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Some Biological Properties of Mosquitofish Populations (*Gambusia affinis*) Living in Inland Waters of the Western Mediterranean Region of Turkey*

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Abstract: *Gambusia affinis*, Baird & Girard, 1853, originally comes from North America and has been distributed all over the world for the biological control of mosquitoes. This study aimed to determine some biological properties, such as structure, age, growth and reproduction of the populations of *G. affinis* in Turkey. For this purpose, between November 1998 and October 1999, 2026 mosquitofish were caught in the wetlands of Fethiye-Akgöl, Dalaman and Ortaca in Muğla province in the western Mediterranean region of Turkey and the data found were compared. In the Fethiye-Akgöl population the percentage of the 0+ age group was 97.59%, and of the 1+ age group was 2.41%; in the Dalaman population percentage of the 0+ age group was 99.71%, and of the 1+ age group was 0.29%; in the Ortaca population percentage of the 0+ age group was 94.37%, and of the 1+ age group was 5.63%. The mosquitofish population in Fethiye was 81.42% female and 18.58% male, in Dalaman 71.55% female and 28.45% male, and in Ortaca 70.42% female and 29.58% male. Total length (TL) in the Fethiye-Akgöl population was 1.3-5.5 cm, in Dalaman 1.7-5.5 cm and in Ortaca 1.3-5.8 cm; and total weight (W) in Fethiye-Akgöl was 0.02-2.31 g, in Dalaman 0.06-2.58 g and in Ortaca 0.02-5.83 g. In each population the gonadosomatic index (GSI) increased in March and April, had a slight decrease in May and increased again in mid May. At the beginning of January the GSI of the Fethiye population started to decrease again and the GSI decreased in Dalaman and Ortaca populations beginning in mid July. This shows that the mosquitofish is a bivoltine species. The average number of eggs belonging to each age group was 21.90 (0+) and 52.81 (1+) in Fethiye, 27.11 (0+) and 91.0 (1+) in Dalaman, and 28.24 (0+) and 81.78 (1+) in Ortaca. Average fecundity per gram was between 27.71 (0+) and 31.71 (1+) in Fethiye-Akgöl, between 42.97 (0+) and 39.99 (1+) in Dalaman, and between 35.28 (0+) and 37.39 (1+) in Ortaca.

Key Words: Mosquitofish, *Gambusia affinis*, population structure, age, growth, reproduction, Muğla, Turkey

Türkiye'nin Batı Akdeniz Bölgesinin İç Sularında Yaşayan Sivrisinek Balığı (*Gambusia affinis*) Populasyonlarının Bazı Biyolojik Özellikleri

Özet: Asıl vatanı Kuzey Amerika olan *Gambusia affinis*, Baird & Girard, 1853, sivrisineklere karşı biyolojik savaşım için tüm dünyaya dağıtılmıştır. Bu çalışma ile, Türkiye *G. affinis* populasyonlarının yapısı, yaş, büyüme ve üreme gibi bazı biyolojik özelliklerini belirlemeyi amaçladık. Bu amaçla, Türkiye'nin Batı Akdeniz Bölgesi'nde bulunan Muğla'nın Fethiye-Akgöl, Dalaman, Ortaca bölgelerindeki sulak alanlardan Kasım 1998 ve Ekim 1999 tarihleri arasında 2026 sivrisinek balığı yakalanarak incelenmiş ve bulunan değerler karşılaştırılmıştır. Fethiye-Akgöl populasyonunda bulunan yaş grupları dağılımı 0+ % 97,59, 1+ % 2,41, Dalaman'da 0+ % 99,71, 1+ % 0,29, Ortaca'da 0+ % 94,37, 1+ % 5,63' tür. Fethiye-Akgöl sivrisinek balığı populasyonunun % 81,42'si dişi, % 18,58'i erkek, Dalaman'ın % 71,55'i dişi, % 28,45'i erkek, Ortaca'nın % 70,42'si dişi, % 29,58'i erkek olarak saptanmıştır. Total boylar (TL) Fethiye-Akgöl populasyonunda 1,3-5,5 cm, Dalaman'da 1,7-5,5 cm ve Ortaca'da 1,3-5,8 cm arasında; total ağırlıklar (W) ise Fethiye Akgöl'de 0,02-2,31 gr, Dalaman'da 0,06-2,58 gr ve Ortaca'da 0,02-5,83 gr arasında değişmiştir. Populasyonlarda Gonadosomatik İndeks (GSI) Mart ve Nisan aylarında arttı, Mayıs ayında bir miktar düştü ve Mayıs ortalarında tekrar yükseldi. Fethiye populasyonunun GSI değerleri Haziran başlangıcında, Dalaman ve Ortaca populasyonlarının GSI değerleri Temmuz ortalarında tekrar düşmeye başladı. Bu durum sivrisinek balıklarının bivoltin tür olduğunu göstermektedir. Populasyonların yaş gruplarına ait ortalama yumurta sayısı, Fethiye-Akgöl'de 21,90 (0+) ile 52,81 (1+), Dalaman'da 27,11 (0+) ile 91,0 (1+), Ortaca'da 28,24 (0+) ile 81,78 (1+) dir. Gram başına düşen ortalama fekondite Fethiye-Akgöl'de 27,71 (0+) ile 31,71 (1+), Dalaman'da 42,97 (0+) ile 39,99 (1+) ve Ortaca'da 35,28 (0+) ile 37,39 (1+) yumurta/gram arasında bulunmuştur.

Anahtar Sözcükler: Sivrisinek balığı, *Gambusia affinis*, populasyon yapısı, yaş, büyüme, üreme, Muğla, Türkiye

* This research is part of Ş. ÖZTÜRK's doctoral thesis.

Introduction

Gambusia affinis was brought to Turkey by the French for controlling malaria and was introduced into Lake Amik. Later it was distributed to various wetlands of Anatolia by the Turkish Malaria Control Agency (1). The ecological and biological properties of mosquitofish populations of Turkey, such as distribution, biological properties, success in malaria control and interactions with other living things in the ecosystem, have not been studied. In this study, some biological properties of the *G. affinis* populations in some western Mediterranean regions (Fethiye, Dalaman, and Ortaca in Muğla) were examined in order to contribute to the knowledge on this subject.

The mosquitofish is an important alternative to pesticides, which cause environmental problems. It is remarkably successful in controlling mosquitoes (2,3). In the mosquitofish, which is ovoviviparous and small, the males use the anal fin, which has become long and thin, as a copulative organ (gonopodium). The structure of the gonopodium was a significant criterion in the distinction of the mosquitofish species (4). The mosquitofish lives in small lakes, ditches, ponds and warm waters flowing slowly and rich in vegetation. This species, which survives and reproduces easily, is resistant to poor environmental conditions such as low oxygen levels, high temperature, high salinity etc. (5–7). The mosquitofish is carnivorous, feeding on the floating larvae of mosquitoes, small crustacea and insects. Cannibalism is also observed in the feeding of the mosquitofish (8–10). Studies on the

mosquitofish were carried out in its natural range (11) and several areas (12–15) of introduction. However, detailed studies on the mosquitofish populations in Turkey have not been performed. This study aimed to determine the present status of mosquitofish populations, especially its structure and reproduction, in the western Mediterranean region (Muğla, Turkey).

Materials and Methods

Mosquitofish were obtained from 3 localities, Akgöl marsh in Fethiye, drainages and small marshes in Dalaman and Ortaca district in Muğla in the western Mediterranean region of Turkey (Figure 1). In the research areas, the water is still and 0 to 100 cm deep. Rich aquatic vegetation at the localities serves as good shelters for the fry of the mosquitofish. The annual temperature variation of the waters in Fethiye is 11.3 to 34.8 °C, in Dalaman 13.2 to 29.5 °C and in Ortaca 12.9 to 31.7 °C.

A total of 2026 specimens (705 in Fethiye-Akgöl, 682 in Dalaman and 639 in Ortaca) were caught from November 1998 to October 1999. All samples were collected by dip net with a 1 mm mesh-size. Fish samples were preserved in 4% formalin. Total length (TL) and weight (W) were measured to the nearest 1.0 mm and 0.01 g, respectively. Scales were used for age determination. For this purpose, 8-10 scales were taken from a region under the dorsal fin. They were observed and the annuli read under a binocular stereomicroscope.



Figure 1. The sampling areas of *G. affinis*.

Sex was determined from the morphology of the anal fin (15) because the anal fin of the males takes the form of a gonopodium. The individuals with an immature gonopodium were excluded from the study. The length-weight regression was carried out with logarithmic transformed data by the formula $W = aTL^b$. The gonadosomatic index (GSI) was calculated as follows: $GSI = GW/W-GW$; where GW = gonad weight (g) and W = body weight (g). Fecundity (F) was estimated from mature eggs and embryos in the oviduct. They were counted under the binocular stereomicroscope. Fecundity (F) – total length (TL), fecundity (F) – body weight (W) and fecundity (F) – gonad weight (GW) relationships were estimated with the following equations: $\log F = \log a + b \log TL$, $\log F = \log a + b \log W$ and $\log F = \log a + b \log GW$. The diameters of mature eggs were also measured with an ocular scaled binocular stereomicroscope (15).

Differences were examined by *t*-test and χ^2 . A value of $P < 0.05$ was considered to represent statistical significance (16).

Results

Age and sex: At the Fethiye-Akgöl station 705 mosquitofish were caught; 688 of them belonged to the 0+ age group (97.59%) and 17 to the 1+ age group (2.41%); 574 were female (81.42%) and 131 male

(18.58%). In Dalaman 680 of 682 were in the 0+ group (99.71%) and the rest in the 1+ group (0.29%); 488 were female (71.55%) and 194 male (28.45%). In Ortaca 603 of 639 were in the 0+ group (94.37%), and 36 in the 1+ group (5.63%); 450 were female (70.42%) and 189 male (29.58%). In each population, the difference between the sexes was statistically significant (χ^2 test, $P < 0.05$).

Length at age: In the Fethiye-Akgöl population the average total length (TL) in the 0+ group was 2.98 ± 0.02 cm (95% confidence limits) (min. 1.3; max. 5.1) and in the 1+ group 4.74 ± 0.12 cm (95% C.L.) (min. 3; max. 5.5). In Dalaman, TL in the 0+ group was 3.11 ± 0.03 cm (95% C.L.) (min. 1.7; max. 5.0) and in the 1+ group 5.4 ± 0.04 cm (95% C.L.) (min. 5.4; max. 5.5). In the Ortaca population, TL in the 0+ group was 3.15 ± 0.03 cm (95% C.L.) (min. 1.3; max. 5.5) and in the 1+ group 4.94 ± 0.09 cm (95% C.L.) (min. 3.2; max. 5.8).

Weight at age: Body weight in the Fethiye-Akgöl population was 0.02-2.31 g; in females 0.03-2.31 g, and in males 0.02-0.37 g. In Dalaman, body weight was 0.06-2.58 g; in females 0.06-2.58 g, and in males 0.08-0.42 g. In Ortaca body weight was 0.02-5.83 g; in females 0.03-5.83 g, and in males 0.02-0.45 g.

Length-weight relationship: The equations and coefficients of the length and weight relationship in Fethiye-Akgöl, Dalaman and Ortaca mosquitofish populations are shown in Table 1.

Table 1. Length-weight relationship equations ($\log W = \log a + b \log TL$) of mosquitofish in Fethiye-Akgöl, Dalaman and Ortaca. S.E.(_b), the standard error of b, F, female; M, male.

| Station | Sex | N | Log a | b | S.E.(_b) | r |
|---------------|-------|-----|---------|--------|----------------------|--------|
| Fethiye-Akgöl | F | 574 | -2.0368 | 3.2303 | 0.0181 | 0.9910 |
| | M | 131 | -1.9966 | 3.0061 | 0.1135 | 0.9190 |
| | F + M | 705 | -2.0148 | 3.1700 | 0.0190 | 0.9883 |
| Dalaman | F | 488 | -2.0219 | 3.2351 | 0.0252 | 0.9855 |
| | M | 194 | -2.1378 | 3.3475 | 0.0832 | 0.9454 |
| | F + M | 682 | -2.0785 | 3.2741 | 0.0247 | 0.9822 |
| Ortaca | F | 450 | -2.0345 | 3.3014 | 0.0251 | 0.9872 |
| | M | 189 | -1.8250 | 2.6737 | 0.1400 | 0.8129 |
| | F + M | 639 | -2.0176 | 3.2685 | 0.0310 | 0.9740 |

Sexual maturity: In the Fethiye-Akgöl population, 100% of 1+ group individuals began to reach sexual maturity and 52.81 eggs per individual developed. In the 0+ age group 41.40% of individuals reached sexual maturity and the average number of eggs per individual was 21.90. In the Dalaman population, 100% of the 1+ age group started egg development and 91.0 eggs per individual developed. In the 0+ group, 58.23% of individuals reached sexual maturity and developed 27.11 eggs per individual. In Ortaca 97.05% of 1+ group individuals reached maturity and each developed 81.78 eggs. In the 0+ group 54.23% of individuals became sexually mature and each individual developed 28.24 eggs (Table 2).

Reproduction period and GSI: The egg development in each population generally started in March, when the

water temperature was approximately 20 °C, and continued until October, when the temperature went down to 20 °C. In each population, the GSI increased from mid February until mid April, decreased slightly thereafter until mid May and increased between mid May and mid June. In mid June the GSI for the Fethiye-Akgöl population started to decrease and the GSI decrease in the Dalaman and Ortaca populations began in mid July. This proves that mosquitofish are bivoltine species. Maximum GSI values were found in the female individuals of the Fethiye-Akgöl population in April, in males in July, and in both sexes in April. In Dalaman female individuals GSI values were highest in July, in males in May, and in both sexes in March. In Ortaca female individuals, maximum GSI values were found in July, in males in August, and in both sexes in July (Figures –4).

Table 2. Sexual maturity of females in the Fethiye-Akgöl, Dalaman and Ortaca *G. affinis* populations (N, number of fish).

| Station | Age | N | Mature (N) | Mature (%) | Number of eggs |
|---------------|-----|-----|------------|------------|----------------|
| Fethiye-Akgöl | 0 | 558 | 231 | 41.40 | 21.90 |
| | 1 | 16 | 16 | 100.00 | 52.81 |
| Dalaman | 0 | 486 | 283 | 58.23 | 27.11 |
| | 1 | 2 | 2 | 100.00 | 91.00 |
| Ortaca | 0 | 402 | 218 | 54.23 | 28.24 |
| | 1 | 34 | 33 | 97.05 | 81.78 |

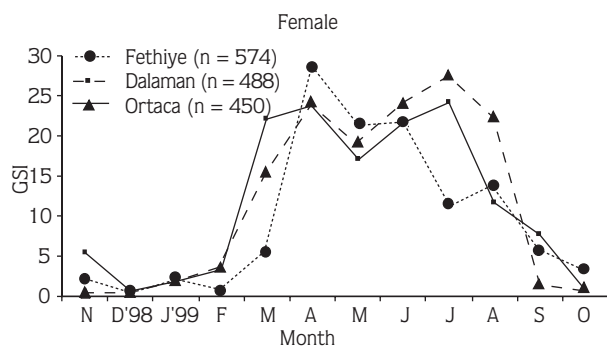


Figure 2. Comparison of GSI values in the *G. affinis* populations (female).

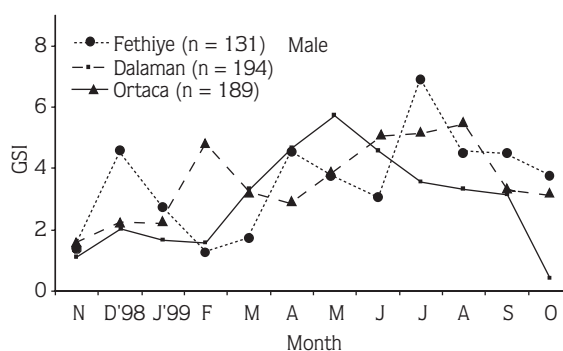


Figure 3. Comparison of GSI values in the *G. affinis* populations (male).

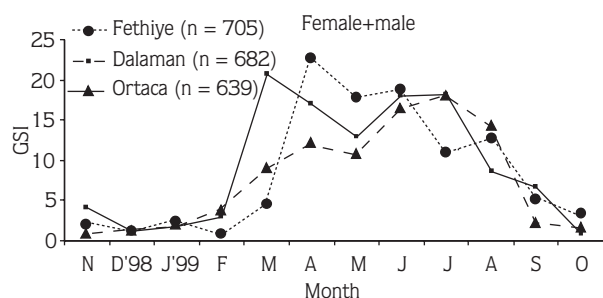


Figure 4. Comparison of GSI values in the *G. affinis* populations (female + male).

The total length, weight and gonad weight of the mosquitofish populations studied during this research are compared in Table 3.

Fecundity: After the calculation of the developing eggs and embryos of 247 sexually mature individuals in Fethiye-Akgöl population, the total fecundity was observed to vary between 1 and 107. The relationships between the total fecundity and total length, body weight and gonad weight were as follows:

$$\text{Log F} = -1.0831 + 4.0289 \log \text{TL} \quad (r = 0.845)$$

$$\text{Log F} = -1.4540 + 1.2602 \log \text{W} \quad (r = 0.884)$$

$$\text{Log F} = 2.0428 + 0.7690 \log \text{GW} \quad (r = 0.878)$$

In Dalaman, 285 mature individuals were studied and total fecundity varied between 3 and 128. The relationships between total fecundity and total length, body weight and gonad weight were as follows:

$$\text{Log F} = 0.2358 + 1.9736 \log \text{TL} \quad (r = 0.443)$$

$$\text{Log F} = 1.4761 + 0.6831 \log \text{W} \quad (r = 0.491)$$

$$\text{Log F} = 1.9439 + 0.6011 \log \text{GW} \quad (r = 0.642)$$

In the Ortaca population, after the study of 251 sexually mature individuals, total fecundity was found to vary between 2 and 146. The relations were as follows:

$$\text{Log F} = -0.5827 + 3.4457 \log \text{TL} \quad (r = 0.827)$$

$$\text{Log F} = 1.5273 + 1.0642 \log \text{W} \quad (r = 0.853)$$

$$\text{Log F} = 2.0450 + 0.7237 \log \text{GW} \quad (r = 0.866)$$

Compared fecundity values of the 3 populations are shown in Table 4.

Egg size: Average egg diameter was calculated in eggs in the second embryonic developmental stage, newly starting to develop and still uneyed. In the Fethiye-Akgöl population the diameter was $1797.68 \pm 237.23 \mu\text{m}$ (95% C.L.), in Dalaman $1610.81 \pm 239.29 \mu\text{m}$ (95% C.L.), and in Ortaca $1583.63 \pm 247.93 \mu\text{m}$ (95% C.L.).

Table 3. Comparison of the total length (TL), weight (W) and gonad weight (GW) of mosquitofish in Fethiye-Akgöl, Dalaman and Ortaca populations. Values are means \pm S.E.

| | Fethiye (n = 705) | | Dalaman (n = 682) | | Ortaca (n = 639) | |
|----|-------------------|-------------------|-------------------|-------------------|------------------|-------------------|
| | M (n = 574) | F (n = 131) | M (n = 488) | F (n = 194) | M (n = 450) | F (n = 189) |
| TL | 3.13 \pm 0.84 | 2.56 \pm 0.26 | 3.29 \pm 0.72 | 2.66 \pm 0.27 | 3.46 \pm 0.83 | 2.76 \pm 0.32 |
| W | 0.47 \pm 0.42 | 0.17 \pm 0.05 | 0.53 \pm 0.36 | 0.20 \pm 0.07 | 0.70 \pm 0.64 | 0.23 \pm 0.08 |
| GW | 0.06 \pm 0.09 | 0.005 \pm 0.002 | 0.07 \pm 0.09 | 0.005 \pm 0.002 | 0.11 \pm 0.18 | 0.007 \pm 0.002 |

Table 4. Comparison of absolute and relative fecundity values of mosquitofish in the Fethiye-Akgöl, Dalaman and Ortaca populations. Values are means \pm S.E.

| Station | Fecundity | F/length (mm) | F/weight (g) |
|-------------------------|------------------|-----------------|------------------|
| Fethiye-Akgöl (n = 247) | 21.90 \pm 0.97 | 0.54 \pm 0.20 | 27.71 \pm 0.70 |
| Dalaman (n = 285) | 27.11 \pm 0.94 | 0.72 \pm 0.22 | 42.97 \pm 1.98 |
| Ortaca (n = 251) | 28.24 \pm 1.48 | 0.71 \pm 0.28 | 35.28 \pm 0.79 |

Discussion

Age composition showed no remarkable difference between the mosquitofish populations of Fethiye-Akgöl, Dalaman and Ortaca. The age composition varied between 0 and 1 and most of the individuals were in the 0+ age group. The data correlate with those of studies on the mosquitofish populations in the estuary of the Guadalquivir River in Spain (14,15). The reason for this is that most individuals forming the population die in winter and the survivors begin to reproduce and reform the population in spring (14,15,17,18).

In the 3 populations the sex ratios are almost the same; the difference between the sexes is statistically significant ($P < 0.05$). This difference may originate from the specimen collection. However, these ratios are near to the values found in the Arkansas River basin (19).

Females were greater in size and weight than males in the populations studied. The length values in this study are similar to those in the Arkansas River basin (19). The compared weight values of mosquitofish caught in the research areas are similar. The mosquitofish population in Fethiye-Akgöl shows its maximum weight in April, in Dalaman in May and in Ortaca in July. The length-weight relationships in the populations were studied and value b was 3.23 in females, 3.0 in males and 3.17 in both in Fethiye-Akgöl; in Dalaman it was 3.23 in females, 3.34 in males and 3.27 in both sexes; and in Ortaca it was 3.30 in females, 2.67 in males and 3.26 in both sexes.

The GSI was at its maximum value in Fethiye-Akgöl in April, in Dalaman in March and in Ortaca in July. In the 3 populations, the GSI increased from mid February until

mid April, slightly declined in May, and increased again in mid May until mid June. In mid June the GSI for the Fethiye-Akgöl population started to decrease and the GSI decrease for Dalaman and Ortaca populations began in mid July. The GSI progressively declined in August and September, and was lowest in October, November, December, January and February. Egg development in surviving individuals after winter started in late February, continued in March and April and therefore the GSI showed a rapid increase in April, and once breeding of these individuals started in April. The GSI values decreased in May. After newly born individuals developed and were mature enough to reproduce, the GSI in populations started to increase again in June, and this was followed by the births of a new generation in July and August. Therefore the GSI started to decline again in August and September. The GSI progressively declined in September and October (Figures 2–4). In the light of these data, 2 different generations of mosquitofish propagate in 1 reproduction period. However, because not all of the new generation matures and takes part in reproduction, the mosquitofish is considered to be a partly bivoltine species (14,15,17,19,20).

The fecundity values were lower in the 0+ age groups than in the 1+ groups. The data showed that there was an important connection between the size of the mother and the number of embryos in the ovary. There was no significant difference between egg diameters in the 3 populations.

We think that the biological data obtained from this study will help in further planning and modifications of the efforts in mosquito control.

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