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Review on the ornamental fish species potentials of the Caspian Sea and its Southern Basin

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ABSTRACT

The Caspian Sea and its southern basin are habitats for a wide range of the temperate waters ornamental fish (cold water ornamental fish) that, despite many commonalities with other water resources in Asia and Europe, have received less attention in the aquarium and ornamental fish industries in the world. The results showed that there are 43 ornamental fish species in 27 genera, 16 families, 8 orders and 1 class in the Caspian Sea and its southern basin. The most diverse order is Cypriniformes with 17 species (39.53%), followed by Gobiiformes with 11 species (25.58%), Acipenseriformes with 6 species (13.95%), Siluriformes with 3 species (6.98%), Cyprinodontiformes and Gasterosteiformes each with 2 species (each 4.65%), and Characiformes and Syngnathiformes each with one species (2.33%). Considering that the change in approach to the export of ornamental fish, from traditional markets to new markets and from species caught in nature to species produced in captivity, has become an important general and strategic trend over the past decade, it is better to pay more attention to the biotechnology of production of these fish and its development in the ornamental fish industry. In this study, all fish species of the Caspian Sea and its southern basin were studied in terms of ornamental function (aquarium industry).

Key Words: Ornamental fish trade, Aquarium trade, Conservation biology, Cold water.
Article type: Review Article.

INTRODUCTION

Ornamental fishes

Aquarium fish keeping is amongst the most popular of hobbies with millions of enthusiasts worldwide and next only to photography in popularity (Das *et al.* 2005; Singh & Ahmed 2005). All small water living animals of class Pisces (fish) which are kept as pets and as decorative pieces can be called Ornamental Fish. They also come under the broader category of 'Pets'. Though the term 'Aquarium Pets' is the term used to denote these small pets kept at home; nowadays it is being replaced by the term 'Ornamental Fish'. However, the rarity of these small fish, there and manageability makes them more preferable for being kept as pets. Colours, shapes, forms and variety of these small fish are predominant criteria for home aquarium (Khiabani *et al.* 2019). Ornamental fishes are often used as a generic term to describe aquatic animals kept in the aquarium hobby. These fishes are often colorful (multicolored), especially, have a unique color pattern, have a special elegance and beauty, unique behavior or have a specific body shape. These fishes, kept in public aquariums, personal aquariums, water gardens, ponds, and used for decorating different places (e.g., the houses, offices, public places). The trade in marine ornamental fishes appears to have commenced around the 1930s, and the number and diversity of species traded remain unclear. Figures currently available are based on estimates or are inferred using limited information from various formal and trade organizations (Biondo & Burki 2020). Over 1 billion ornamental fish comprising more than 4000 freshwater and 1400 marine species are traded internationally each year (Whittington & Chong 2007). The high demand for ornamental fishes has made them an important component of the world fish trade (Tlusty *et al.* 2013). Although most fish kept in aquariums are from tropical and subtropical (from freshwater or marine), the acquisition of temperate ornamental fish has increased. Temperate ornamental fish have evolved to live in water

at a temperature of 14–24°C. They are not cold-water fish, nor are they strictly tropical and subtropical. Some are suitable for keeping in ponds and aquatic gardens (e.g., Koi, Goldfish, Tench) and some can be keeping in aquariums (e.g., Fancy Goldfish, Three-spined stickleback, Bitterling). Others are important and widely used vertebrate model organism in scientific research for studying in humans and other species (Khiabani 2015; Khiabani *et al.* 2020a,b). The aquarium industry is sighted as both positively (ecologic, conservation biology, sub-industry of model fishes, socio-economic and livelihood benefits) and negatively (over-exploitation of wild species, degradation of natural ecosystems, alien species invasions, development of alien invasive pathogens) influential (Watson & Moreau 2006; Dadgar *et al.* 2014; Abd Rahman & Matthew 2021; Khiabani 2021). Experienced aquarium keepers prefer to go in for rare species and varieties of ornamental fish. Certain types of these small ornamental fish require special environments and specially diet for their health and survival. There are many of these small fish from tropical and subtropical regions, which require maintenance of the water temperature in the aquarium if kept in colder climates. Similarly, those small aquarium pets with origin of colder region (such as temperate regions) will get in to distress if the temperature rises above the optimum. However, today the possibility of keeping large fish in public aquariums is well provided (Khiabani *et al.* 2019; Khiabani 2021). Perception the biological characteristics of these fish along with recent advances in the ornamental fish husbandry industry and aquarium equipment technology have further facilitated the hobby. However, the unmanaged collections of these endemic species could be a much more severe threat to freshwater biodiversity than hitherto recognized. A review of literature reveals that although much work has been undertaken on the general fish resources of the Caspian Sea (Coad 1995, 1998; Coad & Vilenkin 2004; Naseka & Bogutskaya 2009; Esmaeili *et al.* 2010; AnvariFar *et al.* 2013; Esmaeili *et al.* 2015; Khosravi *et al.* 2020, Jouladeh-Roudbar *et al.* 2020; Esmaeili & Abbasi 2021), no information is available on the potential aquarium fishes.

The Caspian Sea

The Caspian Sea is surrounded by the five coastal countries: the Republic of Azerbaijan (Azerbaijan), the Islamic Republic of Iran (Iran), the Republic of Kazakhstan (Kazakhstan), the Russian Federation and Turkmenistan. The Caspian Sea and remnants of the intracontinental Paratethys basin, possess a spectacular diversity of the biota. The term "Paratethys" was coined by Laskarev (1924) to designate the string of epicontinental basins originally stretching from the Alps to what was the Aral Sea that has been separated from the rest of the Tethys by the uplift of the Alpine Caucasian Mountain chain since the Early Oligocene. Many groups of aquatic organisms including fishes have radiated in this region. Diversification in the Paratethys has been traditionally linked to isolation events from the Mediterranean Sea, the Atlantic and Indian Oceans resulted in restricted marine, brackish lacustrine, and freshwater lacustrine environments, as well as induced the evolution of endemic species and higher taxa among mollusks, ostracods, fish, and other groups of animals (Naseka & Bogutskaya, 2009). During the last major high-stand in the Late Pleistocene Lake levels rose up to 50 m above global sea level (77 m above current Caspian Sea water level), and an overflow gateway existed north of the Caucasus towards the Black Sea (Chepalyga 2007; Yanina 2014). In contrast, at the time of the last big regression in the early Holocene (Yanina 2014; Bezrodnykh & Sorokin 2016), the level of the Caspian Sea was about 100 m below the global sea level (73 m below the current Caspian Sea water level). Actually, The Caspian Sea has a volatile history of large-scale and rapid lake level change (Badyukova & Kalashnikov 2009; Svitoch 2014; Krijgsman *et al.* 2019), which greatly affected the extent of the lake and coinciding with those huge changes. The Caspian endemic fauna has undergone a protracted series of diversifications and extinctions during the Quaternary (Nevesskaja 2007; Yanina 2014; Krijgsman *et al.* 2019). The Caspian Sea is a unique natural reservoir and is the world's largest inland body of water, variously classed as the world's largest lake or a full-fledged sea. It is a land locked water body located on the border of two large parts of the continent of Eurasia. The area of the sea is 371,000 km^2 and the sea level lies 27 m below global sea level (Arpe et al., 2019; Krijgsman *et al.* 2019; UNEP 2021). It is an anomalohaline lake (or strongly alkaline), whose water level and salinity regimes are determined by a balance of runoff and evaporation. Based on the features of the morphological structure and physical and geographical conditions, the Caspian Sea is conventionally divided into three parts including the Northern (25%), the Middle (36%), and the Southern (39%) basins. Each basin is characterized by its own temperature, depth, salinity and ecology features and faunas (Kosarev & Yablonskaya 1994; Krijgsman *et al.* 2019). The Caspian Sea is home to a wide range of species and may be best known for its sturgeons and oil industries. Many multinational companies are exploring the region for oil and gas, and it has increased the concerns of environmentalists about the damage to animal and plant diversity, especially aquatic life in this closed sea. In this article, it means the Caspian Sea and its southern area,

habitats such as small and large wetlands, lagoons, marshes, deltas and rivers that join it or the territorial waters of Iran that discharge to this sea. Researchers have estimated this area to be 193,161 km^2 included 864 small and large rivers in the southern basin of the Caspian Sea with a catchment (Zakeri 1997).

Geoecology

The Caspian Sea is the world's largest inland water body, which extends 1,200 km from north to south and contains over 40% of the inland waters of the world. The Sea depth varies ranging from 5-6m in the North to 1,025 in its deepest point in the South. The northern basin is highly influenced by freshwater inflow from the Volga and Ural rivers and has a very low salinity while in the middle and southern basins the water is consistently brackish and varies between 10 to 13psu (practical salinity unit: dissolved salts in parts per thousand: ‰). Most of the water (80%) derives from the Volga River, resulting in a strong north-south salinity gradient in the lake (Table 1; Kosarev 2005, Kostianoy & Kosarev 2005). The Caspian Lowland lies on the northern and eastern shores of the Caspian Sea at elevations between -28 to 100 m above sea level. Four rivers traverse the region on their way to the Caspian Sea: Volga, Ural and Emba from the north, and Atrek from the southeast. The shelf area of the sea adjacent to the Caspian shore is very shallow: the 10 m isobathe (or depth curve) extends 10 to 20 km from shore. The coastal zone is built of Tertiary and Quaternary Sea sediments. To the south of the Caspian Lowland in Turkmenistan lies the delta of the Atrek River – the only river to enter the Caspian Sea from the east (Babaev 1994); Most of its flow is used for irrigation, so only flood waters actually reach the sea. The coastal morphology of the western shore of the middle Caspian Basin is largely determined by wave-action, rapid sea-level change, tectonic uplift, as well as local input of terrigenous erosive products from the Caucasian hinterlands (Kroonenberg *et al.* 2007). The geology of Iran (As the southern catchment area of the Caspian Sea) suggests rapid isolation of multiple areas from one another. Extensive indentation of the Arabian plate into the Iranian plate starting 10 million years ago (Dercourt *et al.* 1986) caused uplifting of the Zagros mountains at the southern edge of the Iranian plate. Continued northeastern movement of the Arabian plate and a northerly movement of India resulted in additional mountain building by 5 million years ago along the northern edge of the Iranian plateau as well as along the sutures of the Iranian, Lut and Helmand plates, making different drainage basins. These events have affected the gene flow of different populations present in this area and have provided preliminary population isolations, promoted speciation and caused high ichthyo-diversity in Iran (Esmaeili *et al.* 2015). The Iranian plateau is located in the Palearctic region bordering the Oriental and African zones (Coad & Vilenkin 2004). However, based on its ichthyofauna composition, the Iranian plateau borders the Eastern Mediterranean (Western-Palearctic), the Southern Asian (Indo-Oriental) and the Ethiopian regions (Nalbant & Bianco 1998; Coad 1998).

Table 1. Main characteristics of the Caspian Sea (CEP 2002; Krijgsman *et al.* 2019).

Surface area (km^2)		**371,000**	
Volume (km^3)		78,100	
Catchment area (km^2)		3,500,000	
Coastline (km)		7,000	
Length (km)		1,200	
Width (min – max) (km)		196-435	
Average depth (m)	North	5 (max 20)	
	Middle	190 (max 790)	
	South	330 (max 1025)	
Average surface temperature (°C)	North	Winter: 0	Summer: 25
	South	Winter: 10	Summer: 26
Surface salinity (‰)	North	0.1	
	Middle	10	
	South	13	

In many southern areas of the Caspian Sea coast, the shores are dotted with shallow saline pools in which birds, small fish, crustaceans and invertebrates thrive. Birds are present throughout the year, and many species use the Caspian Sea as a migratory refuge. Coastal areas along with wetlands, swamps and coastal reeds provide suitable places for the reproduction and camouflage of many nesting and migratory fish. In the last three decades, several ecological factors were changed and affected the commercial fish stocks in the Caspian Sea (Fazli *et al.* 2021). The elevated levels of heavy metals (Saeedi Saravi & Shokrzadeh 2013), microplastics (Abadi *et al.* 2021), Ecocide (Dumont 1995), overfishing, habitat destruction, extensive dam construction (AnvariFar *et al.* 2011; Madani 2014), climate change, and pollution from the oil industry (UNEP 2021) in the Caspian Sea made a serious concern about ecosystem, food chain, and aquatic survival contamination.

MATERIALS AND METHODS

This checklist is based on information collected from extensive searches in reputable databases, with more emphasis on Eschmeyer's Catalogue of Fishes - version of 8 Aug 2023 (Eschmeyer 2023) and the Zoological Record, Catalogue of Fishes, Fish-base, Biological Abstracts, Helminthological Abstracts, Google Scholar, Aquatic Sciences and Fisheries Abstracts Bibliography, Web of Knowledge, and also by examination of ichthyological collections in Iran and Caspian Sea as well as an extensive case study of the biodiversity of ornamental fish in Iran and world from 2015 to date. The species are listed alphabetically within the orders, families, and genus. The nomenclature is as per the online "Catalogue of Fishes" at the California Academy of Sciences provides summary taxonomic conclusions on generic placement and species validity, references for these conclusions, and type localities for synonyms mentioned in the present list (Abbasi *et al.* 2019, Eschmeyer *et al.* 2022; Eschmeyer 2023). The synonyms given are those recently used in Iran and do not include those dating from the early twentieth and nineteenth centuries. Conservation status of the ornamental fish species is based on the IUCN Red List of Threatened Species in 2022 (Table 3). The ornamental attractions, aesthetic features and the possibility of maintainability of each species were described based on the opinions of several fish biologists and aquarium industry experts, as well as books published in this field. The possibility of maintainability (keeping) and display any species in pond or water garden (PW), home aquariums (HA) or public aquariums (PA) was considered in the description of each species (Table 4).

RESULTS

The total confirmed ornamental fish species of the Caspian Sea and its southern basin comprise 43 species in 27 genera, 16 families, 8 orders and 1 class. The most diverse order is Cypriniformes with 17 species or 39.53% of the Caspian Sea ornamental ichthyofauna, followed by Gobiiformes with 11 species (25.58%), Acipenseriformes with 6 species (13.95%), Siluriformes with 3 species (6.98%), Cyprinodontiformes and Gasterosteiformes each with 2 species (each 4.65%), as well as Characiformes and Syngnathiformes each with one species (2.33%). The most diverse family is Gobiidae with 11 confirmed species (25.58%), followed by Acipenseridae with 6 species (13.95%), Cyprinidae with 5 species (11.63%), Cobitidae with 4 species (9.3%), Nemacheilidae with 3 species (6.98%), Leuciscidae, Poeciliidae, and Gasterosteidae each with 2 confirmed species (4.65%), and Serrasalmidae, Acheilognathidae, Tincidae, Gobionidae, Siluridae, Pangasiidae, Loricariidae, and Syngnathidae each with 1 confirmed species (2.33%). The most diverse genus is *Acipenser* with 5 species (11.63%), followed by *Carassius*, *Neogobius*, and *Ponticola* with 3 species (6.98%). Six genera also have two species (4.65%) including *Cobitis*, *Sabanejewia*, *Cyprinus*, *Paracobitis*, *Benthophilus*, and *Knipowitschia*. Other genera (17 genera) have only one species (each 2.33%) including *Huso*, *Serrasalmidae*, *Rhodeus*, *Oxynoemacheilus*, *Tinca*, *Blicca*, *Scardinius*, *Pseudorasbora*, *Gambusia*, *Poecilia*, *Proterorhinus*, *Gasterosteus*, *Pungitius*, *Silurus*, *Pangasius*, *Hypostomus*, and *Syngnathus*. The Caspian Sea and its southern basin comprises 4 ornamental endemic fish species (9.30% of total ornamental species ichthyofauna) in 2 families (Cobitidae and Nemacheilidae); Cobitidae with 3 species and Nemacheilidae with 1 species. The Caspian Sea and its southern basin comprises 28 ornamental native fish species (65.12% of total ornamental species ichthyofauna) in 11 families. Gobiidae with 11 species (39.29% of the total native species) is ranked first followed by the Acipenseridae with 6 species (21.43% of the total native species). Also, families such as Nemacheilidae and Leuciscidae each have 2 native fish species (each 7.14%), while Acheilognathidae, Cyprinidae, Tincidae, Gasterosteidae, Siluridae, and Syngnathidae have only one endemic species in this ecosystem (each 3.57%). Eleven exotic species (introduced to this ecosystem) in 7 families are listed from the Caspian Sea and its southern basin (25.58% of total ornamental species ichthyofauna; Table 3). Cyprinidae with 4 species (36.36% of the total exotic species) is ranked first followed by the Poeciliidae with 2

species (18.18% of the total native species). Other families including Serrasalmidae, Gobionidae, Gasterosteidae, Pangasiidae, and Loricariidae have only one exotic species (each 9.09%). The Caspian ornamental fish have often evaluated by International Union for Conservation of Nature (IUCN) between 2008 and 2016 and among these, 14 species (32.56%) had not been recorded in evaluation reports. Therefore, all species require accurate and up-to-date assessment information. The IUCN Red List of Threatened Species (2022) showed that three Caspian endemic ornamental species are in "Not Evaluated" status and one species is in "Least Concern" status. Among the 28 native fish species, 17 species (60.71%) come under the 'Least Concern' (LC) category, 5 species (17.86%) under 'Critically Endangered' (CR), 4 species (14.29%) under 'Not Evaluated' (NE), and 2 species (7.14%) under 'Vulnerable' (VU). Among the 11 introduced fish species, 6 species (54.55%) come under the 'Least Concern' (LC) category; 4 species (36.36%) under 'Not Evaluated' (NE) and one species (9.09%) under 'Vulnerable' (VU). The results showed that among the endemic and native ornamental species of the Caspian Sea (a total of 32 species), 21 species can be kept in the home aquariums (65.62%), 7 species in public aquariums (21.87%), while 4 species (12.5%) in public aquariums and pond or water garden (PW).

Checklist

Class Actinopteri

Order Acipenseriformes (1 family, 2 genera and 6 species)

Family Acipenseridae (2 genera and 6 species)

Genus *Acipenser* Linnaeus, 1758.

1. *Acipenser gueldenstaedtii* (Brandt & Ratzeburg, 1833).
2. *Acipenser nudiventris* (Lovetzky, 1828).
3. *Acipenser persicus* (Borodin, 1897).
4. *Acipenser ruthenus* (Linnaeus, 1758).
5. *Acipenser stellatus* (Pallas, 1771).

Genus *Huso* Brandt & Ratzeburg, 1833.

6. *Huso huso* (Linnaeus, 1758).

Order Characiformes (1 family, 1 genus and 1 species)

Family Serrasalmidae (1 genus and 1 species)

Genus *Piaractus* Eigenmann 1903.

7. *Piaractus brachypomus* (Cuvier, 1818).

Order Cypriniformes (7 family, 11 genera and 17 species)

Family Acheilognathidae (1 genus and 1 species)

Genus *Rhodeus* Agassiz, 1832.

8. *Rhodeus caspius* (Esmaeili, Sayyadzadeh, Japoshvili, Eagderi, Abbasi, & Mousavi-Sabet, 2020).

Family Cobitidae (2 genera and 4 species)

Genus *Cobitis* Linnaeus, 1758.

9. *Cobitis faridpaki* (Mousavi-Sabet, Vasil'eva, Vatandoust & Vasil'ev, 2011).
10. *Cobitis saniae* (Eagderi, Jouladeh-Roudbar, Jalili, Sayyadzadeh and Esmaeili, 2017).

Genus *Sabanejewia* Vladykov, 1929.

11. *Sabanejewia aurata* (De Filippi, 1863).
12. *Sabanejewia caspia* (Eichwald, 1838).

Family Cyprinidae (2 genera and 5 species)

Genus *Carassius* Jarocki, 1822.

13. *Carassius auratus* (Linnaeus, 1758).
14. *Carassius gibelio* (Bloch, 1782).
15. *Carassius langsdorfii* (Temminck & Schlegel, 1846).

Genus *Cyprinus* Linnaeus, 1758.

16. *Cyprinus carpio* (Linnaeus, 1758).
17. *Cyprinus rubrofuscus* (Lacepède, 1803).

Comment: Koi (*Cyprinus rubrofuscus*) are ornamental varieties of domesticated carp that are often erroneously identified as European Carp (*C. carpio;* Kottelat & Freyhof 2007). The Koi has gone through a lot of taxonomic changes due to extensive cultivation and breeding history (Gross *et al.* 2002; Zhou *et al.* 2003; Khiabani 2015),

and its origins are uncertain, leaving its taxonomic status ambiguous (Dong *et al.* 2015). Contrary to what is often believed, the European carp is not introduced in Europe from Asia (Kottelat 2002; Kottelat & Freyhof 2007). The molecular data of some researchers support this conclusion (Zhou *et al.* 2004). Therefore, given that most of the description of Koi fish in Iran has been under the previous scientific name (*C. carpio*), it can be inferred that this fish (*C. rubrofuscus*) has entered the aforementioned water resources due to its extensive reproduction and breeding in the southern Caspian Sea basin.

Family Nemacheilidae (2 genera and 3 species)

Genus *Paracobitis* Bleeker 1863.

18. *Paracobitis atrakensis* (Esmaeili, Mousavi-Sabet, Sayyadzadeh, Vatandoust & Freyhof, 2014).
19. *Paracobitis hircanica* (Mousavi-Sabet, Sayyadzadeh, Esmaeili, Eagderi, Patimar & Freyhof, 2015).

Genus *Oxynoemacheilus* Bănărescu & Nalbant 1966.

20. *Oxynoemacheilus bergianus* (Derjavin, 1934).

Family Tincidae (1 genus and 1 species)

Genus *Tinca* Garsault, 1764.

21. *Tinca tinca* (Linnaeus, 1758).

Family Leuciscidae (2 genera and 2 species)

Genus *Blicca* Heckel, 1843.

22. *Blicca bjoerkna* (Linnaeus, 1758).

Genus *Scardinius* Bonaparte, 1837.

23. *Scardinius erythrophthalmus* (Linnaeus, 1758).

Family Gobionidae (1 genus and 1 species)

Genus *Pseudorasbora* Bleeker, 1860.

24. *Pseudorasbora parva* (Temminck & Schlegel, 1846).

Order Cyprinodontiformes (1 family, 2 genera and 2 species)

Family Poeciliidae (2 genera and 2 species)

Genus *Gambusia* Poey, 1854.

25. *Gambusia holbrooki* (Girard, 1859).

Genus *Poecilia* Bloch & Schneider 1801.

26. *Poecilia reticulata* (Peters, 1859).

Order Gobiiformes (1 family, 5 genera and 11 species)

Family Gobiidae (5 genera and 11 species)

Genus *Benthophilus* Eichwald 1831.

27. *Benthophilus ctenolepidus* (Kessler, 1877).
28. *Benthophilus leobergius* (Berg, 1949).

Genus *Knipowitschia* Iljin 1927.

29. *Knipowitschia longecaudata* (Kessler, 1877).
30. *Knipowitschia caucasica* (Berg, 1916).

Genus *Neogobius* Iljin, 1927.

31. *Neogobius caspius* (Eichwald, 1831).
32. *Neogobius melanostomus* (Pallas, 1814).
33. *Neogobius pallasi* (Berg, 1916).

Genus *Ponticola* Iljin, 1927.

34. *Ponticola bathybius* (Kessler, 1877).
35. *Ponticola gorlap* (Iljin, 1949).
36. *Ponticola iranicus* (Vasil'eva, Mousavi-Sabet and Vasil'ev, 2015).

Genus *Proterorhinus* Smitt 1900.

37. *Proterorhinus nasalis* (De Filippi, 1863).

Order Gasterosteiformes (1 family, 2 genera and 2 species)

Family Gasterosteidae (2 genera and 2 species)

Genus *Gasterosteus* Linnaeus, 1758.

38. *Gasterosteus aculeatus* (Linnaeus, 1758).

Genus *Pungitius* Annone, 1760.
39. *Pungitius platygaster* (Kessler, 1859).
Order Siluriformes (3 family, 3 genera and 3 species)
Family Siluridae (1 genus and 1 species)
Genus *Silurus* Linnaeus, 1758.
40. *Silurus glanis* (Linnaeus, 1758).
Family Pangasiidae (1 genus and 1 species)
Genus *Pangasius* Valenciennes 1840.
41. *Pangasius sanitwongsei* (Smith, 1931).
Family Loricariidae (1 genus and 1 species)
Genus *Hypostomus* Linnaeus, 1758.
42. *Hypostomus plecostomus* (Linnaeus, 1758).
Order Syngnathiformes (1 family, 1 genus and 1 species)
Family Syngnathidae (1 genus and 1 species)
Genus *Syngnathus* Linnaeus, 1758.
43. *Syngnathus caspius* (Eichwald, 1831).

Table 3. List of the ornamental fish taxonomy of the Caspian Sea and its southern basin in different status groups. VU, Vulnerable; LC, Least Concern; LR, Lower Risk; NE, Not Evaluated.

Order	Family	Genus	Species	Status	IUCN status	IUCN date assessed
Acipenseriformes	Acipenseridae	*Acipenser*	*Acipenser gueldenstaedtii* (Brandt & Ratzeburg, 1833)	native	CR	01 January 2008
			Acipenser nudiventris (Lovetzky, 1828)	native	CR	01 August 1996
			Acipenser persicus (Borodin, 1897)	native	CR	-
			Acipenser ruthenus (Linnaeus, 1758)	native	VU	-
			Acipenser stellatus (Pallas, 1771)	native	CR	05 March 2010
		Huso	*Huso huso* (Linnaeus, 1758)	native	CR	24 January 2013
Characiformes	Serrasalmidae	*Piaractus*	*Piaractus brachypomus* (Cuvier, 1818)	introduced	NE	-
Cypriniformes	Acheilognathidae	*Rhodeus*	*Rhodeus caspius* (Esmaeili, Sayyadzadeh, Japoshvili, Eagderi, Abbasi, & Mousavi-Sabet, 2020)	native	NE	-
	Cobitidae	*Cobitis*	*Cobitis faridpaki* (Mousavi-Sabet, Vasil'eva, Vatandoust & Vasil'ev, 2011)	endemic	NE	-
			Cobitis saniae (Eagderi, Jouladeh-Roudbar, Jalili, Sayyadzadeh & Esmaeili, 2017)	endemic	NE	-
		Sabanejewia	*Sabanejewia aurata* (De Filippi, 1863)	native	LC	04 August 2010
			Sabanejewia caspia (Eichwald, 1838)	endemic	NE	-
	Cyprinidae	*Carassius*	*Carassius auratus* (Linnaeus, 1758)	introduced	LC	-

			Carassius gibelio (Bloch, 1782)	introduced	NE	-
			Carassius langsdorfii (Temminck & Schlegel, 1846)	introduced	NE	-
		Cyprinus	*Cyprinus carpio* (Linnaeus, 1758)	introduced	VU	01 January 2008
			Cyprinus rubrofuscus (Lacepède, 1803)	introduced	LC	05 March 2010
		Paracobitis	*Paracobitis atrakensis* (Esmaeili, Mousavi-Sabet, Sayyadzadeh, Vatandoust & Freyhof, 2014)	native	NE	-
	Nemacheilidae		*Paracobitis hircanica* (Mousavi-Sabet, Sayyadzadeh, Esmaeili, Eagderi, Patimar & Freyhof, 2015)	native	NE	-
		Oxynoemacheilus	*Oxynoemacheilus bergianus* (Derjavin, 1934)	endemic	LC	18 March 2013
	Tincidae	*Tinca*	*Tinca tinca* (Linnaeus, 1758)	native	LC	01 January 2008
	Leuciscidae	*Blicca*	*Blicca bjoerkna* (Linnaeus, 1758)	native	LC	01 January 2008
		Scardinius	*Scardinius erythrophthalmus* (Linnaeus, 1758)	native	LC	20 July 2016
	Gobionidae	*Pseudorasbora*	*Pseudorasbora parva* (Temminck & Schlegel, 1846)	introduced	LC	01 January 2008
Cyprinodontiformes	Poeciliidae	*Gambusia*	*Gambusia holbrooki* (Girard, 1859)	introduced	LC	20 May 2016
		Poecilia	*Poecilia reticulata* (Peters, 1859)	introduced	LC	18 May 2020
		Benthophilus	*Benthophilus ctenolepidus* (Kessler, 1877)	native	LC	04 March 2020
			Benthophilus leobergius (Berg, 1949)	native	LC	01 January 2008
		Knipowitschia	*Knipowitschia caucasica* (Berg, 1916)	native	LC	01 January 2008
			Knipowitschia longecaudata (Kessler, 1877)	native	LC	24 October 2009
		Neogobius	*Neogobius caspius* (Eichwald, 1831)	native	LC	04 March 2020
Gobiiformes	Gobiidae		*Neogobius melanostomus* (Pallas, 1814)	native	LC	24 October 2009
			Neogobius pallasi (Berg, 1916)	native	LC	01 January 2008
		Ponticola	*Ponticola bathybius* (Kessler, 1877)	native	LC	04 March 2020
			Ponticola gorlap (Iljin, 1949)	native	LC	01 January 2008
			Ponticola iranicus (Vasil'eva, Mousavi-Sabet & Vasil'ev, 2015)	native	NE	-
		Proterorhinus	*Proterorhinus nasalis* (De Filippi, 1863)	native	LC	01 January 2008

Gasterosteiformes	Gasterosteidae	*Gasterosteus*	*Gasterosteus aculeatus* (Linnaeus, 1758)	introduced	LC	24 October 2009
		Pungitius	*Pungitius platygaster* (Kessler, 1859)	native	LC	24 October 2009
Siluriformes	Siluridae	*Silurus*	*Silurus glanis* (Linnaeus, 1758)	native	LC	24 October 2009
	Pangasiidae	*Pangasius*	*Pangasius sanitwongsei* (Smith, 1931)	introduced	CR	01 March 2007
	Loricariidae	*Hypostomus*	*Hypostomus plecostomus* (Linnaeus, 1758)	introduced	NE	-
Syngnathiformes	Syngnathidae	*Syngnathus*	*Syngnathus abaster* (Risso, 1827)	native	LC	24 October 2009

Table 4. Ornamental attractions, Aesthetic characteristics and Keeping tank coordinates, for Caspian Sea and its southern basin Ornamental fishes. PW, Pond or Water gardens; HA, Home Aquariums; PA, Public Aquariums.

Species	**Common name**	**Ornamental attractions and Aesthetic characteristics**						
		Recommended keeping tank	**Body shape**	**Body pattern**	**Coloring**	**Mating behavior**	**Elegance and beauty**	**More explanation (Other items)**
Acipenser gueldenstaedtii	Russian sturgeon	PA	*	*	*		*	Being ancient
Acipenser nudiventris	Ship Sturgeon	PA	*	*	*		*	
Acipenser persicus	Persian sturgeon	PA	*	*	*		*	
Acipenser ruthenus	Sterlet sturgeon	PA	*	*	*		*	
Acipenser stellatus	Stellate sturgeon	PA	*	*	*		*	
Huso huso	Beluga	PA	*	*	*		*	
Rhodeus caspius	Persian bitterling	HA	*		*	*	*	
Cobitis faridpaki	Faridpaki spined loach	HA	*	*	*		*	
Cobitis saniae	Sania's spined loach	HA	*	*	*		*	
Sabanejewia aurata	Golden spined loach	HA	*	*	*		*	
Sabanejewia caspia	Caspian spined loach	HA	*	*	*		*	
Cyprinus carpio	Common carp	PW, PA	*		*		*	
Paracobitis atrakensis	Atrak crested loach	HA	*	*	*		*	
Paracobitis hircanica	Hircan crested loach	HA	*	*	*		*	
Oxynoemacheilus bergianus	Safidrud stone loach	HA	*	*	*		*	
Tinca tinca	Tench	PW, PA	*		*		*	
Blicca bjoerkna	White bream	PW, PA	*		*		*	
Scardinius erythrophthalmus	Rudd	PW, PA	*		*		*	
Benthophilus ctenolepidus	Transparent tadpole goby	HA	*	*	*		*	
Benthophilus leobergius	Caspian stellate tadpole-goby	HA	*	*	*		*	
Knipowitschia caucasica	Caucasian dwarf goby	HA	*	*	*		*	
Knipowitschia longecaudata	Longtail dwarf goby	HA	*	*	*		*	
Neogobius caspius	Caspian goby	HA	*	*	*		*	
Neogobius melanostomus	Round goby	HA	*	*	*		*	
Neogobius pallasi	Caspian sand goby	HA	*	*	*		*	
Ponticola bathybius	Bottom dwelling goby	HA	*	*	*		*	
Ponticola gorlap	Caspian bighead goby	HA	*	*	*		*	
Ponticola iranicus	Iranian Goby	HA	*	*	*		*	
Proterorhinus nasalis	Eastern tubenose goby	HA	*	*	*		*	
Pungitius platygaster	Southern ninespine stickleback	HA	*	*	*	*	*	
Silurus glanis	Wels catfish	PA	*	*			*	
Syngnathus caspius	Black-striped pipefish	HA	*	*		*	*	

DISCUSSION

According to Naseka & Bogutskaya (2009), Black, Azov, Caspian and Aral seas are remnants of the intercontinental Paratethys basin, possess a spectacular diversity of the biota (Naseka & Bogutskaya 2009). The Caspian Sea is the world's largest lake of inner drainage, with no outlet to the ocean (M Dolukhanov *et al.* 2009) and the world's largest brackish waterbody (Dumont 1998). One of the remarkable aspects of its fauna is the high level of endemism (Dumont 2000). Diversification in the Paratethys has been traditionally linked to isolation events from the Mediterranean and the Atlantic and Indian oceans resulted in restricted marine, brackish lacustrine, and freshwater lacustrine environments, and induced the evolution of endemic species and higher taxa among molluscs, ostracods, fish, and other groups of animals (Dumont 2000; Naseka & Bogutskaya 2009). In general, the ancient origins of the Caspian Sea, the role of closing of the Tethys Sea, long history of the connection and isolation from fresh and marine waters, multiple sources of species, wide latitudinal extent, uneven distribution of inflows and nutrient inputs, and low to moderate salinity, different habitat types (both fresh and brackish habitats, rivers, lakes, lagoons, marshes, and marine environments; Allen *et al.* 2004, Naseka & Bogutskaya 2009; Esmaeili *et al.* 2010; Esmaeili *et al.* 2015), all have contributed to the greatest ichthyodiversity in the Southern Caspian Sea basin. Coad (1988) listed 155 species in 67 genera, 24 families, 15 orders and 3 classes found in 19 drainage basins of Iran. He reported the greatest diversity in the Southern Caspian Sea basin comprising 74 species and 42 genera followed by Tigris basin with 54 species and 28 genera. These are large basins with diverse habitat and connection to a brackish or marine environment which provide such high diversity. Twenty years later, Esmaeili *et al.* (2010) listed the freshwater fishes of Iran and confirmed the presence of 202 species in 104 genera, 28 families, 17 orders and 3 classes in 19 basins which is obviously higher than those listed by Coad (1988). They also reported 23 species whose presence in Iranian waters needed confirmation by specimens. In 2019, Abbasi *et al.* examined one of the most important aquatic habitats in the southern Caspian Sea basin, Anzali Lagoon, in terms of the diversity of fish species. 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 (Abbasi *et al.* 2019). In 2018, Esmaeili *et al.* published a Checklist of Freshwater Fishes of Iran, clearing many doubts about the species of Iran and of course the water area of the Caspian Sea. In this report, they announced 297 species in 109 genera, 30 families, 24 orders and 3 classes reported from different Iranian basins. However, presence of 23 reported species in Iranian waters needs confirmation by specimens (Esmaeili *et al.* 2018). In 2019, Mousavi Sabet published a report on Exotic ornamental fishes in Iranian inland water basins. All recorded exotic aquarium fishes are listed in this report, including 8 species in 7 genera, 5 families, and 5 orders. Some of these species have been found in the southern part of the Caspian Sea. In this report it was announced that the number of exotic freshwater ornamental fish species released from the aquarium trade in Iran has been increasing in recent years (Mousavi-Sabet 2019). None of the ichthyological studies to date have examined the fish in this catchment area from the perspective of ornamental valuation. The results of this study showed that there are 43 ornamental fish species in 27 genera, 16 families, 8 orders and 1 class in the Caspian Sea and its southern basin. The most diverse order is Cypriniformes with 17 species or 39.53% of the Caspian Sea ornamental ichthyofauna, followed by Gobiiformes with 11 species (25.58%), Acipenseriformes with 6 species (13.95%), Siluriformes with 3 species (6.98%), Cyprinodontiformes and Gasterosteiformes each with 2 species (each 4.65%), as well as Characiformes and Syngnathiformes each with one species (2.33%). The most diverse family is Gobiidae with 11 confirmed species (25.58%), followed by Acipenseridae with 6 species (13.95%), Cyprinidae with 5 species (11.63%), Cobitidae with 4 species (9.3%), Nemacheilidae with 3 species (6.98%), Leuciscidae, Poeciliidae, and Gasterosteidae each with 2 confirmed species (4.65%), as well as Serrasalmidae, Acheilognathidae, Tincidae, Gobionidae, Siluridae, Pangasiidae, Loricariidae, and Syngnathidae each with one confirmed species (2.33%). These species, like other fish in the Caspian watershed, are endangered due to water pollution, hydrological changes in rivers, overfishing, climate change, barriers to spawning habitats, etc. and are often classified as endangered species by the International Union for Conservation of Nature (IUCN). The Caspian Sea and its southern basin comprises 4 ornamental endemic fish species (9.30% of total ornamental species ichthyofauna) in 2 families (Cobitidae and Nemacheilidae); Cobitidae with 3 species and Nemacheilidae with 1 species. All of these endemic species (include *Cobitis faridpaki*, *Cobitis saniae*, *Sabanejewia caspia*, and *Oxynoemacheilus bergianus*) can be kept in the aquarium, provided the favourable living conditions are created. Out of 28 native Caspian ornamental species, 17 species (60.71% include *Rhodeus caspius*, *Sabanejewia aurata*, *Paracobitis atrakensis*, *P. hircanica*, *Benthophilus ctenolepidus*, *B. leobergius*, *Knipowitschia caucasica*, *K. longecaudata*,

Neogobius caspius, *N. melanostomus*, *N. Pallasi*, *Ponticola bathybius*, *P. gorlap*, *P. iranicus*, *Proterorhinus nasalis*, *Pungitius platygaster*, and *Syngnathus caspius*) can be kept in home aquariums (HA), 7 species (25% include *Acipenser gueldenstaedtii*, *A. nudiventris*, *A. persicus*, *A. ruthenus*, *A. stellatus*, *Huso huso*, and *Silurus glanis*) can be kept in public aquariums (PA) after 8 to 12 months from hatching (in the aforementioned age range, they can be kept in home aquariums), and 4 species (14.28% include *Cyprinus carpio*, *Tinca tinca*, *Blicca bjoerkna*, and *Scardinius erythrophthalmus*) can be kept in both pond or water gardens (PW) and public aquariums (PA). In sales and trade, transportation, quarantine issues, and ultimately the keeping of some Caspian species such as sturgeons (Acipenseriformes), serious attention should be paid to international rules restricting endangered species (CITES Appendices). These appendices are lists of species afforded different levels or types of protection from over-exploitation. The presence of 11 ornamental species introduced (exotics) to the Caspian Sea from 8 families and 9 genera (including *Piaractus brachypomus*, *Carassius auratus*, *C. gibelio*, *C. langsdorfii*, *Cyprinus rubrofuscus*, *Pseudorasbora parva*, *Gambusia holbrooki*, *Poecilia reticulata*, *Gasterosteus aculeatus*, *Pangasius sanitwongsei*, and *Hypostomus plecostomus*) is a warning for this ecosystem. Many ecosystems in the world have been profoundly impacted through species invasion, few have been more fundamentally changed than the Great Lakes (Ricciardi 2006). Transferring non-native fish species to freshwater ecosystems is strongly attributed to shipping industry, commercial and ornamental fish trades, artificial modification of water bodies, aquaculture and fisheries, biological control, human mistakes, and intentionally inter-basin translocations (Dudgeon *et al.* 2006; Tarkan *et al.* 2015; Mousavi-Sabet 2019; Khiabani 2019; Khiabani & Esteghlalian 2021; Khiabani 2021). The presence of 11 exotic species (exotic) in this ecosystem, which are often from the Cyprinidae (36.36%), confirms the role of aquaculture and the need to control the entry of these species into other ecosystems (transportation management of non-native aquatic larvae). Given the restricted freshwater sources in Iran and the southern basin of the Caspian Sea, invasive species may have severe negative impacts on native ecosystems. Accordingly, it can be proposed that it is essential to conduct more detailed studies on species identification in this ecosystem and it is better be extended to other non-investigated regions in Eurasia. The exotic species are being introduced in the region without any regulation, subsequently turning invasive and threatening the indigenous fauna. Thus, there is a need for developing scientific guidelines and regulatory mechanisms for importing exotic aquarium fishes (Sharma & Dhanze, 2018). Climate change and warming temperatures may lead to the increased exotic species success and elevated impact of invasive species that are already present. For instance, sea lamprey, *Petromyzon marinus*, parasitic fish native to the Atlantic Ocean, are now found in the Great Lakes. Climate change will make control efforts more difficult as the lamprey thrive in warming temperatures. In the Lake Superior watershed, lamprey have been observed to reach larger body weights before spawning during years with longer growing seasons (Cline *et al.* 2014). Continuity of attendance of livebearers species in this ecosystem, especially *Gambusia holbrooki*, which entered the water ecosystems of Iran from 1922-30 to control the anopheline mosquito shows its high flexibility (Tabibzadeh *et al.* 1970). Therefore, introduced species that currently exhibit a capacity to be flexible to adapt the conditions of the Caspian Sea, provided that all living conditions and the possibility of reproduction available, may increase in the future. Furthermore, major concerns for future climate change and the presence of invasive species are how these changes will impact host-parasite interactions and the development of new pathogenic and parasitic species. So, understanding changes in natural barriers to invasion, shifts in spatial distributions, and growth or impact potentials will be critical for adaptive ecosystem management in the future. This report emphasizes that, eradication programs need to be accompanied by a public awareness campaign to ensure that the aquarium trade and hobbyists do not release these pet fishes into natural habitats. The aquaculture of organisms for the aquarium industry is often viewed in competition with wild-capture. While in some cases there is an overlap of species supplied to the aquarium industry by both sources, there are several considerations necessitating further development of aquaculture within this industry. Many of the perceived benefits of producing aquarium organisms through aquaculture as distinct from wild-capture are not established. They should be the focus of future research. It is important to address these perceptions to obtain an understanding of the market appeal, production targets, and future role of aquaculture in the aquarium industry. Aquaculture provides the opportunity for organisms supplying the aquarium industry to originate entirely from captivity. This is the basis for species survival programs and the capacity for the aquarium industry to the context of preserving natural diversity (Lucas *et al.* 2019). Accordingly, the Asian Arowana, *Scleropages formosus*, Bala Shark, *Balantiocheilos melanopterus*, Tequila fish, *Zoogoneticus tequila*, and Dwarf Botia, *Ambastaia sidthimunki* are all endangered freshwater fishes in demand by the aquarium industry and have been conserved through

aquaculture production. In the marine sector, aquaculture supply of the Bangai Cardinalfish, *Pterapogon kauderni* helps mitigate the continuing unregulated wild collection of this endangered species (Ng & Tan 1997; Domínguez *et al.* 2018; Mardiastuti & Soehartono 2020). Aquaculture production also plays a key role in supplying species listed on CITES Appendices I and II to the aquarium industry. Aquaculture production of giant clams (Tridacninae), seahorses (Syngnathidae), and hard corals (Scleractinia) allows for a sustainable and legal supply of these organisms, given their listing under CITES Appendix II. In addition to supplying the aquarium industry with cultured organisms, aquaculture offers the opportunity for restocking natural populations that have been depleted or eliminated. Successful examples include barbs (*Barbus*) being reintroduced in Sri Lanka and giant clams to some Pacific islands (Southgate *et al.* 2016). The increasingly popular aquarium hobby is fueling the rapid growth of the aquatic ornamental industry, particularly the trade of marine ornamental species. However, currently there is a heavy reliance on wild-caught marine ornamentals to satisfy consumer demand. Research efforts towards captive-breeding of marine ornamental species, also known as marine ornamental aquaculture, stand to supplement or replace the supply of wild-caught specimens for the marine ornamental trade, and potentially help boost reef recovery efforts through restocking (Moorhead & Zeng 2010). A global monitoring system to gather accurate and timely information on the number and species of ornamental fishes in commerce, where specimens originated, and whether they were wild-caught or captive-bred, is an urgent need (Biondo & Burki 2020). Unfortunately, the Caspian ornamental aquaculture (especially in the case of endemic and native species) sector is still in its infancy, receiving limited research attention, and, in turn, has experienced very slow development compared to the technical and industrial advances made in food fish aquaculture. Therefore, major areas in need of increased research efforts include broodstock management (selective breeding, specific broodstock diets, husbandry, spawning induction, and water quality management), species-specific larval rearing techniques, including system design and larval culture conditions as well as larval feeds and nutrition.

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