

Is *Gambusia holbrooki* Known as an Invasive Fish Species in Küçük Menderes River Basin Lakes (Turkey)?

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ABSTRACT

The aim of this study was to investigate the level of awareness of the species *Gambusia holbrooki* Girard, 1859, in the Küçük Menderes River Basin lakes, a species which is considered to be a threat, particularly to the persistence of endemic species. Interviews regarding the species in the basin were conducted with a total of 104 people between 2016 and 2017. Data were collected from fishermen (n=52) and local people (n=52) who had an association with the Belevi, Barutçu, Gebekirse, Kocagöz and Kazan lakes in the Selçuk district, and the method used was that of face-to-face questionnaires. The questionnaire included questions about the recognition of the species and the harm that this species might cause. Furthermore, some demographic characteristics (e.g. age, marital status and education level) of participants were included in the present study.

Keywords: Mosquitofish, alien species, fish awareness, Selçuk

INTRODUCTION

Turkey forms a natural corridor in terms of distribution of biological species (Tarkan, Marr & Ekmekçi, 2015) and with its unique geomorphological feature, it is the only country in the world that can boast hosting 3 of 34 hot spots (Caucasus, Iran-Anatolia and Mediterranean) (Şekericioğlu et al., 2011). However, invasiveness is an increasing threat for the sustainability of biodiversity (Copp et al., 2005), and this threat also applies to freshwater fish species distributed throughout Anatolia (Freyhof et al., 2014; Tarkan, Marr & Ekmekçi, 2015).

The Mosquitofish *Gambusia holbrooki* & *G. affinis* were introduced worldwide for the biological control of malaria (Krumholz 1948). They were introduced into Turkey for the biological control of malaria between the years 1920-1929 (Walton, Henke & Why, 2012). It is claimed that French people brought *G. affinis* from European countries and introduced this species to Lake Amik (Hatay, the southernmost city of

Turkey) (Geldiay & Balık, 1996) but the exact year of the introduction is not clear. Mosquitofish was the first "exotic species" that was introduced into the Turkey's freshwaters (İnnal & Erk'akan, 2006). The first official introduction of the species into Turkey was in the Çukurova Region (in the southern part of Turkey) in 1960 (Bahadıroğlu & Büyükçapar, 1997).

Although the potential ecological impact of mosquitofish on other species was kept secret last century, today this is a well-known phenomenon. *Gambusia* is one of about 29 aquarium species listed as harmful to native fauna and aquatic ecosystem collectively (Arthington & Marshal, 1999). They cause harm to the native fish fauna, especially in terms of endemic species persistence (Milton & Arthington, 1983; Rupp 1996; Ling 2004; Pyke 2008; Buttermore et al., 2011).

Turkey's geography is divided into 25 major river basins. Küçük Menderes River Basin is one of these river basins and is located within the bor-

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ders of the Aegean Region. This basin is adjacent to the Büyük Menderes River Basin in the south and the Gediz River Basin in the north. Küçük Menderes River Basin borders are in 3 cities; İzmir (95%), Aydın (4%) and Manisa (1%); more than half of the lands in the basin are forest and semi-natural areas, 39% are agricultural areas and 1% are water surfaces (OSİB, 2016).

Selçuk district is a very rich place in terms of natural lakes. There are 5 lakes in the district, Belevi, Barutçu (Çatal), Gebekirse, Kazan, and Kocagöz lakes. Belevi Lake is an important natural lake located at the entrance of the Selçuk district, next to Belevi and Halkapınar villages. Barutçu and Gebekirse lakes are located in Zeytinköy village, and they are composed of alluvium brought by the Küçük Menderes River, as are the other main lakes in the same location. Kazan Lake is a famous touristic lake which is located in the same village. Finally, Kocagöz is the other lake in the district which is closest to the Aegean Sea. In some of the dried marshes, the land can be cultivated in all seasons and used for agricultural purposes by the people in the region (OSİB, 2016).

These lakes, especially Belevi and Barutçu lakes, are important water bodies in terms of regional fishing activities. Gebekirse Lake and its surroundings was established as a Wildlife Protection Area (1000 ha) on 31 December, 1984 and was declared to be a Wildlife Development Area (545.3 ha) with the decision of the Council of Ministers (TOB, 2019). Fishing is the mainstay of some of the local people. In addition, a significant number of local people are occupied in doing different kinds of fishing activities in these lakes.

The present study aimed to determine awareness of the invasive fish species in two groups of people who have contact with the lakes in the Küçük Menderes River Basin. The aim was to investigate whether or not fishermen and local people knew the harm caused by the *G. holbrooki*. Public survey studies are substantial for determining the status of invaders and such surveys contribute to fisheries management.

MATERIAL AND METHODS

In this research, two study groups were chosen due to the fact that they live closest to the five lakes (Belevi, Barutçu, Gebekirse, Kocagöz, Kazan lakes) which are located in the Selçuk district (Figure 1 and Figure 2). The first group consisted of local fishermen living close to Belevi, Halkapınar and Zeytinköy villages. The second group consisted of local people living in the same villages. All fishermen and local people who were interviewed had had previous contact in at least some with a lake.

In reviews with local headmen of the villages, it was found that a maximum of 60 fisherman were living there. The sample volume to be selected was calculated with the formula given below (95% confidence level, $\alpha = 0.05$; $p = 0.5$; $d = 0.05$) (Sümbüloğlu & Sümbüloğlu, 2005). As a result of this formula, $n = 52$ fishermen of sample size were found to be sufficient for the research. Interviews were conducted with almost a full count of the Fishermen in the years 2016 and 2017. In addition, for the second group (consisting of local people) the same sample number ($n = 52$) was targeted as similar to the number of fishermen who were interviewed.

Formula:

$$n = Np(1-p)t^2 / (d^2(N-1)) + (t^2p(1-p))$$

N: Number of individuals in the target.

n: Number of individuals to be sampled.

p: Frequency of occurrence of the examined event.

t: t-table value.

d: The frequency of occurrence of the event.

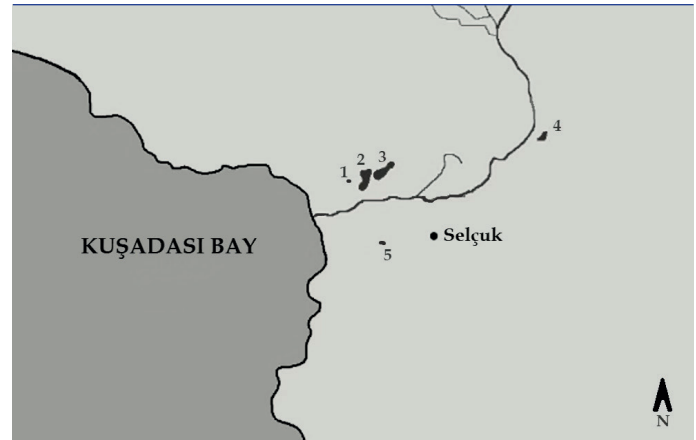


Figure 1. The map of the locations (1: Kazan Lake, 2: Gebekirse Lake, 3: Barutçu Lake, 4: Belevi Lake, 5: Kocagöz Lake).



Figure 2. The photos of Belevi Lake (upper) and Kazan Lake (lower) (Selçuk, İzmir).

The purpose of the questions was to specify the recognition level of the species in the study area. Face-to-face questionnaires gathered information about whether the fish had been seen before, whether the name of the fish was known or not, and whether the fish was known for the harm that it caused. The 6 questions used for the survey are given below (Table 1). Photos of both male and female *G. holbrooki* were shown to all the people who were interviewed.

Table 1. The questions about awareness of *G. holbrooki* and their harm.

No	Questions
1	Have you seen the fish in the photo before?
2	Do you know the name of the fish in the photo?
3	Are mosquitofish useful?
4	Are mosquitofish harmful?
5	Do you know how the fish were introduced into the water resource?
6	Have you ever caught mosquitofish?

To test the aforementioned awareness of the species using fishermen and local people knowledge level differences, Kolmogorov-Smirnov test (95%) was performed to analyse the differences in the two groups (*Chi-square test could not be applied because of the frequency in some parts <5*). The answers of fishermen and local people were grouped as sufficient and insufficient according to the level of knowledge. Statistical analyses were performed with the SPSS 20.0. The mean ages of fishermen and people from the public were given with their standard deviation (\pm SD).

RESULTS AND DISCUSSION

All fishermen who attended the face-to-face questionnaire were males and during the study females were not interviewed in either group. The mean age of the fishermen was 51.11 ± 2.95 years, and 45.09% of fishermen were aged between 50 and 59. Almost all fishermen were married, whilst a few were single. Regarding the education level of the fishermen, 92.15% had at least completed primary school, whilst a few fishermen had a high school degree.

The mean age of people from the public was 49.03 ± 3.48 years, and 34.07% of them were aged between 50 and 59. Many of the people who were interviewed were married. The replies of fishermen and people from the public, and total reply numbers, are given below according to questions (Table 2).

In reply to the first question regarding having seen the *G. holbrooki* before in any water resources the fishermen mostly replied in the affirmative. The results showed that 83% of fishermen declared that they had seen the fish before in any water resources, and that 86% of people from the public had not seen the fish before (Figure 2). In both groups the results seem almost similar for the second question, with 83% of fishermen and 98% of people from public declaring that they had never heard the name of "mosquitofish" before.

Table 2. The replies of fishermen and people from the public.

Reply numbers (n _{total} = 104)									
No	Fishermen			Local People			Total		
	Y	N	?	Y	N	?	Y	N	?
1	43	7	2	4	45	3	47	52	5
2	9	43	0	1	51	0	10	94	0
3	14	3	35	4	0	48	18	3	83
4	2	13	37	0	4	48	2	17	85
5	0	52	0	0	52	0	0	104	0
6	19	33	0	0	52	0	19	85	0

Y: Yes, N: No, ?: I do not know.

Almost all people from the public had no idea about the threat of the species. Furthermore, all participants interviewed had no idea about how the fish had been introduced into the waters. In addition, 36.53% of fishermen had caught the species before.

Kolmogorov-Smirnov test (95%) was performed to analyse the differences between the replies of the fishermen and local people according to the six questions (Table 3).

There were significant differences between the replies of the fishermen and those of local people regarding having seen the invasive *G. holbrooki* before or knowing the name of the species (for the 1st and 2nd questions). Moreover, there was no significant difference between the fisherman and local people in terms of their awareness of how harmful the species is (for the 3rd question). There were significant differences between the fishermen and the local people regarding having caught the species before (for the 6th question).

In the present study, it was determined that the fishermen were aware of the *G. holbrooki*. In addition, it was observed that the local people in the study area were mostly not aware of the mosquitofish; also they had no idea about their negative effects on native fish fauna.

Throughout this research, the most dramatic result might be the replies for the 4th question about the harmful effects of the *G. holbrooki*. Almost all the people interviewed did not know about the *G. holbrooki*'s harm to the ecosystem. In particular, many fishermen did not even know the name of the fish.

G. holbrooki has a very large distribution in the inland waters of Turkey, and is well known in Turkey's western freshwater resources. They were recorded in Yuvarlakçay (Muğla) (Balık et al., 2005) and Afyonkarahisar water resources (Yeğen et al., 2007) as well as in Marmara Lake (Manisa) (İlhan & Sarı, 2015). The first record of this species from the study area was done more than 30 years earlier and was conducted in Barutçu Lake (Balık & Ustaoglu, 1988). In addition, the first study of the species was recorded in the region in question (namely, Belevi, Gebekirse, Kocagöz and Kazan lakes) in 2016 and 2017 years for the first time (Kurtul & Sarı, 2019). Despite its wide distribution in Turkey and in the Küçük Menderes River Basin, it is not a harmful species and the

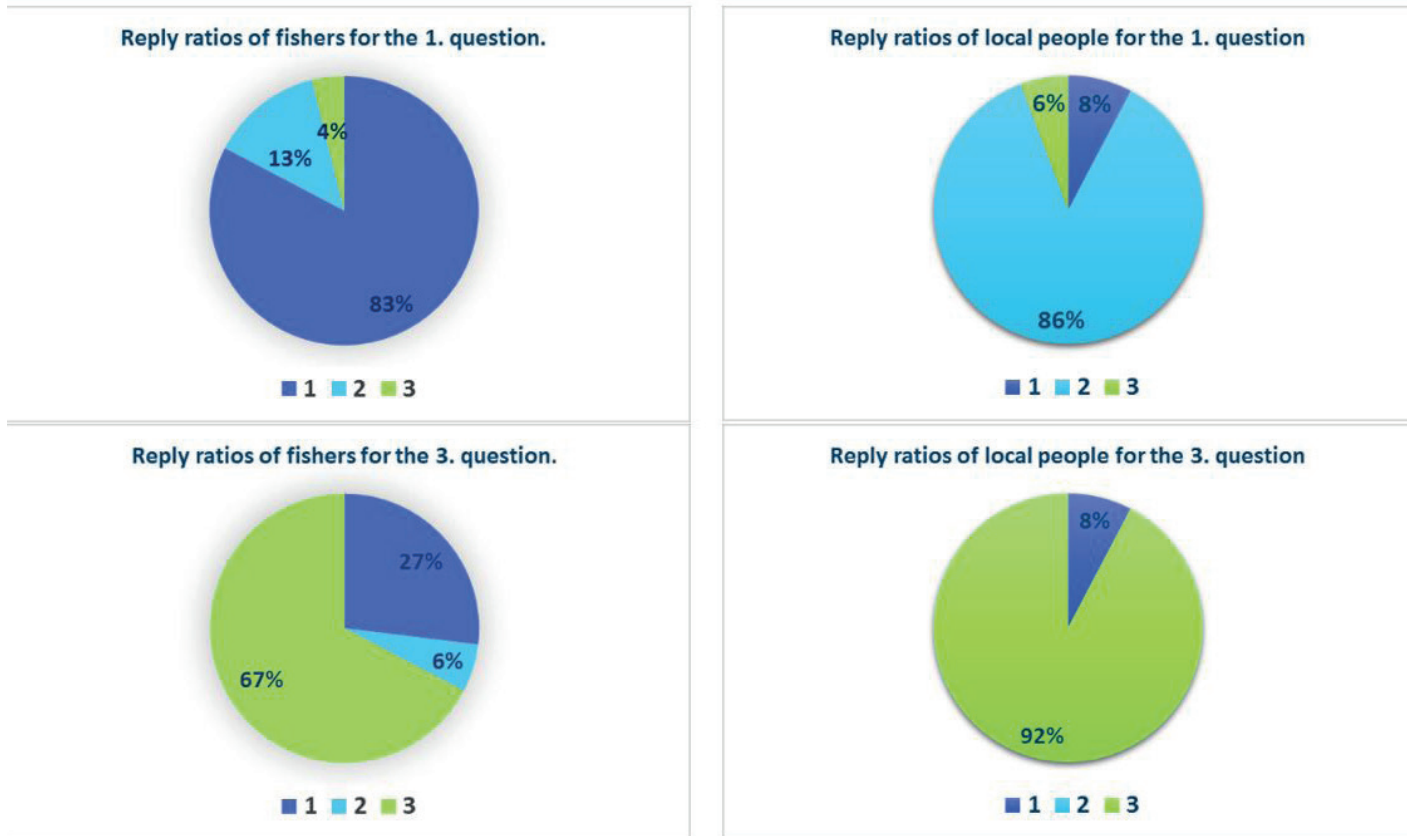


Figure 2. Reply ratios of fishermen and local people for the 1st and 3rd questions..

Table 3. Comparison of the level of knowledge of fishermen and local people.

1 Question		Knowledge Level		4 Question		Knowledge Level	
Group	Sufficient	Insufficient	Group	Sufficient	Insufficient		
Fishermen	43	9	Fishermen	2	50		
Local People	4	48	Local People	0	52		
$p < 0.05$				$p < 0.05$			
2 Question		Knowledge Level		5 Question		Knowledge Level	
Group	Sufficient	Insufficient	Group	Sufficient	Insufficient		
Fishermen	9	43	Fishermen	0	52		
Local People	1	51	Local People	0	52		
$p < 0.05$				$p > 0.05$			
3 Question		Knowledge Level		6 Question		Knowledge Level	
Group	Sufficient	Insufficient	Group	Sufficient	Insufficient		
Fishermen	14	38	Fishermen	19	33		
Local People	4	48	Local People	0	52		
$p > 0.05$				$p < 0.05$			

negative effects of the species are not known by fishermen and public. Despite an increase in the population of the *G. holbrooki* in the river basin over the years, awareness of the invader was found to be very low.

The law prohibits the movement of *Gambusia* by humans in Turkey. After *G. holbrooki* is collected from any kind of water resource it must be disposed of promptly, never introduced or transported to any other water resources. Although the Republic of Turkey's Ministry of Agriculture and Forestry have declared the

negative effects of the species, most of the fishermen and local people do not care about laws.

There are some literature regarding awareness studies of some other invasive species in Turkey and in the world, but there is no similar study for *G. holbrooki*. For example, angling is known as one way to raise public awareness about invasive fish species and also it is used to eliminate invaders from water resources. For example, in some countries where the *Carassius gibelio*, Prussian Carp is spread, awareness of the fish is created in the public through fishing competitions. There were some competitions for Prussian Carp in Asia, Africa, Australia and Europe (Næsje, Hay & Kapirika, 2001; Allendorf & Lundquist, 2003; Vrdoljack, 2014). Today, the Prussian Carp is a very famous invasive species and this species is left out of every kind of fishing limit. These competitions about *C. gibelio* have enabled species to be recognized. There should be such kinds of public studies for *Gambusia*.

In Turkey, there were two Prussian Carp fishing competitions in 2014 and 2015 held by Konya Amateur Fishery Association (KOABDER) in Konya. In addition, a third one was held in Denizli (Topkara, Bayhan & Sayçi, 2020).

CONCLUSION

Invasive species demonstrate both ecological and economic impacts in both marine and freshwater ecosystems (Oreska & Aldridge, 2011; Birkan & Öndes, 2020). As a result of deliberate attempts to improve fisheries, this threat is further exacerbated by uncontrolled studies for aquaculture, or for biological control (Gaygusuz et al., 2015). They cause some changes in the food web, exhibit negative effects on native species, damage fishing gear and some of them even cause health problems in case of their consumption by humans (Öndes et al., 2018). Hence, it is important to monitor these alien species and determine their distribution and impacts in their new localities.

The most important way to prevent the spread of the invasive mosquitofish species is to raise awareness of the public and of fishermen. Furthermore, it should be noted that if the fishermen do not recognize the species, it is impossible to prevent them from spreading. Scientific projects about invaders should carry the responsibility of raising the awareness of the public (Topkara et al., 2020).

The main conservation ideas for *G. affinis* and *G. holbrooki* were declared as awareness and education. Involving the community in struggle activities ensures that local people have a sense of ownership of the potential harm of certain fish and an improved understanding of the difficulties of managing invasive fish species. Scientific literature, posters and prospectuses might be used to inform the public about the harm of invasive fish, in particular those known to be noxious under state and commonwealth statute.

For example, in Australia, the *Gambusia* species are being monitored as part of official stream and river health monitoring programs (Kennard et al., 2005). Monitoring programs similar to these might be accomplished for Turkey's water resources, and this kind of practice would contribute to awareness and control of the invasive species.

By way of a suggestion, some part of the budget which is used for the management of fisheries in the freshwaters of Turkey, might be used for the training of fishermen. It would be extremely important for the sustainable management of freshwater fisheries. The important point here is that the goals of training programs should be for very good planning and access to previous experiences.

Although this option is economically challenging at the beginning, further economic loss can only be prevented in the long-term. It is well known that, if an invasive species is introduced into a freshwater environment suddenly, it is next to impossible to remove it again.

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Ethics committee approval: This study was conducted in accordance with ethics committee procedures.

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