

## Age, growth, sex ratio and diet of eastern mosquitofish *Gambusia holbrooki* Girard, 1859 in Seyhan Dam Lake (Adana/Turkey)

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### Abstract

The aim of this study is to provide necessary information on the biology of mosquitofish in Seyhan Dam Lake in Adana, which is located in southern part of Turkey. The population structure of eastern mosquitofish *Gambusia holbrooki* Girard, 1859 was studied in Seyhan Dam Lake. A total of 1582 specimens (772 males and 810 females) were collected monthly from January to December, 2007. The age composition of the sample range between 0+ and 2+ in both sexes. The sex ratio was M:F= 1:1.04. The length-weight relationship calculated for all individuals, with  $W=0.0129 \times L^{2.927}$ . von Bertalanffy growth parameters were for males,  $L_{\infty}=3.31\text{cm}$ ,  $K=0.6597 \text{ year}^{-1}$ ,  $t_0=0.9483 \text{ year}$ ; for females  $L_{\infty}=6.62\text{cm}$ ,  $K=0.2369 \text{ year}^{-1}$ ,  $t_0=0.9259 \text{ year}$ ; for all samples,  $L_{\infty}=5.84\text{cm}$ ,  $K=0.2369 \text{ year}^{-1}$ ,  $t_0=-1.0740 \text{ year}$ . A total of 102 stomachs were examined and total of organisms identified from alimentary canal. The diet mainly consist of Diptera (Chironomidae (pupa) 29.40%; Diptera (adult) 24.50%), Egg (mosquito 14.70%; different organisms 1.96%), Crustacea (Copepoda 9.80%, Cladocera 3.92%), Coleoptera 4.90%, Hemiptera 1.96%, Fishes (*G. holbrooki* 3.92%), Other Hymenoptera 1.96%, Tricoptera 0.98%, Plecoptera 0.98%, Formicidae 0.98%. These data were conducted to compare with the results of other studies to carry out for other geographic areas.

**Keywords:** Mosquitofish, *Gambusia holbrooki*, Life history, Seyhan Dam Lake, Turkey

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## Introduction

*Gambusia holbrooki* (Cyprinodontiformes, Poeciliidae), originally comes from North America, has been widely used as ecological agent for combating *Anolopheles* spp. larvae. *G. holbrooki* is the most widespread freshwater fish and has been successfully introduced to most of the world (Lloyd, 1986).

The genus *Gambusia* is classified in the family Poeciliidae which is represented by several species. *Gambusia* have become acclimatized in all the South European countries, Germany and Austria included, as well as in China, Japan and Thailand (Sokolov and Chvaliova, 1936). This fish is commonly used as a biological control for mosquitoes (Miura et al., 1984; Kramer et al., 1988; Castleberry and Cech, 1990; Linden and Cech, 1990; Honski et al., 1994). The mosquitofish was brought to Turkey by the French for controlling mosquito and was introduced into Lake Amik (Antakya).

*G. holbrooki* typically occurs in shallow, calm water among dense vegetation near shore (Rosen and Bailey, 1963; Walden, 1964; Goodyear and Ferguson, 1969; Hubbs and Peden, 1969). In addition, the mosquitofish lives in brackish water, standing to slow-flowing water, vegetated ponds and lakes (Page and Burr, 1991; Allen et al., 2002). The mosquitofish is hardly surviving in waters of very low oxygen saturations, high salinities and high temperatures. In habitats where they occur *Gambusia*, are generally common to abundant fish (Vooren, 1972; Berra et al., 1975; Webb and Joss, 1997; Pyke, 2006). They have

adapted to living and feeding at near the surface of the water. Their color varies according to the habitat. But they are usually dark grey or olive on the head and back, becoming lighter on the belly (Al-Hafedh, 2007).

*Gambusia* has varied diet, which includes insect larvae, insects, zooplankton (copepod, cladocer etc.), plants, worms, crustaceans, snails, amphibian eggs, fish eggs and small fish. *Gambusia* are carnivorous, feeding on mosquito larvae and mosquitofish (canibalism), small crustacean, insects, tadpole and mosquitofish, highly damaging to endemic fish and other endemic aquatic life. They are aggressive, and tends to attack other fish and nip their fins, leading to infection or death (Allen et al., 2002).

*Gambusia* species from inland water of Turkey has been reported by scientists (Kuru, 2004; Ozulug et al., 2005a, b, 2007; Ozulug, 2008). There are few studies on the some biological parameters (population structure, age, growth, reproduction and feeding habits) of *G. affinis* were reported by Öztürk and İviz (2003, 2004) and Erguden Alagoz and Erguden (2008), Erguden Alagoz and Goksu (2009).

The presence of *G. holbrooki* has been previously reported in the Seyhan River Basin by Erkakan and Ozdemir (2011) and Onsoy et al. (2011), but there is no information on biology (population structure, age, growth, and feeding habits) in Turkish freshwaters. Up to now, there is one report of a study that investigated the relationship the length-weight of *G.*

*holbrooki* in Omerli and Buyukcekmece Dam Lake (Tarkan et al., 2006).

The objective of the present study was to provide information on the age, growth, sex ratio and diet of the mosquitofish in the Seyhan Dam Lake and compare these results with other studies on mosquitofish.

### Materials and methods

The study was carried out in Seyhan Dam Lake (37°03'38" N; 35°19'32" E), one of the most important reservoirs in the Mediterranean region in Turkey. The lake has a total surface area of 67.82 km<sup>2</sup> and maximum depth 45 m in spring. The average height from the sea is 67 m. The Seyhan Dam Lake is classified as a mesotrophic lake with mean temperature and pH 26.43°C and 7.41, respectively (Cevik et al., 2007).

Samples were monthly collected from January to December, 2007. Fish samples were collected using by dip nets of tulle with a 1mm mesh size. Fish samples were preserved in 4% formalin. Age was determined on 1582 fish (772 males and 810 females) by taking 8-10 scales from each fish. Age determination was done according to Lagler (1966). The age was determined from scales taken from the left side of the body, between the end of pectoral fin and the beginning of the dorsal fin, and then observations were made by using a stereomicroscope with transmitted light.

Von Bertalanffy's (1957) growth-model equations, which require measurement and weighting procedures to obtain averages of length-weight mathematically, were used to determine age-length and age-weight relationships among the age groups. Age-length

relationship (growth parameters  $L_{\infty}$ ,  $k$ ,  $t_0$ ) was assessed by the following equation:

$$L_t = L_{\infty} * (1 - e^{-k(t-t_0)})$$

In order to estimate the length-weight relationship,  $W = a.L_t^b$  (Ricker, 1975) was applied, where  $W$  is the total weight (g),  $L_t$  is total length (cm) and  $a$  (intercept of the relationship) and  $b$  (slope) are parameters of regression. The coefficient of determination ( $r^2$ ) was used as an indicator of the quality of the linear regression (Scherrer, 1984). Additionally, the 95% confidence limits of parameter  $b$  and the statistical significance level for  $r^2$  were estimated. The relationship weight and length was evaluated by analysis of covariance (ANCOVA) for males and females and all specimens. (Sokal and Rohlf, 1981). In the calculation of condition factor ( $C$ ), we used the formula of Fulton's coefficient of condition factors  $C = (W*100)/L^3$  (Ricker, 1975). Differences between condition factors for the female and male groups within the same age groups were tested by t-test. The stomach content was analyzed by using frequency of occurrence (F%), numerical abundance (N%) method as described by Hyslop (1980). Each food organisms were identified in the alimentary canal as a percentage of stomach containing food using various textbooks (Merritt and Cummins, 1996).

### Results

#### *Age structure and sex ratio*

Age was determined based on scales from 1582 eastern mosquitofish specimens caught from Seyhan Dam Lake, and three age groups (0+,1+,2+) were identified in both sexes. 1+ and 2+ year-old fish

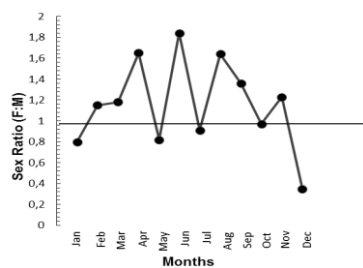
dominated the population. The obtained size-age key is presented in Table 1.

**Table 1: Age-length key of *Gambusia holbrooki* caught in the Seyhan Dam Lake**

Length Groups (cm)	Age groups (year)			Total
	0+	1+	2+	
1.0-1.4	53			53
1.5-1.9	97			97
2.0-2.4		311		311
2.5-2.9		403	237	640
3.0-3.4			152	152
3.5-3.9			91	91
4.0-4.4			61	61
4.5-4.9			94	94
5.0-5.4			73	73
5.5-5.9			10	10
<b>Total</b>	150	714	718	1582
<b>Mean TL</b>	1.54	2.41	3.58	2.85
<b>Std. Dev.</b>	0.02	0.07	0.03	0.02
<b>Males (% n)</b>	117 (7.40)	482 (30.47)	173 (10.93)	772 (48.80)
<b>Females (% n)</b>	33 (2.08)	232 (14.67)	545 (34.45)	810 (51.20)
<b>M:F</b>	1:0.29	1:0.49	1:3.15	1:1.04

The overall sex ratio was 1:1.04 males to females. There was significant difference in monthly sex distribution throughout the year. Catches were predominantly males in

January, May, July and December, whereas females were dominant in the rest of the year (Figure 1).



**Figure 1: Sex ratio (F: M) of eastern mosquitofish from Seyhan Dam Lake during the present study**

### Length frequency and weight distribution

The total length (TL) of all the studied individuals ranged from 1.0 to 5.7 cm (average length  $2.85 \pm 0.23$  cm). Males total length (TL) from 1.0 to 3.3 cm (average,  $2.34 \pm 0.14$  cm) and females from 1.3 to 5.7 cm (average,  $3.35 \pm 0.35$  cm). Length-frequency distribution is shown in Figure 2. Length-frequency distribution indicates that the 2.0 cm length classes had the highest number of males and females

specimens, respectively. The distribution of observed length-at-age data was different between the sexes, and females were found longer than males (ANCOVA,  $P < 0.05$ ). The *G. holbrooki* population in Seyhan Dam Lake consisted of 0+ to 2+ age groups, 45.39% of the samples for combined sexes belong to age group 2+. Total weight (TW) in males and females ranged from 0.01 to 0.49 g and 0.01 to 1.90 g, respectively (Table 2).

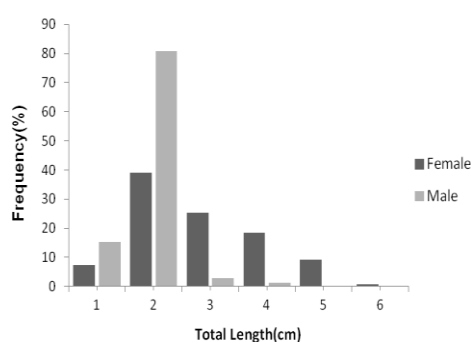


Figure 2: Length-frequency distribution of eastern mosquitofish (n=1582, both sexes combined)

Table 2: Mean total length (cm) and mean total weight (g), standard error (SE) in age groups for eastern mosquitofish in Seyhan Dam Lake

AGE	N	Female		N	Male		N	All samples	
		TL(cm)±SE (TL Range)	W(g)±SE (TW Range)		TL(cm)±SE (TL Range)	W(g)±SE (TW Range)		TL(cm)±SE (TL Range)	W(g)±SE (TW Range)
0+	33	1.72±0.04 (1.30-1.90)	0.06±0.00 (0.01-0.09)	117	1.50±0.02 (1.00-1.90)	0.05±0.00 (0.01-0.07)	150	1.55±0.02 (1.00-1.90)	0.05±0.00 (0.01-0.09)
1+	232	2.51±0.01 (2.00-2.60)	0.19±0.00 (0.08-0.24)	482	2.36±0.01 (2.00-2.60)	0.15±0.00 (0.08-0.22)	714	2.41±0.00 (2.00-2.60)	0.16±0.00 (0.08-0.24)
2+	545	3.82±0.04 (2.70-5.70)	0.76±0.01 (0.25-1.90)	173	2.81±0.01 (2.70-3.30)	0.27±0.00 (0.23-0.49)	718	3.58±0.03 (2.70-5.70)	0.64±0.01 (0.23-1.90)

$$W = 0.0129 * L^{2.927} \quad (r^2 = 0.980; n = 1582)$$

### Length - weight relationship

The length-weight relationship was based on all specimens (both sexes pooled) (Figure 3). The equation for this relationship was:

Length-weight relationships for females and males were based only on the identified individuals from the samples and were as follows:

Females:

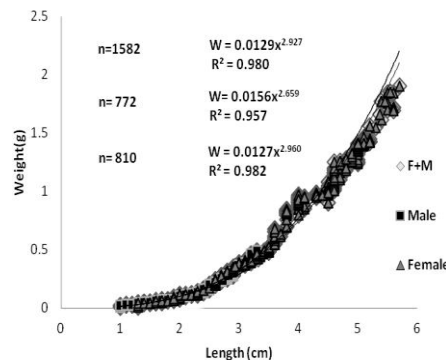
$$W=0.0127*L^{2.960} (r^2=0.982; n=810)$$

Males:

$$W=0.0156*L^{2.659} (r^2=0.957; n=772)$$

The correlation coefficient ( $r$ ) showed that the population growth was highly

correlated. The slopes ( $b$  value) of the length-weight relationship, which were statistically significant for both sexes (ANCOVA,  $P<0.05$ ), indicated negative allometric growth ( $b=2.927$ ).



**Figure 3: Relationship between total length and total weight of all specimens in the present study**

### Growth

The mean lengths of the individuals assigned to each age group were used to fit to von Bertalanffy's growth model. Asymptotic TL for both sexes was 5.84 cm. Males ( $K=0.6597 \text{ year}^{-1}$ ) grew faster than females ( $K=0.2369 \text{ year}^{-1}$ ). Asymptotic values of length ( $L_{\infty}$ ) were higher for females than those for males. The growth equation for the entire sample (both sexes pooled) was found to be:

$$L_t=5.84*[1-e^{-0.2369(t+1.074)}]$$

The VBGF equation for males was:

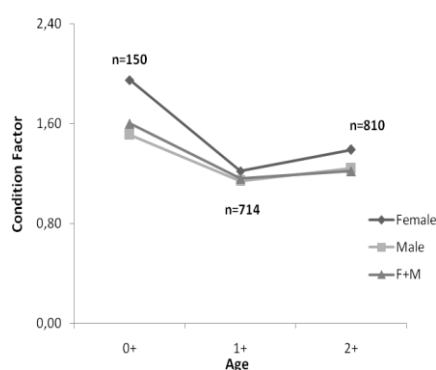
$$L_t=3.31*[1-e^{-0.6597(t+0.9483)}]$$

The VBGF equation for females was:

$$L_t=6.62*[1-e^{-0.2369(t+0.9259)}]$$

### Condition Factor

The condition factors were calculated for age groups and sexes. Maximum values were found to be 1.95 for 0+ age groups females, and 1.51 for 0+ age groups males (Figure 4). Condition values showed increase for 0+ age groups specimens. Average condition factor values were for females 1.52, for males 1.30 and for all samples 1.36. At the same time average condition factor value calculated  $1.38 \pm 0.26$  for *G. holbrooki* entire population.



**Figure 4: Condition factors according to age of eastern mosquitofish in Seyhan Dam Lake**

### Diet

A total of 102 stomachs (females and males) were examined and total of organisms identified from alimentary canal (Merritt and Cummins, 1996). *G. holbrooki* diet was composed of Diptera (Chironomidae (pupa) 29.40%; Diptera (adult) 24.50%, Egg (mosquito 14.70%;

different organisms 1.96%), Crustacea (Copepoda 9.80%, Cladocera 3.92%), Coleoptera 4.90%, Hemiptera 1.96%, Fishes (*G. holbrooki* 3.92%), Other Hymenoptera 1.96%, Tricoptera 0.98%, Plecoptera 0.98%, Formicidae 0.98% (Table 3).

**Table 3: Diet composition of eastern mosquitofish (N%: Numerical composition, F%: Frequency of occurrence)**

Species	N%	F%
<b>Aquatic invertebrates</b>		
<b>Diptera</b>		
Chironomidae (pupa)	33.2	29.4
<b>Hemiptera</b>	24.8	1.96
<b>Coleoptera</b>	0.76	4.90
<b>Tricoptera</b>	2.86	0.98
<b>Plecoptera</b>	0.38	0.98
<b>Crustacea</b>		
Copepoda	2.86	9.80
Cladocera	4.77	3.92
<b>Terrestrial invertebrates</b>		
<b>Diptera</b>	9.92	24.5
<b>Other Hymenoptera</b>	0.95	1.96
Formicidae	0.38	0.98
<b>Fishes</b>		
<i>G. holbrooki</i>	0.38	3.92
<b>Other</b>		
Egg (mosquito)	9.54	14.7
Egg (different organisms)	9.16	1.96

## Discussion

There is very scarce data on the population structure of eastern mosquitofish *G. holbrooki* in the Turkish freshwaters (Tarkan et al., 2006). The maximum length (5.7 cm) was observed in this study slightly more than length of 4.7 cm reported by Tarkan et al. (2006). In this study, females in sizes were greater and heavier than males. The mean length values were similar when compare to values of Ebro delta and Segura River eastern mosquitofish data results (Vargas and Sostoa, 1996; Andreu-Soler et al., 2006). The differences in maximum size of the fish among habitats might be in habitat quality, growth rate, and natural selection. The maximum observed age groups for *G. holbrooki* in this study was 2+ years. Patimar et al. (2011) estimated maximal age of Tajan River (southern Caspian Sea) *G. holbrooki* to be 0+ to 1+ years, while Ozturk and Ikiz (2003) found a maximum age of 0+ to 1+ years for *G. affinis*, in Akgol, Turkey. According to Krumholz (1948), *Gambusia* may live for 4 to 5 years aquaria, but they seldom survive more than 2 years in the wild.

The sex ratio of females to males of *G. holbrooki* from the Seyhan Dam Lake was 1.04:1 (females: males) ( $P < 0.05$ ). This result was different from the values found by Ozturk and Ikiz (2004) in Akgol (4.38:1), Dalaman (2.51:1), and Ortaca (2.38:1) for *G. affinis*. Differences between our and other studies might be attributing from the methodology of collection. Nikolsky (1980) reported that sex ratio varied considerably from species to

species; but in the majority of species, it is close to one. However, subsequent changes in this ratio may be explained by a number of hypotheses, including differences in habitat preference according to the season or sex, sampling errors, or selective mortality (Fernandez and Rossomanno, 1997).

Le Cren (1951), Brown (1957) and Ricker (1975) reported that the *b* value ranged from 2 to 4 and may vary according to age and sexual maturity in fish. In the present study, the *b* value (negative for males:  $b = 2.659$  and negative for females:  $b = 2.960$ ) determined for *G. holbrooki* population in Seyhan Dam Lake, shows (-) allometric growth. The *b* values estimated in the studied population are similar with those reported in the population (negative for males:  $b = 2.442$  and positive for females:  $b = 3.232$ ) from the Tajan River, (central region of the southern Caspian basin, Iran) (Patimar et al., 2011). However the *b* value in the present study was different *G. holbrooki* in both sexes in the Omerli and Buyukcekmece Dam reported by Tarkan et al. (2006) and Segura River basin by Andreu Soler et al. (2006). The difference in the exponents could be attributed to the different sampling area, as well as the differences in age, maturity and sex. A comparison between the growth parameters determined in this study and those found by other previous researchers on *Gambusia* species from different areas is given in Table 4.



**Table4: Comparison of length (TL) (cm) – weight (W) (g) relationships parameters in different areas**

Reference	Locality	n	Sex	$L_{min}$ - $L_{max}$	$W_{min}$ - $W_{max}$	$W = a.L^b$		$r^2$
						a	b	
Present study	Seyhan Dam L.	1582	mixed	1.0-5.7	0.01-1.90	0.0129	2.92	0.980
Andreu Soler et al., 2006	Segura River Basin (Spain) (tributaries)	60	mixed	1.9-4.9	-	0.0078	3.37	0.861
Andreu Soler et al., 2006	Segura River Basin (Spain) (main watercourse)	57	mixed	2.0-5.7	-	0.0052	3.59	0.938
Andreu Soler et al., 2006	Segura River Basin (Spain) (reservoirs)	119	mixed	2.2-5.7	-	0.0044	3.81	0.944
Esmaeli and Ebrahimi, 2006	Iran fresh waters	35	mixed	2.4-4.1	-	0.0114	3.04	0.936
*Erguden Alagoz and Erguden 2008	Seyhan Dam Lake	224	mixed	1.0-4.0	0.01-0.70	0.0178	2.55	0.906
*Koutrakis and Tsikliras, 2003	Rihios estuary, NW Aegean	671	unsexed	1.0-5.1	-	0.0084	3.38	0.973
*Ozturk and Ikiz, 2003	Fethiye –Akgöl	705	mixed	1.3-5.5	0.02-2.31	0.0190	3.23	0.998
*Ozturk and Ikiz, 2004	Dalaman	682	mixed	1.7-5.5	0.06-2.58	0.0084	3.27	0.982
*Ozturk and Ikiz, 2004	Ortaca	639	mixed	1.3-5.8	0.02-5.83	0.0096	3.27	0.974
Patimar et al., 2011	Tajan River (Iran)	744	mixed	1.5-5.0	0.06-1.59	0.0080	3.23	0.813
Tarkan et al., 2006	Omerli Dam (Turkey)	19	mixed	2.0-4.4	-	0.0064	3.49	0.948
Tarkan et al., 2006	Buyukcekmece Dam (Turkey)	15	mixed	3.2-4.7	-	0.0087	3.42	0.970

\*LWRs reported for *G. affinis* in FishBase (Froese and Pauly, 2012)

The overall growth rates, indicated by the von Bertalanffy growth coefficient, were similar within the range of results from previous investigators. In our computations, the asymptotic length of

mosquitofish was  $L_{\infty} = 3.31$  cm (males) and  $L_{\infty} = 6.62$  cm (females). Beaudouin et al. (2008) estimated  $L_{\infty} = 5.77$  cm TL, for females and  $L_{\infty} = 2.50$  for males in Brittany, France. It is clear that there must

be some differences between the growth characteristics from one area to another because of quantity and quality of food and hydrographical and climatic conditions (Wotton, 1990).

Average condition factor value was  $1.38 \pm 0.26$  for *G. holbrooki* entire population in the present study. Previously Erguden (Alagoz) and Erguden (2008) worked in Seyhan Dam Lake and reported a similar condition factor value ( $1.28 \pm 0.04$ ) for *G. affinis*. The small differences that were not statistically significant may have originated from species and number of fish sampled.

The present finding showed that *G. holbrooki* is carnivore, feeds on *Diptera* (adult and Chironomidae (pupa)), Crustacea, Fish and Fish egg that densely inhabits in the habitat. Sokolov and Chvaliova (1936) mentioned that Anopheles, Cladocera, Coleoptera, Rotatoria and Acarina are Chironomidae are the major food items, whereas; Ephemeroptera, Algae, Copepoda, Trichoptera are minor food items for *G. affinis* from the rice field of Turkestan. Arthington (1989) and Etnier and Starnes (1993) indicated that mosquitofish ingest a wide range of terrestrial and aquatic insects, crustaceans, and other invertebrates. Ozturk and Ikiz (2003) reported that stomach content of *G. affinis* was determined Diptera (mosquito larvae), Diptera species, Nereidae, Amphipoda, Formicidae, Coleoptera, Carabidae, Homoptera, Odonata, Hymenoptera, fish (*G. affinis*) and Coccinellidae. In addition, Garcia-Berthou (1999) reported that stomach content of *G. holbrooki*

determined other plants (algae), terrestrial insects and crustaceans rather than mosquito in Lake Banyoles (Spain). However, Margaritora et al. (2001) mentioned that in most habitats, eastern mosquitofish diet consists of zooplankton, namely ostracods and copepods (Soto and Hurlbert, 1991), with a preference for cladocerans in many biotopes, such as seminatural ponds (Miura et al., 1979), rice fields (Blaustein and Karban, 1990), and drainage channels (Crivelli and Boy, 1987).

The present study showed that both similarities and differences with other studies related to the stomach content of *G. holbrooki* and *G. affinis*. Many factors could have effected the amount and type of food found in the stomach content of mosquitofish. For example, we only sampled fish during late morning and early afternoon. This fish species could be fed differently at different times of the day.

In conclusion, the mosquitofish are found in several natural and dam lakes in Turkey. The present study provides some basic information about the population structure (age, growth, sex) and gives first information on the feeding habits of eastern mosquitofish, *G. holbrooki* in Seyhan Dam Lake. We hope that our results will contribute to the other studies on this species to be carried out in future.

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**References**

- Andreu-Soler, A., Oliva-Paterna F. J. and Torralva, M., 2006.** A review of length-weight relationships of fish from the Segura River basin (SE Iberian Peninsula). *Journal of Applied Ichthyology*, 22, 295-296.
- Al-Hafedh, S. Y., 2007.** An Ecobiological study of the mosquitofish, *Gambusia affinis*, from the Eastern Province of Saudi Arabia. *Saudi Journal of Biological Science*, 14, 115-122.
- Allen, G. R., Midgley, S. H. and Allen, M., 2002.** Field guide to the freshwater fishes of Australia. Western Australian Museum, Perth, Western Australia. 394P.
- Arthington, A. H., 1989.** Diet of *Gambusia affinis holbrooki*, *Xiphophorus helleri*, *X. maculatus*, and *Poecilia reticulata* (Pisces: Poeciliidae) in streams of southeastern Queensland, Australia. *Asian Fisheries Science*, 2, 193-212.
- Beaudouin, R., Ginot, V. and Monod, G., 2008.** Growth characteristics of eastern mosquitofish *Gambusia holbrooki* in a northern habitat (Brittany, France). *Journal of Fish Biology*, 73, 2468-2484.
- Berra, T. M., Moore, R. and Reynolds, L.F., 1975.** The freshwater fishes of the Laloki River System of New Guinea. *Copeia*, 3, 316-326.
- Beverton, R. J. H. and Holt, S. J., 1959.** A review of the lifespans and mortality rates of fish in nature and their relation to growth and other physiological characteristics. In: Wolstenholme GEW, O'Connor M, eds. CIBA Foundation colloquia on ageing: the lifespan of animals. Volume 5. J & A Churchill Ltd, London. pp. 142-180.
- Blaustein, L. and Karban, R., 1990.** Indirect effects of the mosquitofish *Gambusia affinis* on the mosquito *Culex tarsalis*. *Limnology and Oceanography*, 35, 767-771.
- Brown, M.E., 1957.** Experimental studies on growth. In: Brown ME, ed. The physiology of fishes. Metabolism. Academic Press, New York. pp. 361-400.
- Castleberry, D. T. and Cech, J. J., 1990.** Mosquito control in wastewater: a controlled and quantitative comparison of pupfish {*Cyprinodon nevadensis amargosae*}, mosquitofish (*Gambusia affinis*) and guppies (*Poecilia reticulata*) in Sago pondweed marshes. *Journal of the American Mosquito Control Association*, 6, 223-228.
- Cevik, F., Derici, B. O., Koyuncu, N. and Tugyan, C., 2007.** Water quality and its relation with

- Chlorophyll-*a* in dry season, in a reservoir of Mediterranean region. *Asian Journal of Chemistry*, 19, 2928-2934.
- Crivelli, A. J. and Boy, V., 1987.** The diet of mosquitofish *Gambusia affinis* (Baird & Girard) (Poeciliidae) in Mediterranean France. *Journal of Ecology*, 42, 421-435.
- Dulcic, J. and Glamuzina, B., 2006.** Length-weight relationships for selected fish species from three eastern Adriatic estuarine systems (Croatia). *Journal of Applied Ichthyology*, 22, 254-256.
- Erguden Alagoz, S. and Erguden, D., 2008.** A Preliminary Research on Growth Feature of the Mosquitofish (*Gambusia affinis* (Baird and Girard, 1853) Determined in Seyhan Dam Lake (Adana-Turkey). *Journal of Fisheries Sciences.com*, 2 (3), 312-320.
- Erguden Alagoz, S. and Goksu, M. Z. L., 2009.** Length-weight relationships for 12 fish species caught in Seyhan Dam Lake in southern Anatolia, Adana, Turkey. *Journal of Applied Ichthyology*, 25, 501-502.
- Etnier, D. A. and Starnes, W. C., 1993.** The Fishes of Tennessee. The University of Tennessee Press, Knoxville, Tennessee.
- Erkakan, F. and Ozdemir, F., 2011.** Revision of the fish fauna of the Seyhan and Ceyhan River basins in Turkey. *Research Journal of Biological Sciences*, 6(1), 1-8.
- Esmaeli, H. R. and Ebrahimi, M., 2006.** Length-weight relationships of some freshwater fishes of Iran. *Journal of Applied Ichthyology*, 22, 328-329.
- Fernandez-Delgado, C. and 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.
- Froese, R. and Pauly, D. (Eds), 2012.** Fishbase. WorldWide Web electronic publication, <http://www.fishbase.org>. Version (03/2012).
- García-Berthou, E., 1999.** Food of introduced mosquitofish: ontogenetic diet shift and prey selection. *Journal of Fish Biology*, 55, 135-147.
- Goodyear, C. P. and Ferguson, D. E., 1969.** Sun-compass orientation in the mosquitofish, *Gambusia affinis*. *Animal Behaviour*, 17, 636-640.
- Homski, D., Goren, M. and Gasith, A., 1994.** Comparative evaluation of the larvivorous fish *Gambusia*

- affinis* and *Aphanius dispar* as mosquito control agents. *Hydrobiologia*, 284, 137-146.
- Hubbs, C. and Peden, E., 1969.** *Gambusia georgii* sp. nov. from San Marcos, Texas. *Copeia*, 1969, 357-364.
- Hyslop, E. J., 1980.** Stomach content analysis: a review methods and their application. *Journal of Fish Biology*, 17, 411-429.
- Koutrakis, E. T. and Tsikliras, A. C., 2003.** Length–weight relationships of fishes from three northern Aegean estuarine systems (Greece). *Journal of Applied Ichthyology*, 19, 258-260.
- Kramer, V. L., Garcia, R. and Colwell, A.E., 1988.** An evaluation of *Gambusia affinis* and *Bacillus thuringiensis* var. *israelensis* as mosquito control agents in California wild rice fields. *Journal of the American Mosquito Control Association*, 4, 470-478.
- Krumholz, L. A., 1948:** Reproduction in the western mosquitofish *Gambusia affinis affinis* (Baird and Girard), and its use in mosquito control. *Ecological Monographs*, 18, 1- 43.
- Kuru, M., 2004.** Türkiye içsu balıklarının son sistematik durumu. *Gazi Eğitim Fakültesi Dergisi*, 3, 1-21.
- Lagler, K. F., 1966.** Freshwater fishery biology. W.M.C. Brown Company Publishers, Iowa. pp. 131-159.
- Le Cren, E. D., 1951.** The length-relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*). *Journal of Animal Ecology*, 20, 210-218.
- Linden, A. L. and Cech, J. J., 1990.** Prey selection by mosquitofish (*Gambusia affinis*) in California rice fields: effect of vegetation and prey species. *Journal of the American Mosquito Control Association*, 6, 115-120.
- Loyd, L., 1986.** An alternative to insect control by ‘mosquitofish’, *Gambusia affinis*. *Arbovirus Research, Australia*, 1986,156-163.
- Margaritora, F. G., Ferrara, O. and Vagaggini, D., 2001.** Predatory impact of the mosquitofish (*Gambusia holbrooki* Girard) on zooplanktonic populations in a pond at Tenuta di Castelporziano (Rome, Central Italy). *Journal of Limnology*, 60(2), 189-193.
- Merritt, R. W. and Cummins, K. W., 1996.** An introduction to the aquatic insects of North America. In: Merritt RW, Cummins KW, eds, Kendall-Hunt Publishing Company, Dubuque, Iowa. 862 p.
- Miura, T., Takahashi, R. M. and Stewart, R.J., 1979.** Habitat and food selection by the mosquitofish

- Gambusia affinis*. *Proceeding of the California Mosquito Vector Control Association*, 47, 46-50.
- Miura, T., Takahashi, R. M. and Wilder, W. H., 1984.** Impact of the mosquitofish (*Gambusia affinis*) on a rice field ecosystem when used as a mosquito control agent. *Mosquito news*, 44, 510-517.
- Nikolsky, G. V., 1980.** Theory of fish population dynamics. Otto Koeltz Science Publishers, Koenigstein. 323 p.
- Onsoy, B., Filiz, H., Tarkan, A. S., Bilge, G. and Tarkan, A. N., 2011.** Occurrence of non-native fishes in a small man-made lake (Lake Ula, Muğla): Past, present, future perspectives. *Turkish Journal of Fisheries and Aquatic Sciences*, 11, 209-215.
- Ozturk, S. and Ikiz, R., 2003.** Some biological properties in the Akgöl (Fethiye-Muğla) population of the mosquitofish *Gambusia affinis* (Baird and Girard, 1853). *Turkish Journal of Veterinary and Animal Science*, 27, 911-915.
- Ozturk, S. and Ikiz, R., 2004.** Some biological properties of the mosquitofish populations (*Gambusia affinis*) living in inland waters of the Western Mediterranean Region of Turkey. *Turkish Journal of Veterinary and Animal Science*, 28, 355-361.
- Ozulug, M., Altun, O. and Meric, N., 2005a.** On the fish fauna of Lake İznik (Turkey). *Turkish Journal of Zoology*, 29, 371-375.
- Ozulug, M., Acipinar, H., Gaygusuz, O., Gürsoy, C. and Tarkan, A. S., 2005b.** effects of human factor on the fish fauna in a drinking-water resource (Ömerli Dam Lake-Istanbul, Turkey). *Research Journal of Agriculture and Biological Sciences*, 1, 50-55.
- Ozulug, M., Tarkan, A. S., Gaygusuz, O. and Gursoy, C., 2007.** Two new records for the fish fauna of Lake Sapanca Basin (Sakarya, Turkey). *Journal of Fisheries Sciences*, 1(3), 152-159.
- Ozulug, M., 2008.** The fish fauna of the Durusu Lake Basin (İstanbul-Turkey). *IUFS Journal of Biology*, 67(1), 73-79.
- Page, L. M. and Burr, B. M., 1991.** A field guide to freshwater fishes of North America north of Mexico. Houghton Mifflin Company, Boston. 432 p.
- Patimar, R., Ghorbani, M., Gol-Mohammadi, A. and Azimi-Glugahi, H., 2011.** Life history pattern of mosquitofish *Gambusia holbrooki* (Girard, 1859) in the Tajan River (Southern Caspian Sea to Iran). *Chinese Journal of Oceanology and Limnology*, 29(1), 167-173.

- Pyke, G. H., 2006.** A review of the biology of *Gambusia affinis* and *G. holbrooki*. *Reviews in Fish Biology and Fisheries*, 15, 339-365.
- Ricker, W. E., 1975.** Computation and Interpretation of Biological Statistics Fish Populations. *Bulletin Fisheries Research Board of Canada*, 191, 1-382.
- Rosen, D. E. and Bailey, R. M., 1963.** The Poeciliid fishes (Cyprinodontiformes), their structure, zoogeography, and systematics. *Bulletin of the America Museum of Natural History*, 126, 1-176.
- Scherrer, P., 1984.** Biostatistique, Morin, Montreal, Paris. SPSS Inc., 1999. Systat version 9. SPSS. Inc., USA.
- Sokal, R. R. and Rohlf, F.J., 1981.** Biometry. In: Fremann WH and Co., eds, San Fransisco, 766 p.
- Sokolov, N. P. and Chvaliova, M.A., 1936.** Nutrition of *Gambusia affinis* on the rice fields of Turkestan. *The Journal of Animal Ecology*, 5(2), 390-395.
- Soto, D. and Hurlbert, S. H., 1991.** Long-term experiments on calanoid-cyclopoid interaction. *Ecological Monograph*, 61, 245-265.
- Tarkan, A. S., Gaygusuz, O., Acipinar, H., Gürsoy, C. and Ozulug, M., 2006.** Length-weight relationship of fishes from the Marmara region (NW-Turkey). *Journal of Applied Ichthyology*, 22, 271-273.
- Walden, H. T., 1964.** Familiar Freshwater Fishes of America. In: Walden HT, ed, Harper & Row, New York. 324 p.
- Webb, C. and Joss, J., 1997.** Does predation by the fish *Gambusia holbrooki* (Atheriniformes: Poeciliidae) contribute to declining frog populations. *Australian Zoologist*, 30, 316-324.
- Wotton, R. J., 1990.** Ecology of teleost fishes. Chapman and Hall, England, 392 p.
- Vargas, M. J. and Sostoa, A. 1996.** Life history of *Gambusia holbrooki* (Pisces, Poeciliidae) in the Ebro delta (NE Iberian peninsula). *Hydrobiologia*, 341(3), 215-224.
- von Bertalanffy, L., 1957.** Quantitative laws in metabolism and growth. *The Quarterly Review of Biology*, 32(3), 217-231.
- Vooren, C. M., 1972.** Ecological aspects of the introduction of fish species into natural habitats in Europe, with special reference to the Netherlands. *Journal of Fish Biology*, 4, 565-583.