicle University Reservoir, and Efteni Lake, whereas positive allometric growth was determined in Azap Lake, Barutçu Lake, Vali Recep Yazıcıoğlu Reservoir, Uluabat Lake, Akyatan Lagoon canal 1, Sarısu Stream 2, Gölbaşı Lake (Adıyaman), Bahçecik Reservoir, Miliç River, and Sapanca Lake.

In the case of negative allometric growth, it may be considered that the fish were experiencing nutritional competition with other species, especially with members of *Aphanius*; for example, as in Eğirdir Lake, where the sampled fish populations occurred as 84.35% *Aphanius iconii*, 3.04% other species, and 12.61% *G. holbrooki*. Another reason for negative allometric growth in females might have been related to the intraspecific competition of *G. holbrooki*, as it was observed that the population was quite crowded in Işıklı Lake (although relative abundance (specimen/m^2) data was not given in this study, it was found as 9.013). The positive allometric growth in some localities may have been related to the pregnancy period; for example, in Azap Lake, females were observed as pregnant.

It was determined that male specimens had isometric growth at almost all of the lentic and lotic localities. Male specimens did not exhibit positive allometric growth at the sampling localities. In Azap Lake and Sarısu River 2, it was observed that, while the female population had positive allometric growth, males had negative allometric growth. This suggested that the females at these localities received food more frequently than the males.

Turkey is an unmatched area for the distribution of biological species (Tarkan et al., 2015) and it is host to 3 of 34 hot spots (Caucasus, Iran-Anatolia, and Mediterranean) worldwide (Şekercioğlu et al., 2011). Most of the freshwater fish species are known as endemic fish (n > 215) within the freshwater fish fauna members (n > 320) of Turkey (Freyhof et al., 2014; Çiçek et al., 2018). However, invasion has become an increasing threat for the permanence of biodiversity (Copp et al., 2005b), and this threat also applies to freshwater fish species distributed in Anatolian freshwaters (Freyhof et al., 2014; Tarkan et al.,

Table 5. Regression parameters of the female specimens obtained from the localities.

		Regression parameters						Growth parameters	
Aegean Region									
No.	n	*a*	SE_a	*b*	SE_b	*r*	$r_{(tcal)}$	t_{test}	GT
G1	30	0.016	0.002	2.922	0.118	0.978	32.60	$t_{cal} = -0.661 < t_{0.05, n = 30} = 2.04$	I
G2	8	0.014	0.002	2.903	0.148	0.992	19.84	$t_{cal} = -0.655 < t_{0.05, n = 8} = 2.31$	I
G3	52	0.012	0.001	3.057	0.106	0.971	32.36	$t_{cal} = 0.537 < t_{0.05, n = 52} = 2.01$	I
G4	45	0.013	0.002	2.875	0.086	0.981	49.05	$t_{cal} = -1.453 < t_{0.05, n = 45} = 2.02$	I
G5	35	0.016	0.002	2.905	0.116	0.975	32.50	$t_{cal} = -0.818 < t_{0.05, n = 35} = 2.03$	I
G11	11	0.013	0.003	3.092	0.161	0.988	19.76	$t_{cal} = 0.571 < t_{0.05, n = 11} = 2.20$	I
G12	40	0.034	0.009	2.353	0.195	0.890	44.50	$t_{cal} = -3.317 > t_{0.05, n = 40} = 1.97$	A (–)
G17	27	0.010	0.001	3.297	0.084	0.992	49.60	$t_{cal} = 3.353 > t_{0.05, n = 27} = 2.05$	A (+)
G18	20	0.010	0.001	3.352	0.060	0.997	99.70	$t_{cal} = 5.866 > t_{0.05, n = 20} = 2.09$	A (+)
G19	10	0.010	0.002	3.256	0.237	0.982	16.36	$t_{cal} = 1.080 < t_{0.05, n = 10} = 2.28$	I
G25	35	0.011	0.001	3.251	0.084	0.989	49.45	$t_{cal} = 2.988 > t_{0.05, n = 35} = 2.03$	A (+)
A20	25	0.016	0.003	2.958	0.119	0.982	32.73	$t_{cal} = -0.352 < t_{0.05, n = 25} = 2.06$	I
A21	30	0.015	0.002	2.904	0.162	0.959	19.18	$t_{cal} = -0.592 < t_{0.05, n = 30} = 2.04$	I
A27	8	0.008	0.001	3.057	0.093	0.997	33.23	$t_{cal} = 0.612 < t_{0.05, n = 8} = 2.31$	I
Mediterranean Region									
G6	6	0.010	0.003	3.303	0.270	0.987	12.33	$t_{cal} = 1.122 < t_{0.05, n = 6} = 2.45$	I
G7	25	0.007	0.003	4.009	0.589	0.817	6.80	$t_{cal} = 1.713 < t_{0.05, n = 25} = 2.06$	I
G9	25	0.010	0.001	3.092	0.122	0.982	32.73	$t_{cal} = 0.754 < t_{0.05, n = 25} = 2.48$	I
G14	15	0.011	0.002	3.173	0.178	0.980	19.60	$t_{cal} = 0.971 < t_{0.05, n = 15} = 2.13$	I
G21	10	0.024	0.010	2.621	0.010	0.944	8.13	$t_{cal} = -37.9 > t_{0.05, n = 10} = 2.28$	A (–)
G29	10	0.013	0.003	2.816	0.261	0.967	10.74	$t_{cal} = -0.704 < t_{0.05, n = 10} = 2.28$	I
A1	34	0.010	0.003	3.280	0.222	0.934	15.56	$t_{cal} = 1.261 < t_{0.05, n = 34} = 2.04$	I
A2	33	0.017	0.003	2.862	0.125	0.972	24.30	$t_{cal} = -1.104 < t_{0.05, n = 33} = 2.04$	I
A4	15	0.013	0.001	3.126	0.066	0.997	49.85	$t_{cal} = -1.909 < t_{0.05, n = 15} = 2.13$	I
A6	15	0.010	0.001	3.172	0.117	0.991	33.03	$t_{cal} = 1.47 < t_{0.05, n = 15} = 2.13$	I
A8	20	0.009	0.001	3.398	0.119	0.989	32.96	$t_{cal} = 3.344 > t_{0.05, n = 20} = 2.09$	A (+)
A10	25	0.018	0.003	2.918	0.129	0.978	24.45	$t_{cal} = -0.635 < t_{0.05, n = 25} = 2.06$	I
A14	39	0.011	0.001	3.199	0.053	0.995	62.18	$t_{cal} = 3.754 > t_{0.05, n = 39} = 2.03$	A (+)
A19	10	0.015	0.001	2.957	0.065	0.988	19.76	$t_{cal} = -0.661 < t_{0.05, n = 10} = 2.28$	I
Southeastern Anatolian Region									
G30	10	0.060	0.001	3.726	0.170	0.992	24.80	$t_{cal} = 4.270 > t_{0.05, n = 10} = 2.28$	A (+)
G38	12	0.013	0.003	2.537	0.209	0.968	13.82	$t_{cal} = -2.215 > t_{0.05, n = 12} = 2.18$	A (–)
G39	16	0.013	0.002	3.104	0.107	0.992	33.60	$t_{cal} = 0.971 < t_{0.05, n = 16} = 2.12$	I
Central Anatolian Region									
G22	7	0.015	0.006	2.845	0.306	0.972	9.25	$t_{cal} = -0.506 < t_{0.05, n = 7} = 2.36$	I
G37	20	0.008	0.001	3.288	0.131	0.986	32.86	$t_{cal} = 2.198 > t_{0.05, n = 20} = 2.09$	A (+)
Black Sea Region									
G33	25	0.013	0.001	2.865	0.085	0.990	49.50	$t_{cal} = -1.588 < t_{0.05, n = 25} = 2.06$	I
G35	9	0.018	0.003	2.571	0.188	0.982	14.02	$t_{cal} = -2.281 > t_{0.05, n = 9} = 2.26$	A (–)
A22	25	0.006	0.001	3.653	0.108	0.990	49.50	$t_{cal} = 6.046 > t_{0.05, n = 25} = 2.06$	A (+)
A23	21	0.016	0.008	2.402	0.589	0.683	4.08	$t_{cal} = -1.015 < t_{0.05, n = 21} = 2.08$	I
Marmara Region									
G28	43	0.011	0.002	3.114	0.253	0.887	12.67	$t_{cal} = 0.45 < t_{0.05, n = 43} = 2.02$	I
G27	15	0.010	0.002	3.366	0.153	0.987	32.90	$t_{cal} = -0.136 < t_{0.05, n = 25} = 2.06$	I
G31	25	0.012	0.001	2.987	0.095	0.989	32.96	$t_{cal} = 2.392 > t_{0.05, n = 15} = 2.13$	A (+)
G32	9	0.034	0.021	1.755	0.707	0.684	2.48	$t_{cal} = -1.76 < t_{0.05, n = 9} = 2.26$	I
G34	35	0.008	0.001	3.434	0.064	0.994	99.40	$t_{cal} = 6.781 > t_{0.05, n = 35} = 2.03$	A (+)
A25	25	0.010	0.001	3.097	0.119	0.983	32.76	$t_{cal} = 0.815 < t_{0.05, n = 25} = 2.06$	I
A26	10	0.018	0.003	2.544	0.241	0.966	10.73	$t_{cal} = -1.892 < t_{0.05, n = 10} = 2.28$	I

$P < 0.05$, WRs: water resources, SE: standard error, cal: calculated, GT: growth type, I: isometric, A: allometric.

Table 6. Regression parameters of the male specimens obtained from the localities.

		Regression parameters						Growth parameters	
Aegean Region									
No.	n	*a*	SE_a	*b*	SE_b	*r*	$r_{(tcal)}$	t_{test}	GT
G1	21	0.008	0.002	3.322	0.281	0.938	11.87	$t_{cal} = 1.145 < t_{0.05, n = 21} = 2.08$	I
G2	9	0.013	0.004	2.879	0.330	0.957	8.70	$t_{cal} = -0.366 < t_{0.05, n = 9} = 2.26$	I
G3	19	0.019	0.006	2.522	0.347	0.870	7.31	$t_{cal} = -1.377 < t_{0.05, n = 19} = 2.09$	I
G5	22	0.009	0.002	3.107	0.183	0.967	19.34	$t_{cal} = 0.584 < t_{0.05, n = 22} = 2.07$	I
G11	11	0.007	0.002	3.558	0.490	0.924	7.27	$t_{cal} = 1.138 < t_{0.05, n = 11} = 2.20$	I
G12	35	0.012	0.003	2.884	0.256	0.891	11.27	$t_{cal} = -0.453 < t_{0.05, n = 35} = 2.03$	I
G15	12	0.010	0.002	2.999	0.236	0.970	11.97	$t_{cal} = -4.237 > t_{0.05, n = 12} = 2.18$	A (–)
G17	11	0.016	0.002	2.587	0.113	0.992	23.61	$t_{cal} = -3.654 > t_{0.05, n = 11} = 2.20$	A (–)
G18	24	0.015	0.002	2.744	0.169	0.961	19.22	$t_{cal} = -1.514 < t_{0.05, n = 24} = 2.06$	I
G19	6	0.009	0.005	3.197	0.674	0.921	4.84	$t_{cal} = 0.292 < t_{0.05, n = 6} = 2.45$	I
G23	15	0.009	0.005	3.203	0.561	0.845	5.70	$t_{cal} = 0.361 < t_{0.05, n = 15} = 2.13$	I
G25	25	0.008	0.002	3.383	0.301	0.920	11.35	$t_{cal} = 1.272 < t_{0.05, n = 25} = 2.06$	I
A20	18	0.015	0.004	2.813	0.276	0.931	10.34	$t_{cal} = -0.677 < t_{0.05, n = 18} = 2.10$	I
A21	21	0.015	0.003	2.752	0.290	0.909	10.10	$t_{cal} = -0.855 < t_{0.05, n = 21} = 2.08$	I
A27	6	0.009	0.011	2.941	1.274	0.756	2.31	$t_{cal} = -0.046 < t_{0.05, n = 6} = 2.45$	I
Mediterranean Region									
G7	20	0.025	0.005	2.154	0.266	0.886	8.12	$t_{cal} = -1.827 < t_{0.05, n = 20} = 2.09$	I
G9	19	0.012	0.003	2.721	0.246	0.937	11.71	$t_{cal} = -1.134 < t_{0.05, n = 19} = 2.09$	I
G14	11	0.014	0.005	2.719	0.418	0.908	6.53	$t_{cal} = -0.672 < t_{0.05, n = 11} = 2.20$	I
G21	19	0.015	0.005	2.659	0.340	0.885	7.90	$t_{cal} = -1.002 < t_{0.05, n = 19} = 2.09$	I
G24	19	0.001	0.003	3.068	0.243	0.951	13.58	$t_{cal} = 0.279 > t_{0.05, n = 19} = 2.09$	I
A1	10	0.014	0.007	2.828	0.476	0.903	5.94	$t_{cal} = -0.361 < t_{0.05, n = 10} = 2.28$	I
A2	30	0.011	0.005	2.964	0.469	0.767	6.33	$t_{cal} = -0.076 < t_{0.05, n = 30} = 2.04$	I
A6	30	0.012	0.002	2.836	0.182	0.947	15.78	$t_{cal} = -0.901 < t_{0.05, n = 30} = 2.04$	I
A10	32	0.013	0.004	2.979	0.335	0.851	9.45	$t_{cal} = -0.062 < t_{0.05, n = 32} = 2.04$	I
A14	30	0.014	0.002	2.648	0.141	0.963	19.26	$t_{cal} = -2.496 > t_{0.05, n = 30} = 2.04$	A (–)
A19	10	0.020	0.006	2.362	0.321	0.933	7.34	$t_{cal} = -1.987 < t_{0.05, n = 10} = 2.28$	I
Southeastern Anatolian Region									
G30	10	0.020	0.006	2.362	0.321	0.933	7.34	$t_{cal} = -1.987 < t_{0.05, n = 10} = 2.28$	I
Central Anatolian Region									
G36	6	0.006	0.002	3.665	0.365	0.981	10.90	$t_{cal} = 1.821 < t_{0.05, n = 6} = 2.45$	I
G37	10	0.006	0.004	3.583	0.750	0.860	4.77	$t_{cal} = 0.777 < t_{0.05, n = 10} = 2.28$	I
Black Sea Region									
G33	10	0.025	0.009	2.115	0.382	0.890	5.52	$t_{cal} = -2.316 > t_{0.05, n = 10} = 2.28$	A (–)
A22	19	0.008	0.003	3.339	0.433	0.882	7.73	$t_{cal} = 0.782 < t_{0.05, n = 19} = 2.09$	I
Marmara Region									
G27	9	0.010	0.005	2.982	0.558	0.896	5.33	$t_{cal} = -0.032 < t_{0.05, n = 9} = 2.26$	I
G31	15	0.014	0.005	2.815	0.333	0.920	8.51	$t_{cal} = -0.555 < t_{0.05, n = 15} = 2.13$	I
A25	25	0.015	0.003	2.698	0.225	0.929	13.27	$t_{cal} = -1.342 < t_{0.05, n = 25} = 2.06$	I

$P < 0.05$, WRs: water resources, SE: standard error, cal: calculated, GT: growth type, I: isometric, A: allometric.

Table 7. Some other LWR data of some studies on *G. holbrooki*.

Locality	Sex	n	b	a	r
Everglades, USA (Klassen et al., 2014)	F	6799	3.020	0.0195	0.806
Everglades, USA (Klassen et al., 2014)	M	1181	3.220	0.0145	0.809
Kashmar, Iran (Eagderai and Radkhah, 2015)	F+M	43	3.086	0.000007	0.979
Sirzar River, Iran (Eagderai and Radkhah, 2015)	F+M	25	2.986	0.00001	0.989
Gamasiab River, Iran (Eagderai and Radkhah, 2015)	F+M	50	3.763	0.000008	0.979
Dinor River Kermanshah, Iran (Sedaghat and Hoseini, 2012)	F	51	3.490	0.05	0.994
Dinor River Kermanshah, Iran (Sedaghat and Hoseini, 2012)	E	59	2.870	0.05	0.916
Doñana Marshlands, Spain (Moreno-Valcárcel et al., 2012)	F	2338	3.270	0.007	0.966
Doñana Marshlands, Spain (Moreno-Valcárcel et al., 2012)	M	1172	3.120	0.007	0.887
Büyük Çekmece Reservoir, Turkey (Tarkan et al., 2006)	F+M	15	3.420	0.008	0.970
Ömerli Reservoir, Turkey (Tarkan et al., 2006)	F+M	19	3.490	0.006	0.948
Seyhan Reservoir, Turkey (Ergüden, 2013)	F	810	2.960	0.012	0.990
Seyhan Reservoir, Turkey (Ergüden, 2013)	M	772	2.659	0.015	0.978
Marmara Lake, Turkey (İlhan and Sarı, 2015)*	F+M	5	2.945	0.014	0.904
Dalaman River, Turkey (Öztürk and İkiz, 2004)*	F	488	3.235	-	0.985
Dalaman River, Turkey (Öztürk and İkiz, 2004)*	M	194	3.347	-	0.945
Ortaca Marshes, Turkey (Öztürk and İkiz, 2004)*	F	450	3.301	-	0.987
Ortaca Marshes, Turkey (Öztürk and İkiz, 2004)*	M	189	2.673	-	0.812
Akgöl Lake, Turkey (Öztürk and İkiz, 2004)*	F	574	3.230	-	0.991
Akgöl Lake, Turkey (Öztürk and İkiz, 2004)*	M	131	3.006	-	0.919
Seyhan Reservoir, Turkey (Ergüden, 2013)	F	810	2.960	0.012	0.990
Seyhan Reservoir, Turkey (Ergüden, 2013)	M	772	2.927	0.012	0.978
Acıgöl-Başmakçı WR, Turkey (Sta. 1) (Yoğurtçuoğlu and Ekmekçi, 2017)	F	322	3.480	0.006	0.993
Acıgöl-Başmakçı WR, Turkey (Sta. 1) (Yoğurtçuoğlu and Ekmekçi, 2017)	M	186	3.270	0.007	0.967
Acıgöl-Başmakçı WR, Turkey (Sta. 2) (Yoğurtçuoğlu and Ekmekçi, 2017)	F	128	3.250	0.007	0.991
Acıgöl-Başmakçı WR, Turkey (Sta. 2) (Yoğurtçuoğlu and Ekmekçi, 2017)	M	84	2.950	0.009	0.986
Acıgöl-Başmakçı WR, Turkey (Sta. 3) (Yoğurtçuoğlu and Ekmekçi, 2017)	F	134	3.330	0.007	0.987
Acıgöl-Başmakçı WR, Turkey (Sta. 3) (Yoğurtçuoğlu and Ekmekçi, 2017)	M	80	3.090	0.008	0.958

**G. affinis*, Sta: station.

2015). As a result of unrestrained studies for biological control and aquaculture activities, this threat has been further exacerbated (Gaygusuz et al., 2015).

Within the actual study, invasive *G. holbrooki* specimens were sampled in larger frequency of occurrence in the freshwater resources of Turkey. The current study showed that, due to its suitability for climatic needs, populations of *G. holbrooki* should be monitored more carefully in Turkey. This was the first study to provide information on the LWRs of *G. holbrooki* inhabiting 23 different river basins of Turkey. The present study considered basic information on the LWRs for an established population of exotic fish species *G. holbrooki* in Turkey, which would be useful for fish biologists to control exotic species in the region. As a further study, the invasion potential in different locations should be investigated.

The best way to effectively and accurately contend with *G. holbrooki* is to increase the number of scientific studies about the species. Studies on the population characteristics of the species should be increased, and the similarities and differences between the population characteristics of other species should be investigated.

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References

Alcaraz C, García-Berthou E (2007). Life history variation of invasive mosquitofish (*Gambusia holbrooki*) along a salinity gradient. Biological Conservation 139 (1-2): 83-92. doi: 10.1016/j.biocon.2007.06.006

Balık S, Ustaoğlu MR, Sarı HM, İlhan A, Topkara ET (2005). Yuvarlakçay (Köyceğiz, Muğla)'ın balık faunası. Ege Journal of Fisheries and Aquatic Sciences 22 (1-2): 221-223 (in Turkish).

Berber S, Şaşı H, Topkara ET, Cengiz Ö (2011). Apolyont Gölü (Bursa) balık faunasının belirlenmesi. Ege Journal of Fisheries and Aquatic Sciences 26 (1): 27-55.

Birecikligil S, Çiçek E (2011). Gaziantep ili sınırları içindeki Fırat ve Asi Havzası akarsuları balık faunası. Biyoloji Bilimleri Araştırma Dergisi (BİBAD), 4 (2): 29-34 (in Turkish).

Buttermore KF, Litkenhaus PN, Torpey DC, Smith GR, Retting JE (2011). Effects of Mosquitofish (*Gambusia affinis*) cues on wood frog (*Lithobates sylvaticus*) tadpole activity. Acta Herpetologica 6 (1): 81-85. doi: 10.13128/Acta_Herpetol-9580

Cech JJ, Massingill MJ, Vondracek B, Linden AL (1985). Respiratory metabolism of mosquitofish, Gambusia affinis: effects of temperature, dissolved oxygen, and sex difference. Environmental Biology of Fishes 13: 297-307.

Copp GH, Bianco PG, Bogutskaya N, Erős T, Falka I et al. (2005a). To be, or not to be, a non-native freshwater fish? Journal of Applied Ichthyology 21: 242-262. doi: 10.1111/ j.1439-0426.2005.00690.x

Copp GH, Kováč V, Ojaveer H, Rosenthal H (2005b). The introduction, establishment, dispers aland impact of introduced non-native fishes. Journal of Applied Ichthology Blackwell Verlag Berlin 21: 241. doi: 10.1111/j.1439-0426.2005.00690.x

Çiçek E, Fricke R, Sungur S, Eagderi, E (2018). Endemic freshwater fishes of Turkey. FishTaxa 3 (4): 1-39.

Eagderi S, Radkhah A (2015). Length–weight relationship and condition factor of Mosquitofish (*Gambusia holbrooki*) in three inland basins of Iran. Poeciliid Research 5 (1): 39-43.

Ekmekçi G, Kırankaya ŞG, Gençoğlu L, Yoğurtçuoğlu B (2013). Türkiye içsularındaki istilacı balıkların güncel durumu ve istilanın etkilerinin değerlendirilmesi. İstanbul Üniversitesi Su Ürünleri Dergisi 28 (1): 105-140 (in Turkish).

Ergüden SA (2013). Age, growth, sex ratio and diet of eastern mosquitofish *Gambusia holbrooki* Girard, 1859 in Seyhan Dam Lake (Adana/Turkey). Iran Journal of Fisheries Science 12 (1): 204-218.

Ergüden SA, Ergüden D (2008). A preliminary research on growth feature of the mosquitofish *Gambusia affinis* (Baird&Girard, 1853) determined in Seyhan Dam Lake (Adana-Turkey). Journal of Fisheries Science 2 (3): 312-320. doi: 10.3153/jfscom.mug.200718

Fernández-Delgado C, Rossomanno S (1997). Reproductive biology of the mosquitofish in a permanent natural lagoon in south-west Spain: two tactics for one species. Journal of Fish Biology 51: 80-92.

Freyhof J, Ekmekçi FG, Ali A, Khamees NR, Özuluğ M et al. (2014). Freshwater Fishes. In: Smith KG, Barrios V, Darwall WRT, Numa C (editors). The Status and Distribution of Freshwater Biodiversity in the Eastern Mediterranean. Cambridge (UK), Malaga (Spain) and Gland (Switzerland): IUCN.

Gaygusuz Ö, Tarkan AS, Aydın H, Dorak Z, Top N et al. (2015). Stocking of common carp (*Cyprinus carpio*) into some newly-established reservoirs of North-West Anatolia may enhance the spread of non-native fish. Turkish Journal of Fisheries and Aquatic Science 15 (4): 833-840. doi: 10.4194/1303-2712-v15_4_06

Güçlü SS, Küçük F (2011). Reproductive biology of *Aphanius mento* (Heckel in : Russegger 1843) (Osteichthyes : Cyprinodontidae) in Kırkgöz Spring (Antalya : Turkey). Turkish Journal of Fisheries and Aquatic Sciences 11 (2): 323-327. doi: 10.4194/trjfas.2011.0217

Hamer AJ, Lane SJ, Mahony MJ (2002). The role of introduced mosquitofish (*Gambusia holbrooki*) in excluding the native green and golden bell frog (*Litoria aurea*) from original habitats in south-eastern Australia. Oecologia 132 (3): 445-452. doi: 10.1007/s00442-002-0968-7

Howe E, Howe C, Lim R, Burchett M (1997). Impact of the introduced Poeciliid *Gambusia holbrooki* (Giarad, 1859) on the growth and reproduction of *Pseudomugil signifer* (Kner, 1865) in Australia. Marine and Freshwater Research 48: 425-434.

İlhan A, Sarı HM (2015). Length–weight relationships of fish species in Marmara Lake, West Anatolia, Turkey. Croatian Journal of Fisheries 73 (73): 30-32. doi: 10.14798/73.1.784

İnnal D, Erk'akan F (2006). Effects of exotic and translocated fish species in the inland waters of Turkey. Reviews in Fish Biology and Fisheries 16 (1): 39-50. doi: 10.1007/s11160-006-9005-y

Klassen JA, Gawlik DE, Botson BA, (2014). Length–weight and length-length relationships for common fish and crayfish species in the Everglades, Florida, USA. Journal of Applied Ichthyology 30 (3): 564-566.

Krumholz LA (1948). Reproduction in the western mosquitofish *Gambusia affinis* and its use in mosquito control. Ecological Monographs 18: 1-43.

Kuru M (1975). Dicle-Fırat Kura-Aras Van Gölü ve Karadeniz Havzası Tatlı Sularında Yaşayan Balıkların (Pisces) Sistematik ve Zoocoğrafik Yönden İncelenmesi, PhD, Atatürk University, Erzurum, Turkey (in Turkey).

Küçük F, Sarı HM, Demir O, Gülle İ (2009). Review of the ichthyofaunal changes in Lake Eğirdir between 1915 and 2007. Turkish Journal of Zoology 33 (3): 277-286. doi: 10.3906/zoo-0811-16

Ling N (2004). *Gambusia* in Newzealand: really bad or just misunderstood?. Newzealand Journal of Marine and Freshwater Research 38 (3): 473-480. doi: 10.1080/00288330.2004.9517254

Lloyd L (1987). An alternative to insect control by "mosquitofish" *Gambusia affinis*. In: St. George TD, Kay BH, Blok J (editors). Proceedings 4th Symposium on Arbovirus Research, Australia : Q.I.M.R. Brisbane, pp. 156-163.

Lloyd LN, Tomasow JF (1985). Taxonomic status of the mosquitofish *Gambusia affinis* (Poeciliidae), in Australia. Australian Journal of Marine and Freshwater Research 36 (3): 447-451. doi: 10.1071/MF9850447

Milton DA, Arthington AH (1983). Reproductive biology of *Gambusia affinis holbrooki* Baird and Giarard, *Xiphophorus helleri* (Gunther) and *X. maculates* (Heckel) Pisces; Poeciliidae) in Queensland, Australia. Journal of Fish Biology 23 (1): 23-41. doi: 10.1111/j.1095-8649.1983.tb02879.x

Moreno-Valcárcel R, Oliva-Paterna FJ, Arribas C, Fernández-Delgado C (2012). Lengthweight relationships for 13 fish species collected in the Doñana marshlands (Guadalquivir estuary, SW Spain). Journal of Applied Ichthyology 28: 663-664.

Moutopoulos DK, Stergiou KI (2002). Length–weight and length–length relationships of fish species from the Aegean Sea (Greece). Journal of Applied Ichthyology 18 (3): 200-203. doi: 10.1046/j.1439-0426.2002.00281.x

Nikolsky GV (1980). Theory of fish population Dynamics, Otto Koeltz Science Publishers, Koenigstein, 323.

Öztürk Ş, İkiz R (2003). Akgöl (Fethiye-Muğla) sivrisinek balığı *Gambusia affinis* (Baird & Girard, 1853) popülasyonunun bazı biyolojik özellikleri. Turkish Journal of Veterinary and Animal Sciences 27 (4): 911-915 (in Turkish).

Öztürk Ş, İkiz R (2004). Some biological properties of mosquitofish populations (*Gambusia affinis*) living in inland waters of the Western Mediterranean region of Turkey. Turkish Journal of Veterinary and Animal Sciences 28: 355-361.

Özuluğ M, Saç G, Gaygusuz Ö (2013). İstilacı özellikteki *Gambusia holbrooki*, *Carassius gibelio* ve *Pseudorasbora parva* (Teleostei) türleri için Türkiye'den yeni yayılım alanları. Turkish Journal of Fisheries and Aquatic Sciences 28 (1): 1-22 (in Turkish).

Pajuelo JG, Lorenzo JM (1998). Population biology of common pandora *Pagellus erythrinus* (Pisces : Sparidae) of the Canary Islands. Fisheries Research 36: 75-86.

Petrakis G, Stergiou KI (1995). Weight–length relationships for 33 fish species in Greek waters. Fisheries Research 21: 465-469.

Pyke GH (2005). A review of the biology of *Gambusia affinis* and *Gambusia holbrooki*. Reviews in Fish Biology and Fisheries 15: 339-365. doi: 10.1007/s11160-006-6394-x

Pyke GH (2008). Plague minnow or Mosquitofish? A review of the biology and impacts of introduced *Gambusia* species. Annual Review of Ecology, Evolution, and Systematics 39: 171-191. doi: 10.1146/annurev.ecolsys.39.110707.173451

Ricker WE (1973). Linear regressions in fishery research. Journal of the Fisheries Research Board of Canada 30(3): 409-434. doi: 10.1139/f73-072

Rupp HR (1996). Adverse assessments of *Gambusia affinis*: an alternative view for mosquito control practitioners. Journal of the American Mosquito Control Association 12: 155-166.

Sangun L, Akamca E, Akar M (2007). Weight-length relationships for 39 fish species from the NorthEastern Mediterranean Coast of Turkey. Turkish Journal of Fisheries and Aquatic Sciences 7: 37-40.

Sedaghat S, Hoseini A (2012). Length–weight and length-length relationships of *Gambusia* (*Gambusia holbrooki*) in the Dinor River Kermanshah, Iran. World Journal of Fish and Marine Sciences 4 (5): 530-532.

Şekercioğlu ÇH, Anderson S, Akçay E, Bilgin R, Can, ÖE et al. (2011). "Turkey's globally important biodiversity in crisis". Biological Conservation 144 (2011): 2752-2769. doi: 10.1016/j.biocon.2011.06.025

Tarkan AS, Gaygusuz Ö, Acıpınar H, Gürsoy Ç, Özuluğ M (2006). Length–weight relationship of fishes from the Marmara region (NW-Turkey). Journal of Applied Ichthyology 22 (4): 271-273. doi: 10.1111/j.1439-0426.2006.00711.x

Tarkan AS, Marr SM, Ekmekçi FG (2015). Non-native and translocated freshwater fish species in Turkey. Fishes in Mediterranean Environments 3: 28.

Uğurlu S, Polat N (2007). Samsun ili tatlı su kaynaklarında yaşayan egzotik balık türleri. Journal of Fisheriessciences 1 (3): 139-151. doi:10.3153/jfscom.2007017

Wootton RJ (1998). Ecology of teleost fishes. Kluwer Academic Publishers, Dordrecht, 396 pp.

Yeğen V, Balık S, Bilçen E, Sarı HM, Uysal R et al. (2007). Afyon ili akarsularında yayılış gösteren balık türleri ve dağılımları. Türk Sucul Yaşam Dergisi Ulusal Su Günleri Year : 3-5, 5 (8): 419-428.

Yoğurtçuoğlu B, Ekmekçi FG (2017). Variation in Life History and Feeding Ecology of the Invasive Eastern Mosquitofish, *Gambusia holbrooki* Girard, 1859 (Poeciliidae), in a Groundwater-dependent Wetland in Turkey. Acta Zoologica Bulgarica 9: 117-130.

Zarev VY (2012). Some life-history traits of *Gambusia holbrooki* (Pisces : Poecilidae) from Bulgaria. Acta Zoologica Bulgarica 64 (3): 263-272.

Zar JH (1999). Biostatistical analysis. 4th ed. Upper Saddle River, NJ, USA: Prentice Hall, 662.