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Research Article

Ichthyo-diversity in the Anzali Wetland and its related rivers in the southern Caspian Sea basin, Iran

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Abstract

The Anzali Wetland is one of the most important water bodies in Iran, due to the Caspian migratory fish spawning, located in the southern Caspian Sea basin, Iran. During a long-term monitoring program, between 1994 to 2019, identification and distribution of fish species were surveyed in five different locations inside the Anzali Wetland and eleven related rivers in its catchment area. In this study 72 fish species were recognized belonging to 17 orders, 21 families and 53 genera, including 66 species in the wetland and 53 species in the rivers. Among the 72 identified species, 34 species were resident in freshwater, 9 species were anadromous, 9 species live in estuarine and the others exist in different habitats. These species include 4 endemic species, 50 native species and 18 exotic species to Iranian waters. The number of species in different locations inside the Anzali Wetland was comparatively similar while it had high variation in different rivers. Twenty fish species are new records for the Anzali Wetland basin, including 10 estuarine, 5 ornamental, 2 riverine, one anadromous, one euryhaline and a small exotic fish.

Key words: Biodiversity, ichthyo-fauna, distribution, endemic, exotic, Anzali Wetland

Introduction

The Anzali Wetland located in Guilan Province, is located in the western part of the southern Caspian Sea, northern Iran. It consists of four main sections: Siahkeshim (southern part), Sheijan (eastern part), Sorkhankol (central part) and Abkenar (western part) (Fig. 1C). It covers an area of 19100 ha and is 22 km long and 2–4 km in width (Naderi et al., 2017).

The Anzali Wetland, is the most important freshwater ecosystem in the southern Caspian Sea basin, is confronted with many problems and negative impacts (Mirzajani, 2009), and is listed in the Montreux record as a priority site for conservation (Naderi et al., 2017). It acts as an Ecotone between different ecosystems: terrestrial, the Caspian Sea, brackish and freshwater environments (Kimbal and Kimbal, 1974).

Under the Department of Environment conservation management program, there is one protected area (Siahkeshim) and three wildlife refuges (Sorkhankol, Chokam, and Selkeh).

Eleven rivers flow into the wetland, while five canals discharge the water directly to the Caspian Sea (Naderi et al., 2017).

The Anzali Wetland is under severe stress, with such impacts as sedimentation, eutrophication, different types of contaminants, overgrowth of aquatic vegetation and the invasion of exotic species; particularly in the last decades (Mirzajani, 2009; Mirzajani et al., 2010).

Today, most areas of the Anzali Wetland have been drained and degraded to shallow marshes, seasonally flooded grasslands and only the western part is distinguished by a large and shallow freshwater habitat (Mirzajani et al., 2010).

The Anzali Wetland is an important habitat for fisheries activity. According to an FAO report (Hydrorybproject, 1965), from the beginning of the 1960s, it was important both as a source of fishes and as the spawning ground of especially anadromous fish species. According to the statistics, the fish catches from 1932 to 1940 varied from 3100 to 5700 metric tons and at that time contributed 70% of the total Iranian catch of fish in Guilan Province (Hydrorybproject, 1965).

The major fish species in the catch were the anadromous Kutum, *Rutilus kutum* Kamenskii, 1901; Pike-perch, *Sander lucioperca* (Linnaeus, 1758), and Bream, *Abramis brama* (Linnaeus, 1758), which enter the wetland in autumn or in spring and spawn there. By the beginning of the 1960s, the total catch from the Anzali Wetland was only 100 metric tons, i.e., slightly less than 2% of the original catch (Holcik and Oláh, 1992).

Regarding the ichthyo-diversity of wetland, the first ichthyological investigation was by Holcik and Oláh (1992) and they reported 41 species from the Anzali Wetland and then Karimpour (1998) added one other species to the species list. After that, Abbasi et al. (1999) identified 49 species from the Anzali Wetland and its catchment area.

The present study is a review of the distribution and diversity of fishes in different parts of the Anzali Wetland and its related rivers, based on comprehensive fieldwork by the authors during the past 25 years.

Material and Methods

The sampling was carried out during different times and seasons over the years 1994 to 2019. All parts of the Anzali Wetland have been collected, including Abkenar, Sheijan, Sorkhankol, Siahkeshim and the estuary (Fig. 1). Furthermore, all eleven rivers (NGO-IRAN, 2003) including Chafroud, Bahambar, Morghak, Khalkai, Palangvar, Masooleh-Roudkhan, Siahdarvishan, Pasikhan, Pirbazar (Siahroud), Tashroud and Sheijanroud (Fig. 1; Appendix 1) were collected. Different habitats in each part of the wetland and three sections of each river, including upper, middle and downstream were sampled (see figures in the Appendix 1).

Different sampling methods were used including cast net, haul seine, gill net, electro-fisher, hand line, dip net and handle nets. Also, some rare species which were caught by local fishermen were included in the studied samples.

A few specimens of each species were subsampled randomly and any others released. General characteristics such as color of the body and fins were documented by taking photographs. The collected individuals were fixed in 10% formalin solution after a natural death or anesthesia in a solution of 0.01% clove. The fixed specimens were transferred to the ichthyological laboratories (Inland Waters Aquaculture Research Center and University of Guilan) for further analysis.

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Fish identification followed Holcik (1989) and Kottelat and Freyhof (2007) using descriptive characteristics (the number of dorsal fins, type of mouth and caudal fin, oral and pharyngeal teeth, sensory organs on the head and number of barbs), meristic counts (the number of branched and unbranched rays of dorsal, pectoral, anal and caudal fins, the number of gill rakers and branchiostegal rays, lateral line scales), morphometric measurements (length and height of fins, distance between fin origins, length of head sections) and anatomical features (stomach form, the number and form of pyloric caeca, type of swim bladder and color of peritoneum).

Fish classification to family followed Nelson (1994; 2006) and Nelson et al. (2016) and determination to genus and species followed identification keys provided by different authors (Berg, 1948; 1949a, b; Svetovidov, 1952; Kazancheev, 1981; Abbasi et al., 1999; Abdoli, 2000; Naderi and Abdoli, 2004; Coad, 2005; 2010; Kottelat and Freyhof, 2007; Abdoli and Naderi, 2009; Mousavi-Sabet et al., 2015; Vasil'eva et al., 2015; Keivany et al., 2016; Abbasi, 2017; Eagderi et al., 2017; Jouladeh-Roudbar et al., 2017; Froese and Pauly, 2019).

Finally, the scientific name of each identified fish was checked against the last checklist of freshwater fishes of Iran (Esmaeili et al., 2018) and the catalogue of fishes (Fricke et al., 2019).

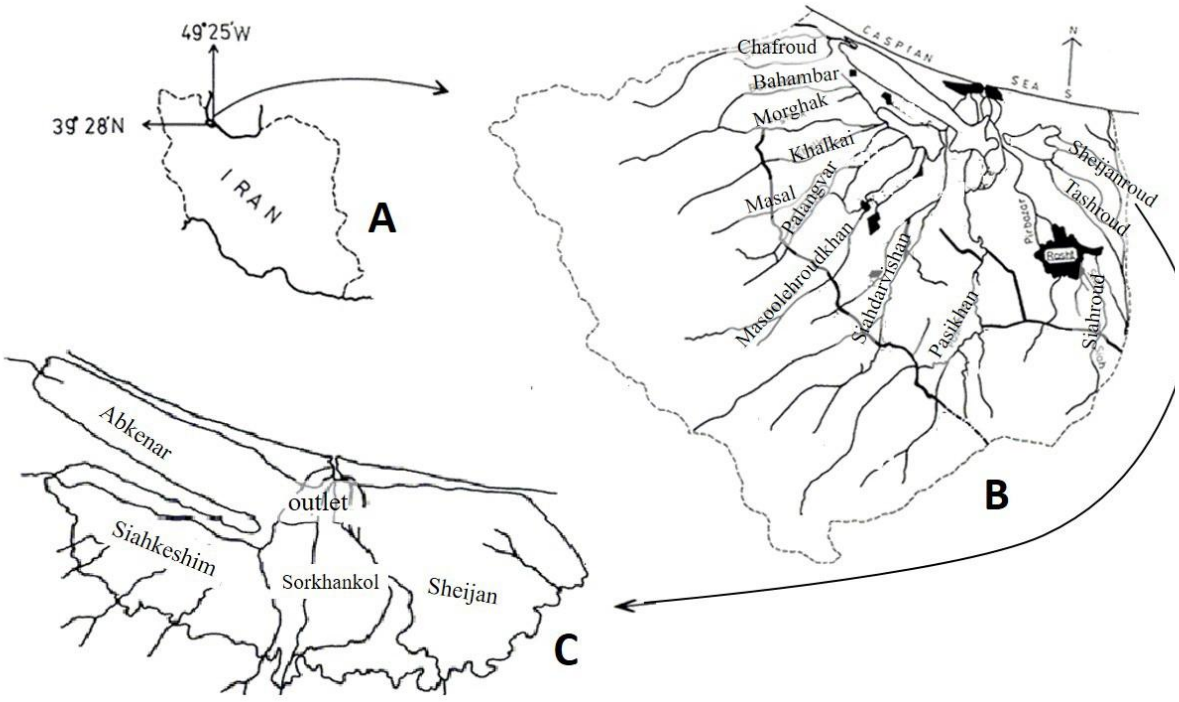

Figure 1: The studied area: Geographical point of the Anzali Wetland (A), catchment area with the main inlet rivers (B) and the different parts of the Anzali Wetland water body (C).

Results

The long-term ichthyological monitoring (1994–2019) confirmed the presence of 72 fish species in the Anzali Wetland and its catchment area. The fish belong to two classes the Petromyzontida, including *Caspiomyzon wagneri* (Kessler, 1870), and Actinopterygii (the other 71 species), 17 orders, 21 families and 53 genera. Eighteen families were recognized inside the wetland while nineteen families were present in the studied rivers (Table 1).

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Among the families, the Cyprinidae, Gobiidae and Clupeidae had the most diversity with 28, 13 and 4 species, respectively, while eleven families were recognized with only one representative (Table 1).

In total 66 species were identified inside the Anzali Wetland and in the adjacent estuary. Five exotic ornamental species, namely *Channa micropeltes* (Cuvier, 1831), *Pangasius sanitwongsei* Smith, 1931, *Hypostomus plecostomus* (Linnaeus, 1758), *Piaractus brachypomus* (Cuvier, 1818) and *Poecilia reticulata* Peters, 1859 were occasionally observed inside the wetland (Table 1; Appendix 2).

The number of fish species was approximately equal in different parts of the Anzali Wetland, except for the western part (Fig. 2). The most common species inside the wetland were from the cyprinids, followed by the gobiids (Fig. 3).

In the studied rivers 53 species were identified, of which only 6 species were not also observed inside the wetland and estuary; including the Caspian anadromous fishes, *Acipenser persicus* Borodin, 1897, *Acipenser stellatus* Pallas, 1771, and freshwater species, *Barbus cyri* De Filippi, 1865, *Oxynoemacheilus bergianus* (Derzhavin, 1934), *Oncorhynchus mykiss* (Walbaum, 1792) and *Salmo trutta* Linnaeus, 1758 (Table 1; Appendix 2).

Table 1: Distribution and ecological characteristics of identified fish species in the Anzali Wetland basin. En: Endemic, N: Native, A: Alien, Or: Ornamental, W: Western, S: Southern, C: Central, E: Eastern and O: Outlet (Estuary). Rivers: 1. Chafroud, 2. Bahambar, 3. Morghak, 4. Khalkai, 5. Palangvar, 6. Masoolehroudkhan, 7. Siahdarvishan, 8. Pasikhan, 9. Pirbazar, 10. Tashroud and 11. Sheijanroud.

Order	Family	Scientific name	Common name	Origin	Wetland areas	Rivers	Ecological group
Petromyzontiformes	**Petromyzontidae**	*Caspiomyzon wagneri* (Kessler, 1870)	Caspian lamprey	N	WE	4–8	G-II
Acipenseriformes	**Acipenseridae**	*Acipenser persicus* Borodin, 1897	Persian sturgeon	N		7	G-II
		Acipenser stellatus Pallas, 1771	Stellate sturgeon	N		5, 7, 8	G-II
Anguilliformes	**Anguillidae**	*Anguilla anguilla* (Linnaeus, 1758)	European eel	N	O		G-IV
Clupeiformes	**Clupeidae**	*Alosa braschnikowi* (Borodin, 1904)	Caspian marine shad	N	O		G-IV
		Alosa caspia (Eichwald, 1838)	Caspian shad	N	WCEO	7	G-VI

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Table 1. (Continued)

Order	Family	Scientific name	Common name	Origin	Wetland areas	Rivers	Ecological group
Clupeiformes	Clupeidae	*Alosa kessleri* (Grimm, 1887)	Caspian anadromous shad	N	EO		G-V
		Clupeonella caspia Svetovidov, 1941	Caspian tyulka	N	WSCEO	5, 7	G-VI
Cypriniformes	Cyprinidae	*Abramis brama* (Linnaeus, 1758)	Common bream	N	WSCEO	2, 4, 5, 7–9	G-III
		Alburnoides samiii Mousavi-Sabet, Vatandoust and Doadrio, 2015	Safidrud spirlin	En	SCE	1–11	G-I
		Alburnus chalcoides (Güldenstaedt, 1772)	Caspian shemaya	N	WSCEO	1–11	G-II
		Alburnus filippi Kessler, 1877	Kura bleak	N	WSCE	4–8	G-I
		Alburnus hohenackeri Kessler, 1877	North Caucasian bleak	N	WSCEO	1, 2, 4–11	G-I
		Barbus cyri De Filippi, 1865	Kura barbel	N		1–4, 6–9	G-I
		Blicca bjoerkna (Linnaeus, 1758)	Silver bream	N	WSCEO	2, 4, 5, 7–11	G-I
		Capoeta razii Jouladeh-Roudbar, Eagderi, Ghanavi and Doadrio, 2017	Caspian scraper	En	WSCO	1–11	G-I
		Carassius auratus (Linnaeus, 1758)	Goldfish	A, Or	WSCE	2, 4, 5, 7–9	G-I
		Carassius gibelio (Bloch, 1782)	Prussian carp	A	WSCEO	1–11	G-I
		Ctenopharyngodon idella (Valenciennes, 1844)	Grass carp	A	WSCE	2, 7, 8	G-I
		Cyprinus carpio Linnaeus, 1758	Common carp	N	WSCEO	2, 4, 5, 7, 8, 11	G-III
		Hemiculter leucisculus (Basilewsky, 1855)	Sharpbelly	A	WSCEO	1, 2, 5–11	G-I

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Table 1. (Continued)

Order	Family	Scientific name	Common name	Origin	Wetland areas	Rivers	Ecological group
Cypriniformes	Cyprinidae	*Hypophthalmichthys molitrix* (Valenciennes, 1844)	Silver carp	A	WSCE	7, 8	G-I
		Hypophthalmichthys nobilis (Richardson, 1844)	Bighead carp	A	WSCE	7, 8	G-I
		Leucaspius delineatus (Heckel, 1843)	Moderlieschen	N	WSCE	2, 5, 7, 8, 10	G-I
		Leuciscus aspius (Linnaeus, 1758)	European asp	N	WO	5, 7, 8	G-III
		Luciobarbus capito (Güldenstaedt, 1773)	Bulatmai barbel	N	WSEO	1–11	G-III
		Luciobarbus caspius (Berg, 1914)	Caspian barbel	N	SO	5, 7, 8	G-II
		Pelecus cultratus (Linnaeus, 1758)	Ziege	N	WCO		G-II
		Pseudorasbora parva (Temminck and Schlegel, 1846)	Topmouth gudgeon	A	WSCE	1, 2, 4–11	G-I
		Rhodeus amarus (Bloch, 1782)	European bitterling	N	WSCE	1–11	G-I
		Rutilus lacustris (Pallas, 1814)	Vobla	N	WSCEO	2, 7, 8	G-III
		Rutilus kutum Kamenskii, 1901	Kutum	N	WSCEO	2, 4–9, 11	G-II
		Scardinius erythrophthalmus (Linnaeus, 1758)	Rudd	N	WSCE	2, 5, 7, 8	G-I
		Squalius turcicus De Filippi, 1865	Transcaucasian chub	N	SE	1–9	G-I
		Tinca tinca (Linnaeus, 1758)	Tench	N	WSC	2, 4–9	G-I
		Vimba persa (Pallas, 1814)	Caspian vimba	N	WSCEO	1, 2, 4–9	G-II
	Cobitidae	*Cobitis saniae* Eagderi, Jouladeh-Roudbar, Jalili, Sayyadzadeh and Esmaeili, 2017	Sania's spined loach	En	WSCE	1–11	G-I
		Sabanejewia caspia (Eichwald, 1838)	Caspian loach	N	WSCE	1, 2, 5, 7, 10	G-I
	Nemacheilidae	*Oxynoemacheilus bergianus* (Derzhavin, 1934)	Safidrud stone loach	N		6–8	G-I

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Table 1. (Continued)

Order	Family	Scientific name	Common name	Origin	Wetland areas	Rivers	Ecological group
Characiformes	Serrasalmidae	*Piaractus brachypomus* (Cuvier, 1818)	Pirapitinga	A, Or	E, W		G-I
Siluriformes	Siluridae	*Silurus glanis* Linnaeus, 1758	Wels catfish	N	WSCEO	2, 4–8	G-I
	Pangasiidae	*Pangasius sanitwongsei* Smith, 1931	Giant pangasius	A, Or	E, W	7	G-I
	Loricariidae	*Hypostomus plecostomus* (Linnaeus, 1758)	Suckermouth catfish	A, Or	E, W	7	G-I
Salmoniformes	Salmonidae	*Oncorhynchus mykiss* (Walbaum, 1792)	Rainbow trout	A		1, 5–8	G-I
		Salmo caspius Kessler, 1877	Caspian trout	N	W, S, O	4, 5, 7, 8	G-II
		Salmo trutta Linnaeus, 1758	Brown trout	N		1, 4–8	G-I
Esociformes	Esocidae	*Esox lucius* Linnaeus, 1758	Northern pike	N	WSCEO	2, 4–8, 10, 11	G-I
Gobiiformes	Gobiidae	*Benthophilus ctenolepidus* Kessler, 1877	Transparent tadpole goby	N	O		G-IV
		Benthophilus leobergius Berg, 1949	Caspian stellate tadpole goby	N	O		G-IV
		Knipowitschia caucasica (Berg, 1916)	Caucasian dwarf goby	N	WSCEO		G-V
		Neogobius caspius (Eichwald, 1831)	Caspian goby	N	O		G-IV
		Neogobius melanostomus (Pallas, 1814)	Round goby	N	WSEO		G-V

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Table 1. (Continued)

Order	Family	Scientific name	Common name	Origin	Wetland areas	Rivers	Ecological group
Gobiiformes	Gobiidae	*Neogobius Pallasi* (Berg, 1916)	Caspian sand goby	N	O		G-IV
		Ponticola bathybius (Kessler, 1877)	Deepwater Goby	N	O		G-IV
		Ponticola goebelii (Kessler, 1874)	Ratan goby	N	WO		G-V
		Ponticola gorlap (Iljin, 1949)	Caspian bighead goby	N	WSCEO	1–11	G-VII
		Ponticola iranicus Vasil'eva, Mousavi-Sabet and Vasil'ev, 2015	Persian goby	En	WSEO	1–11	G-I
		Ponticola syrman (Nordmann, 1840)	Syrman goby	N	WO		G-V
		Proterorhinus nasalis (De Filippi, 1863)	Eastern tubenose goby	N	WSCEO	1, 2, 7, 10, 11	G-VII
		Rhinogobius lindbergi Berg, 1933	Lake goby	A	WSCE	1, 2, 4, 5, 7, 8	G-I
Mugiliformes	Mugilidae	*Chelon auratus* (Risso, 1810)	Golden grey mullet	A	O		G-IV
		Chelon saliens (Risso, 1810)	Leaping mullet	A	WCEO	5, 11	G-V
Atheriniformes	Atherinidae	*Atherina caspia* Eichwald, 1831	Caspian silverside	N	WCEO	2, 7	G-VI
Cyprinodontiformes	Poeciliidae	*Gambusia holbrooki* Girard, 1859	Eastern mosquitofish	A	WSCE	1, 2, 4–11	G-I
		Poecilia reticulata Peters, 1859	Guppy	A, Or	C	7	G-I
Anabantiformes	Channidae	*Channa micropeltes* (Cuvier, 1831)	Indonesian snakehead	A, Or	E, W		G-I
Syngnathiformes	Syngnathidae	*Syngnathus caspius* Eichwald, 1831	Caspian pipefish	N	WCO		G-V

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Table 1. (Continued)

Order	Family	Scientific name	Common name	Origin	Wetland areas	Rivers	Ecological group
Perciformes	Percidae	*Perca fluviatilis* Linnaeus, 1758	Perch	N	WSCEO	2, 5, 7, 8	G-I
		Sander lucioperca (Linnaeus, 1758)	Pike perch	N	WCEO	2, 5, 7, 8	G-III
		Sander marinus (Cuvier, 1828)	Estuarine perch	N	O		G-IV
Scorpaeniformes	Gasterosteidae	*Gasterosteus aculeatus* Linnaeus, 1758	Three-spined stickleback	A	WCEO	7, 8	G-VII
		Pungitius platygaster (Kessler, 1859)	Ukrainian stickleback	N	WCEO		G-V

Species diversity varied between different rivers within the Anzali Wetland catchment area with the most and the least number of fish species observed in the Siahdarvishan and Morghak Rivers with 52 and 11 species, respectively (Fig. 4).

The cyprinids were also dominant in the rivers (Table 1; Fig. 5). About 70–80% of the identified fish in the rivers were freshwater residents and the others were anadromous. *Alburnus chalcoide*s (Güldenstaedt, 1772) and *Carassius gibelio* (Bloch, 1782) were distributed in all rivers, and *Alburnoides samiii* Mousavi-Sabet, Vatandoust and Doadrio, 2015, *Alburnus hohenackeri* Kessler, 1877, *Capoeta razii* Jouladeh-Roudbar, Eagderi, Ghanavi and Doadrio, 2017, *Cobitis saniae* Eagderi, Jouladeh-Roudbar, Jalili, Sayyadzadeh and Esmaeili, 2017, *Gambusia holbrooki* Girard, 1859, *Hemiculter leucisculus* (Basilewsky, 1855), *Luciobarbus capito* (Güldenstaedt, 1773), *Ponticola gorlap* (Iljin, 1949), *Ponticola iranicus* Vasil'eva, Mousavi-Sabet and Vasil'ev, 2015, *Pseudorasbora parva* (Temminck and Schlegel, 1846), *Rhodeus amarus* (Bloch, 1782), and *Squalius turcicus* De Filippi, 1865 were observed in more than 80% of the studied rivers (Table 1; Appendix 2).

Among the recognized fishes, four endemic (5.56%) and 50 native species (69.44%) were identified, while 18 species (25%) are listed as exotic/alien (six of them are ornamental fish, introduced via the aquarium trade) (Fig. 6; Appendix 2). All the identified fish species in the Anzali Wetland basin belong to seven ecological groups (Table 1, Fig. 7).

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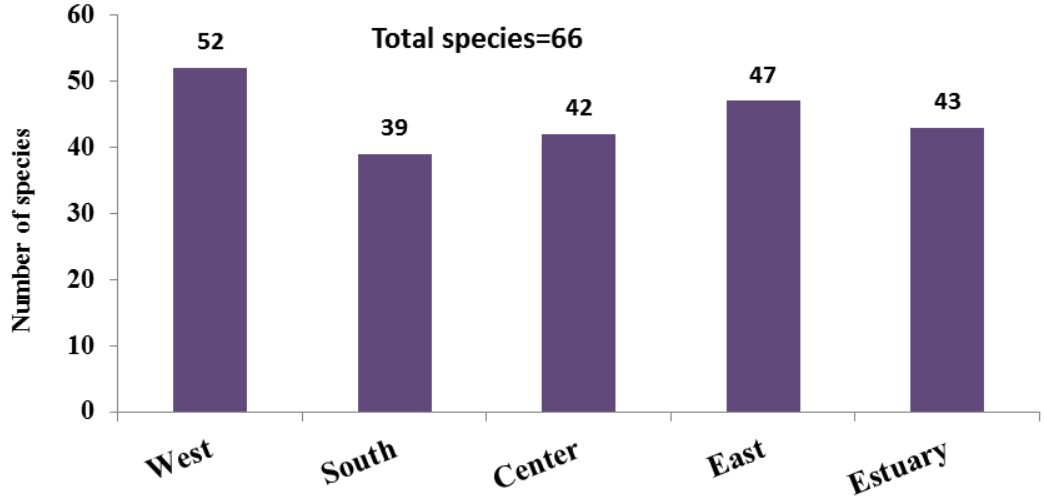

Figure 2: Number of fish species in different parts of the Anzali Wetland.

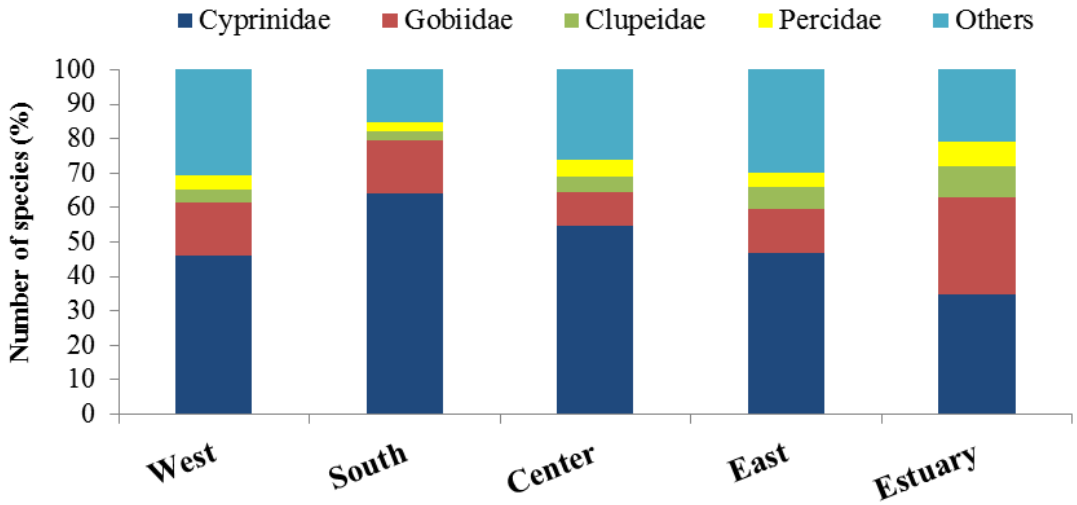

Figure 3: Number of species in each family in different parts of the Anzali Wetland.

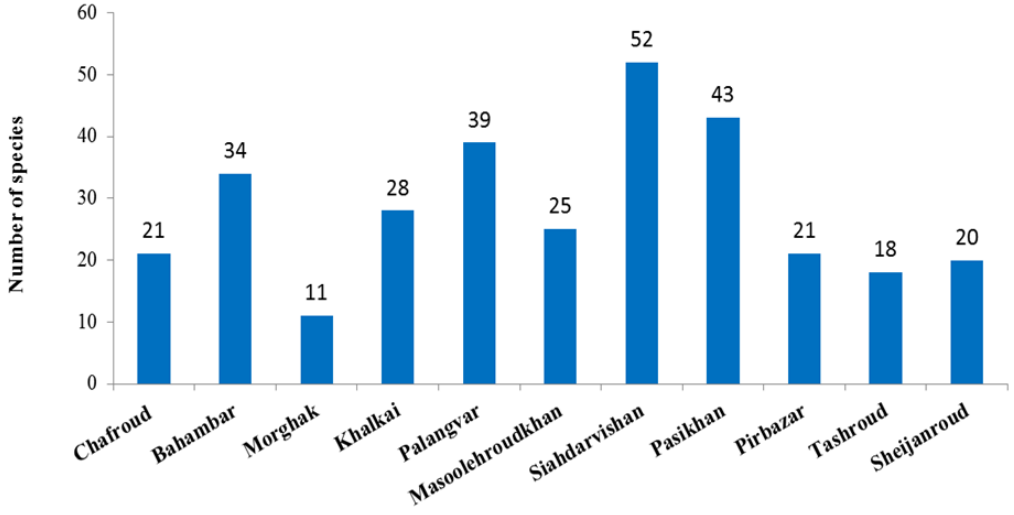

Figure 4: Number of fish species in different rivers of the Anzali Wetland basin.

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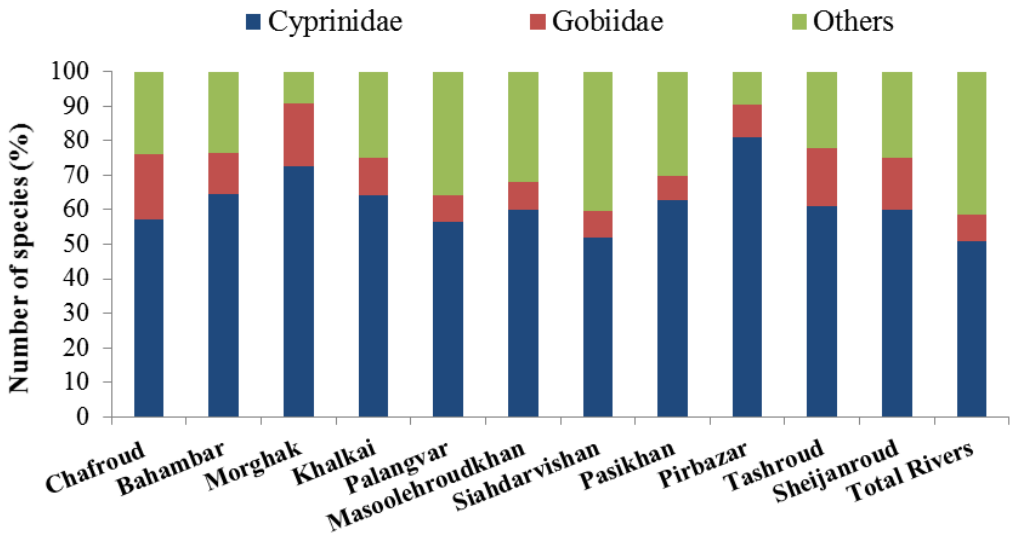

Figure 5: Number of species in each family in different rivers of the Anzali Wetland basin.

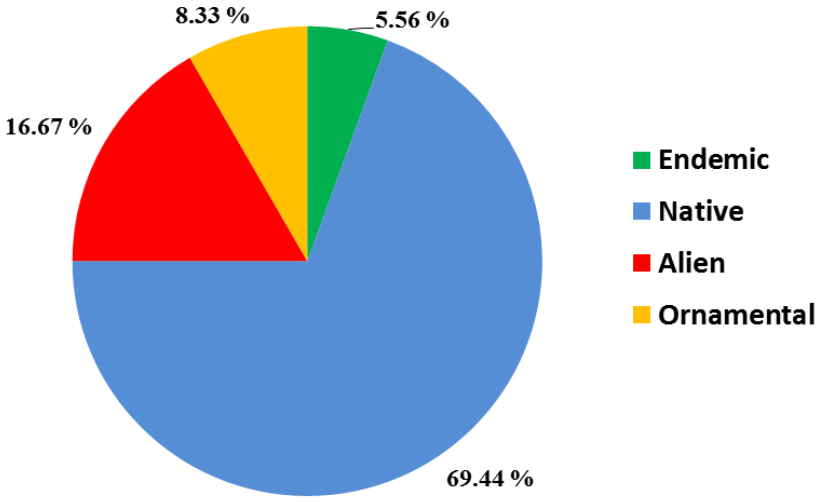

Figure 6: Origin of fish species in the Anzali Wetland basin.

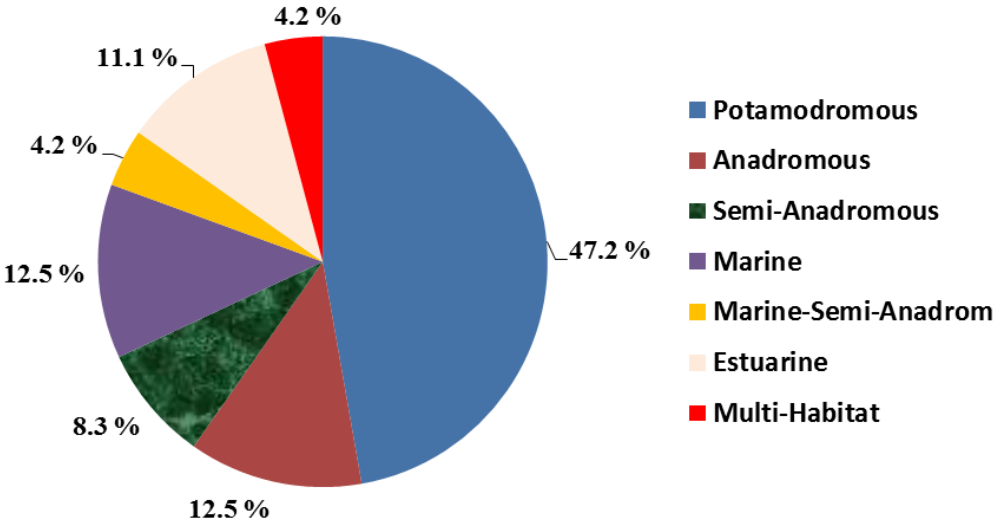

Figure 7: The ecological groups of identified fish species in the Anzali Wetland basin.

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Discussion

The present study shows the fish distribution in different parts of the Anzali Wetland and its related rivers for the first time. Here, we report 72 fish species from the Anzali Wetland basin, whereas previous reports included 26 species (Gmelin, 1785; Mel'gunov, 1836; Derzhavin, 1934; Kozhin, 1957, Hydrorybproject, 1965; RaLonde and Walczak, 1972), 41 species (Holcik and Oláh, 1992), 42 species (Karimpour, 1998) and 49 species (Abbasi et al., 1999). The longer sampling period, more sampled localities and the use of different fishing equipment in the present study are the main reasons for increasing the number of species. According to the obtained results, the number of exotic fishes is increasing in the Anzali Wetland in recent decades, especially due to the release of ornamental fishes through the aquarium trade.

The ichthyo-diversity of the Anzali Wetland is significantly richer than the other wetlands in the southern Caspian Sea basin, for example the Amirkelayeh Wetland with 15 species (Nezami Baluchie and Khara, 2004), Kiashahr National Park with 25 species (Khara and Nezami Baluchie, 2005), and Gomishan Wetland with 15 species (Patimar et al., 2009). The fish species richness of the wetland can be related to the permanent connection with the Caspian Sea, variable habitats, and the larger area of the Anzali Wetland in comparison with the other mentioned wetlands.

Due to the degradation of the Anzali Wetland environment, many areas were drained and others completely covered by dense aquatic plants. These changes could affect the fish diversity in different parts of the Anzali Wetland. The high sedimentation in the central and southern parts of wetland can be considered as the main reason for the low number of fishes in this region (Fig. 2).

Among the identified fishes, members of the family Cyprinidae were dominant inside the Anzali Wetland and its related rivers, similar to previous reports from the region (Holcik and Oláh, 1992; Abbasi et al., 1999; Nezami Baluchie and Khara, 2004; Khara and Nezami Baluchie, 2005; Patimar et al., 2009), and also from the rivers that discharge into the Caspian Sea from the southern part (Abbasi et al., 1998; 2007; 2011; 2014; Afraei and Lalooei, 2000; Abbasi, 2006a; 2006b; Mostafavi and Abdoli, 2006; Mostafavi, 2007; Banagar et al., 2009; Abdoli et al., 2014; Naderi Jelodar et al., 2016; Sarpanah et al., 2019). This is due to the high tolerance of cyprinids to habitat variation (Winfield and Nelson, 1991; Wootton, 1990).

Four freshwater species, *B. cyri*, *O. bergianus*, *S. trutta* and *O. mykiss* were only observed in the rivers and this shows their riverine dependence. Two species, *A. persicus* and *A. stellatus* were only observed in a few rivers. These are the Caspian anadromous fishes that have to pass through the corridor of the Anzali Wetland toward the rivers, but nowadays their abundance is very low in the Caspian Sea (Iran Fisheries Organization, 2017; Hashemi et al., 2019) and they are rarely observed in these freshwater regions.

In the adjacent rivers to the wetland, 23 species were previously reported by Holcik and Oláh (1992), in comparison with 53 identified fish species in the present investigation. It can be concluded that the longer sampling period with more sampling sites and various fishing techniques could have made the difference.

Nine species (particularly gobiids) are only observed in the estuarine region (Table 1) due to their main habitat in the brackish water of the Caspian Sea (Kazancheev, 1981; Abdoli and Naderi, 2009; Mirzajani et al., 2016; Abbasi, 2017), and it seems these species cannot enter the freshwater environments. Whereas *A. chalcoides*, *A. hohenackeri*, *C. gibelio*, *R. amarus*, *C. saniae* and *P. gorlap* are present in all areas inside the wetland and in almost all the adjacent rivers.

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Diversification of fish species in different rivers is related to ecological parameters such as length and width of rivers, water volume, type of substrate, situation of vegetation and man-made interventions such as dams and other barriers (Wootton, 1990; Rahel and Hubert, 1991). Generally more species diversity is observed in rivers which are longer in length, wider in width, lower in their slope, higher in aquatic plants (Varley, 1967; Rahel and Hubert, 1991), and also greater values of water flow and depth (Sheldon, 1968; Foltz, 1982; Adebisi, 1988). The Morghak is a short river with the least number of fish species while the Siahdarvishan is a long river with numerous streams and has the most number of fish species (Fig. 4). This pattern of ichthyo-diversity has been observed in many rivers, discharging to the southern Caspian Sea. Investigations of 20 rivers, flowing toward the southern Caspian Sea, by different authors (Ramin, 1997; Abbasi et al., 1998; 1999; 2007; 2011; 2014; Kiabi et al., 1999; Afraei and Lalooei, 2000; Abbasi and Sarpanah, 2001; Nazari, 2002; Abbasi, 2006a; 2006b; Mostafavi, 2007; Banagar et al., 2009; Abdoli et al., 2014; Naderi Jelodar et al., 2016; Sarpanah et al., 2019) showed that the number of fish species varied from 12 to 67 species.

Eighteen exotic, or alien, fish species were observed in the present study versus 7 and 9 reported species by Holcik and Oláh (1992) and Abbasi et al. (1999), respectively. Some of these alien fish were introduced with fisheries development to the Caspian Sea such as the golden grey mullet (*Chelon auratus*) and leaping mullet (*C. saliens*) (Kazancheev, 1981; Esmaeili et al., 2014b; 2018; Coad, 2016), while others were introduced for aquaculture purposes including *Cyprinus carpio*, *Hypophthalmichthys molitrix*, *H. nobilis* and *O. mykiss*. Two species *Ctenopharyngodon idella* and *G. holbrooki* were introduced to the Anzali Wetland to control aquatic plants and mosquitos, respectively (Coad, 2016; Esmaeili et al., 2014b; 2017; 2018). Most of the exotic species were introduced inadvertently to the Anzali Wetland as commercial species transplanted by Iranian Fisheries Organization (Shilat) for aquaculture developments, or released by people as ornamental fishes (Coad and Abdoli, 1993; Coad, 1995; 2016; 2019; Abdoli, 2000; Abdoli and Naderi, 2009; Esmaeili et al., 2014b; 2017; 2018; Keivany et al., 2016; Abbasi, 2017; Mousavi-Sabet, 2019).

At present, most water bodies have been occupied by alien species in Iran (Coad and Abdoli, 1993; Abdoli, 2000; Abbasi and Sarpanah, 2001; Abbasi et al., 1999; 2011; 2014; Khara and Nezami Balouchi, 2005; Mostafavi, 2007; Patimar et al., 2009; Naderi Jelodar et al., 2016; Abbasi, 2017; Coad, 2019; Sarpanah et al., 2019), and in some places the exotic species comprise 13 to 40 % of identified fish species. The dispersal ability of exotic species might promote the risk of gene introgression and competition between wild and introduced fish, as well as disease transmission to wild populations (Naylor et al., 2005; Fisher et al., 2014).

In this study, *A. samiii*, *C. razii*, *C. saniae* and *P. iranicus* were recognized as Iranian endemic species (Mousavi-Sabet et al., 2015; Vasil'eva et al., 2015; Eagderi et al., 2017; Jouladeh-Roudbar et al., 2017; Esmaeili et al., 2018) and a further 50 species were documented as Iranian native species (Kazancheev, 1981; Abdoli and Naderi, 2009; Esmaeili et al., 2014a; 2017; 2018; Coad, 2016; Froese and Pauly, 2019).

Using available literature (Berg, 1948; 1949a, b; Kazancheev, 1981; Wootton, 1990; Agarwal, 1999; Kottelat and Freyhof, 2007; Abdoli and Naderi, 2009; Coad, 2010; 2016; Keivany et al., 2016; Abbasi, 2017; Froese and Pauly, 2019), the identified species were divided into seven groups (Table 1, Fig. 7: G I-VII).

The freshwater resident or potamodromous species (G-I) include 34 species that exist inside the Anzali Wetland and its adjacent rivers, and are rarely observed in the estaurine region (inshore) for the purpose of feeding. According to potamodromous behavior (Acolas and Lambert, 2016), these species may move between the Anzali Wetland and its adjacent rivers to find suitable spawning grounds or feeding areas.

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Nine species (12.5 %) are anadromous (G-II) which live in the Caspian Sea and migrate to the Anzali Wetland and its adjacent rivers for spawning. While *Pelecus cultratus* spawn freely in open water, two species *Vimba persa* and *Rutilus kutum* are phytophilus-lithophilus and other species are only lithophilus and require aquatic vegetation or gravel substrates for spawning. Six species (G-III) are semi-anadromous existing in all regions and needing freshwater areas for spawning.

Nowadays, as a global problem (e.g., see Lassalle and Rochard, 2009; Vignon and Sasal, 2010; Johnson et al., 2013), barriers, pollution, modification of the hydraulic regime, substrate destruction, and illegal fisheries activities along rivers cause many threats to the spawning of anadromous fish species.

Nine species (G-IV) are marine fish, observed only in the Caspian Sea and they never enter into rivers, but remain in the estuarine region for feeding and spawning. Three species (G-V) were mostly observed in the estuarine region, rarely inside the wetland and downstream of some rivers, and they spawn in both freshwater and the Caspian Sea environment. Eight species (G-VI) were mostly observed in the Caspian Sea and rarely inside the wetland but these species were not observed in rivers.

Three species (G-VII) *P. gorlap*, *Proterorhinus nasalis* and *Gasterosteus aculeatus* were recorded from all regions; inside the wetland, rivers and estuary in all seasons and they can spawn both in freshwater and brackish water (estuary). The European eel, *Anguilla anguilla*, although it is a catadromous fish species (Froese and Pauly, 2019) hitherto has been reported from the coast and not from its rivers in the southern Caspian Sea (Kazancheev, 1981; Abdoli and Naderi, 2009; Coad, 2010; 2016; Keivany et al., 2016; Abbasi, 2017).

There are two previously reported species *Abramis sapa bergi* Belyaev, 1929 (now *Ballerus sapa* (Pallas 1814)) and *Platichthys flesus luscus* Pallas, 1811 (now *Platichthys flesus* (Linnaeus, 1758)) from the Anzali Wetland (Gmelin, 1785; Mel'gunov, 1836; Derzhavin, 1934; Kozhin, 1957; Hydrorybproject, 1965; RaLonde and Walczak, 1972) with no new records (Holcik and Oláh, 1992; Karimpour, 1998; Abbasi et al., 1999; Abdoli and Naderi, 2009; Coad, 2016; Abbasi, 2017; Esmaeili et al., 2018; present study).

Twenty fish species are recorded for the first time from the Anzali Wetland basin, including 10 estuarine species (*Alosa braschnikowi*, *A. kessleri*, *Benthophilus ctenolepidus*, *B. leobergius*, *Neogobius caspius*, *Ponticola bathybius*, *P. goebelii*, *P. syrman*, *Sander marinus* and *Chelon saliens*), five ornamental fish (*P. brachypomus*, *P. sanitwongsei*, *H. plecostomus*, *C. micropeltes* and *P. reticulata*), a rare upstream fish (*S. trutta*), a rare anadromous fish (*A. persicus*), a rare multi-habitat fish (*K. caucasica*), a newly small exotic fish (*R. lindbergi*) and an escaped farm fish (*O. mykiss*).

Based on the obtained results it can be concluded that 66 species (with the exception of six rare ornamental fishes) exist in different regions of the Anzali Wetland. Some of these species are rare with low abundance. Many species (20 species) belong to the Caspian Sea environment which are dependent on the Anzali Wetland due to different reasons, particularly for reproduction. Conservation of different habitats of the Anzali Wetland is necessary to preserve rare, freshwater and anadromous fish species.

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Appendix 1: Different habitats in the Anzali wetland basin, including five parts of the wetland, as follow: Western, Southern, Central, Eastern, Estuary (A-E), and eleven rivers, including, Chafroud (F), Bahambar (G), Morghak (H), Khalkai (I), Palangvar (J), Masoolehroudkhan (K), Siahdarvishan (L), Pasikhan (M), Pirbazar (N), Tashroud (O) and Sheijanroud (P), respectively.

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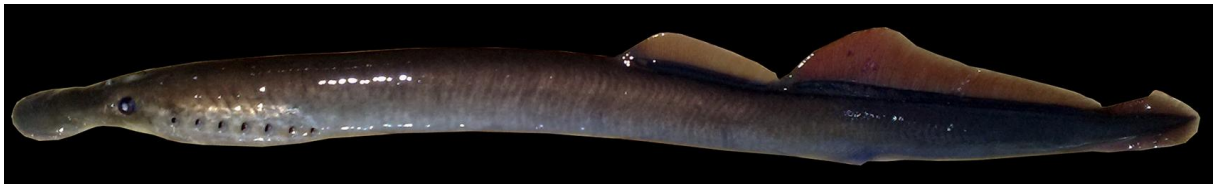
Appendix 2: Seventy two identified fish species in the Anzali Wetland basin. The order of appearance of species is in accordance with Table 1.



Caspiomyzon wagneri

Acipenser persicus

Acipenser stellatus

Anguilla anguilla

Alosa braschnikowi

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Alosa caspia

Alosa kessleri

Clupeonella caspia

Abramis brama

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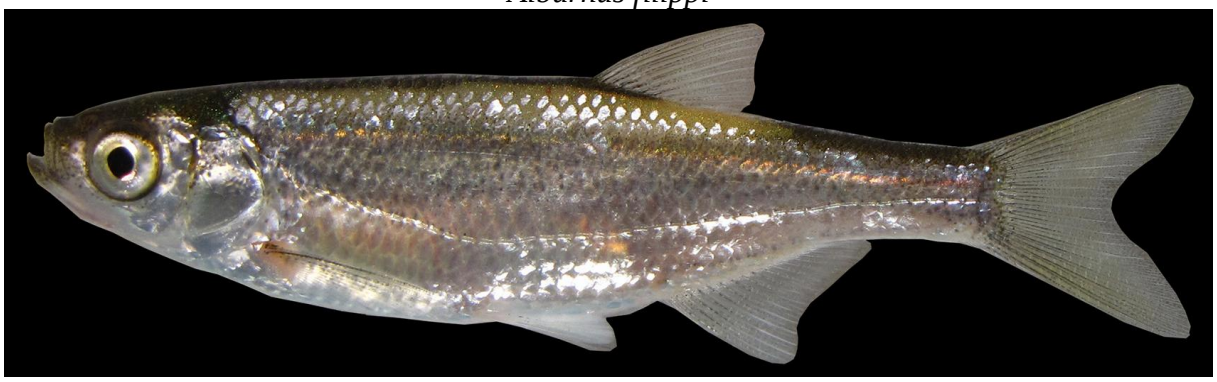
Alburnoides samiii

Alburnus chalcoides

Alburnus filippi



Alburnus hohenackeri

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Barbus cyri

Blicca bjoerkna

Capoeta razii

Carassius auratus

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Carassius gibelio

Ctenopharyngodon idella

Cyprinus carpio

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Hemiculter leucisculus

Hypophthalmichthys molitrix

Hypophthalmichthys nobilis

Leucaspius delineatus

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Leuciscus aspius

Luciobarbus capito

Luciobarbus caspius

Pelecus cultratus

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Pseudorasbora parva

Rhodeus amarus

Rutilus lacustris

Rutilus kutum

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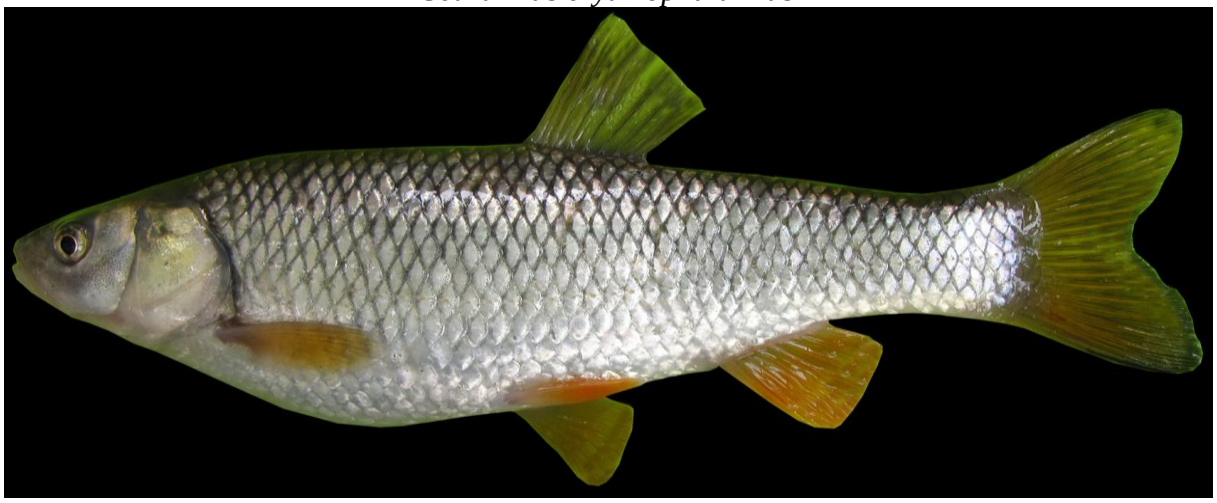
Scardinius erythrophthalmus



Squalius turcicus

Tinca tinca

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Vimba persa

Cobitis saniae

Sabanejewia caspia

Oxynoemacheilus bergianus

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Piaractus brachypomus

Silurus glanis

Pangasius sanitwongsei

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Hypostomus plecostomus

Oncorhynchus mykiss

Salmo caspius

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Salmo trutta

Esox lucius

Benthophilus ctenolepidus

Benthophilus leobergius

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Knipowitschia caucasica

Neogobius caspius

Neogobius melanostomus

Neogobius pallasi

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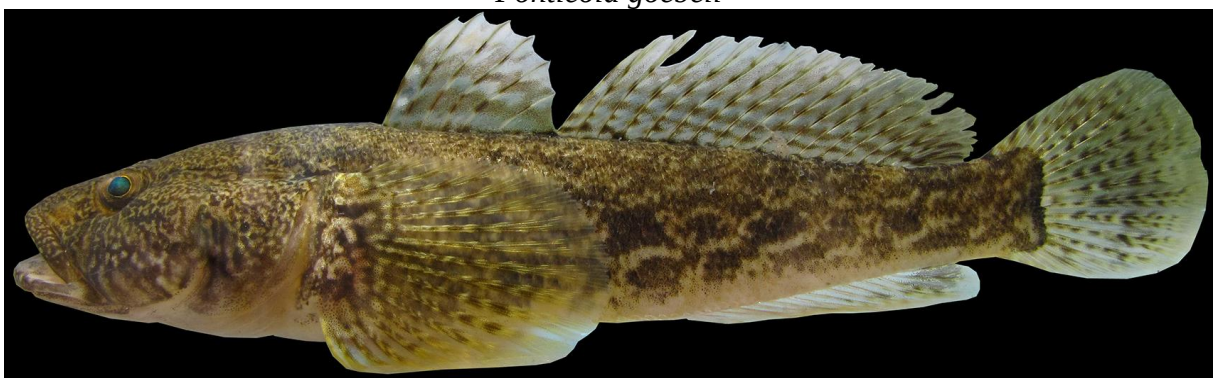
Ponticola bathybius

Ponticola goebeli



Ponticola gorlap

Ponticola iranicus

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Ponticola syrman

Proterorhinus nasalis

Rhinogobius lindbergi

Chelon auratus

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Chelon saliens

Atherina caspia

Gambusia holbrooki

Poecilia reticulata

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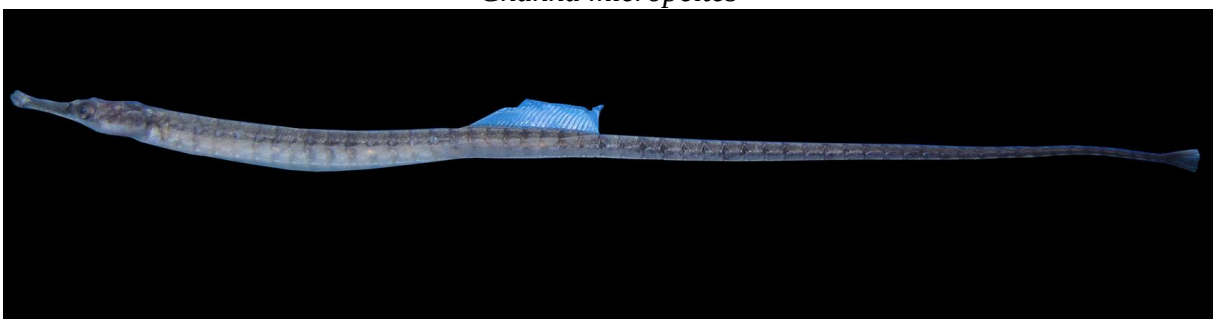
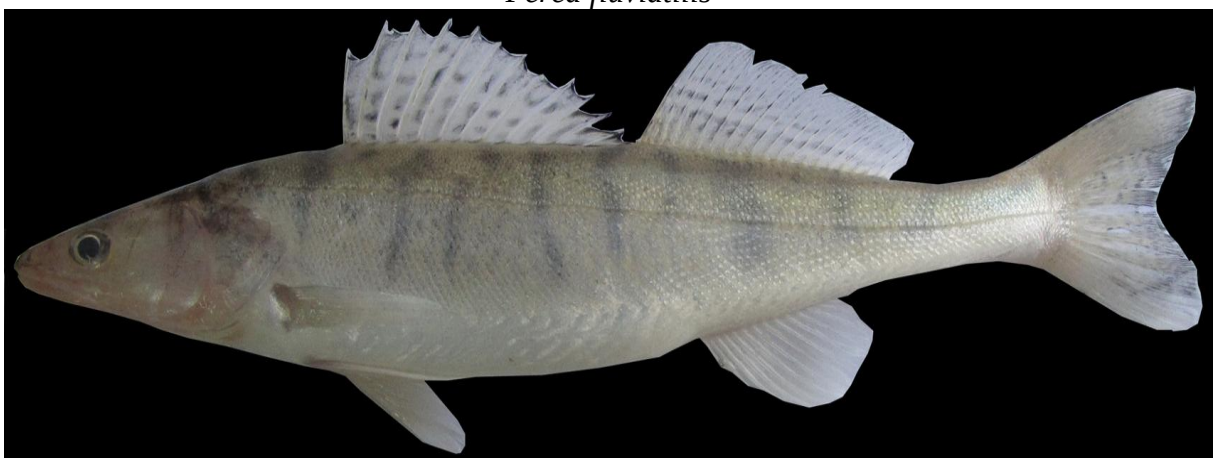
Channa micropeltes



Syngnathus caspius

Perca fluviatilis



Sander lucioperca

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Sander marinum

Gasterosteus aculeatus

Pungitius platygaster

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