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Piscivorous Vertebrates That May Pose a Risk to the Critically Endangered Mandra Shemaya, *Alburnus mandrensis* (Drensky, 1943) (Actinopterygii; Leuciscidae)

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Abstract: In the present study, we provide a checklist of the predators that may impact the population of the critically endangered Mandra shemaya (*Alburnus mandrensis* Drensky, 1943). This endemic fish only inhabits the basin of Mandra Lake in the Burgas district (SE Bulgaria) and data on its biology are scarce. We have confirmed the presence of the Mandra shemaya in Mandra Lake for the last six years (including 2024) and provided an analysis on the potential predatory pressures on *A. mandrensis*. The recently recorded presence of a highly invasive piscivorous predatory fish in Mandra Lake is considered potentially dangerous for the sustainability of native fish species.

Keywords: ecology; habitat; predator–prey interaction; bio-risk; invasion; extinction

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1. Introduction

The Leuciscidae family includes 94 genera and more than 670 species [1]. One of these species, the Mandra shemaya, *Alburnus mandrensis* (Drensky, 1943), has a rather restricted range and inhabits only the Mandra Lake and some of its tributaries in the district of Burgas city (southeastern Bulgaria). The biology of the species is poorly documented, and the position of the leuciscid in the trophic food web is not well understood. The Mandra shemaya has been listed under the Red list category as "Critically Endangered B1ab(ii,iii)" by the IUCN [2]. Besides the limited range of the species (extent of occurrence < 100 km^2), ref. [2] recognized the most important risks for the species to be related to the deterioration of its habitat and the pollution of the Mandra Lake aquatic system with domestic and industrial toxins. The impoundment of the spawning waters was listed as an additional threat.

Mandra Lake belongs to the Burgas Lakes complex. These lakes are among Europe's most important locations for bird conservation as they provide permanent or transient habitat for a great variety of avian species [3–6]. The Burgas wetland complex is inhabited by a great variety of piscivorous vertebrates (predominantly birds), which use the fish resources of the freshwater basins and the Black Sea for feeding. Some predators are facultative fish eaters and, in several species, fish are consumed only sporadically. Some of the piscivorous species rely exclusively on fish for nutrition. In limnic habitats, the piscivorous vertebrates may be very important top predators, which may severely impact fish populations (see [7–17]).

In the present study, we assessed the risk of carnivorous vertebrate diminishing the population of the critically endangered *A. mandrensis*. Additionally, we provided an analysis on the potential pressure that the non-native piscivorous fish species are placing on the local population of Mandra shemaya.

2. Materials and Methods

The presence of the piscivorous birds in the vicinity of Mandra Lake was monitored in regular intervals of 15 days from the early spring of 2010 and the presence was documented (Appendix A). The main objective was to monitor all bird species that are known to consume fish, regardless of the method of predation or quantity. We recorded the taxonomic specifics of all detected specimens, their ontogenetic status, and specific features, if present. We divided the bird species into categories concerning their diet and feeding ethology, annual presence, the density of their population, and the potential impact that the species may put on the population of *A. mandrensis*. Data on the diet and the feeding behavior of piscivorous bird species in Bulgaria are rather scarce. For our analysis, we selected relevant information from publications that provide such data within Europe. For several species, we used information from other continents because the data were recognized as important for our study (see Table 1).

Table 1. Avian piscivorous species, which inhabit or can be detected in the vicinity of Mandra lake (SE Bulgaria).

Common Name	Latin Name	Presence in Mandra Lake Area	Piscivorous	Potential Impact on *A. mandrensis*	Data on Diet	Detected since 2010, Maximum Specimens per Day
Common merganser	*Mergus merganser*	Wintering	Obligatory	Very low	[18]	3 ind
Red-breasted merganser	*Mergus serrator*	Wintering, migrant	Obligatory	Very low	[19]	10 ind
Smew	*Mergellus albellus*	Wintering, migrant	Obligatory	Low	[20]	30 ind
Red-throated loon	*Gavia stellata*	Wintering, migrant	Obligatory	No	[21,22]	1 ind
Black-throated loon	*Gavia arctica*	Wintering, migrant	Obligatory	No	[22]	3 ind.
Great crested grebe	*Podiceps cristatus*	Resident	Obligatory	Low	[23]	8000 ind.
Red-necked grebe	*Podiceps grisegena*	Migrant	Facultative	No	[24]	5 ind
Little grebe	*Tachybaptus ruficollis*	Resident	Facultative	Very low	[25]	700 ind.
Black-necked grebe	*Podiceps nigricollis*	Wintering, migrant	Obligatory	No	VM, ID, DD, personal data	50 ind.
Horned grebe	*Podiceps auritus*	Wintering, migrant	Obligatory	No	[26]	1 ind.
Great white pelican	*Pelecanus onocrotalus*	Wintering, migrant	Obligatory	Moderate	[27]	10,000 ind.
Dalmatian pelican	*Pelecanus crispus*	Wintering, migrant	Obligatory	Low	[28]	1300 ind.
Great cormorant	*Phalacrocorax carbo*	Resident	Obligatory	Moderate	[29]	20,000 ind.

Table 1. *Cont.*

Common Name	Latin Name	Presence in Mandra Lake Area	Piscivorous	Potential Impact on *A. mandrensis*	Data on Diet	Detected since 2010, Maximum Specimens per Day
Pygmy cormorant	*Microcarbo pygmeus*	Resident	Obligatory	Moderate	[30]	16,000 ind.
Purple heron	*Ardea purpurea*	Breeding, migrant	Facultative	No	[31]	15 ind.
Black-crowned night heron	*Nycticorax nycticorax*	Breeding, migrant	Facultative	Low	[32–35]	100 ind.
Great egret	*Ardea alba*	Wintering, migrant	Facultative	Moderate	[36–38]	1200 ind.
Little egret	*Egretta garzetta*	Breeding, migrant	Facultative	Low	[39]	70 ind.
Eurasian bittern	*Botaurus stellaris*	Wintering	Obligatory	Very low	[40]	20 ind.
Squacco heron	*Ardeola ralloides*	Breeding, migrant	Facultative	low	[41]	90 ind.
Grey heron	*Ardea cinerea*	Resident	Facultative	Moderate	[42]	200 ind.
White-tailed eagle	*Haliaeetus albicilla*	Resident	Facultative	Very low	[43,44]	16 ind.
Osprey	*Pandion haliaetus*	Migrant	Obligatory	Very low	[45]	10 ind.
Black-headed gull	*Chroicocephalus ridibundus*	Wintering, migrant	Facultative	Low	[46]	5000 ind.
Great black-headed gull	*Ichthyaetus ichthyaetus*	Wintering, migrant	Obligatory	Low	[47]	128 ind.
Mediterranean gull	*Larus melanocephalus*	Migrant	Facultative	No	[48]	20 ind.
Slender-billed gull	*Larus genei*	Migrant	Facultative	No	[47]	400 ind.
Little gull	*Larus minutus*	Migrant	Facultative	No	[48]	300 ind.
Yellow-legged gull	*Larus michahellis*	Resident	Facultative	Low	[49]	3500 ind.
Caspian tern	*Hydroprogne caspia*	Migrant	Obligatory	Low	[50]	85 ind
Black tern	*Chlidonias niger*	Migrant	Exceptionally	Very low	VM, ID, DD, Personal data	3800 ind.
White-winged tern	*Chlidonias leucopterus*	Migrant	Facultative	Low	VM, ID, DD, Personal data	800 ind.
Whiskered tern	*Chlidonias hybrida*	Migrant	Facultative	Low	[51]	1000 ind.
Gull-billed tern	*Gelochelidon nilotica*	Migrant	Facultative	Very low	[48]	120 ind.
Common tern	*Sterna hirundo*	Breeding, migrant	Obligatory	Low	[52,53]	300 ind.
Common kingfisher	*Alcedo atthis*	Resident	Obligatory	Very low	[54]	20 ind.

We recorded the presence of piscivorous birds in the range of Mandra Lake and grouped the species into the following four categories:

"Resident" referred to species that bred in the area and remained there throughout the year;

"Breeding" referred to species that bred in the area, but were not present for some seasons of the year;

"Migrant" referred to species that appeared in the area during migrations;

"Wintering" referred to species that were detected in the area during the winter. Some species were included in more than one category as part of the birds of one species may display different behavior (e.g., some birds may be nesting, and other parts of the population may be only migrating through the region).

The monitoring of the fish species in Mandra Lake started in the spring of 2018 and is still ongoing. We studied the anglers catch in irregular intervals of about 20 days during the active fishing season. During the field surveys, we recorded the presence of grass snake (*Natrix natrix*) and dice snake (*Natrix tesselata*). We also documented the spraints and prints of the European otter (*Lutra lutra*). Data on the diet and the feeding behavior of non-avian piscivorous vertebrates was found in relevant articles (see Table 2).

Table 2. Non-avian piscivorous vertebrates, which inhabit Mandra Lake (SE Bulgaria) or its vicinity. "Resident" were considered species that inhabited permanently the Mandra Lake; "Sporadic" were considered species that were found only occasionally in Mandra Lake; "Obligatory" were considered species, which rely exclusively on fish in their diet; "Predominantly" were considered species that consume mainly fish, but also consume other prey; "Facultative" were considered species that occasionally feed on fish; "Permanent" were considered local species, which were detected regularly in Mandra lake; "Invasive" were considered non-native species that were detected to inhabit Mandra Lake.

Vertebrate Group	Common Name	Latin Name	Resident	Piscivorous	Potential Impact on *A. mandrensis*	Data on Diet	Detected since 2018
Fish	European wels	*Silurus glanis*	Resident	Obligatory	Low	[55]	Permanent
Fish	European perch	*Perca fluviatilis*	Resident	Facultative	Moderate	[56–59]	Permanent
Fish	Pike-perch	*Sander lucioperca*	Resident	Obligatrory	Moderate	[60–62]	Permanent
Fish	Northern pike	*Esox lucius*	Resident	Obligatory	Moderate	[63–66]	Permanent
Fish	Eurasian ruffe	*Gymnocephalus cernuus*	Resident	Facultative	Very low	Data Deficiency	Invasive, detected in 2002 and 2022
Fish	Jaguar cichlid	*Parachromis managuensis*	Sporadic	Obligatory	Very low	[67]	Invasive, detected in 2023
Fish	Largemouth bass	*Micropterus salmoides*	Resident?	Obligatory	High	[68]	Invasive, detected in 2022, 2023
Reptile (Turtle)	Red-eared slider complex	*Trachemys scrypta*	Resident	Facultative	Very low	[69]	Invasive, Detected 2018–2023
Reptile (Snake)	Grass snake	*Natrix natrix*	Resident	Facultative	Very low	[70]	Permanent
Reptile (Snake)	Dice snake	*Natrix tessellata*	Resident	Predominantly	Low	[70]	Permanent
Mammal	European otter	*Lutra lutra*	Resident	Facultative	Very low	[71,72]	Permanent

Keeping in mind the high conservation status of *A. mandrensis* and the anthropogenic pressure on the habitat, we assessed the threat that every predator species may represent for the Mandra shemaya. Changes in the ecological equilibrium may lead to an increase in the number of some predatory species, and we provide our expert opinion concerning the potential of the piscivorous predators to harm the population of *A. mandrensis* in extreme conditions. We assessed the potential risk of every predator species as follows:

"No" in case no impact is expected in any circumstance;

"Very low" in case both the population density, as well as the presence regularity of the predator increase drastically in a short time, it would not threaten the fish population;

"Low" in case both population density, as well as the presence regularity of the predator increase gradually, it would not threaten the fish population;

"Moderate" in case both population density, as well as the presence regularity of the predator increase gradually, it may threaten the fish population;

"High" in case the increase in the predator's population may lead to extinction of the Mandra shemaya.

3. Results

During our field survey, we confirmed the presence of Mandra shemaya in Mandra Lake and its tributaries—Sredetska, Fakiiska, and Izvorska rivers. One unconfirmed report was provided for the presence of *A. mandrensis* in the Promed Dam near Mandra Lake. Data on the longest spawning migration was from the region of Prohod village on the Sredetska river. This is the furthermost locality of mature specimens upstream of the river mouth. The largest specimen detected was with a total length of 16.6 cm standard length (Sl).

A total of 36 piscivorous bird species were detected in the vicinity of Mandra Lake (Table 1). Five species were identified as a "moderate" potential threat for *A. mandrensis*; these include the great white pelican, the pygmy cormorant, the great cormorant, the great egret, and the great heron. The most of the piscivorous birds inhabiting the location were considered to represent a "Low" risk for the endangered fish species, even in case of an increase in their populations and presence in the region. For nine species, the assessment was that they represent a "Very low" potential threat, because they do not rely largely on fish as a food source, however they rarely consume and only as an addition to their main diet. Other criteria for the assessment of "Very low" risk was that the species was rarely found in the habitat.

Seven piscivorous fish species, two snakes, one terrapin, and one mammal were identified as potential risks for *A. mandrensis* (Table 2). The terapod vertebrates from that list represented a "Low" or "Very low" risk for the endangered fish species. Three of the piscivorous fishes were assessed as a moderate threat and the invasive Largemouth bass was assessed as highly dangerous for the population of the Mandra shemaya.

4. Discussion

According to [8], predation by piscivorous birds is considered a substantial threat to the aquaculture industry; however, for the local population of fish, this is not the main threat. The impact of piscivorous birds, such as grey herons, great crested grebes, and even of Cormorants, on fish populations may be massive but it is not leading to the significant diminishing of prey fish. The combined impact of all piscivorous birds on fish populations is often much lower than that of commercial fishing (see [15]). It was reported by [73] that the commercial catches may be 10–20 times higher than the consumption by predatory birds. According to the author, in the European limnic ecosystems, the fishermen catch was 4–12 times as much as the cormorant catch. Most predatory birds switch easily between the species of fish they are capturing [74] and birds are seldom a real threat for a particular fish species. This is the reason why practices like eradication of piscivorous birds were largely abandoned in the past (see [75]). In the case of *A. mandrensis*, no avian species was recognized as a danger to the endangered species' population. Mandra Lake is inhabited by over 20 species of fish, some of which are found in abundance—*Carassius gibelio*, *Rutilus*

rutilus, etc. (K.V., T.S., N.K., personal unpublished data), so the food basis for predatory birds is present. Even specialized piscivorous species that consume fish in large quantities, like the grey heron, great egret, great cormorant, great white pelican, were not recognized as a severe threat in the present article. These are local species, which have been an object of intense monitoring in the last 14 years, and none of them were found specifically to prey on *A. mandrensis*. According to our observations, the hunting ecology of the pygmy cormorant may represent a special threat for the Mandra shemaya; however, this species is not that numerous so as to be regarded as highly dangerous for the fish population.

The non-avian piscivorous species, which hunt in the lake, were also numerous. Among them the only mammal was the European otter. The otter feeds on fish, but is rather opportunistic in its diet (see [72]). The number of these predators is relatively too low to represent a threat for the fish populations of Mandra Lake. Of the piscivorous reptiles, the only one specialized for preying on fish is the dice snake (*N. tessellata*) [70]. The consumption of very few prey items per active season by this snake limits the potential of this species to significantly impact the populations of critically endangered fish species. The other reptile species (*N. natrix* and *T. selegans* complex) rely to lower degree on fish consumption [69,70].

Fish predators like the European perch (*Perca fluviatilis*), the Northern pike (*Esox lucius*) and the Pike-perch (*Zander lucioperca*) represent a more significant danger [56–66]. All of these species were numerous and are presumed to feed on *A. mandrensis*. We propose that the long-term coexistence and ethological co-evolution at the local level of the shemaya and the native carnivore fishes resulted in the prey fish's adaptation to the pressure from said predators. We also admit that the local piscivorous fish species regulates the population of *A. mandrensis*; however, their impact is not destructive.

The Jaguar cichlid was detected only once in Mandra Lake, and we propose that this species would not be able to overwinter in the local climatic conditions. The newly detected presence of numerous sub-adult and adult specimens of the Largemouth black bass (*Micropterus salmoides*) in Mandra Lake and its adjacent water basins (see [76]) is, however, rather alarming. The Largemouth black bass was included in the list of the 100 most dangerous invasive species [77] and can inflict catastrophic effects in the new habitats it invades [78,79]. Here we have to stress that Mandra Lake is inhabited by another invasive centrarhid—the pumpkinseed (*Lepomis gibbosus*). This fact increases the risk for the local ichthyofauna. When both invasive centrarchids coexist, they prevail over the native fish species and create an imbalance in the ecosystem—the pumpkinseeds may appear in great numbers and totally dominate other fish species [80]. Unfortunately, the authors of the present study were not able to find sound scientific source concerning the eradication of a particular invasion of *M. salmoides*. In the current situation, immediate measures have to be undertaken to diminish the impact of *M. salmoides* in Mandra Lake. In particular, educational work with the local fishermen has to be provided and the "catch and release" fishing of the Largemouth black bass has to be terminated. New releases of that predator have to be banned.

Our findings demonstrate that, in addition to anthropogenic threats (related to pollution and habitat deterioration), which were recognized by [2], in recent years the invasion of predatory alien fish species have to be regarded as a rather alarming factor. The infestation Mandra Lake with *M. salmoides* could be regarded as a direct and already activated mechanism that is reducing the resources of the critically endangered Mandra shemaya.

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Appendix A

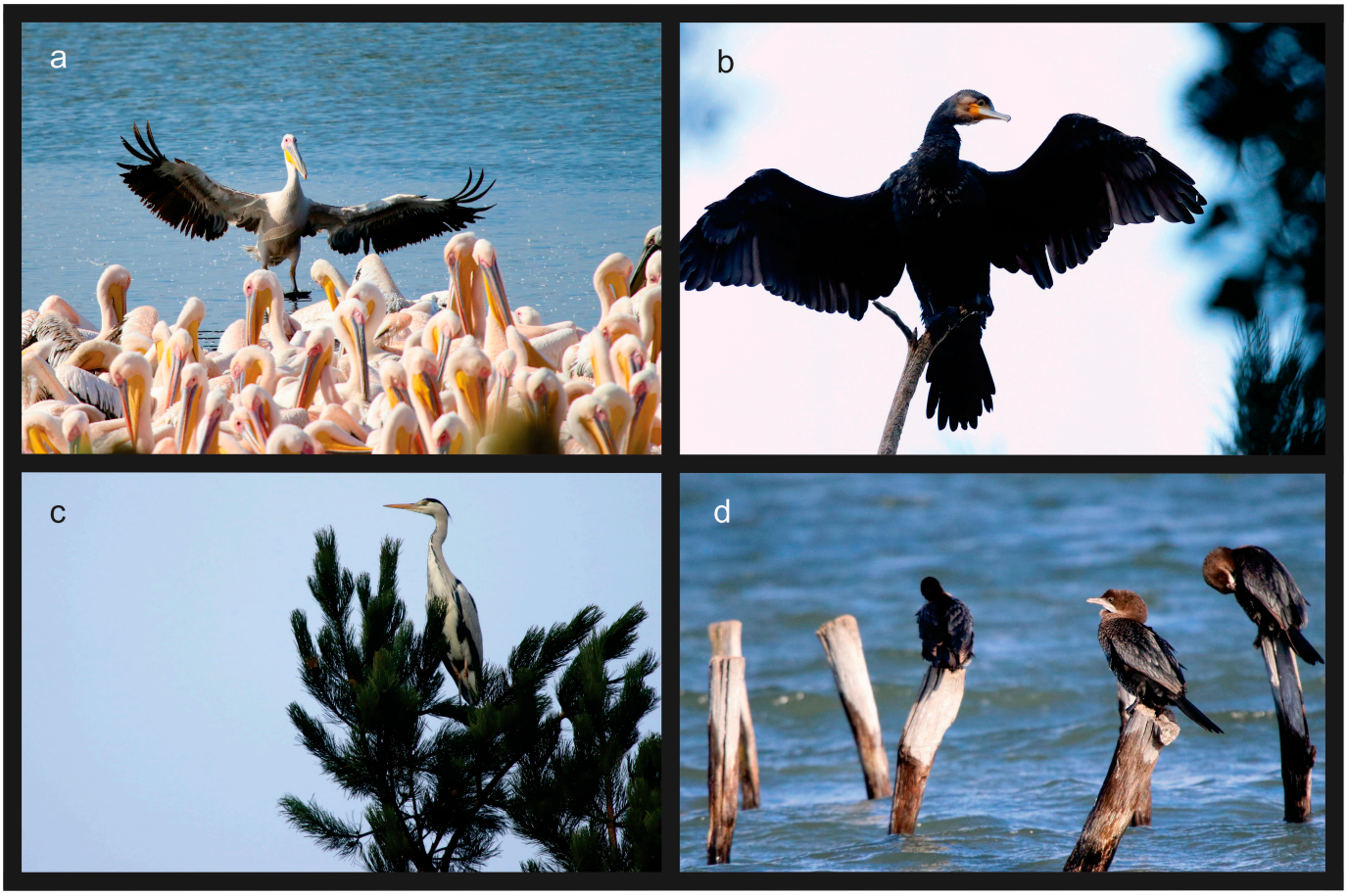

Figure A1. Images of some important piscivorous birds that inhabit the vicinity of Mandra Lake: (**a**) great white pelican (*Pelecanus onocrotalus*), (**b**) great cormorant (*Phalacrocorax carbo*), (**c**) grey heron (*Ardea cinerea*), (**d**) pygmy cormorant (*Microcarbo pygmeus*).

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