http://www.egejfas.org
Ege Journal of Fisheries and Aquatic Sciences, 39(3), 191-196 (2022)

Su Ürünleri Dergisi (2022)
DOI: 10.12714/egejfas.39.3.03

RESEARCH ARTICLE ARAŞTIRMA MAKALESİ

The remarkable observation for a mallard (*Anas platyrhynchos)* food from estuarine/coastal area (İzmir/Turkey): A mosquitofish (*Gambusia holbrooki*)

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Received date: 17.02.2022 *Accepted date: 08.06.2022*

How to cite this paper:
Salman, A., Kurtul, I., & Sarı, H.M. (2022). The remarkable observation for a mallard (*Anas platyrhynchos)* food from estuarine/coastal area (İzmir/Turkey): A mosquitofish (*Gambusia holbrooki*). *Ege Journal of Fisheries and Aquatic Sciences,* 39(3), 191-196. DOI: 10.12714/egejfas.39.3.03

Abstract: The purpose of this study is to create awareness about the species of mosquito fishes (*Gambusia holbrooki* Girard, 1859) both vectors and ways of introduction to new aquatic habitats. Because the species creates risks, especially for the circumstance of the native and endemic fish fauna, studies about introduction stories of the species are quite important to prevent the risk. In the current report, mosquitofishes which are known as a highly invasive species were found in the crop content of a hen mallard duck (*Anas platyrhynchos* L., 1758) in an estuarine area, the Gediz River Basin (İzmir, Turkey). This report is the first record of a duck consuming mosquitofish. Although nevertheless, it is known that mallard duck feeding behaviour does not predominantly contain fish (they mainly feed on plant seeds), according to this observation, mosquitofish might be added to the prey list of mallards as a new type of food. Therewith, this feeding behavior also indicates that ducks might be a potential vector for the transport of invasive mosquitofishes.

Keywords: Vector, pathway, long-distance dispersal, waterbirds, invaders, feeding behaviour

INTRODUCTION

The itinerary by which invaders are introduced, transported, or imported into the new habitats are known as pathways. In the literature, natural pathways mean that they are not human-mediated. There are some examples of natural pathways, such as river canals, and birds. Both pathways may naturally bring some fish species or their eggs (invasive- or not) to a new aquatic area. These introduction cases can sometimes even be intercontinental.

The current evidence shows that waterbirds can transport plants and invertebrates as internal and external of their body (Reynolds et al., 2015). To the prevailing knowledge, waterbirds are sometimes cited as playing a role as a vector of alien invasive species (Green and Figuerola, 2005; MacIsaac, 2011; Sánchez et al., 2012). There are some studies that consider the waterbirds being a vector in the introduction of alien species (Green et al., 2008; Brochet et al., 2010; Twigg et al., 2009). Even so, the evidence for waterbird-mediated introduction is restricted. Even not many studies that waterbirds play a role in dispersing the vertebrates, studies focusing on the dispersal of native aquatic plants and invertebrates have established that waterbirds are highly suitable dispersal vectors (Figuerola and Green, 2002; Van Leeuwen et al., 2012; Lovas-Kiss et al., 2020).

Gambusia affinis and *G. holbrooki* species originate from North America, are biological agents in the fight against malaria, and started to be introduced in many different habitats of the world in the 1900s (Courtenay and Meffe, 1989; Walters and Freeman, 2000). They have become a pest in many different habitats following initial introductions in the early 20th century as a biological control agent. They are known as one of the 100 invasive species of the earth and pose a risk to the existence of endemic species (ISSG, 2013). More than this, they are listed as one of the harmful 29 aquarium species (Arthington and Marshal, 1999).

The mosquitofish is highly predatory fish and can cause adverse effects in the habitats they spread, which can lead to the extinction of native fauna members (Pyke, 2008). They prey on endangered rare indigenous fish and invertebrate species and eat the eggs of native fish species. They pose a risk, especially in terms of endemic species persistence (Margaritora et al., 2001; Buttermore et al., 2011). This threat is signally higher, especially for “microendemic” (which have a

very limited distribution) fish species (Giannetto and Innal, 2021). In Turkey, many of the endemic fish species have microendemic status, which makes their survival more at risk. For example, Yoğurtçuoğlu and Ekmekçi (2014) stated that *G. holbrooki* species threats the genus *Aphanius* in the aquatic habitats.

It is widely known that mosquitofish are poorly adapted to lotic waters. But in lots of countries stream populations are known including in the introduced range (Wach and Chambers, 2007; Kurtul and Sarı, 2019). The mosquitofish species seem poor dispersers (Pyke, 2005; Zogaris, 2014), because of their characteristics, their dispersal from a point source will depend on other, external factors. Some researchers have reported that mosquitofish can be introduced to new habitats by fishing gear (Zięba et al., 2010). More than this, humans, waterways, and possibly waterbirds are kind of vectors for transfer. However, empirical support for this is lacking, it is considered that fish introduction events are by waterbirds, transporting fish eggs externally (Lovas-Kiss et al., 2020). According to Lovas-Kiss et al. (2020) 10 Prussian carp eggs (ca. 0.25%) and eight intact common carp eggs (ca. 0.2% of those ingested) were recovered from the duck's feces. In the observation, four *Carassius gibelio* eggs and all of the *Cyprinus carpio* eggs had viable embryos.

Gambusia spp., which are known to be used as bait, for mosquito control, as pet fish, etc., can easily create a strong population once introduced to the new freshwater ecosystems. Mosquitofish are live-bearing fish. Therefore, it seems impossible to transport it with birds. Although this seems like a very small possibility, it may be possible if the bird swallowed these fish during feeding and vomited from the crop without digesting them during short-haul flights. Although it's still a theory and there is still no scientific evidence for such transport is; the fact that the species is consumed by ducks indicates that it is still possible to be transported between different waters.

The mallard ducks (*Anas platyrhynchos*) generally prefer subtropical parts of Eurasia, Americas, and Africa continentals (Braithwaite and Miller, 1975). They are known as a median migratory and their speed is approximately 82.5 km h^{-1} (McDuie et al., 2019). It is known that there were some small fish in the feeding behaviour of mallard ducks which is known as omnivorous (Hocaoğlu, 1992). They are known as opportunistic animals and rarely prey on small fish (Swanson et al., 1985; del Hoyo et al., 1992; Snow and Perrins, 1998). The most common knowledge, feeding of mallard duck is formed mainly from plant seeds. According to a study conducted in brackish-water areas and salt marshes, it was found that they mainly ate seeds such as *Salicornin* spp., *Atriples* spp., etc. Also, they consumed animal materials such as molluscs and crustaceans (Olney, 1964). More than this, it has also been reported that a mallard duck eats *Anguilla anguilla* European eel juveniles (Salman, 2017).

Biological invasions come to be following habitat loss as a risk to global biodiversity (Sala et al., 2000; Mooney and Cleland, 2001; Strayer, 2010). Freshwater habitats are in danger because of biological invasions (Ruiz et al., 1999; Green et al., 2008). The biological invasions' negative results, prompted study in terms of management and impacts of invasion (Reynolds et al., 2015). It is known that new management strategies are needed for all invasive species. In order to create the new management strategy for them, both the predators and the vectors of the invasive species should be determined in detail.

Figure 1. A hen (left) and a drake (right) mallard duck (*A. platyrhynchos* from Şirince, Selçuk/İzmir in 2019 (Photo by Irmak KURTUL).

In the current reports, *G. holbrooki* species were recorded in different kinds of water resources in Gediz River Basin- or namely Gediz Delta, where the dead mallard duck was found. This river basin is in the Aegean Region (the west part of Anatolia). The lentic water resources in the area are Marmara Lake, Sülüklügöl Lake, Sazlıgöl Lake; the lotic water resource is Gediz River (Kurtul and Sarı, 2019). Gediz River Basin (or known as Gediz Delta) contains İzmir Bird Paradise and its environs. Gediz Delta is one of the Cultural and Natural Asset; Wildlife Protection Areas and a significant part of the delta is protected by Ramsar Status. The delta has a huge coastal side. It considers bays, salt and freshwater marshes, large saltpans, lagoons located downstream of the Gediz River. It is close to the centre of Izmir.

All of the fauna move through the habitats to obtain resources important for gaining energy (Pianka, 1981). The wetlands are known as one of the most sensitive habitats to the pressures (Kaplan et al., 2005). The communities both fauna and flora permanently change in response to fluctuations in water degree and salinity, in the meantime, periodic droughts induce grand changes in wetland communities (Swanson and Meyer, 1977). The activity of the water regimes, and the changes in the community that it creates, is known as an important parameter influencing the availability to breed waterfowl (Swanson et al., 1985). Also, due to the loss of wetlands, the trophic relationships between fauna and flora members here have become more important for the sustainability of ecosystem health. According to the reports, environmental conditions affect the level of food availability on a marsh (Chura, 1962). Both *G. holbrooki* and mallard ducks use similar water bodies and it seems that they have a trophic relationship with each other. The scope of the study is to give new data and evaluate on review existing literature on the ability of mallard duck to spread *G. holbrooki* which is known as an invasive species.

Figure 2. The map of the dead mallard duck was found (www.earth.google.com)

MATERIALS AND METHODS

The dead *Anas platyrhynchos,* hen mallard duck (highly probably is yet dead- cause of death unknown) was found by a fisherman in the estuarine area of the Aegean Region, Gediz River Basin (İzmir, Turkey) on December 27th 2017. The delta area is approximately 14900 ha. It was found in a location that is quite close to the Gediz River's downstream. The coordinates are 38°30'N, 26°55'E. The locality is given Figure 2 and the area enclosed in a red rectangle.

The species identification processes of individuals were carried out at Ege University, Faculty of Fisheries, Department of Marine–Inland Waters Sciences and Technology, Limnology Laboratory. In the investigation, *G. holbrooki* specimens were identified from the crop content of the mallard duck. Because the species represents sexual dimorphism, the sexes were determined by external examination of the presence of gonopodium. The general body morphology of the individuals were examined and the gonopodium structures of the male specimens have been investigated in species identification (Berg, 1965). In the present study, each *G. holbrooki* specimen was weighed with a digital scale to the ±0.01 g and the total length was measured with a vernier calliper to the ±0.05 mm. The digestibility rates of *G. holbrooki* individuals were determined by visual inspection and given as a percentage.

RESULTS

The mallard duck's crop content was investigated by the naked eye. Totally ten *G. holbrooki* specimens were found in the crop content. In the content, three of the specimens were male, four of the specimens were female, and the sex of three of the specimens was not determined because of the digesting. All of the specimens were adults.

The total lengths of the species were between 2.0 and 3.8 cm. The weight of the specimens varies from 0.12 to 0.49 g. One of the specimens was found partly digested with no head (50%). However, most of the specimens were found as almost not digested (Table 1). They were most likely consumed a very short time ago. *G. holbrooki* specimens which were detected in the crop contents of the mallard duck are given in Figure 3.

Table 1. Fish samples from crop contents of the hen mallard (F:Female, M: Male, U: Unidentified, TL: Total length, TW:Total weight, PIF: Physical integrity of the fishes (%).

No	Sex	TL (cm)	TW (g)	PIF (%)
1	M	2.6	0.14	100%
2	U	2.8	0.25	70%
3	M	2.8	0.17	90%
4	M	2.0	0.25	80%
5	U	2.3	0.12	90%
6	F	3.1	0.36	90%
7	F	3.8	0.49	100%
8	F	2.4	0.18	80%
9	U	2.7	0.24	50%
10	F	2.8	0.26	80%

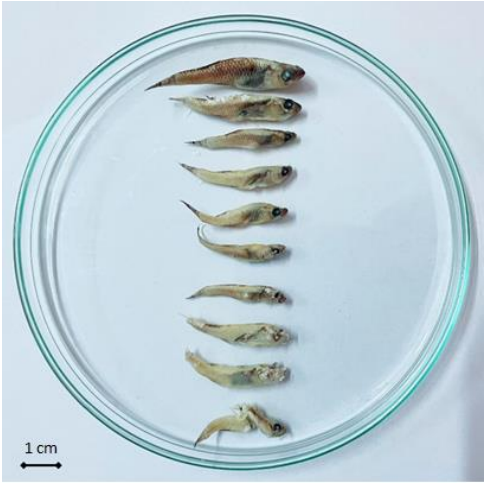

Figure 3. The content of the mallard duck's crop. The undigested *G. holbrooki* individual (on the top), the half-digested *G. holbrooki* individual (on the bottom) from the crop content.

DISCUSSION

Mosquitofishes are small bodied members of the world's freshwater fish. Their total length within their population usually varies between 1-5 cm. However, maximum male and female lengths were found as 3.5 cm and 8.0 cm, respectively (Doadrio, 2002). It means that these fish are small enough to be easily eaten by ducks. As a matter of fact, as they are quite small individuals, they can easily be prey by the predator fishes, aquatic vertebrate species, and birds. The mallard can take this fish species and then release it into another habitat when it is still surviving (vomiting without digesting). In other words, ducks can be vectors for the transportation of this species.

Although *G. holbrooki* seems poor dispersers (Pyke, 2005; Zogaris, 2014), they have a global dispersion today because of their use for biological control. As reported in studies, there may be other vectors besides fishing nets in transporting fish to different habitats (Zięba et al., 2010). Up to date, the aquatic birds, i.e. mallard ducks, might also be a vector which is overlooked affecting this spreading power. It is reported that waterbirds can transport some fauna and flora members as internal and external of their body (Reynolds et al., 2015; Lovas-Kiss et al., 2020) and it is also possible for waterbirds to carry offspring in their feathers. Because the mallard ducks frequently visit different kinds of water sources over short distances and it is very speedy (McDuie et al., 2019). This rapidity means that the fish can stay alive during the mallard duck's transition from one water source to one another.

While both fauna and flora give reactions to the fluctuations in communities, (Swanson and Meyer, 1977) and the wetlands are pretty sensitive habitats (Kaplan et al., 2005), the trophic relationships between fauna members in these regions should be followed carefully all the time. Although it has been reported that mallard ducks rarely prey on small fish (Swanson et al., 1985; Del Hoyo et al., 1992; Snow and Perrins, 1998), it is unclear which of these fish species are. The mallard ducks probably feed on many fish species. According to our observation, it is clear that mallard ducks feed on *G. holbrooki* specimens. While being a vector for a duck is harmless for some fish species, they can create problems if they are vectors of invasive species such as mosquitofishes. In the case of mosquitofishes, it is not easy to eradicate once it creates a population in a new aquatic habitat. In fact, the rotenone (a kind of poison), might be used to eliminate *G. holbrooki* from aquatic habitats. But the rotenone is indiscriminate, so the poison has a negative impact on the native fauna (both vertebrate and invertebrate) (Willis and Ling, 2000). It is almost impossible to eradicate them from the environment they introduced.

As they are invasive species (Arthington and Marshal, 1999; Pyke, 2008; ISSG, 2013), there should be a provision in many different ways to prevent the invasive mosquitofish from dispersing more. Mostly, *G. holbrooki* introduced new habitats through a variety of pathways, including the pet/aquarium trade and deliberate introductions for biological control. Nevertheless, this study predicts that mallard ducks can also be potential carriers. More data is needed to manifest the preferences of the mallard duck about *G. holbrooki* fishes. Because it is known that environmental conditions affect the level of food availability on a marsh, it should be revealed whether the mallard duck consumed this species by preference or whether it was consumed by food deprivation in the wetland area.

CONCLUSION

It is known that ducks are carriers for many species. If these species have invasive properties, then they may cause environmental problems. More data are needed to establish the livebearing carriage status of ducks such as *G. holbrooki*. Therefore, monitoring programs (catch and release) for ducks might be helpful for understanding their feeding behaviours. Thus, this introduction pathway might be understood as the mechanism for further introductions.

ACKNOWLEDGEMENT

We would like to thank the Gediz Delta local fishermen who are sensitive to academic studies.

AUTHORSHIP CONTRIBUTIONS

All authors contributed to the idea, design, material preparation, investigation, writing/editing of the study and all authors have read and approved the article.

CONFLICT OF INTEREST STATEMENT

The authors declare that there are no conflicts of interest or competing interest.

ETHICS APPROVAL

No specific ethical approval was necessary for this study.

DATA AVAILABILITY

For questions regarding datasets, the corresponding author should be contacted.

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