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ORIGINAL ARTICLE

Wetlands of the Maharlu Lake basin, southern Iran: ichthyofauna and negative effects of exotic fish farming and wetlands drying

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Abstract
The endorehic Maharlu Lake basin in the valley of Shiraz is located in Fars Province, southern Iran. Maharlu Lake is fed by minor streams and springs around its margin and the Khoshk River. In the present study, based on field observations made from August 2017 to March 2018, we provide brief reviews of some wetland habitats of Maharlu Lake basin, present new fish taxa records from this area, and comment on the conservation status of freshwater fish species with regard to the visited habitats. The freshwater resources of the basin host fourteen fish species and two reptile species, among which *Acanthobrama persidis* (Leuciscidae), *Capoeta saadii* (Cyprinidae), *Oxynoemacheilus persa*, *Paraschistura naumanni* (Nemacheilidae), and *Esmaeilius persicus* (Aphaniidae) are endemic Iranian species. During the last decade, several exotic carp species have been introduced for aquaculture, namely *Carassius auratus*, *Ctenopharyngodon idella*, *Cyprinus carpio*, and *Hypophthalmichthys molitrix*, especially to the freshwater bodies at the northern margin of Lake Maharlu, along with the incidentally introduced species *Pseudorasbora parva*. Our wetland survey efforts did not yield any records for several locally endemic or native taxa (including *Acanthobrama persidis*, *Capoeta saadii*, *Carasobarbus luteus*, *Garra rufa*, and *Esmaeilius persicus*). These results, together with our field observations of habitat dehydration suggest that the native and endemic fauna of the Maharlu Lake basin are presently under threat from both natural and anthropogenic factors including drought and introduction of exotic fish species for aquacultural purposes. As a consequence, if the environmental management of the restricted resources of the basin is not implemented in the near future, the combination of these threatening factors will eventually lead to the local extinction of most, if not all, of the populations of these endemic and native species.

Keywords: Exotic fishes, Endemic, Ichthyofauna, Maharlu Lake basin, Fars Province, Iran

INTRODUCTION

The freshwater fish of Iran inhabit waterbodies comprising 19 main basins, several of which are endorheic, that is, closed systems without outflow to the sea (Coad 2007; Esmaeili et al. 2010; Mostafavi et al. 2021). According to the systemization of Coad (2024), the water resources of Fars Province in southern Iran are included in five of the main Iranian basins, namely: Kor (Kor River), Maharlu (Maharlu Lake), Persis (Persian Gulf), Hormuz (Hormozgan), and Karun (Tigris) basins. Of these, the Kor and Maharlu are endorehic basins, and are also limited to Fars Province (Esmaeili & Teimori 2016). Many other areas of Fars Province are located within the catchment area of the Persian Gulf.

The wetlands of Fars Province support a large part of the province's and Iran's biodiversity (e.g., Joolaee et al. 2011; Dolatkhahi et al. 2012; Zamanpoore 2021). There are approximately 20 important natural and artificial wetlands in Fars Province, which account for 1.5% of the total area province area (ca. 190,128 hectares) (Jolaei & Ebrahimi Karnami 2014). Several of these (Bakhtegan, and Tashk (considered as Neiriz Lakes), Kamjan (Kamjan Marshes), Parishan (Parishan Lake), and Dasht-e-Arjan wetlands) have been registered as "internationally important" on the Ramsar Convention list (Ramsar Convention 2024). The wetlands of Fars Province can be divided into two main groups based on salinity, i.e., saltwater wetlands and freshwater to semi-saline wetlands. The natural wetlands of Fars Province can be further classified as seasonal wetlands or permanent wetlands, regardless

of whether they are saltwater or freshwater bodies. The permanence of the wetland can be determined by the permanence of the source, with some of the Fars wetlands being fed by streams or springs, and others by rivers (Gholamifard 2018a, 2021).

The wetland ichthyofauna of Fars has been studied by Golchin Manshadi et al. (2014), Jolaei & Ebrahimi Karnami (2014), Esmaeili & Teimori (2016), Zamanpoore & Yaripour (2017), Gholamifard (2018a; 2018b; 2021), adding important information on local diversity, but there are several areas in Fars Province that require further attention, especially considering ongoing environmental changes.

The endorheic Maharlu Lake basin is located in the valley of Shiraz (Esmaeili et al. 2010; Eagderi et al. 2022). The basin is named for Maharlu (Maharloo) Lake in the east of Shiraz city, the capital of Fars Province. Maharlu Lake is fed by minor freshwater streams and springs around its margins, and the Khoshk River ("Dry River"), a wastewater discharge of Shiraz city. Maharlu Lake basin represents a system of diverse habitats including the saline lake itself (Zamanpoore et al. 2019) and associated minor freshwater streams and springs that support freshwater fish species including several endemics. However, polluting agents in the system via industrial, agricultural, and municipal activity, as well as periodic drying (Zamanpoore et al. 2019) present conservation issues.

In order to better understand the distribution of freshwater fish species in the wetlands of Fars Province, multiple types of wetland habitats in the Maharlu Lake basin area were visited. Herein, based on observations from these field visits, we provide brief reviews of some wetland habitats of Maharlu Lake basin, present new fish records from this area, and comment on the conservation status of the freshwater fish species with regard to the visited habitats.

MATERIAL AND METHODS

The division of basins by Esmaeili & Teimori (2016) was followed so that the main basins of Fars Province were considered as Kor, Maharlu, Persis (Persian Gulf), Hormuz and Karun and the following as subbasins: Helleh, Mond, Zohreh and Kol. Taxonomic nomenclature and IUCN Red List of Threatened Taxa conservation status has been given as per the checklist by Eagderi et al. (2022) and Fishbase website (Froese & Pauly, 2024). Study on the various habitats of Maharlu lake basin was carried out between August 2017 and March 2018 with waterbodies of the Maharlu Lake basin considered as 'wetland' according to the Ramsar Convention definition (Ramsar Convention Secretariat 2013) stated above. A hand net and cast net were used to collect individuals of different fish species in the wetlands of Maharlu Lake basin in March 2017 and May 2018. A Canon G10 digital camera was used to photograph the fresh specimens.

Study area

The Maharlu Lake basin: Maharlu Lake basin, Fars Province, is bordered by the Bakhtegan Lake subbasin (Kor River basin) in the north and the Qara-Aghaj River subbasin and the Mond subbasin (Persis basin) in the south.

The Maharlu Lake basin, with a total area of 4100km^2 includes the Shiraz Plain (area of 988km^2), the Kavar Plain (area of 268km^2), the Sarvestan Plain (area of 800km^2), and the Karabagh Plain (area of 162km^2). The Maharlu Lake basin stretches from northwest to southeast and its length is 160km^2 along the mentioned stretch and its width along the Sarvestan Plain and Maharlu Lake is about 43km^2. The bottom of Maharlu Lake with a height of about 1460m above the sea level (a.s.l.) and the Qalat Mountain in the western part of the Shiraz Plain with a height of about 2990m a.s.l. are, respectively, the lowest and highest points of the Maharlu Lake basin.

In terms of water resources, the basin does not have a permanent river, and the floods of this area are caused by several channels and seasonal rivers, including: the seasonal river of Shiraz (Khoshk River), Rahdar River, Nazarabad River (Sarvestan), and Mian Jangal channel. They join to Maharlu Lake. The surface water resources of the Maharlu Lake

basin, which are limited to two rivers, namely the Shiraz (Dry) River and Rahdar River, are located in the north and northwest of this basin, but the southern areas, which form more than half of the Maharlu Lake basin in terms of size, are poor surface and underground water potential. Additionally, every year, about 100 million cubic meters of water enters this basin from the adjacent basins, namely Mand and Bakhtegan, through canals and pipelines or directly (Jolaei & Ebrahimi Karnami 2014).

Details on the six wetland habitat areas of the Maharlu Lake basin that were surveyed in this study (Maharlu Lake, Large Barm-e Shoor, Small Barm-e Shoor, Dobaneh, Barm-e Delak, and Barm-e Baboobak) are given in Table 1 (Appendix-FP).

RESULTS

Review of Maharlu Lake Basin Wetland Habitats

Maharlu Lake: The Maharlu Lake (wetland) is located 23 kilometers southeast of Shiraz and is a part of the Maharlu Hunting Prohibited Zone. The wetland has an area of 21,600 hectares. The length of Maharlu Lake is 31km, and its maximum width is 11km. The maximum depth of the wetland is 3 meters in the wettest season of the year, and its area reaches the maximum size of 24,000 hectares in the autumn and winter seasons. Fluctuations of the water level of it depends on the amount of annual rainfall (Fig. 1). The saline lake can experience total drying following drought (Zamanpoore et al. 2019). The lake is fed from the west by the Babahaji River, Chenar Rahdar River, and Khoshk River with seasonal and intermittent flow, and from the east by the Nazarabad channel; numerous other waterways provide input from the surrounding areas (Jolaei & Ebrahimi Karnami 2014) (Fig. 2).

The permanent river of Sultan Abad enters Maharlu Lake with low water flow. Also, there are many springs in the catchment area of Maharlu Lake, most of them are located on the slopes of the limestone hills, and their water supply is significant. The water flow of these springs has caused the formation of 'barm(s)' (a local name for a type of pond-like wetlands) of various depths with the same names of those wetlands

Fig.1. Maharlu Lake in the low water season of summer 2017. Photo by A. G.

(Fig. 3).

Barm-e Shoor Wetland: The Barm-e Shoor Wetland, which includes Large Barm-e Shoor and Small Barm-e Shoor, is located 24km southeast of Shiraz in the southwest corner of Maharlu Lake, near the Lower village of Barm-e Shoor (Fig. 4). The area of the Barm-e Shoor Wetland is about 1.5km^2 and its water flows into Maharlu Lake.

Dobaneh Spring and Dobaneh Wetlands (Ponds): Two ponds, another type of wetland, that were created from Dobaneh Spring are located on the way from Shiraz to Sarvestan, before Dobaneh village. These small-scale local wetlands are located to the south of Maharlu Lake at an altitude of 1,352m a.s.l. Their water flow is discharged into Maharlu Lake during the high-water state and during the rainy season (Fig. 5).

Barm-e Delak Wetland: Barm-e Delak Wetland is located 14km east of Shiraz (Shiraz to Kaftarak Road) and 4km from Abu Nasr Palace. This wetland, a lagoon, is formed on a mountainside from the water overflow of the spring of the same name from the mountain gap. Reeds and mixed vegetation thickly surround this wetland (Fig. 6). At the location of this wetland, there are three stone reliefs carved on the mountain that are related to the ancient era of the Sasanian Empire (Fig. 6), and a shrine (Emamzadeh in Persian); these cultural features generate tourism potential in this area.

Fig.2. The embankment of the Baboonak waterway leading to Maharlu Lake from the north. Photo by A. G., May 2010.

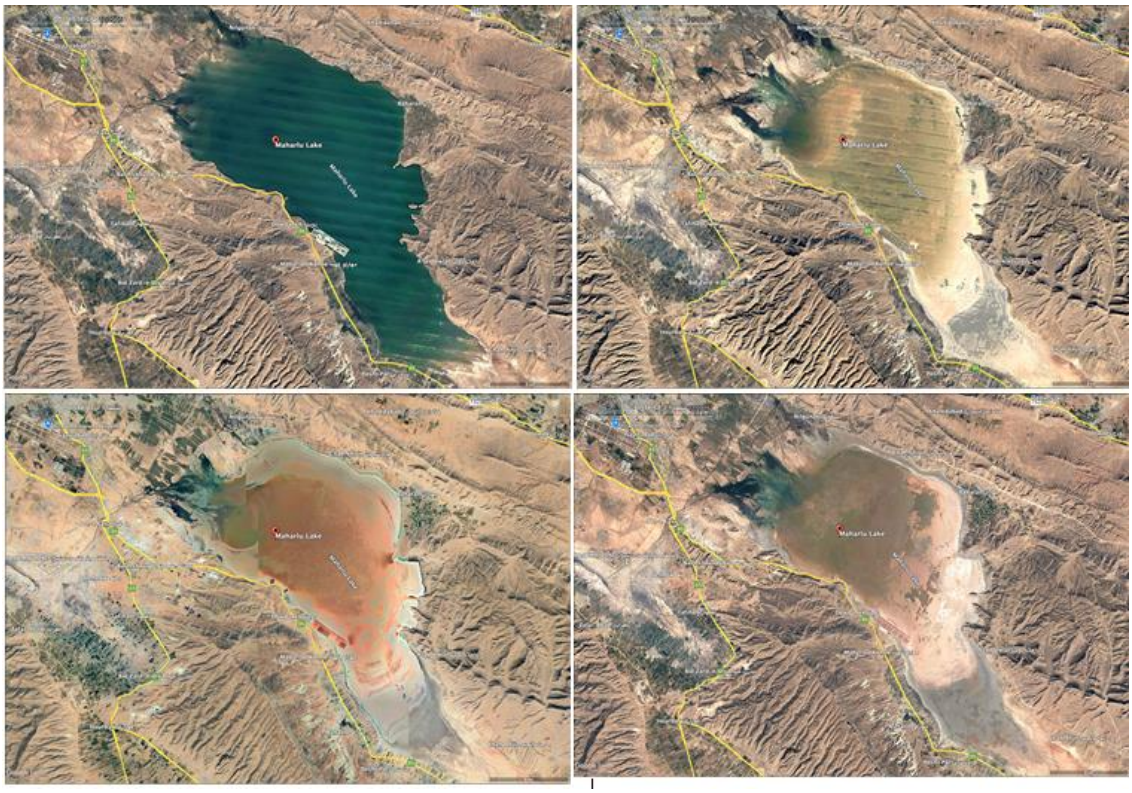

Fig.3. Satellite photo of the saltwater Maharlu Lake and surrounding water resources (wetlands) as the habitats of fish. Photo from Google Earth (from above left and in clockwise direction, 2005, 2010, 2010, 2023).

Fig.4. The wetland of Large Barm-e Shoor (above, March 2010), and a part of the Small Barm-e Shoor wetland (below, May 2010), Maharlu Lake basin. Photo: A. G.

Fig.5. Two ponds associated with Dobaneh Spring are additional wetland habitats to the south of Maharlu Lake with the first pond of Dobaneh, view north to the lake), and the second pond of Dobaneh (below, view to southeast). Photo: A. G., March 2010.

Fig.5. Continued. The second pond of Dobaneh (below, view to southeast). Photo: A. G., March 2010.

Fig.6. The wetland of Barm-e Delak (above on May 2010), and the nearby Sasanian petroglyph on the mountainside (below, summer 2017) on the way from Shiraz to Kaftarak, north of Maharlu Lake. Photo: A. G.

The path of the water channel from Barm-e Delak Spring, with a depth of ca. two meters and a width of ca. three meters, enters from the south and feeds the agricultural fields downstream (Fig. 6).

Barm-e Baboonak Wetland: The permanent freshwater wetland of 'Bram-e Baboonak', which is fed by underground springs, is located on the way from Shiraz to Kaftarak (after Kafatrak village, next to the asphalt road) on the north side of Maharlu Lake (Fig. 7). The depth of this wetland is such that swimming in it is prohibited. There are several warm-water fish (exotic carps) breeding farms in the vicinity of this wetland. The water from the springs adjacent to the wetland also flows in waterways towards Maharlu Lake (Fig. 7). The Bram-e Baboonak wetland and its nearby springs are important habitats for several species of endemic and native fishes and aquatic reptiles.

Ichthyofauna of the Maharlu Lake basin: The studied freshwater wetlands of the Maharlu Lake basin host twelve fish species belonging to seven families and three orders. Among these, three are endemic: *Acanthobrama persidis* (Coad, 1981) (Leuciscidae); *Capoeta saadii* (Heckel, 1847) (Cyprinidae, Cypriniformes); and *Esmaeilius persicus* (Jenkins, 1910) (Aphaniidae, Cyprinodontiformes) (Table 2, Appendix-SP). In the last decade, several exotic species of carps, namely *Carassius auratus*, *Ctenopharyngodon idella*, *Cyprinus carpio*, *Hypophthalmichthys molitrix*, have been introduced for aquaculture into this basin, especially to the freshwater bodies of the northern margin of the Maharlu Lake, as have been other incidentally introduced species. Our surveys conducted on numerous visits to the wetlands showed that the native fauna of this basin is, at present, under a significant threat of decline by drought (based on recent droughts and overharvesting of the groundwater resources). Despite the negative ecological threats of the exotic fish species and that most water resources of the lake margins have dried up, the few remaining water resources are used for the aquaculture of exotic Chinese carps. Field observations showed that local breeders of exotic fishes can regard the native fish and reptile species (*M. c. ventrimaculata* and *Natrix tessellata*) as pests, and these are discarded via seasonal drying of their natural habitats, direct removal from the habitat, or in some cases intentional killing. As a consequence, if the environmental management of the restricted resources of the basin is not carried out in the near future, the combination of these threatening factors will eventually lead to the extinction of most, if not all, of the populations of these native species.

Fig.7. Barm-e Baboonak Wetland (above, March 2010) and the feeding spring of the wetland (below, May 2010), on the north side of Maharlu Lake. Photo: A. G.

Observational account of Maharlu Lake basin wetland habitats

The current status of the Maharlu Lake basin wetlands and threats to their ichthyodiversity: The factors that threaten various levels of biological diversity (species, ecological, and genetic levels) of the wetlands in the Maharlu Lake basin can be divided into two

Fig.8. Photo series demonstrating the observed process of drying up of the Bram-e Shoor Wetland due to the reduction of underground aquifer storage and decreased rainfall over a period of years from 2010–2018. Clockwise from the bottom right: 2010, 2010, 2017 and 2018. Photo: A. G.

Fig.9. Dobaneh Spring, the main input source of the Dobaneh Wetlands, at the southern margin of Maharlu Lake in 2018 (right) and 2010 (left). Photo: A. G.

categories: 1) natural factors and 2) anthropogenic factors. Regarding the natural factors, in recent years, most of the water resources of Fars Province including the Maharlu Lake basin, especially the wetlands, have undergone severe biological changes, and in most cases, the entire wetland ecosystem has been destroyed. These major environmental changes are the result of long-term droughts and a lack of formal and proper planning to prevent negative consequences, as well as climate changes on a regional scale. Observations of the visited locations showed that most of the springs, and consequently the wetlands around Maharlu Lake, have completely dried up (Figs. 8–11). The biggest natural threat to Maharlu Lake, like other

Fig.10. Well drilling and water harvesting for industrial use around Dobaneh Spring and wetlands, Maharlu Lake basin area. Photo: A. G., 2010.

Fig.11. Dobaneh Wetland after destruction (left, 2018), and before drying up (right, 2010). In the post-destruction figure to the left a large congregation of tourists can be seen due to NowRuz (Iranian New Year) Ceremony, but the potential for ecotourism is missed. Photo: A. G.

wetlands in Fars Province, is the decrease in the amount of rain and as a result the decrease in its water rights from the seasonally Khoshk (Dry) river of Shiraz and the Sultan Abad River, as well as springs and wetlands are around it.

Anthropogenic factors also had observable impacts on some visited wetland habitats. With the urban and industrial development of Shiraz and its suburbs, and the increased human population, the amount of water withdrawal from surface streams and underground aquifers of this watershed has increased, especially for agriculture and food supply usage. This process, in turn, produces a higher volume of physical and chemical pollutants through urban and industrial sewage, as well as wastewater from agricultural lands (fertilizers and chemical pesticides). These enter the Maharlu Lake basin wetlands through the Khoshk (Dry) and Sultan Abad Rivers and other waterways, gradually altering the nutrient content of the wetland and changing the flora and fauna of the Maharlu Lake wetlands (Fig. 12).

The research visits to the above wetland habitats and surveys showed that the springs and wetlands on the south side of Maharlu Lake (Dobaneh Spring, Large Barm-e Shoor, and Small Barm-e Shoor) have completely dried up, and as a result, the populations of endemic and native species of fishes and aquatic reptiles including Persian tooth-carp *Esmaeilius persicus*, Persian bleak *Acanthobrama persidis*, Abu mullet *Planiliza abu*, Spot-bellied Caspian turtle *Mauremys caspica ventrimaculata*, and Dice snake *Natrix tessellate* are no longer present. (Fig. 9).

According to past and the present field observations, apart from the decrease in the amount of

Fig.12. Wastewater inflow and polluted effluents into Maharlu Lake via various local waterways are a factor threatening its biodiversity. Photo: A. G., 2018.

Fig.13. The completely dry wetland of the Barm-e Delek and the subsidence of the land next to it, due to the direct and indirect withdrawal of water from the spring. Photo by A. G., 2017 and 2018.

rainfall and the decrease in the level of underground water for agricultural use, the extraction of underground water in the southern side of Maharlu Lake for factories and industrial salt mines is one of the main causes of the drying of Dobaneh Spring (Fig. 10).

It was also observed that the southern springs (such as Dobaneh) that supply water to freshwater wetlands at the southern ridge of the Maharlu Lake, as well as water for industrial and agricultural uses, which were valuable habitats and had high potential for ecotourism, are now dried up, and have subsequently been neglected and even intentionally destroyed (Fig. 11). As shown in Figure 11, destroyed wetland sites that are on popular holiday routes lose their value for encouraging public interest in conservation and ecotourism.

On the north side of the Maharlu Lake, two wetlands ('Barm'), namely Barm-e Baboonak and Barm-e Delak, and several warm-water fish breeding farms are present. The research visits to these habitats showed that Barm-e Delak Wetland has completely dried up, due to the decrease in rainfall and the decrease in the level of underground aquifers that results from overharvesting for agricultural and industrial purposes (Fig. 13).

We observed that the ground in this area has depressions that show the deterioration of the situation. In the past, the water of this wetland had industrial and agricultural uses, as well as attraction for tourists. A sand mine located in the mountain near Barm-e Delak Wetland consumes a lot of water for industrial purposes; this, along with deep wells being dug in this area, reduces the chance of rehydrating Barm-e Delak Wetland. Barm-e Baboonak Wetland, the springs that feed it, and fish farms around it have previously been one of the best habitats in the Maharlu Lake basin in terms of highest species richness and species abundance. In the present study, it was observed that now only one fish farm continues to work, and this has destroyed or changed many associated natural habitats (ponds) of fish, directly and indirectly. Based on the first author's (A. G.) field observations, *N. tessellata* and *M. c. ventrimaculata*,

Fig.14. Direct removing of *Planiliza abu* and *Natrix tessellata* as nontarget species of Chinese carp fish farms because of their natural habits of feeding and predation. Photo: A. G., 2017.

Fig.15. Effect of decreasing rainfall on Barm-e Baboonak Wetland and its surrounding spring on summer 2017 (right) and spring 2018 (left). Photo: A. G.

Fig.16. *Gambusia holbrooki* (left) and *Mauremys capsica ventrimaculata* (right) are among the few remaining living vertebrates observed in Barm-e Baboonak Wetland. Photo: A. G., 2018.

as well as Abu mullet *Planiliza abu*, which are natural inhabitants of these habitats, are subject to population and habitat damage due to the fact that they are predators and competitors of exotic farmed carps. They are removed or discarded directly and indirectly from fish farms, while all the habitats of these native and endemic species (*E. persicus* and *Acanthobrama persidis*) have been completely destroyed at the southern side of Maharlu Lake (Fig. 14). The populations of endemic species in this area, namely *E. persicus*, *Acanthobrama persidis*, and *Capoeta saadii*, as well as native species including

Carasobarbus luteus and *Garra rufa*, have most likely been completely destroyed; only the exotic invasive fish *Gambusia holbrooki* and *P. abu* were observed in Barm-e Baboonak Wetland and a nearby fish farm (Figs. 15 and 16).

Wetland habitats on the north side of the Maharlu Lake are more suitable for fish than those of on the southern region due to the lower salinity of the water, and therefore the variety of fishes reported on this side of Maharlu Lake is greater compared to its south side; this includes *C. saadii*, *C. luteus* and *Garra rufa*, as well as farmed native and exotic species. Unfortunately, no samples of these fishes were observed during this research, where *Gambusia holbrooki* was the only fish species observed in the limited waters on the southern side.

DISCUSSION

Following the field observations of sites and survey results, it seems that if the situation of freshwater resources (habitats) in Fars Province continues, in terms of the decrease in rainfall and the increase in groundwater extraction, the few remaining habitats for fish and aquatic reptiles in the Maharlu Lake basin will also be lost, and as a result, the populations of aquatic vertebrates will be unsustainable. In some habitats, anthropogenic activity has had a major role in the destruction of the natural habitats (Fig. 17). Ongoing or future anthropogenic threats to biodiversity in the Maharlu Lake basin wetlands are the development of industrial salt mines in the lake, the plan to transfer surface water from Shiraz to the Sarvestan Plain, and the proposal to build the Tang-e Sorkh Dam upstream of the Khoshk River of Shiraz, as a feeder of Lake Maharlu (Jolaei & Ebrahimi Karnami 2014).

In the present study, twelve fish species were recorded in the freshwater bodies around Maharlu Lake including five exotic species, four native species, and three endemic species. If two additional species of the family Nemacheilidae, namely *Oxynoemacheilus persa*, and *Paraschistura naumanni*, from other habitats of the Maharlu Lake basin are included with our list the number of endemics in this area can be regarded as five species. Although, these two species were previously observed by the first author also in water sources outside the lake region. Eagderi et al. (2022) recorded fourteen species for the Maharlu Lake basin, including three native, four endemic, and seven exotic species. When we compared our lists of recorded species with that the checklist of Eagderi et al. (2022), it seemed that the discrepancies in the numbers of taxa in each category are based on a mistake in numeration of endemic taxa (four recorded endemic instead of five endemic species), specifically the consideration of *Cyprinus carpio* as a native species by Eagderi et al. (2022). In a study by Jouladeh-Roudbar et al. (2020), nineteen species belonging to seventeen genera and nine families including four endemic, nine non-native (exotic), and one unconfirmed species were recorded from the Maharlu Lake basin; of those records, Mossul bleak *Alburnus sellal* Heckel, 1843 was recorded as present in the basin, but this species was not recorded by Eagderi et al. (2022). Also, the presence of the Gibel carp *Carassius gibelio* (Bloch, 1782), Sharpbelly *Hemiculter leucisculus* (Basilewsky, 1855), and Bighead carp *Hypophthalmichthys nobilis* (Richardson, 1844) was recorded in the Maharlu Lake basin by Jouladeh-Roudbar et al. (2020), but the Maharlu Lake basin was not named in the records of these species by Eagderi et al. (2022). It is possible that the presence of these exotic species is a result of deliberate introduction as targets of fish farming or as a side effect of introduction with other exotic species.

The Rainbow trout *Oncorhynchus mykiss* (Walbaum, 1792) is a cold-water exotic species that has been introduced to the Tigris, Caspian Sea, Urmia Lake, Namak Lake, Kavir, Esfahan and Kor River basins and is widely farmed (Esmaeili et al. 2017; Eagderi et al. 2022). Yet, in a personal unpublished observation by the first author from about 15 years ago, a population of the species was recorded in the head spring of the Barm-e Baboonak Wetland. At that time, the owner of the farm announced that it was an unsuccessful experience of breeding this cold-water fish in relatively warm water.

According to Table 2, all endemic species of the

Fig.17. Burning of the reeds at the margin of Barm-e Baboonak Wetland (left) and drying the wetland for exotic fish farming (right). Photo: A. G., 2018.

basin are in the category NE (Not Evaluated) in the IUCN Red List of Threatened Species, among them is the Persian tooth-carp *Esmaeilius persicus* (junior synonym: *Aphanius farsicus* Teimori, Esmaeili and Reichenbacher, 2011), which is known only from the Maharlu Lake basin (Eagderi et al. 2022). Previously, we recorded it from all freshwater resources around Maharlu Lake, but today most of its natural habitats are destroyed or occupied by *Gambusia holbrooki*. Unfortunately, it can tentatively be said that the natural populations of this species around the lake (even the entire basin) have been destroyed by continuous droughts and the effects of human and environmental factors. Esmaeili et al. (2016) in their review article, discussed various aspects of the natural history of this critically endangered species, including conservation threats. Information from that study (Esmaeili et al. 2016) and another study on the embryogenesis and development of *E. persicus* (Sanjarani Vahed et al. 2018) can be useful in the conservation and sustainable management of this fish and other species of the Maharlu Lake basin.

Regarding the conservation status of *Acanthobrama persidis*, its habitats in the Maharlu Lake basin are dried out or are under severe pressure, and it seems that the populations of this endemic fish are now restricted to small streams in the upper reaches of the Kor River basin (Jouladeh-Roudbar et al. 2020). Water diversions by various means and purposes severely reduce water level, especially the pumping of water from the aquifer that feeds the systems. In addition, drainage rehabilitation, water pollution from domestic and agricultural sources, and severe drought in recent years seems to affect populations of the basin drastically. The same conditions are true in most of the wetlands of Fars Province, including the habitats of Tashk Wetland that houses several native and endemic fish species (Jouladeh-Roudbar et al. 2020; Gholamifard 2021).

CONCLUSIONS

The Maharlu Lake basin has special significance because of the diverse wetland habitats it presents in the midst of arid surroundings, supporting biodiversity in the area. It can be concluded from our observations that it is necessary to re-evaluate the conservation status of all native and endemic species in the basin and that this should be done urgently, due to the deteriorating conditions of the wetland habitats.

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Table 1. Wetland freshwater fish habitats of the Maharlu Lake basin surveyed in this study.

Assigned number	Name of wetland	Coordinate	Location	Ecosystem	Figure
1	Maharlu	29°29'–29°57' N, 52°14'–53°28' E	23 kilometers southeast of Shiraz; is a part of the Maharlu Hunting Prohibited Zone	Permanent, Saltwater	Figs. 1, 3
2	Large Barm-e Shoor	29°29' N, 52°42' E; 1480 m a.s.l	24 km southeast of Shiraz; in the southwest corner of Maharlu Lake, near the Lower village of Barm-e Shoor	Permanent, Freshwater	Figs. 3, 4
3	Small Barm-e Shoor	29°00' N, 52°42' E; 1465 m a.s.l.	24 km southeast of Shiraz; in the southwest corner of Maharlu Lake, near the Lower village of Barm-e Shoor	Permanent, Freshwater	Figs. 3, 4
4	Dobaneh	25°29° N, 52°46' E; 1352 m a.s.l	On the way from Shiraz to Sarvestan, before Dobaneh village	Permanent, Freshwater	Figs. 3, 5
5	Barm-e Delak	29°35' N, 52°39' E	14 km east of Shiraz (Shiraz to Kaftarak Road) and 4 km from the Abu Nasr Palace	Permanent, Freshwater	Figs. 3, 6
6	Barm-e Baboonak	29°31' N, 52°47' E	On the way from Shiraz to Kaftarak, after Kaftarak village, on the north side of the Maharlu Lake	Permanent, Freshwater	Figs. 3, 7

Table 2. List of recorded fish species from the wetlands of the Maharlu Lake basin. NE: Not evaluated, LC: Least concern, VU: Vulnerable, NT: Near threatened. Species were recorded in the present study (see Appendix) with the following exception: * = Not recorded in the present study, recorded based on Eagderi et al. (2022). Regarding distribution: + = Any previous record in any Lake Maharlu basin wetlands by the authors; − = Not recorded in the present study. Numbers in the most left column are the assigned numbers of wetlands based on Table 1, in which we record the species previously.

Family	Common and Scientific name	IUCN status	Occurrence
Cyprinidae	Saadi scraper *Capoeta saadii* (Heckel, 1847)	NE	Endemic+−6
	Gold fish *Carassius auratus* (Linnaeus, 1758)	LC	Exotic++6
	Mesopotamian himri *Carasobarbus luteus* (Heckel, 1843)	LC	Native+−6
	Common carp *Cyprinus carpio* Linnaeus, 1758	VU	Native++6
	Red garra *Garra rufa* (Heckel, 1843)	LC	Native+−6
Gobionidae	Topmouth gudgeon *Pseudorasbora parva* (Temminck and Schlegel, 1846)	LC	Exotic++6
Leuciscidae	Persian bleak *Acanthobrama persidis* (Coad, 1981)	NE	Endemic+−2, 6
Nemacheilidae	*Oxynoemacheilus persa* (Heckel, 1847)*	NE	Endemic− −
	Paraschistura naumanni Freyhof, Sayyadzadeh, Esmaeili and Geiger, 2015*	NE	Endemic− −
Xenocyprididae	Grass carp *Ctenopharyngodon idella* (Valenciennes, 1844)	NE	Exotic++6
	Silver carp *Hypophthalmichthys molitrix* (Valenciennes, 1844)	NT	Exotic++6
Mugilidae	Abu mullet *Planiliza abu* (Heckel, 1843)	LC	Native++2, 6
Aphaniidae	Persian tooth−carp *Esmaeilius persicus* (Jenkins, 1910)	NE	Endemic+−2, 3, 4, 5, 6
Poeciliidae	Eastern mosquitofish *Gambusia holbrooki* Girard, 1859	LC	Exotic++2, 3, 4, 5, 6

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Appendix. List of recorded fish species in the wetlands around the Lake Maharlu, Maharlu Lake basin, Iran. (A) *Acanthobrama persidis* (Coad, 1981), (B) *Capoeta saadii* (Heckel, 1847), (C) *Carassius auratus* (Linnaeus, 1758), (D) *Carasobarbus luteus* (Heckel, 1843), (E) *Ctenopharyngodon idella* (Valenciennes, 1844), (F) *Cyprinus carpio* Linnaeus, 1758, (G) *Garra rufa* (Heckel, 1843), (H) *Hypophthalmichthys molitrix* (Valenciennes, 1844) , (I) *Pseudorasbora parva* (Temminck and Schlegel, 1846), (J) *Planiliza abu* (Heckel, 1843), (K) male *Esmaeilius persicus* (Jenkins, 1910), (L) female *Esmaeilius persicus*, (M) female *Gambusia holbrooki* Girard, 1859. Photos: First author (A. G).

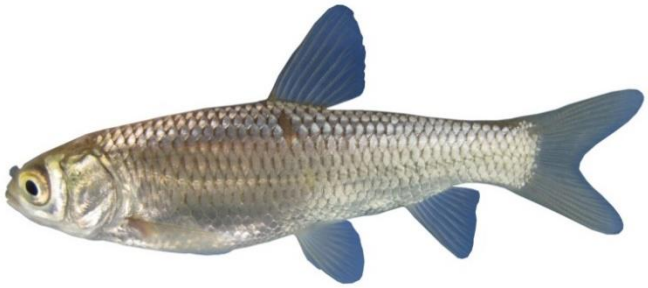
A

B

C

D

E



F

G

H

I

J

K

L

M

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مقاله کامل

تالاب‌های حوضه آبریز دریاچه مهارلو، جنوب ایران: فون ماهیان و اثرات منفی پرورش ماهیان غیربومی و خشک شدن تالاب‌ها

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چکیده: حوضه آبریز بسته دریاچه مهارلو در دره شیراز، در استان فارس، جنوب ایران واقع شده است. دریاچه مهارلو توسط نهرها و چشمه‌های کوچک پیرامون حاشیه آن، و رودخانه خشک تغذیه می‌شود. در مطالعه حاضر، بر پایه عملیات میدانی انجام شده در مردادماه ۱۳۹۶ و فروردین ماه ۱۳۹۷، مرور مختصری بر برخی از زیستگاه‌های تالابی حوضه آبریز دریاچه مهارلو ارائه خواهد شد، گزارش‌هایی از فون ماهیان این ناحیه را ثبت نموده و در مورد وضعیت حفاظتی گونه‌های ساکن در زیستگاه‌های بررسی شده اظهار نظر خواهد گردید. منابع آب شیرین این حوضه آبریز میزبان چهارده گونه ماهی و دو گونه خزنده است که در میان آنها *Acanthobrama persidis* (کپورهای سرمخروطی)، *Capoeta saadii* (کپورماهیان)، *Oxynoemacheilus persa*، *Paraschistura naumanni* (لوچ ماهیان)، و *Esmaeilius persicus* (گورماهیان) به‌عنوان گونه‌های بومزاد ایران در این حوضه آبریز نیز پراکنش دارند. در طول دهه گذشته، چندین گونه غیربومی از کپورماهیان، یعنی *Carassius auratus*، *Ctenopharyngodon idella*، *Cyprinus carpio*، *Hypophthalmichthys molitrix*، به‌علاوه گونه معرفی شده تصادفی *Pseudorasbora parva*، برای آبزی‌پروری به این حوضه به‌ویژه به منابع آب شیرین حاشیه شمالی دریاچه مهارلو معرفی شده‌اند. بررسی‌های ما نشان می‌دهد که فون ماهیان بومی و بومزاد این حوضه آبریز، در حال حاضر، تحت تهدید از هر دو عوامل طبیعی و انسانی شامل خشکسالی و معرفی گونه‌های غیربومی برای اهداف آبزی‌پروری هستند، به‌طوری که در طول این مطالعه هیچ رخدادی از این گونه‌ها شامل *Acanthobrama persidis*, *Capoeta saadii*, *Carasobarbus luteus*, *Garra rufa*, *Esmaeilius persicus* درتالاب‌ها ثبت نگردید. به‌عنوان یک نتیجه، اگر مدیریت زیست‌محیطی منابع محدود این حوضه آبریز در آینده نزدیک انجام نشود، ترکیب این عوامل تهدید کننده در نهایت منجر به انقراض محلی بیشتر، اگر نه همه، از جمعیت‌های این گونه‌های بومی و بومزاد ماهیان خواهد شد.

کلمات‌کلیدی: ماهیان غیربومی، بومزاد، فون ماهیان، حوضه آبریز دریاچه مهارلو، استان فارس، ایران