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Review

Status of Endemic Freshwater Fish Fauna Inhabiting Major Lakes of Turkey under the Threats of Climate Change and Anthropogenic Disturbances: A Review

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Abstract: Due to its peculiar geographical position and its environmental heterogeneity, Turkey represents an important biodiversity hotspot for freshwater fish fauna. Unfortunately, native fish communities of Turkey, mainly from lentic ecosystems, have been massively altered in the past decades. Furthermore, these species, especially the endemic species, are now threatened by several human activities in addition to the global issue of climatic changes. The aim of this paper is to provide an updated review on the current status of endemic fish species from main lakes of Turkey including major threats affecting fish assemblages. By gathering data from the literature and authors' personal observations, 62 endemic fish species were reported to occur in the considered 37 Turkish Lakes. The presence of non-native species, agriculture activities, climatic drought, and decreasing water level were found to be the threats that most affect the fish communities of the considered Turkish Lakes.

Keywords: Anatolia; IUCN; non-native species; water drought; aquatic biodiversity

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1. Introduction

Due to its crossroads location and the diversity of its geographic features and climatic conditions, Turkey hosts a very rich biodiversity. This richness is also clearly reported by the global map of biodiversity hotspots showing that 3 out of 34 world biodiversity hotspots meet in Turkey: The Mediterranean, Caucasus, and Irano-Anatolian [1]. This unique biodiversity is the result of various biogeographic factors [2] and land-use history [3] that, over the centuries, have shaped the territory. Turkey is also a core of intraspecific diversity given that during the last glacial age it served as the so-called South-Eastern refugium for several European taxa [4,5].

The Asian part of Turkey, also known as Anatolia or Asia Minor (hereinafter referred to as Anatolia), is perhaps one of the richest regions in the world in terms of lakes. The Eastern Anatolian region and north of the Taurus Mountains in the Mediterranean region, also known as the "Lakes Region", hosts the majority of the Turkish lakes. These lakes are the remains of large inland lakes that once covered Central and Eastern Anatolia and often have distinct features deriving from their surrounding soils. For this reason, all these lakes have peculiar water features that make them worthy of worldwide interest. Among them, Lake Van is the world's largest soda lake and also one of the largest of few endorheic lakes located in Eastern Anatolia; Lake Tuz is one of the world's largest hypersaline lakes with a surface and water level that vary seasonally [6]. These lakes are also important wetlands providing breeding, accommodation, and wintering areas for water birds. This is because Turkey is the passage for two major bird migration routes extending from northern Europe to Africa. In more detail, among the Turkish wetland protected areas, 91 to 135 in Turkey are special areas for birds [7].

Despite this richness and these peculiarities, half of these wetland areas are currently threatened by drought. In the last 100 years, about 1.3 million hectares of Turkish wetlands

have completely dried out [8]. The diminution of annual and winter precipitation occurring in Turkey (and principally in the Aegean and Mediterranean regions) in the last decades has led to a gradual degradation of soil moisture and a general decrease in the water level of the Turkish lakes [9,10]. This is mainly due to increasing temperature caused by climate change and the pressure generated by anthropogenic activities, mainly consisting of draining activities for the control of malaria or the creation of new agricultural lands [8]. Also, the alteration of water flows, water pollution, and eutrophication represent the most severe threats to Turkish wetlands [11]. In addition to these, a further degradation of these habitats derives from the overexploitation of marginal vegetation of the lakes by local communities for livestock farming [2,12]. In particular, Türkeş [13] reported that by an examination of the regional and historical changes in precipitation and drought index series in Turkey showed that extreme drought in the southeast and middle Anatolia regions is mostly due to climatic effects, whereas in the Mediterranean and Aegean regions it is principally due to anthropogenic disturbances.

The peculiar characteristics of these aquatic environments are also reflected in their fauna, which, having been isolated for very long time due to the above cited factors, have undergone an original process of speciation. As a result of this isolation, Turkish lakes host several rare species [14]. Moreover, the fauna inhabiting the lakes are particularly vulnerable to climate change because they have limited possibility to disperse in case of rapid environment changes and because, as mentioned above, they are already exposed to numerous human-induced pressures [15]. Among these human-induced threats, the presence of non-native species is reported worldwide as the second main factor threatening aquatic fauna after climate change [16]. Among the non-native species, some become invasive and are able to establish viable populations that can negatively impact the new environment [17,18]. With regard to Turkey, it is known that the composition of the fish communities of Turkish inland waters has been significantly altered in the last decades by a huge number of non-native species that have been introduced, deliberately or accidentally, into inland water, leading to alterations in ecosystem structure and impacting the abundance and composition of native communities [19]. Non-native species can cause detrimental impacts on the environment, not only indirectly because of their impacts on native fauna through predation, competition, hybridization, or disease transmission; they can also be a direct cause of habitat degradation [20–23].

Although several local studies focusing on fish species of some Turkish lakes are available in the literature, there is a lack of a comprehensive summary of the threats posed to them or the endemic fish species inhabiting these valuable ecosystems.

Thus, the aim of this study was to provide an updated review on the current status of endemic fish species from main lakes of Turkey, including the major threats affecting fish assemblages.

2. Materials and Methods

In order to create a complete and exhaustive background, the available literature and published data reported in recent international publications (papers, proceedings, and books from 1990 to 2020) were assembled and supplemented with information accessible from grey literature (theses, project reports) and personal unpublished observations of the authors.

Specifically, 37 lakes located across Turkey and chosen considering those most studied and for which information was available in literature were taken under consideration (Figure 1).

Firstly, a list of the endemic freshwater fish species occurring in the considered Turkish lakes was created taking into consideration the local endemic species (endemic only to a restricted lake or watershed) or regional endemism (species occurring only in several of the selected lakes). For each fish species, all taxonomic information follows FishBase and Eschmeyer's Catalog of Fishes [24,25], and its IUCN Red List Category [26] is also provided.

Thus, for each lake, a detailed list of the major threatening factors was created taking into consideration the following 14 threats organized by impact from highest to lowest:

climatic drought; decreasing water level; presence of non-native species; agricultural activities; water pollution; wastewater discharge; overfishing; urbanization; presence of industrial activities; tourism activities; massive fish death; cutting/burning of the reeds; aquaculture activities; and presence of power plants.

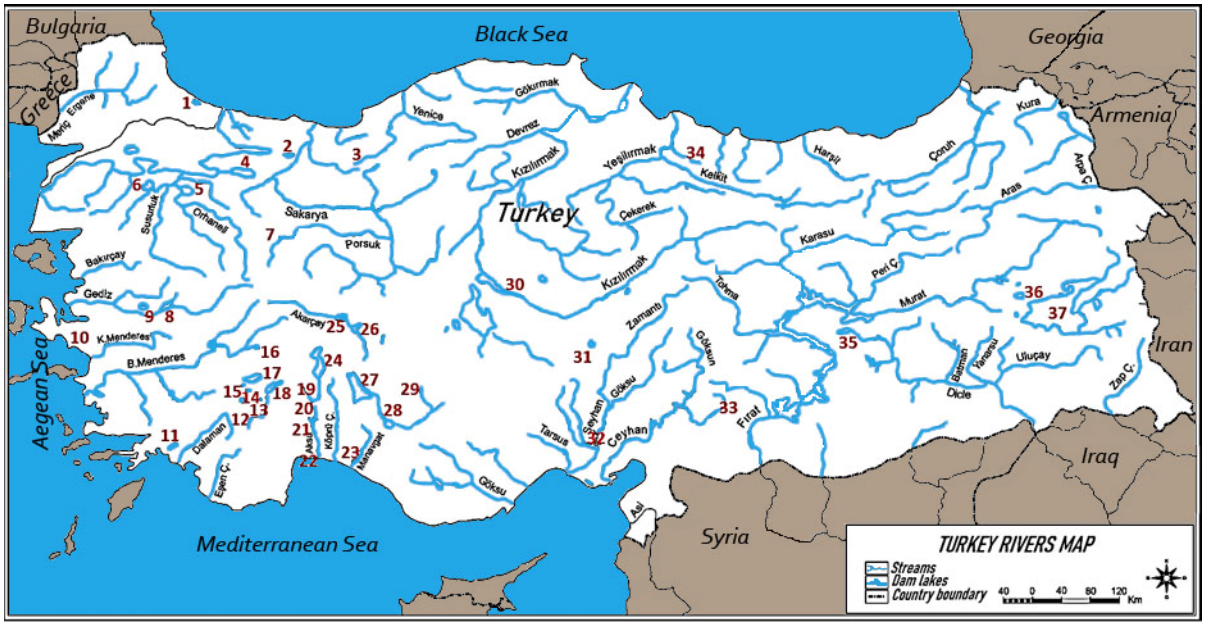

Figure 1. Map reporting the locations * of the 37 lakes in Turkey considered in the study, together with their river systems (*: 1—Lake Durusu, 2—Lake Sapanca, 3—Lake Abant, 4—Lake Iznik, 5—Lake Apolyont (Uluabat), 6—Lake Manyas, 7—Dam Lake Enne, 8—Dam Lake Demirköprü, 9—Lake Marmara, 10—Lake Kocagöz, 11—Lake Köyceğiz, 12—Dam Lake Yapraklı, 13—Lake Gölhisar, 14—Lake Yarışlı, 15—Lake Salda, 16—Lake Işıklı, 17—Lake Acıgöl, 18—Lake Burdur, 19—Lake Gölcük, 20—Dam Lake Onaç, 21—Lake Kırkgöz, 22—Lake Yamansaz, 23—Dam Lake Manavgat, 24—Lake Eğirdir, 25—LakeEber, 26—Lake Akşehir, 27—Lake Beyşehir, 28—Lake Suğla, 29—Lake Altınapa, 30—Dam Lake Hirfanlı, 31—Marshes Sultan, 32—Dam Lake Seyhan, 33—Lake Gölbaşı, 34—Dam Lake Almus, 35—Lake Hazar, 36—Lake Nazik, 37—Lake Van).

For the threat ''presence of non-native species'', specific details on the non-native species are reported for each lake. Specifically, the following categories for introduced species (non-native and translocated) were considered: *Atherina boyeri* Risso 1810, *Carassius gibelio* (Bloch 1782), *Cyprinus carpio* Linnaeus 1758, *Esox lucius* Linnaeus 1758, *Gambusia holbrooki* Girard 1859, *Knipowitschia caucasica* (Berg 1916), *Lepomis gibbosus* (Linnaeus 1758), *Oncorhynchus mykiss* (Walbaum 1792), *Pseudorasbora parva* (Temminck & Schlegel 1846), *Sander lucioperca* (Linnaeus 1758), *Tinca tinca* (Linnaeus 1758), and other species. This last category includes some non-native and translocated species that are reported to occur only in some locations of Turkey (i.e., *Clarias gariepinus* (Burchell 1822); *Coptodon rendalli* (Boulenger 1897); *Coptodon zillii* (Gervais 1848); *Ctenopharyngodon idella* (Valenciennes, 1844); *Oreochromis niloticus* (Linnaeus 1758); *Perca fluviatilis* Linnaeus 1758 and so on).

3. Results and Discussion

Table 1 reports a summary of information about the 37 selected Turkish lakes. Together with physical characteristics (area, water depth, and elevation), information about the river basin and the lake origin is provided (Table 1).

A total of 62 freshwater fish species endemic to Turkey have been reported to occur in the 37 selected Turkish lakes (Table 2). The most represented family was Leuciscidae (26 species), followed by Aphaniidae (9), then Cyprinidae, Cobitidae, and Nemacheilidae (6 each) (Table 2).

Table 1. Details of physical characteristics (area, water depth, elevation), the river basin, and the origin for each of the 37 considered Turkish lakes (N: lake number in Figure 1 from west to east).

Lake	N	River Basin	Area (km^2)	Height from Sea (Altitude) (m)	Maximum Depth (m)	Origin
Abant	3	Western Black Sea	1.28	1335	18	Landslide Set
Acıgöl	17	Burdur (Closed)	92	844	2	Tectonic
Aksehir	26	Akarçay	102	958	4	Tectonic
Almus Dam	29	Yeşilırmak	31.3	817	75	Artificial
Altınapa Dam	5	Konya (Closed)	2.20	1257	30	Artificial
Apolyont	27	Susurluk	135	6	10	Tectonic
Beyşehir	18	Konya (Closed)	656	1125	10	Tectonic–Karstic
Burdur	34	Burdur (Closed)	150	845	61	Tectonic
Demirkopru Dam	8	Gediz	47.7	238	50	Artificial
Durusu Dam	1	Marmara	30.4	2	3.4 (mean)	Coastal set–artificial
Eber	25	Akarçay	120	967	6	Tectonic
Eğirdir	24	Antalya	470	916	13	Tectonic–Karstic
Enne Dam	7	Sakarya	0.94	1001	22	Artificial
Gölbasi	33	Ceyhan	2.19	880	22	Tectonic–Karstic
Gölcük	19	Antalya	1	1360	41	Volcanic
Gölhisar	13	Western Mediterranean	4	946	10	Karstic
Hazar	35	Fırat Dicle	86	1248	210	Tectonic
Hirfanlı Dam	30	Kızılırmak	263	870	40	Artificial
Işıklı	16	Büyük Menderes	65	815	8	Tectonic
Iznik	4	Marmara	298	85	65	Tectonic
Kırkgöz	21	Antalya	<2	302	2	Karstic
Kocagöz	10	Küçük Menderes	<1	8	7	Tectonic–Alluvial Set
Köyceğiz	11	Western Mediterranean	52	8	30	Alluvial Set
Manavgat Dam	23	Antalya	8.6	58	30	Artificial
Manyas	6	Susurluk	161	17	5	Tectonic
Marmara	9	Gediz	41	71	7	Alluvial Set
Nazik	31	Van (Closed)	45	1816	48	Lava Set
Onaç Dam	36	Antalya	3.56	838	21	Artificial
Salda	20	Burdur (Closed)	43	1140	180	Tectonic
Sapanca	15	Sakarya	47	34	61	Alluvial Set
Seyhan Dam	2	Seyhan	67.8	10	45	Artificial
Suğla	32	Konya (Closed)	40	1090	2	Tectonic–Karstic
Sultan Marshes	28	Kızırmak	200	1070	2	Tectonic
Van	37	Van (Closed)	3713	1646	451	Volcanic–Lava Set
Yamansaz	22	Antalya	11	2	5	Karstic
Yapraklı Dam	12	Western Mediterranean	6.5	1070	>20	Artificial
Yarışlı	14	Burdur (Closed)	14	912	2	Tectonic

Table 2. List of the freshwater fish species endemic to Turkey reported [1] to occur in the main lakes of Turkey (N: lake number in Figure 1 from West to East; IUCN: IUCN category according to [26]; Endemism: LE: local endemic, RE: regional endemic).

Lake	N	Family	Species	English Common Name	IUCN	Endemism
Abant	3	Salmonidae	*Salmo abanticus* Tortonese, 1954	Abant trout	NE	LE
Acıgöl	17	Aphaniidae	*Anatolichthys transgrediens* (Ermin 1946)	Acipinar killifish	CR	LE
		Cobitidae	*Cobitis phrygica* Battalgil 1944	Aci spined loach	NE	RE
Aksehir	26	Gobionidae	*Gobio intermedius* Battalgil, 1944	Eber gudgeon	EN	RE
		Leuciscidae	*Squalius recurvirostris* Özulug & Freyhof, 2011	Akşehir chub	VU	RE
Almus Dam	34	Cyprinidae	*Barbus anatolicus* Turan, Kaya, Geiger & Freyhof, 2018	-	DD	RE
Altınapa Dam	29	Leuciscidae	*Squalius anatolicus* (Bogutskaya, 1997)	Beysehir dace	LC	RE
Apolyont	5	Clupeidae	*Clupeonella muhlisi* Neu, 1934	Apolyont sprat	NE	RE
		Leuciscidae	*Alburnus carinatus* Battalgil, 1941	Manyas shemaya	EN	RE
Beysehir	27	Aphaniidae	*Anatolichthys iconii* (Akşiray 1948)	Konya killifish	NE	RE
		Cobitidae	*Cobitis battalgilae* Bacescu, 1962	Battalgil spined loach	EN	RE
			Cobitis bilseli Battalgil, 1942	Beysehir spined loach	EN	LE
		Cyprinidae	*Capoeta mauricii* Küçük, Turan, Şahin & Gülle, 2009	Longsnout scraper	EN	RE
			Garra kemali (Hankó, 1925)	Ereğli minnow	EN	RE
		Gobionidae	*Gobio microlepidotus* Battalgil, 1942	Beyşehir gudgeon	VU	RE
		Leuciscidae	*Alburnus akili* Battalgil, 1942	Beysehir bleak	EX	LE
			Chondrostoma beysehirense Bogutskaya, 1997	Beysehir nase	EN	RE
			Pseudophoxinus anatolicus (Hankó, 1925)	Anatolian minnow	EN	RE
			Pseudophoxinus battalgilae Bogutskaya, 1997	Beysehir minnow	NE	RE
			Pseudophoxinus hittitorum Freyhof & Özulug, 2010	Hittitic spring minnow	EN	RE
			Squalius anatolicus (Bogutskaya, 1997)	Beysehir dace	LC	RE
		Nemacheilidae	*Oxynoemacheilus atili* Erk'akan, 2012	Beysehir loach	NT	RE
Burdur	18	Aphaniidae	*Anatolichthys sureyanus* (Ney 1937)	Sureyan killifish	EN	LE
Demirköprü Dam	8	Gobiidae	*Knipowitschia mermere* Ahnelt, 1995	Marmara goby	VU	RE
Durusu	1	Leuciscidae	*Alburnus istanbulensis* Battalgil 1941	Thracian shemaya	LC	RE
Eber	25	Leuciscidae	*Squalius recurvirostris* Özulug & Freyhof, 2011	Akşehir chub	VU	RE
		Nemacheilidae	*Seminemacheilus lendlii* (Hankó, 1925)	Anatolian loach	VU	RE
Eğirdir	24	Aphaniidae	*Anatolichthys iconii* (Akşiray 1948)	Konya killifish	NE	RE
		Cyprinidae	*Garra klatti* (Kosswig 1950)	Isparta minnow	EN	RE
			Capoeta pestai (Pietschmann, 1933)	Egirdir barb	CR	RE
		Leuciscidae	*Pseudophoxinus egridiri* (Karaman, 1972)	Egirdir minnow	EN	LE
			Pseudophoxinus handlirschi (Pietschmann, 1933)	Handlirsch's minnow	EX	LE
Enne Dam	7	Leuciscidae	*Alburnus escherichii* Steindachner, 1897	Caucasian bleak	LC	RE
Gölbasi	33	Cobitidae	*Cobitis erkakanae* Freyhof, Bayçelebi & Geiger, 2018	Gölbasi spined loach	NE	RE
Gölcük	19	Aphaniidae	*Anatolichthys splendens* Kosswig & Sözer 1945	Splendid killifish	EX	LE
		Cyprinidae	*Garra klatti* (Kosswig 1950)	Isparta minnow	EN	RE
Gölhisar	13	Leuciscidae	*Scardinius elmaliensis* Bogutskaya, 1997	Antalya rudd	EN	RE
Hazar	35	Aphaniidae	*Kosswigichthys asquamatus* Sözer 1942	Scaleless killifish	LC	LE
		Leuciscidae	*Alburnus heckeli* Battalgil, 1944	Hazar bleak	LC	LE
		Nemacheilidae	*Oxynoemacheilus hazarensis* Freyhof & Özulug, 2017	Hazar loach	NE	LE
Hirfanlı Dam	30	Aphaniidae	*Anatolichthys danfordii* (Boulenger 1890)	Danford's killifish	CR	RE

Table 2. *Cont.*

Lake	N	Family	Species	English Common Name	IUCN	Endemism
Işıklı	16	Gobionidae	*Gobio maeandricus* Naseka, Erk'akan & Küçük, 2006	Işıklı gudgeon	EN	RE
		Leuciscidae	*Squalius carinus* Özulug & Freyhof, 2011	Chocolate chub	EN	LE
Iznik	4	Leuciscidae	*Alburnus nicaeensis* Battalgil, 1941	Iznik shemaya	EX	LE
Kırkgöz	21	Aphaniidae	*Paraphanius mentoides* (Akşiray, 1948)	-	NE	RE
Kocagöz	10	Gobiidae	*Knipowitschia ricasolii* (Di Caporiacco 1935)	Ephesus goby	CR	RE
Köyceğiz	11	Gobiidae	*Knipowitschia byblisia* Ahnelt, 2011	Byblis goby	LC	RE
			Knipowitschia caunosi Ahnelt, 2011	Caunos goby	LC	LE
Manavgat Dam	23	Leuciscidae	*Alburnus baliki* Bogutskaya, Küçük & Ünlü, 2000	Antalya bleak	EN	RE
Manyas	6	Leuciscidae	*Alburnus carinatus* Battalgil, 1941	Manyas shemaya	EN	RE
		Leuciscidae	*Alburnoides manyasensis* Turan, Ekmekçi, Kaya & Güçlü, 2013	Manyas spirlin	LC	LE
Marmara	9	Gobiidae	*Knipowitschia mermere* Ahnelt, 1995	Marmara goby	VU	RE
Marsh Sultan	31	Cobitidae	*Cobitis joergbohleni* Freyhof, Bayçelebi & Geiger, 2018	Sultan spined loach	NE	LE
		Leuciscidae	*Pseudophoxinus elizavetae* Bogutskaya, Küçük & Atalay, 2006	Sultan Sazligi minnow	CR	RE
		Nemacheilidae	*Oxynoemacheilus ciceki* Sungur, Eagderi & Jalili, 2017	Loach	NE	LE
			Seminemacheilus ahmeti Sungur, Jalili, Eagderi & Çiçek, 2018	Sultan crested loach	NE	LE
Nazık	36	Cyprinidae	*Capoeta kosswigi* Karaman, 1969	Van barb	DD	RE
		Leuciscidae	*Alburnus tarichi* (Güldenstädt, 1814)	Van bleak	NT	RE
		Nemacheilidae	*Oxynoemacheilus ercisianus* (Erk'akan & Kuru, 1986)	Van loach	EN	RE
Onaç Dam	20	Leuciscidae	*Pseudophoxinus ninae* Freyhof & Özulug, 2006	Onaç spring minnow	CR	RE
Salda watersheds	15	Aphaniidae	*Anatolichthys fontinalis* (Akşiray 1948)	Burdur killifish	NE	RE
			Anatolichthys saldae (Akşiray 1955)	Salda killifish	NE	LE
		Cobitidae	*Cobitis phrygica* Battalgazi, 1944	Aci spined loach	NE	RE
		Leuciscidae	*Pseudophoxinus burduricus* Küçük, Gülle, Güçlü, Çiftçi & Erdogan, 2013	Burdur spring minnow	EN	RE
			Squalius fellowesii (Günther, 1868)	Aegean chub	LC	RE
Sapanca	2	Cobitidae	*Cobitis emrei* Freyhof, Bayçelebi & Geiger, 2018	Sapanca spined loach	NE	LE
Seyhan Dam	32	Leuciscidae	*Chondrostoma ceyhanensis* Küçük, Turan, Güçlü, Mutlu & Çiftçi, 2017	Ceyhan Nase	NE	RE
Suğla	28	Cobitidae	*Cobitis battalgilae* Bacescu, 1962	Battalgil spined loach	EN	RE
		Leuciscidae	*Pseudophoxinus anatolicus* (Hankó, 1925)	Anatolian minnow	EN	RE
			Pseudophoxinus battalgilae Bogutskaya, 1998	Beysehir minnow	NE	RE
Van	37	Leuciscidae	*Alburnus tarichi* (Güldenstädt, 1814)	Van bleak	NT	RE
		Nemacheilidae	*Oxynoemacheilus ercisianus* (Erk'akan & Kuru, 1986)	Van loach	EN	RE
Yamansaz	22	Leuciscidae	*Pseudophoxinus alii* Küçük, 2007	Pamphylian spring minnow	EN	RE
Yapraklı Dam	12	Leuciscidae	*Alburnus carianorum* Freyhof, Kaya, Bayçelebi, Geiger & Turan, 2018	-	EN	RE
Yarışlı	14	Aphaniidae	*Anatolichthys fontinalis* (Akşiray 1948)	Burdur killifish	NE	RE

[1] main references: [25,27–46].

Most of the Leuciscidae species belong to the *Alburnus* (9 species) and *Pseudophoxinus* (9 species) genera (72% in total). *Alburnus* was found to be very rich in Turkey, with 20 valid species reported to occur in the country [46,47]. Hrbek et al. [48] underlined the significant role of central Anatolian plate tectonic events on the diversification and

phylogenetic relationships of the genus *Pseudophoxinus*, which is often co-distributed with *Anatolichthys* (Aphaniidae) in Central Anatolia. Turkey was recognized by Wildekamp [29] and Wildekamp et al. [49] as the center of diversity for the *Aphanius* (now *Anatolichthys*) genus, and Hrbek et al. [50] reported that 6 species and 4 subspecies of the 14 described occur in Anatolia [50]. Nevertheless, these populations are currently in decline due to degradation of habitats, mainly caused by excessive water use for agricultural activities and the presence of non-native species, but there is a lack of knowledge about the status of these species [51].

With regard to Cobitidae, the evolution of the *Cobitis* genus in Anatolia started in the Miocene and led to the formation of a large number of local lineages of this group [28]; to date, 28 species have been reported in Turkey [28], but the taxonomy of the genus is under continuous revision. Among the Nemacheilidae, *Oxynoemacheilus* is the largest genus and in Turkey has a great diversity, with 42 reported species from inland waters (26 endemics) [52–55]. Southwestern Anatolia is also an important biodiversity hotspot for the genus *Knipowitschia* (Gobiidae), with four of the five recorded species being endemic to Turkey (*K. byblisia*, *K. caunosi*, *K. mermere*, and *K. ricasoli*) and reported to occur only in isolated habitats [27,35,56] (Figure 2).

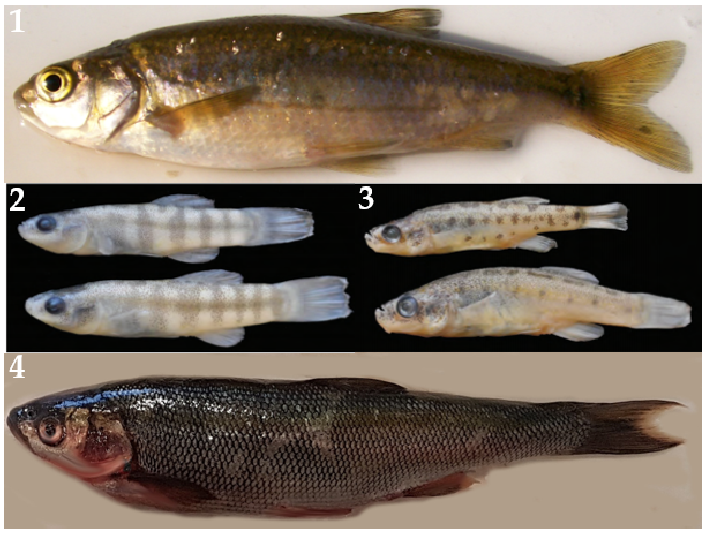

Figure 2. Pictures of some representative species endemic to Turkey: 1: *Pseudophoxinus alii*; 2: *Aphanius transgrediens*; 3: *A. sureyanus*; 4: *Alburnus tarichi*. (Original photos by Deniz Innal.)

Considering the 62 endemic species listed in Table 2 according to their IUCN categories, an alarming result emerged (Figure 3).

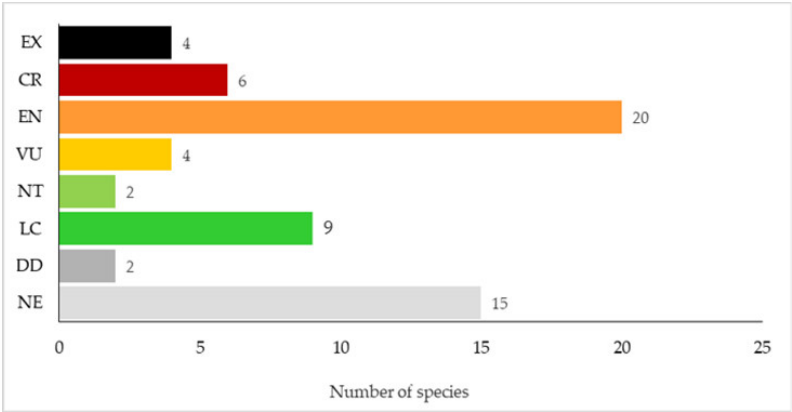

Figure 3. Number of species endemic to Turkish lakes listed in the categories of IUCN (2020) [26].

Among the considered species, four (*A. akili*, *A. nicaeensis*, *A.splendens*, and *P. handlirschi*) are listed as Extinct according to IUCN [26]. *Alburnus nicaeensis* most likely became extinct due to the invasion of non-native and translocated species that were stocked into Lake Iznik to improve fishery yields [57]. Similarly, *A. splendens*, *A. akili*, and *P. handlirschi* are also considered extinct in lakes Gölcük, Beyşehir, and Eğirdir, respectively, given that no individuals have been found in the last decades [58–60]. With regard to Lake Eğirdir, several studies reported that the introduction of zander (*Sander lucioperca*) into the lake in 1955 caused the extinction of some endemic species [61]. Alarmingly, similar collapses of native fish stocks are also underway in Lake Beyşehir [19].

With endemic species often being restricted to only a small and isolated area, they are more sensitive to change in the environment, and threats to their habitat can lead to their disappearance. To give an example, Lake Burdur, one of the saline lakes of Central Anatolia, is known to have undergone a slow decrease in water supply, caused by massive and often uncontrolled water abstraction for agriculture purposes and the construction of dams and reservoirs. Currently, it can be reported that almost no water is left over to feed the lake (authors' personal observation). *Anatolichthys sureyanus* (Figure 2) is strictly endemic to Burdur Lake and it is currently assessed as Endangered, but, given the current status of the lake, it appears that the survival of the species is at a higher risk and that the species requires detailed conservation actions. Although *A. sureyanus* is known to be quite tolerant of the high pollution in Lake Burdur, the species has been observed congregating close to freshwater springs where the salinity is lower, indicating that the increasing salinity of the lake is reaching levels that the species cannot tolerate. Among all the 58 remaining endemic species, 6 are listed as Critically Endangered and 20 are listed as Endangered (Figure 3). In addition, another detail worthy of concern is the high number of species in the categories Not Evaluated and Data Deficient (15 and 2, respectively) (Figure 3). This underlines the lack of information on the biology and ecology of these endemic species and the need for detailed studies to assess their conservation status.

Considering the number of endemic species reported for each lake (Table 2), Lake Beyşehir, the largest freshwater lake in Turkey and in all the Mediterranean basin, is the lake with the highest number of endemic species (13), followed by Lake Eğirdir (5 species).

Salmo abanticus is one of the Salmonidae species endemic to Turkish lakes. Although Kalayci et al. [62] reported the species as a synonym of *S. trutta*, the taxon is still considered as a species and listed as Vulnerable according to IUCN (2019) [63]. In Lake Abant, the population of the species declined due to the introduced *O. mykiss*. Currently, the population is continuously restocked in the lake for fishing purposes, but it is unknown what would happen to the population if stocking was stopped [63]. With regard to Lake Van, only two endemic species have adapted to its hypersodic waters. One of these, *Alburnus tarichi* (Figure 2), is a lacustrine, pelagic species that migrates about 15 km up inflowing rivers to spawn. The population has been in decline due to activities in the spawning streams, illegal fishing, habitat degradation, and wastewater pollution (from domestic and industrial sources). Currently only 12 rivers are available as spawning areas for the species; the other rivers are either too small or are blocked by weirs (with no fish passes).

In Table 3, a detailed list of the main disturbances is reported for each of the lakes studied.

In summary, all the 37 lakes showed exposure to at least five different threats. More specifically, the most disturbed lakes were Lake Seyhan Dam (11 of the 14 threats) followed by Lake Marmara, Lake Demirkopru Dam, Lake Eber, Lake Hazar, and Lake Sapanca (10 of the 14 threats each). On the contrary, those with the lowest number of reported threats (5 of 14) were Lake Kocagöz, Lake Gölcük, and Lake Manavgat Dam. Although this result could sound like good news for these last three cited lakes, it is important to take into consideration that this could also be due to a lack of specific studies focusing on these environments and not an optimistic report of their ecological integrity. Further research focusing on these lakes as well as those showing greater disturbance is therefore suggested. Another result to underline from Table 3 is that Lake Van was the only environment where

no non-native species were reported. This is due, as cited above, to the peculiar chemical characteristic of the lake waters that allows the survival of only specialized fish species like *A. tarichii* able to adapt to this hypersodic environment.

Table 3. List of the main threats reported to occur in the main lakes of Turkey (N: lake number in Figure 1 from west to east).

Lake	N	Main Threats														
		Climatic Drought	Decreasing Water Level	Presence of Non-Native Species	Agricultural Activities	Water Pollution	Wastewater Discharge	Overfishing	Urbanization	Presence of Industrial Activities	Tourism Activities	Massive Fish Death	Cutting/Burning of The Reeds	Aquaculture Activities	Presence of Power Plants	Number of Threats Per Lake
Abant	3	■	■	■		■	■				■					6
Acıgöl	17	■	■	■	■	■	■		■	■						8
Aksehir	26	■	■	■	■	■	■	■	■				■			9
Almus Dam	29	■	■	■	■	■	■	■						■	■	9
Altınapa Dam	5	■	■	■	■	■	■	■								7
Apolyont	27	■	■	■	■	■	■	■	■	■						9
Beyşehir	18	■	■	■	■	■	■	■	■	■						9
Burdur	34	■	■	■	■	■	■		■	■		■				9
Demirkopru Dam	8	■	■	■	■	■	■	■		■		■	■			10
Durusu	1	■	■	■	■	■	■	■								7
Eber	25	■	■	■	■	■	■	■	■	■	■					10
Eğirdir	24	■	■	■	■	■	■	■				■				8
Enne Dam	7	■	■	■	■		■					■				6
Gölbasi	33	■	■	■	■	■	■				■		■			8
Gölcük	19	■	■	■			■				■					6
Gölhisar	13	■	■	■	■	■		■					■			7
Hazar	35	■	■	■	■	■	■	■	■			■			■	10
Hirfanlı Dam	30	■	■	■	■	■	■	■						■	■	9
Işıklı	16	■	■	■	■	■	■	■						■		7
Iznik	4	■	■	■	■	■	■	■	■	■						9
Kırkgöz	21	■	■	■	■	■			■		■		■			8
Kocagöz	10	■	■	■	■	■										5
Köyceğiz	11	■	■	■	■	■	■	■	■		■					9
Manavgat Dam	23	■	■	■	■										■	5
Manyas	6	■	■	■	■	■	■	■		■						8
Marmara	9	■	■	■	■	■	■	■		■		■	■			10
Nazık	31	■	■	■	■	■	■	■								7
Onaç Dam	36	■	■	■	■	■	■				■	■				8
Salda	20	■	■	■	■	■	■				■					7
Sapanca	15	■	■	■	■	■	■	■	■	■	■					10
Seyhan Dam	2	■	■	■	■	■	■	■	■	■				■	■	11
Suğla	32	■	■	■	■	■	■	■		■						8
Sultan Marshes	28	■	■	■	■	■	■						■			7
Van	37	■	■		■	■	■	■								6
Yamansaz	22	■	■	■	■	■			■		■		■			8
Yapraklı Dam	12	■	■	■	■			■				■		■		7
Yarışlı	14	■	■	■	■	■	■									6

Considering the frequencies of occurrence for the 14 examined categories of threats, climatic droughts and decreasing water level (all lakes) were the most reported disturbances, followed by presence of non-native species (36 of 37 lakes) and agricultural activities (35 of 37) (Figures 4–6).

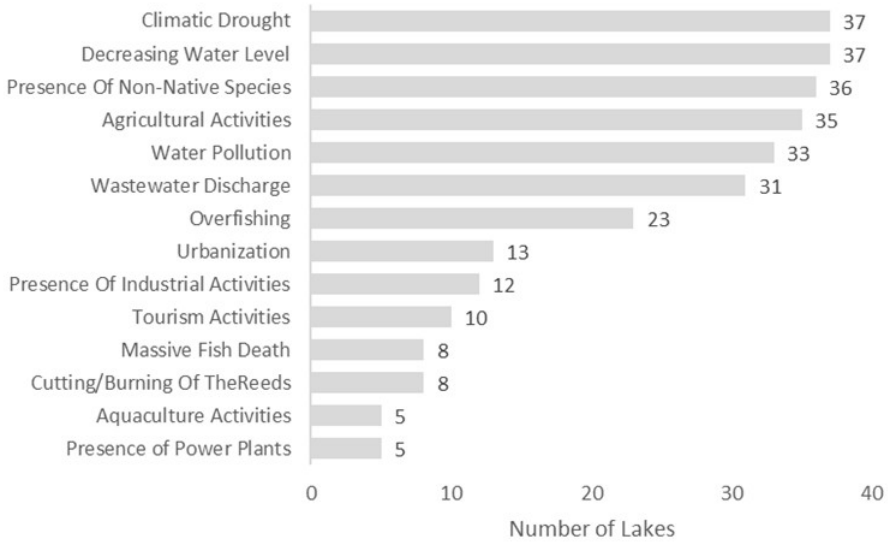

Figure 4. Frequencies of occurrence of the 14 main threats in the examined Turkish lakes.

Figure 5. Satellite images from Google Earth showing the trend of water level decrease in the last decades in some Turkish lakes.

Additionally, water pollution, mainly due to domestic and industrial discharges, appears to be quite common and can lead to massive death of fish that, unfortunately, is reported to occur periodically in Turkish lakes (Figure 6).

It is important to underline that threats often work in synergy, and this represents the real ''threat'' brought about by human activities [64].

Despite the impacts on native species having been widely documented [65,66], the introduction of non-native species continues to be a common practice worldwide. With regard to Turkey, Innal and Erk'akan [67] reported that the major vectors for the introduction of non-native fishes have been government-authorized aquaculture and stocking programs to establish and support cage aquaculture and commercial fisheries. Moreover, several native species have been translocated within Turkey, although it is known that they may have exerted detrimental impacts on the native community of lake fish [67].

From the literature survey, Lake Beyşehir, Lake Eğirdir, and Lake Işıklı were those reporting greater numbers of the considered non-native and translocated species (Table 4).

Figure 6. Pictures reporting some threats in the considered Turkish lakes: **1**: Presence of non-native species in Lake Beyşehir; **2**: Massive fish death in Lake Onaç Dam; **3**: Water extraction for agricultural activities; **4**: Tourism activities in Lake Salda.

Table 4. Occurrence of the main introduced (non-native and translocated) species reported * in Turkey in the examined lakes.

Lake	Introduced (Non-Native and Translocated) Species											
	Atherina boyeri	*Carassius gibelio*	*Cyprinus carpio*	*Esox cucius*	*Gambusia coolbroki*	*Knipowitschia caucasica*	*Lepomis cibbosus*	*Oncorhynchus cykiss*	*Pseudorosbora parva*	*Sander lucioperca*	*Tinca Tinca*	**Other Species**
Abant								■			■	
Acıgöl		■			■							
Aksehir		■	■	■	■	■					■	■
Almus Dam		■	■	■				■			■	■
Altınapa Dam		■	■	■						■	■	
Apolyont		■	■	■	■		■		■		■	■
Beyşehir	■	■	■	■	■	■			■	■	■	■
Burdur			■	■								■
Demirkopru Dam	■	■	■	■		■			■	■		
Eber		■	■	■	■	■					■	■
Eğirdir	■	■	■	■	■	■			■	■	■	■
Enne Dam		■	■	■	■				■		■	■
Gölbasi	■		■	■	■							■
Gölcük	■	■	■	■	■				■	■	■	■
Gölhisar		■	■	■	■	■				■	■	■
Hazar			■	■								■
Hirfanlı Dam	■	■	■	■					■	■	■	■
Işıklı		■	■	■	■	■		■		■	■	■
Iznik	■	■	■	■	■		■				■	■
Kırkgöz					■							
Kocagöz		■			■							
Köyceğiz					■							■
Manavgat Dam		■	■	■	■				■			
Manyas		■	■	■	■				■			■
Marmara	■	■	■	■	■				■	■		■
Nazik		■	■	■								
Onaç Dam		■	■	■	■				■			
Salda			■	■	■							■
Sapanca	■	■	■	■	■		■	■				■
Seyhan Dam		■	■	■	■			■		■	■	■
Suğla		■	■	■		■				■	■	■
Sultan Marshes			■	■				■			■	■
Van												
Yamansaz					■				■			
Yapraklı Dam	■	■	■	■				■				
Yarışlı					■							

*: main references: [45,51,66,68–99].

In Lake Işıklı, located in Central Anatolia in the so-called ''Lake District'', together with the non-native species, two translocated species, highly important for the local economy, are known to occur: *E. lucius* and *T. tinca*. However, the abundances of these two species have rapidly decreased in the last years, mostly due to the massive presence of non-native species like *C. gibelio* and water hyper-eutrophication [100]. Similarly, it can be reported that the massive presence of *C. gibelio* in other lakes of the Lake District (Beyşehir, Eğirdir, Suğla, Karataş, Gölhisar, and Kovada) is also creating a huge economic loss for local fisheries. These species are not used by local fishers as a resource, and fishers spend most of their

energy and efforts removing specimens of *C. gibelio* from their nets without any associated economic income.

Carassius gibelio is the non-native species reported to occur in the most Turkish lakes, followed by *G. holbrooki* and *P. parva* (Figure 7).

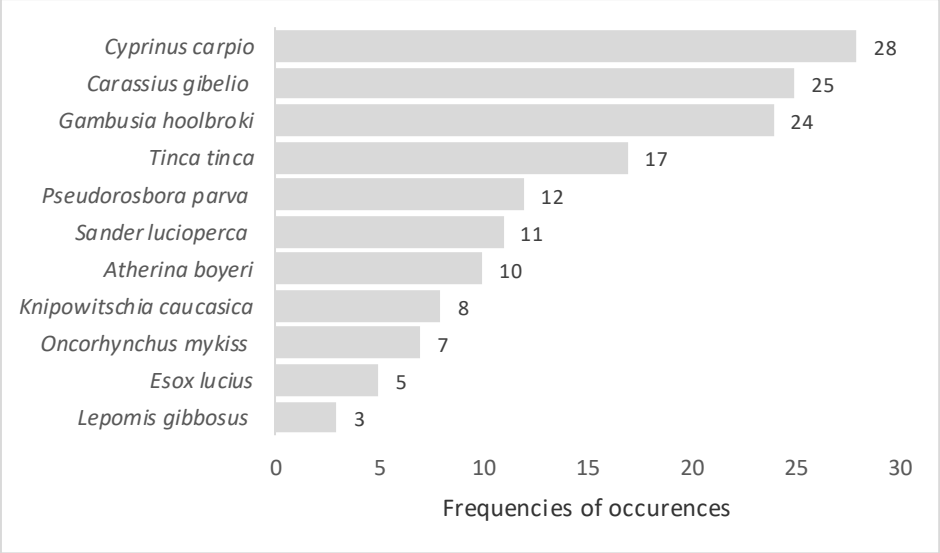

Figure 7. Frequencies of occurrence of the main non-native and translocated species in the examined Turkish lakes.

The wide distribution of these non-native species is of great concern given that they are listed among the 100 worst non-native species in the world [101].

The issue of non-native or translocated species becomes more problematic in the case of those species like *A. boyeri* or *C. carpio* that have a considerable economic value for local fisheries. These species are commonly restocked and translocated by the local institutions in almost every natural lake and reservoir every year.

In this case, the management of these species needs to also take into account the benefit that the species can have for the local economy but always giving priority to preserving the ecological integrity of the aquatic environment for sustainable use of fisheries resources: a disturbed habitat is not able to provide a long-lived economic benefit, as happened in the cited case of Lake Işıklı. However, most of the time, these restocking practices are not supported by a solid scientific background aimed to monitor and control the ecological status of the lake or the success of these activities.

4. Conclusions

Many lakes in Turkey have shrunk considerably over recent years, mainly due to increasing drought and increased ground-water abstraction, leading to profound implications for the whole aquatic ecosystem. The results reported in this study confirm these trends and represent an important point to consider for the future management of these environments.

Forecasted future climatic changes added to the above cited anthropogenic disturbances and changes in land-use would also make the existing conditions progressively worse. Thus, decisions for dealing with the negative impacts of climate change on water resources should include efficient management of existing water and land with forecasting systems to avoid droughts and soil erosion, but also taking into consideration the management of non-native species, which are currently the main reported disturbance in Turkish lakes.

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References

1. Mittermeier, R.S.; Gil, P.R.; Hoffmann, M.; Pilgrim, J.; Brooks, J.; Goettsch Mittermeier, C.; Lamoreux, J.; Da Fonseca, G.A.B. *Hotspot Revisited: Earth's Biologically Richest and Most Endangered Terrestrial Ecoregions*; CEMEX: Mexico City, Mexico, 2011.
2. Şekercioğlu, C.H.; Anderson, S.; Akçay, E.; Bilgin, R. Turkey's rich natural heritage under assault. *Science* **2011**, *334*, 1637–1639. [CrossRef] [PubMed]
3. Ambarlı, S.; Zeydanlı, U.S.; Balkı, Ö.; Aslan, S.; Karaçetin, E.; Sözen, M.; Ilgaz, Ç.; Gürsoy Ergen, A.; Lise, Y.; Demirbas Çağlayan, S.; et al. An overview of biodiversity and conservation status of steppes of the Anatolian Biogeographical Region. *Biodivers. Conserv.* **2016**, *25*, 2491–2519. [CrossRef]
4. Reyjol, Y.; Hugueny, B.; Pont, D.; Bianco, P.G.; Beier, U.; Caiola, N.; Casals, F.; Cowx, I.G.; Economou, A.; Ferreira, M.T.; et al. Patterns in species richness and endemism of European freshwater fish. *Glob. Ecol. Biogeogr.* **2007**, *16*, 65–75. [CrossRef]
5. Bilgin, R. Back to the future: The distribution of intraspecific genetic diversity in and around Anatolia. *Int. J. Mol. Sci.* **2011**, *12*, 4080–4103. [CrossRef] [PubMed]
6. Kashima, K. Environmental and climatic changes during the last 20,000 years at Lake Tuz, central Turkey. *Catena* **2002**, *48*, 1–20. [CrossRef]
7. Özesmi, U.; Maurer, S.L. Sulakalanlar. In *Türkiye'nin onemli doğa alanları*; Eken, G., Bozdoğan, M., İsfendiaroğlu, S., Kılıç, D.T., Lise, Y., Eds.; Doğa Derneği: Ankara, Turkey, 2006; p. 79. ISBN 948-975-98901. (In Turkish)
8. Nivet, C.; Frazier, S. A Review of European Wetland Inventory Information. In *Collaborative Report by Wetlands International and Institute for Inland Water Management and Waste Water Treatment*; Taylor, A.R.D., van Eerden, M., Eds.; Wetland International: Wageningen, The Netherlands, 2004; p. 262.
9. ECSN. *Climate of Europe: Recent Variation, Present State and Future Prospects*; European Climate Support Network (ECSN): Nijkerk, The Netherlands, 1995.
10. Johns, T.C.; Gregory, J.M.; Ingram, W.J.; Johnson, C.E.; Jones, A.; Lowe, J.A.; Mitchell, J.F.B.; Roberts, D.L.; Sexton, D.M.H.; Stevenson, D.S.; et al. Anthropogenic climate change for 1860 to 2100 simulated with the HadCM3 model under updated emissions scenarios. *Clim. Dyn.* **2003**, *20*, 583–612. [CrossRef]
11. Reed, J.M.; Leng, M.J.; Ryan, S.; Black, S.; Altınsaçlı, S.; Griffiths, H.I. Recent habitat degradation in karstic Lake Uluabat, western Turkey: A coupled limnological–palaeolimnological approach. *Biol. Conserv.* **2008**, *141*, 2765–2783. [CrossRef]
12. Beklioğlu, M.; Tan, C.O. Restoration of a shallow Mediterranean lake by biomanipulation complicated by drought. *Fundam. Appl. Limnol.* **2008**, *171*, 105–118. [CrossRef]
13. Türkeş, M. Vulnerability of Turkey to Desertification with Respect to Precipitation and Aridity Conditions. *Turk. J. Eng. Environ. Sci.* **1999**, *23*, 363–380.
14. Balık, S. Freshwater fishes in Anatolia. *Biol. Conserv.* **1995**, *72*, 213–223. [CrossRef]
15. Woodward, G.; Perkins, D.M.; Brown, L.E. Climate change and freshwater ecosystems: Impacts across multiple levels of organization. *Phil. Trans. R. Soc. B.* **2010**, *365*, 2093–2106. [CrossRef] [PubMed]
16. Panlasiguia, S.; Davisa, A.J.S.; Mangiantea, M.J.; Darling, J.A. Assessing threats of non-native species to native freshwater biodiversity: Conservation priorities for the United States. *Biol. Conserv.* **2018**, *224*, 199–208. [CrossRef] [PubMed]
17. Cucherousset, J.; Olden, J.O. Ecological Impacts of Nonnative Freshwater Fishes. *Fisheries* **2011**, *36*, 215–230. [CrossRef]
18. Mack, R.M.; Simberloff, D.; Lonsdale, W.M.; Evans, E.; Clout, M.; Bazzaz, F.A. Biotic Invasions: Causes, Epidemiology, Global Consequences, and Control. *Ecol. Appl.* **2000**, *10*, 689–710. [CrossRef]
19. FAO. Biodiversity of Turkey. In *Contribution of Genetic Resources to Sustainable Agriculture and Food Systems*; FAO: Ankara, Turkey, 2018; p. 222.
20. Britton, J.R.; Cucherousset, J.; Davies, G.D.; Godard, M.J.; Copp, G.H. Non-native fishes and climate change: Predicting species responses to warming temperatures in a temperate region. *Freshw. Biol.* **2011**, *55*, 1130–1141. [CrossRef]
21. Savini, D.; Occhipinti, A.; Marchini, A.; Tricarico, E. The top 27 animal alien species introduced into Europe for aquaculture and related activities. *J. Appl. Ichthyol.* **2010**, *26*, 1–7. [CrossRef]
22. Ribeiro, F.; Leunda, P.M. Non-native fish impacts on Mediterranean freshwater ecosystems: Current knowledge and research needs. *Fish. Manag. Ecol.* **2012**, *19*, 142–156. [CrossRef]

23. Havel, J.E.; Kovalenko, K.E.; Thomaz, S.M.; Amalfitano, S.; Kats, L.B. Aquatic invasive species: Challenges for the future. *Hydrobiologia* **2015**, *750*, 147–170. [CrossRef]
24. Froese, R.; Pauly, D. FishBase. World Wide Web electronic publication. Froese and Pauly Editors. Version (12/2020). 2020. Available online: www.fishbase.org (accessed on 3 April 2021).
25. Fricke, R.; Eschmeyer, W.N.; van der Laan, R. Eschmeyer's Catalog of Fishes: Genera, Species, References. 2021. Available online: http://researcharchive.calacademy.org/research/ichthyology/catalog (accessed on 24 May 2021).
26. IUCN. The IUCN Red List of Threatened Species. Version 2014.1. 2020. Available online: www.iucnredlist.org (accessed on 3 May 2021).
27. Ahnelt, H. Two new species of *Knipowitschia* from Western Anatolia (Turkey). *Mitt. Hamb. Zool. Mus. Inst.* **1995**, *92*, 155–168.
28. Erkakan, F.; Atalay Ekmekçi, F.G.; Nalbant, T.T. A review of the genus *Cobitis* in Turkey (Pisces: Ostariophysi: Cobitidae). *Hydrobiologia* **1999**, *403*, 13–26. [CrossRef]
29. Wildekamp, R.H.; Küçük, H.H.; Ünlüsayın, M.; van Neer, W. Species and subspecies of the genus *Aphanius* Nardo 1897 (Pisces: Cyprinodontidae) in Turkey. *Turk. J. Zool.* **1999**, *23*, 23–44.
30. Kuru, M. Recent systematic status of inland water fishes of Turkey. *J. Fac. Educ. Gaz* **2004**, *24*, 1–21.
31. Darwall, W.R.T.; Smith, K.G. *The Status and Distribution of Freshwater Fish Endemic to the Mediterranean Basin*; IUCN Red List of Threatened Species—Mediterranean Regional Assessment; IUCN: Gland, Switzerland; Cambridge, UK, 2006; p. 34. Available online: https://portals.iucn.org/library/sites/library/files/documents/RL-2006-002.pdf (accessed on 5 April 2021).
32. Van der Laan, R.; Eschmeyer, V.N.; Fricke, R. Family-group names of Recent fishes. *Zootaxa Monogr.* **2014**, *3882*, 1–230. [CrossRef]
33. Kottelat, M.; Freyhof, J. *Handbook of European Freshwater Fishes*; Kottelat Publication: Cornol, Switzerland, 2007; Volume 13, p. 646.
34. Kartal, K.; Öztürk, M.O. Akşehir Gölü (Konya)'ndeki bazı balıkların (*Cyprinus carpio* Linnaeus, 1758; *Cobitis simplicispinna* Hanko, 1924) ektoparazit faunası üzerinde araştırmalar. *Türk. Paraz. Derg.* **2009**, *33*, 101–106. (In Turkish)
35. Ahnelt, H. Two new sympatric *Knipowitschia* species (Teleostei: Gobiidae) from an eastern Mediterranean coastal lake—Examples of different dispersal patterns? *Zootaxa* **2011**, *3114*, 22–30. [CrossRef]
36. Kuru, M.; Yerli, S.V.; Mangıt, F.; Ünlü, E.; Alp, A. Fish Biodiversity in Inland Waters of Turkey. *J. Ac. Doc. Fish. Aquac.* **2014**, *1*, 93–120.
37. Smith, K.G.; Barrios, V.; Darwall, W.R.T.; Numa, C. (Eds.) *The Status and Distribution of Freshwater Biodiversity in the Eastern Mediterranean*; IUCN: Cambridge, UK; Malaga, Spain; Gland, Switzerland, 2014; Volume 14, p. 132.
38. Çiçek, E.; Birecikligil, S.S.; Fricke, R. Freshwater fishes of Turkey; a revised and updated annotated checklist. *Biharean Biol.* **2015**, *9*, 141–157.
39. Gülle, İ.; Küçük, F.; Innal, D.; Güçlü, S.S. Burdur İli Balıkları: Biyoçeşitlilik Envanteri, Popülasyon ve Habitat Durumları. *Mehmet Akif Ersoy Üniversitesi Fen Bilimleri Enstitüsü Dergisi* **2016**, *7*, 232–239. (In Turkish)
40. Küçük, F.; Gülle, İ.; Güçlü, S.S. *Burdur Lake Monograph"-Chapter 7: Burdur Lake Fish Fauna*; Gülle, İ., Atayeter, Y., Eds.; Dumat Ofset: Burdur, Turkey, 2016.
41. Çiçek, E.; Sungur, S.; Fricke, R. Freshwater lampreys and fishes of Turkey; a revised and updated annotated checklist. *Zootaxa* **2018**, *4809*, 241–270.
42. Mangıt, F.; Yerli, S.V. Systematic evaluation of the genus *Alburnus* (Cyprinidae) with description of a new species. *Hydrobiologia* **2018**, *807*, 297–312. [CrossRef]
43. Çiçek, E.; Fricke, R.; Eagderi, S.; Sungur, S.; Vanni, S. *Knipowitschia ephesi* Ahnelt, 1995, a junior synonym of *Gobius ricasolii* Di Caporiaccio, 1935 (Teleostei: Gobiidae). *Zool. Middle East* **2019**, *65*, 330–335. [CrossRef]
44. Doğan, M. Yapraklı Barajı (Burdur/Gölhisar) *Alburnus carianorum* Freyhof, Kaya, Bayçelebi, Geiger & Turan, 2018 (Teleostei: Cyprinidae) Populasyonu için Bazı Populasyon Dinamiği Parametrelerinin Belirlenmesi. Master's Thesis, Nevşehir Hacı Bektaş Veli Üniversitesi, Nevşehir, Turkey, 2019.
45. Çiçek, E.; Sungur, S. Ichthyofauna of Sultan Marshes (Turkey) and Possible Effects of Fish Invasion from Seyhan Basin on Diversity and Conservation. *Kommagene Biyol. Derg.* **2020**, *4*, 115–120. [CrossRef]
46. Çiçek, E.; Sungur, S.; Fricke, R. Freshwater lampreys and fishes of Turkey; a revised and updated annotated checklist. *Zootaxa* **2020**, *4809*, 241–270. [CrossRef]
47. Bektas, Y.; Aksu, I.; Kaya, C.; Bayçelebi, E.; Küçük, F.; Turan, D. Molecular systematics and phylogeography of the genus *Alburnus* Rafinesque, 1820 (Teleostei, Leuciscidae) in Turkey. *Mitochondrial DNA* **2020**, *31*, 273–284. [CrossRef]
48. Hrbek, T.; Stölting, K.N.; Bardakcı, F.; Küçük, F.; Wildekamp, R.H.; Meyer, A. Plate tectonics and biogeographical patterns of *Pseudophoxinus* (Pisces: Cypriniformes) species complex of central Anatolia, Turkey. *Mol. Phylogenet. Evol.* **2004**, *32*, 297–308. [CrossRef]
49. Wildekamp, R.H. A world of killies. Atlas of the oviparous Cyprinodontiform fishes of the world. In *The Genera Adamas, Adinia, Aphanius, Aphyoplatys and Aphyosemion*; American Killifish Association, Ed.; American Killifish Association: Saint Louis, MO, USA, 1993; Volume 1, p. 311.
50. Hrbek, T.; Küçük, F.; Frickey, T.; Stölting, K.N.; Wildekamp, R.H.; Meyer, A. Molecular phylogeny and historical biogeography of the *Aphanius* (Pisces, Cyprinodontiformes) species complex of central Anatolia, Turkey. *Mol. Phylogenet. Evol.* **2002**, *25*, 125–137. [CrossRef]

51. Innal, D.; Güçlü, S.S.; Ünal, M.C.; Doğangil, B.; Giannetto, D. Age Structure and Length-Weight Relationship for Four Species of *Aphanius* Nardo, 1827 (Actinopterygii: Aphaniidae) Endemic to the Lake District, Central Anatolia, Turkey. *Acta Zool. Bulg.* **2019**, *71*, 211–217.
52. Sungur, S.; Jalili, P.; Eagderi, S. *Oxynoemacheilus ciceki*, new nemacheilid species (Teleostei, Nemacheilidae) from the Sultan Marsh, Kayseri Province, Turkey. *Iran. J. Ichthyol.* **2017**, *4*, 375–383.
53. Freyhof, J.; Kaya, C.; Turan, D.; Geiger, M.F. Review of the *Oxynoemacheilus tigris* group with the description of two new species from the Euphrates drainage (Teleostei: Nemacheilidae). *Zootaxa* **2019**, *4612*, 029–057. [CrossRef]
54. Turan, D.; Kaya, C.; Kalaycı, G.; Bayçelebi, E.; Aksu, I. *Oxynoemacheilus cemali*, a new species of stone loach (Teleostei: Nemacheilidae) from the Çoruh River drainage. *J. Fish Biol.* **2019**, *94*, 458–468. [CrossRef]
55. Sungur, S. *Oxynoemacheilus kosswigi* a Junior Synonym of *O. seyhanensis* (Teleostei: Nemacheilidae). *Iran. J. Sci. Technol. Trans. Sci.* **2020**, *44*, 563–573. [CrossRef]
56. Ahnelt, H. A second record of *Knipowitschia byblisia* Ahnelt, 2011 (Teleostei: Perciformes: Gobiidae) from southwestern Anatolia, Turkey. *J. Threat Taxa* **2016**, *8*, 9195–9197. [CrossRef]
57. Freyhof, J. *Alburnus nicaeensis*. The IUCN Red List of Threatened Species 2014: 2014a, e.T19018670A19222798. Available online: https://dx.doi.org/10.2305/IUCN.UK.2014-1.RLTS.T19018670A19222798.en (accessed on 3 May 2021).
58. Freyhof, J. *Alburnus akili*. The IUCN Red List of Threatened Species 2014: 2014b, e.T787A19005895. Available online: https://dx.doi.org/10.2305/IUCN.UK.2014-1.RLTS.T787A19005895.en (accessed on 3 May 2021).
59. Freyhof, J. *Aphanius splendens*. The IUCN Red List of Threatened Species 2014: 2014c, e.T1848A19006085. Available online: https://dx.doi.org/10.2305/IUCN.UK.2014-1.RLTS.T1848A19006085.en (accessed on 2 April 2021).
60. Freyhof, J. *Pseudophoxinus handlirschi*. The IUCN Red List of Threatened Species 2014: 2014d e.T40747A19007061. Available online: https://dx.doi.org/10.2305/IUCN.UK.2014-1.RLTS.T40747A19007061.en (accessed on 3 May 2021).
61. Polat, N.; Zengin, M.; Gümüş, A. İstilacı Balık Türleri ve Hayat Stratejileri. *Karadeniz Fen Bilim. Derg.* **2011**, *2*, 63–86. (In Turkish)
62. Kalayci, G.; Ozturk, R.C.; Capkin, E.; Altinok, I. Genetic and molecular evidence that brown trout Salmo trutta belonging to the Danubian lineage are a single biological species. *J. Fish Biol.* **2018**, *93*, 792–804. [CrossRef]
63. Freyhof, J. *Salmo abanticus*. The IUCN Red List of Threatened Species. 2019, E.T19515210A19849316. Available online: https://dx.doi.org/10.2305/IUCN.UK.2019-1.RLTS.T19515210A19849316.en (accessed on 10 May 2021).
64. Reid, G.M.; MacBeath, T.C.; Csatádi, K. Global challenges in freshwater fish conservation related to public aquariums and the aquarium industry. *Intern. Zoo. Yearb.* **2013**, *47*, 6–45. [CrossRef]
65. Cambray, J.A. Impact on indigenous species biodiversity caused by the globalisation of alien recreational freshwater fisheries. *Hydrobiologia* **2003**, *500*, 217–230. [CrossRef]
66. García-Berthou, E.; Moyle, P.B. Rivers. In *Encyclopedia of Biological Invasions*; Simberloff, D., Rejmánek, M., Eds.; University of California Press: Berkeley & Los Angeles, CA, USA, 2011; pp. 609–612.
67. Innal, D.; Erk'akan, F. Effects of exotic and translocated fish species in inland waters of Turkey. *Rev. Fish Biol. Fish.* **2006**, *16*, 39–50. [CrossRef]
68. Hoş, A.C. Studies on Bio-Ecology of *Salmo trutta abanticus* Tortonese, 1954 (Abant trout) and *Tinca tinca* (Linneaeus 1758) (Tench) Living in Abant Lake (Bolu/Turkey). Ph.D. Thesis, Hacettepe Üniversity, Ankara, Turkey, 2005; p. 147.
69. Özuluğ, M.; Altun, Ö.; Meriç, N. On the fish fauna of Lake İznik (Turkey). *Turk. J. Zool.* **2005**, *29*, 371–375.
70. Balık, S.; Ustaoğlu, M.R. Türkiye'nin göl, gölet ve baraj göllerinde gerçekleştirilen balıklandırma çalışmaları ve sonuçları. In *Balıklandırma ve Rezervuar Yönetimi Sempozyumu Bildiriler Kitabı, T.K.B Akdeniz Su Ürünleri Araştırma, Üretim ve Eğitim Enst*; Emre, Y., Diler, I., Eds.; Yayınları: Antalya, Turkey, 2006; pp. 1–10. (In Turkish)
71. Yeğen, V.; Balık, S.; Bostan, H.; Uysal, R.; Bilcen, E. Göller bölgesindeki bazı göl ve baraj göllerinin balık faunalarının son durumu. In *Balıklandırma ve Rezervuar Yönetimi Sempozyumu Bildiriler Kitabı T.K.B Akdeniz Su Ürünleri Araştırma, Üretim ve Eğitim Enst*; Emre, Y., Diler, I., Eds.; Yayınları: Antalya, Turkey, 2006; Volume 550, pp. 129–141. (In Turkish)
72. Geldiay, R.; Balık, S. *Türkiye Tatlısu Balıkları, 644, No: 46*; Ege Üniv. Su Ürünleri Fakültesi: İzmir, Turkey, 2007. (In Turkish)
73. Özuluğ, M.; Tarkan, A.S.; Gaygusuz, Ö.; Gürsoy, Ç. Two new records for the fish fauna of Lake Sapanca Basin (Sakarya, Turkey). *J. Fish Sci. Com.* **2007**, *1*, 152–159.
74. Zengin, M.; Buhan, E. Almus-Ataköy Baraj Gölleri'nde (Yeşilirmak Havzasi, Tokat) baliklandirma sonrasi balik faunasinda görülen değişimin değerlendirilmesi. In Proceedings of the Ulusal Su Ürünleri Sempozyumu, Antalya, Turkey, 16–18 May 2007. (In Turkish)
75. Gülle, İ.; Yıldırım, M.Z.; Küçük, F. Limnological history of Lake Eğirdir (Turkey): From 1950's to the present. *Nat. Monteneg.* **2008**, *7*, 115–128.
76. Özen, M.R.; Turna, I.I.; Cınar, K. As an example of ecological devastation Egirdir lake (Turkey). *Bulg. J. Agric. Sci.* **2008**, *14*, 195–200.
77. Küçük, F.; Sari, H.M.; Demir, O.; Gülle, İ. Review of the ichthyofaunal changes in Lake Eğirdir between 1915 and 2007. *Turk. J. Zool.* **2009**, *33*, 277–286.
78. Innal, D. Distribution and impacts of *Carassius* species (Cyprinidae) in Turkey: A review. *Manag. Biol. Invasions* **2011**, *2*, 57–68. [CrossRef]
79. Innal, D. Alien fish species in reservoir systems in Turkey: A review. *Manag. Biol. Invasions.* **2012**, *3*, 115–119. [CrossRef]
80. Ergüden, S.A.; Göksu, M.Z.L. The fish fauna of the Seyhan Dam Lake (Adana). *J. Fish. Sci.* **2012**, *6*, 39–52. [CrossRef]

81. Küçük, F. Extinct endemic fishes of Turkey: *Alburnus akili* (gövce) and *Pseudophoxinus handlirschi* (Kavinne) (Pisces: Cyprinidae). *Turk. J. Fish. Aquat. Sci.* **2012**, *12*, 345–347.
82. Çınar, Ş.; Küçükkara, R.; Balık, İ.; Çubuk, H.; Ceylan, M.; Erol, K.G.; Yegen, V.; Bulut, C. Uluabat (Apolyont) Gölü'ndeki Balık Faunasının Tespiti, Tür Kompozisyonu ve Ticari Avciliğin Türlere Göre Dağılımı. *J. Fish. Sci.* **2013**, *7*, 309–316. [CrossRef]
83. Ekmekçi, F.G.; Kırankaya, Ş.G.; Gençoğlu, L.; Yoğurtçuoğlu, B. Türkiye Içsularindaki Istilaci Balıkların Güncel Durumu ve Istilanin Etkilerinin Değerlendirilmesi. *I.U. J. Fish. Aqu. Sci.* **2013**, *28*, 105–140. (In Turkish)
84. Güçlü, S.S.; Küçük, F.; Ertan, Ö.O.; Güçlü, Z. The fish fauna of the Büyük Menderes River (Turkey): Taxonomic and zoogeographic features. *Turk. J. Fish. Aquat. Sci.* **2013**, *13*, 685–698. [CrossRef]
85. Özuluğ, M.; Saç, G.; Gaygusuz, Ö. İstilaci özellikteki *Gambusia holbrooki*, *Carassius gibelio* ve *Pseudorasbora parva* (Teleostei) Türleri için Türkiye'den yeni yayılım Alanları. *I.U. J. Fish. Aqu. Sci.* **2013**, *28*, 1–22. (In Turkish)
86. Yağcı, A.; Apaydın Yağcı, M.; Bostan, H.; Yeğen, V. Distribution of the topmouth gudgeon, *Pseudorasbora parva* (Cyprinidae: Gobioninae) in Lake Eğirdir, Turkey. *Sur. Fish. Sci.* **2014**, *1*, 46–55. [CrossRef]
87. Yerli, S.V.; Alp, A.; Yeğen, V.; Uysal, R.; Apaydın Yağcı, M.; Balık, İ. Evaluation of the Ecological and Economical Results of the Introduced Alien Fish Species in Lake Eğirdir, Turkey. *Turk. J. Fish. Aquat. Sci.* **2013**, *13*, 795–809. [CrossRef]
88. İlhan, A.; Sarı, H.M. Length-weight relationships of fish species in Marmara Lake, West Anatolia, Turkey. *Ribarstvo* **2015**, *73*, 30–32. [CrossRef]
89. Tarkan, A.S.; Marr, S.M.; Ekmekçi, F.G. Non-native and translocated freshwater fish species in Turkey. *FiSHMED Fishes Mediterr. Environ.* **2015**, *3*, 28. [CrossRef]
90. Uysal, R.; Alp, A.; Yeğen, V.; Apaydın Yağcı, M.; Çetinkaya, S.; Yağcı, A.; Bostan, H.; Cesur, M.; Küçükkara, R. İznik Gölü (Bursa/Türkiye)'ndeki Gümüşi Havuz Balığının (*Carassius gibelio* Bloch, 1782) Büyüme Özellikleri. *LIMNOFISH* **2015**, *1*, 19–27. (In Turkish)
91. Yeğen, V.; Uysal, R.; Yağcı, A.; Cesur, M.; Çetinkaya, S.; Bilgin, F.; Bostan, H.; Yağcı, M.A. New Records for Distribution of Invasive Topmouth gudgeon (*Pseudorasbora parva* Temminck & Schlegel, 1846) in Anatolia. *LIMNOFISH* **2015**, *1*, 57–65.
92. Elp, M.; Atıcı, A.A.; Şen, F.; Duyar, H.A. Distribution of Fish Species in the Van Lake Basin. *Yuz. Yıl Univ. J. Agric. Sci.* **2016**, *26*, 563–568.
93. Tarkan, A.S.; Sarı, H.M.; İlhan, A.; Kurtul, I.; Vilizzi, L. Risk screening of non-native and translocated freshwater fish species in a Mediterranean-type shallow lake: Lake Marmara (West Anatolia). *Zool. Middle East* **2017**, *63*, 48–57. [CrossRef]
94. Innal, D.; Çağlan, D.C.; Özdemir, F. Species composition of fish community in Onaç Creek (Burdur-Turkey) and their length-weight relationships. *Acta Biol. Turc.* **2019**, *32*, 135–142.
95. Bayçelebi, E. Distribution and diversity of fish from Seyhan, Ceyhan and Orontes river systems. *Zoosys. Evol.* **2020**, *96*, 747–767. [CrossRef]
96. Bayçelebi, E.; Kaya, C.; Güçlü, S.S.; Küçük, F.; Turan, D. Taxonomic status of endemic fish species in Lake Beyşehir Basin (Turkey). *Acta Aqu. Turc.* **2020**, *16*, 138–147.
97. Saç, G.; Gaygusuz, Ö. Relationships between body size, weight and fecundity of the endangered fish *Alburnus carinatus* Battalgil, 1941 in the Manyas Lake (Turkey). *Aquat. Sci. Eng.* **2020**, *35*, 27–30. [CrossRef]
98. Küçük, F.; Güçlü, S.S.; Gülle, İ. Manavgat Irmağı (Antalya) balık faunasının çeyrek asırlık değişimi. *Acta Aqu. Turc.* **2020**, *16*, 433–446.
99. Saç, G.; Gaygusuz, Ö.; Ertürk, A. Invasive fish threat in Manyas Lake (Turkey). *Biyol. Çeşit. Kor.* **2020**, *13*, 115–119.
100. GEKA Feasibility Report for the Rescue and Sustainable Management of Işık and Gökgöl Wetlands Project. Project Report 2015. Available online: https://geka.gov.tr/uploads/pages_v/isikli-ve-gokgol-sulak-alanlarinin-surdurulebilir-yonetimi-fizibilite-raporu-2014.pdf (accessed on 1 April 2021). (In Turkish)
101. Global Invasive Species Database. Available online: http://www.iucngisd.org/gisd/100_worst.php (accessed on 26 August 2019).