Fishes of the Mashkid and Makran basins of Iran: an updated checklist and ichthyogeography

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Abstract: This study presents, a comprehensive dataset that documents and provides a new and updated checklist of the freshwater fishes of the poorly known area of Iran including Makran and Mashkid River basins in the east and south eastern Iran. The list is based on historical literature records and taxon occurrence data obtained as a result of extensive field expeditions, examination of ichthyological collections and literature review. The total confirmed and recently not confirmed freshwater fish species of the Makran and Mashkid basins comprise 28 species in 21 genera, 9 families, 6 orders and one class. The most diverse order is the Cypriniformes with 17 species (60.71%) followed by Gobiiformes with 4 species (14.28%), Cyprinodontiformes (3 species, 10.71%), Perciformes (2 species, 7.14%) and Gonorynchiformes and Mugiliformes each with 1 species (each, 3.57%). New species are supposed to be discovered, the taxonomic status of some species has been changed, some are being resurrected from synonymy, and some taxonomic problems remain and are commented on briefly. Eight endemic species (28.57%) in 4 genera and 4 families; and 5 exotic species (17.85%) in 5 genera and 2 families are listed here. The fish taxa were classified into different major groups based on the fish ichthyogeographical origin, ecoregion and ecological factors (tolerance to salt water and mode of life). The depauperate fauna of these basins is a consequence of lacking the diverse habitat and having semi-desert to desert environment (despite marine connection for Makran basin).

Keywords: Fish diversity, Biogeography, Ichthyogeography, Ecoregion, Endemic, Iran.

Introduction
The Iranian Plateau is located in the Palearctic region bordering the Oriental and African zones (Coad & Vilenkin 2004) and its north-west, west and south-west are parts of Irano-Anatolian hot spot with high biodiversity especially freshwater fish diversity of great importance (Esmaeili et al. 2010a, 2014a).

Many studies have been compiled on freshwater fishes of Iran till present. Authors have divided Iran into different drainage basins. Saadati (1977) considered 17 basins based on geomorphology and freshwater distribution (Fig. 1). Armantrout (1981) recognized 19 basins and 4 sub basins (including Makran and Mashkid basins). Coad (1987, 1995) divided Iran into 19 basins which slightly different from those of Armantrout (1981). He also recognized Makran and Mashkid basins separately. Coad (1998) recognized 10 drainage basins and included Makran and Mashkid basins in Baluchestan and Persian Gulf basins. The most applicable division for drainage basins in Iran is carried out by Coad (2014), although recent works are currently in process (Esmaeili et al.
Like the geographical zonation, freshwater fish studies in Iran also has long history in the science of ichthyology. The first extensive discussion of freshwater fishes within Iran with descriptions of new taxa dates back to the middle of the 19th century (see Esmaeili et al. 2010). Subsequent studies have yielded dramatic increases in our knowledge of the biodiversity of Iranian freshwater fishes and accounts have been published by many authors in different countries describing fishes subsequently found in Iran (Esmaeili et al. 2010, 2014). The recent lists are: Armantrout (1981) listed 269 species in 31 families, 16 orders and 3 classes. Coad (1995) listed 150 species in 25 families, 14 orders and 3 classes found in 19 drainage basins of Iran and reported a total of 16 species from Makran and Mashkid basins. Coad (1998) listed 155 species in 67 genera, 24 families, 15 orders and 3 classes found in 19 drainage basins of Iran. Esmaeili et al. (2010a) listed the freshwater fishes of Iran and confirmed freshwater fishes of Iran comprise 202 species in 104 genera, 28 families, 17 orders and 3 classes found in 19 different basins which is obviously higher than those listed by Coad (1998). They also reported 23 species whose presence in the Iranian waters is needed confirmation by specimens. They reported 18 and 11 species from Makran and Mashkid basins respectively. The depauperate fauna of these basins is a consequence of lacking the diverse habitat and having semi-desert to desert environment (despite marine connection for Makran basin) (Esmaeili et al. 2010a).

Accordingly, it can be expected that endorheic and exorheic basins of Iran represent the higher diversity of freshwater fish species i.e. approximately 222 species or more (see Esmaeili et al. 2014a, c; Mousavi-Sabet et al. 2015) which is considerably higher than that given in the last checklist provided
Due to ongoing changing in fish fauna, the present study provides an updated checklist including natives, endemics, exotics and transplanted species, ichthyogeography, threats and management of fishes from the Makran and Mashkid basins.

Materials and Methods

**Study area:** This checklist has been compiled from the works listed in the references (see the references) and also by examination or accessing available data in ichthyological collections in Iran (e.g., ZM—CBSU, Zoological Museum of Shiraz University, Collection of Biology Department, Shiraz; CMNFI, Canadian Museum of Nature, Ottawa, Canada; BMNH, Natural History Museum, London, UK) and extensive field expeditions till 2015 from different river systems of the Mashkid and Makran basins of Iran (Fig. 2):

**Mashkid and Makran basins of Iran**

**Hamun-e Mashkid (Mashkid basin):** The Hamun-e Mashkid (= Mashkel) lies within Pakistan with its western edge on the border with Iran (Figs. 1, 2). In this instance Hamun means a salt waste. The mountain ranges in this area of Iran are parallel with the Iran-Pakistan border and run in a northwest-southeast direction.

The Mashkid River rises to the east of the mountains ringing the Hamun-e Jaz Murian basin and flows east into Pakistan where it receives a right bank
tributary, the Rakhshan River, before turning north to flow into the Hamun-e Mashkid. Its total length is ca. 430km. Two tributaries of the Mashkid within Iran are the Rutak River and the Simish (= Sunish River) which drain the lowlands between Kuh-e Birag (27°35'N, 61°20'E) and the Badamo Range (27°38'N, 62°08'E) from the northwest to enter the Mashkid River southeast of Saravan (27°22'N, 62°20'E). The upper Mashkid River is a small mountain stream, probably with a perennial flow (Coad 2014). The lower reaches of this river, and of the Simish, comprise a series of muddy pools of varying size. Some of these pools were isolated and fishless in early December 1977, while larger ones, perhaps 1km long, contained some emaciated specimens. In this area fish are found more abundantly in perennially flowing qanat streams. The Tahlab River and its tributaries drain the eastern slopes of the mountains south of Zahedan. The Tahlab flows in a southeasterly direction into the Hamun over a ca. 160km course. It was dry between Zahedan and Mirjaveh (29°01'N, 61°28'E) in early December 1977. The Ladiz River is a short (ca. 80km) right bank tributary of the Tahlab flowing from Kuh-e Taftan. In its lower reach, it was a small stream flowing in the bottom of a deep and wide canyon. The stream banks were white with salt deposits (Coad 2014).

**Makran basin:** The Makran is the coastal region of southeastern Iran between the Straits of Hormuz and the Pakistan border that drains to Oman Sea (Fig. 2). In the west of this region, the relief runs in a north-south direction parallel to the coast but from Jask eastwards the relief runs west-east, again paralleling the coast, to the Pakistan border. The rivers and streams of the Makran all drain to the sea at the Straits of Hormuz and the Sea of Oman. The inland Hamun-e Jaz Murian basin is isolated by mountain ranges reaching peaks in excess of 2000m. The coastal drainages are often incised and the larger watercourses pass through tangs over 1000m deep (Harrison 1968).

It seems that only the Minab and Sarbaz Rivers have, or nearly have, a perennial and continuous flow along most of their course. Even these rivers are quite shallow and the Sarbaz in particular is easily fordable on foot along its entire length (ca. 280km). The Minab River flows over a shorter course (ca. 220km) than the Sarbaz, but has a greater flow regime. At Minab (27°09'N, 57°05'E) and at Rudan (27°26'N, 57°12'E), the Minab River was up to 100m wide with an estimated maximum depth in pools of 2-3m. The lower Sarbaz River was a series of shallow, muddy pools in the bottom of a canyon with some water flowing over sills connecting the pools (in early December 1977). The lower Sarbaz has been designated a Wetland of International Importance. In its middle and upper course, the Sarbaz River varies from a very shallow and narrow stream connecting pools (some of which were fishless) to what must be termed a river in the semi-desert environment of Baluchestan, with a width of 10m, a depth of about 1m and fast current. The rock fill embankment Pishin Dam built over the rivers Pishin and Sarbaz is 63m high, has a crest length of 400m and can store 175 million cu m of flood waters (Coad 2014). The other streams of the Makran have little running water, often become isolated pools a kilometre or more apart, and regularly dry up along much of their length. Several rivers between the Mazavi (= Geru) River (mouth is at 26°56'N, 56°56'E) and the port of Jask are named and marked prominently on maps, but these were all dry in their lower reaches in late November 1976. Some flow in their upper reaches is to be expected, but its extent will depend on topography and recent climatic conditions. A dam and irrigation network is to be constructed on the Jaghin River east of Jask (Coad 2014).

Coad (1997a) combined the basins of the Makran, Dasht-e Lut, Hamun-e Jaz Murian, Mashkel and the Pakistani Pishin Lora as a single entity, expanding on earlier work by Mirza (1980). Mirza proposed the name Gedrosia for the Baluchistan Plateau west of the Central Brahui and Hala Ranges in Pakistan. The easternmost river along the Makran coast is the Hingol in Pakistan. East of this river the
The species are listed alphabetically within the families, which have been arranged according to Nelson (2006) except those which have been explained. Fish taxa are classified according to their tolerance to salt water and mode of life to Fluvial, Anadromous, Semi-anadromous, Estuarine and Marine following Naseka & Bogutskaya (2009). Global distribution maps of some selected species based on available data in Fishbase (2015) are given in Figures 4-9. Natural habitat of few fish species are given in Figures 10-12.

Results
The total confirmed and recently not confirmed freshwater fishes of the Makran and Mashkid basins comprise 28 species in 21 genera, 9 families, 6 orders and one class. The most diverse order is the Cypriniformes with 17 species (60.71%) followed by Gobiiformes with (4 species, 14.28%), Cyprinodontiformes (3 species, 10.71%), Perciformes (2 species, 7.14%) and Gonorynchiformes and Mugiliformes each with 1 species (3.57% each).

The most diverse family is the Cyprinidae with 13 species (46.42%) followed by Nemacheilidae and Gobiidae each with 4 species (each, 14.28%), Cyprinodontidae with two species (7.14%), and Channidae, Mugilidae, Poeciliidae, Channidae and Cichlidae each with only one species (3.57%). And Mashkid basins comprises 8 endemic species (28.57% of the total Makran and Mashkid basins ichthyofauna) in 4 families: Cyprinidae and Nemacheilidae, each with 3 endemic species (each, 10.71%), and Cyprinodontidae and Cichlidae each
with only one endemic species (each, 3.57%).

Five exotic species (17.85%) in 2 families are listed from these basins (Table 1). Cyprinidae with 4 exotic species (14.28% of the total exotic species in the Makran and Mashkid basins) is ranked first followed by the Poeciliidae with only one exotic species (3.57%) (Table 1). Some exotic species have been established, such as *Pseudorasbora parva* and *Gambusia holbrooki* (Table 1). Some alien species such as *Ctenopharyngodon idella* are questionably established but are abundant in the basin due to stocking by the Department of Fisheries. Live photos of some native and exotic fishes and their habitats in the Makran and Mashkid basins are provided (Fig. 3). We expect more species to be described as new, resurrected from synonymy, recorded for the first time from these basins, or recorded as established introductions. Hence, the fish fauna could soon exceed from those recorded in this checklist. The listing includes selected taxonomic comments including synonyms where these have been used in recent literature. Older synonyms can be found in Coad (1995). The type localities are given for all listed species.

**Checklist**

* = endemic to Iran, ** = exotic. Unconfirmed species are those mentioned in the literature but without confirmatory specimens in a museum. They are included in the totals in the checklist.

**Class Actinopterygii**

**Order Gonorynchiformes** (1 family, 1 genus and 1 species)

Genus *Chanos* Lacepède, 1803

1. *Chanos chanos* (Forsskål, 1775) – Makran basin.

**Type locality:** Jeddah, Saudi Arabia, Red Sea

**Comment:** No major synonyms. *Mugil chanos* was originally described from Jidda on the Red Sea.

**Order Cypriniformes** (2 families, 11 genera and 17 species)
Family Cyprinidae (10 genera and 13 species)
Genus *Bangana* Hamilton, 1822
   Type locality: Brahmaputra River, India. No types known.
   Global distribution map of this species is given in Figure 4.
Genus *Cabdio* Hamilton, 1822
   Type locality: Yamuna and Tista rivers, India. No types known.
Comment: *Aspidoparia morar* (Hamilton, 1822) is a synonym.
   Global distribution map of this species is given in Figure 5.
Genus *Capoeta* Valenciennes, 1842
   Type locality: Pulwar River (Sivand), Kor River basin, near Persepolis, ruins northeast of Shiraz, Iran.
   *Scaphiodon saadii* Heckel, 1849 was described from Persepolis, Pulwar River (Sivand), Kor River basin, ruins northeast of Shiraz, Iran. The following taxa named from Iran have been regarded as synonyms:
Scaphiodon amir Heckel, 1849, Scaphiodon niger Heckel, 1849, Scaphiodon saadii Heckel, 1849, Scaphiodon chebisiensis Keyserling, 1861, Scaphiodon rostratus Keyserling, 1861 and Capoeta capoeta intermedia Bianco and Bănărescu, 1982 (non Capoeta intermedia Temminck and Schlegel, 1846 = Acheilognathus lanceolata (Temminck and Schlegel, 1846). Capoeta damascina (Valenciennes, 1842) was earlier considered by many authors as one of the most common freshwater fish species found throughout the Levant, Mesopotamia, Turkey and Iran. However, it seems that C. damascina is restricted to the Damascus basin, Syria (Alwan et al. 2014).

5. Capoeta sp.*
Comment: under revision.
Genus Carassius Jarocki, 1822
6. Carassius auratus (Linnaeus, 1758) ** - introduced to several Iranian basins.
Type locality: Cyprinus auratus was originally described from China and Japanese rivers.
Genus Ctenopharyngodon Steindachner, 1866
7. Ctenopharyngodon idella (Valenciennes, 1844) ** - introduced to several Iranian basins.
Type locality: China. No types known.
Genus Cyprinion Heckel, 1843
Comment: Scaphiodon Heckel, 1843 has been used for Cyprinion and Capoeta species in Southwest Asia.
Type locality: Quetta, Pakistan.
Comments: Iranian synonyms are Cyprinion kirmanense Nikol'skii, 1900, Cirrhina afghana var. nikolskii Berg, 1905, Scaphiodon macmahoni Regan, 1906 and Scaphiodon baluchiorum Jenkins, 1910. Iranian populations from south east and eastern Iran have been considered as C. watsoni (see Coad 2014).
Type locality: Barbus milesi was described from "a spring at Träl", Pakistan.
Comments: Iranian synonyms are Barbus bam purensis Nikol'skii, 1899 and Barbus baschakirdi Holly, 1929.
Genus Cyprinus Linnaeus, 1758
Type locality: Europe
Comment: Native populations in the Caspian Sea basin; also introduced there and elsewhere in Iran.
Genus Garra Hamilton, 1822
Comments: Under revision with possible new taxa. Phylogenetic relationships of this taxon in the Middle East is under revision by Hashemzadeh et al. (2015).
Type locality: Bampur River, southern Iran; Kiabad in Zirkuh, eastern Khorasan according to Berg (1913) where the original description is found on these fish.

Type locality: Hari River, Turkmenistan; rivers in eastern Iran.

Comments: *Discognathus phryne* Annandale, 1919 and *Discognathus rossicus* var. *nudiventris* Berg, 1905 are Iranian synonyms.  
Global distribution map of this species is given in Figure 6.

Genus *Gonorhynchus* McClelland, 1839  
Comment: It has been considered as synonym of *Crossocheilus* Kuhl & van Hasselt, 1823 by some others.

Type locality: *Cyprinus latius* was described from the Tista River in India/Bangladesh and types are unknown.  
Comment: This species is represented in Sistan and Baluchestan by *Crossocheilus latius diplocheilus* (Heckel, 1838), originally described from Kashmir with syntypes in the Naturhistorisches Museum Wien under NMW 48820 (7 fish). *Discognathus adiscus* Annandale, 1919 is a synonym from Iran (see also Bianco & Banarescu 1982; Bănărescu 1986). Under revision. Global distribution map of this species is given in Figure 7.  
Genus *Pseudorasbora* Bleeker, 1859  
Type locality: *Leuciscus parvus* Temminck and Schlegel, 1846 was originally described from Japan.

**Family Nemacheilidae** (1 genus and 4 species)  
Comments: Formerly included in the family Cobitidae or the family was named Balitoridae (see Tang et al., 2006; Kottelat & Freyhof, 2007; Freyhof et al., 2011; Esmaeili et al., 2014b). Iranian species were placed in the genera *Nemacheilus*, *Adiposia*, *Barbatula*, *Orthrias* and *Schistura* in earlier literature.  
Genus *Paraschistura* Prokofiev, 2009  
Comment: Further study is needed.  
Nemacheilid loaches of the genus *Paraschistura* are a group of poorly known species from the Tigris drainage in Turkey east throughout Iran and Pakistan to the Indus River and the Hari, Murghab and Helmand endorheic basins in Afghanistan, Iran, Pakistan and Turkmenistan (Kottelat, 2012) and thus the revision on this taxon is needed.  
15. *Paraschistura sp.*

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**Fig. 7.** Global distribution map of *Gonorhynchus diplocheilus* (Modified from Fishbase, 2015).
Type locality: Kjagur and Kashin [Kaekin] rivers, Bampur River near Bazman, Iran.

17. *Paraschistura kessleri* (Günther, 1889) - Mashkid River basin.
Type locality: Nushki, Pishin Lora River basin, Afghanistan or Pakistan.

Type locality: Sij-Rischan [Zia Rishan] near Kuh-i-Tuftan volcano, Sargado [Sarhad region], eastern Iran.

Type locality: European Sea.

Type locality: *Lebias dispar* Rüppell, 1829 was originally described from the Red Sea.

Type locality: Shur River along the Bandar Abbas–Minab road, 20km East of Bandar Abbas (27°19_37.6N, 56°28_10.2E, altitude 2m), Iran, Hormozgan Province, collected on 26th September 2010 by A. Teimori, H.R. Esmaeili, A. Gholamifard and R. Khaefi.

Type locality: Palatka, eastern Florida; Charleston, South Carolina, U.S.A.

Orders and Families:

**Order Mugiliformes** (1 family, 1 genus, 1 species)

**Family Mugilidae** (1 genus and 1 species)

Genus *Mugil* Linnaeus, 1758

Type locality: European Sea.

**Order Cyprinodontiformes** (2 families, 2 genera and 3 species)

**Family Cyprinodontidae** (1 genus and 2 species)

Genus *Aphanius* Nardo, 1827
Comments: Various isolated populations may prove to be distinct species. Formerly placed in the genera *Lebias* Goldfuss, 1820 or *Cyprinodon* Lacepède, 1809.

**Family Poeciliidae** (1 genus and 1 species)
Genus *Gambusia* Poey, 1854

Type locality: Palatka, eastern Florida; Charleston, South Carolina, U.S.A.

**Order Perciformes** (2 families, 2 genera and 2 species)

**Family Channidae** (1 genus and 1 species)
Comment: Betancur-R et al. (2013) included this family in Order Anabantiformes
Genus *Channa* Scopoli, 1777

23. *Channa gachua* (Hamilton, 1822) - Makran and
Mashkid River basins.
Type locality: Ponds and ditches of Bengal.
Comment: Formerly in the genus *Ophicephalus*.
Global distribution map of this species is given in Figure 8.

**Family Cichlidae** (1 genus and 1 species)
Genus *Iranocichla* Coad, 1982
24. *Iranocichla hormuzensis* Coad, 1982* – Makran basin.
Type locality: Mehran River, Hormozgan Province, southern Iran.
Global distribution map of this species is given in Figure 9.

**Order Gobiiformes** (1 family, 4 genera and 4 species)
**Family Gobiidae** (4 genera and 4 species)
Comment: Systematic position of this family is under revision.
Genus *Boleophthalmus* Valenciennes, 1837
Type locality: Mumbai, India.
Genus *Glossogobius* Gill, 1859
Type locality: Ganges River, India.
Comment: *Gobius giuris* was originally described from the Ganges River, India.
Genus *Periophthalmus* Bloch and Schneider, 1801
Type locality: Iraq and Pakistan.
Comment: The Memoirs of the Indian Museum for 1938-1942 were published in 1955 (this is the date on the title page).
Genus *Scartelaos* Swainson, 1839
Type locality: Estuaries of Karachi, Sind, Pakistan.
Comment: Originally described as *Boleophthalmus tenuis* Day, 1876 from Estuaries of Karachi, Sind, Pakistan.

**Discussion**

**Biogeographic history:** A central aim of research in modern historical biogeography is to understand the distributions of species and ecosystems in light of historical processes that shape landscape evolution (Cox & Moore 2005; Lomolino et al. 2010). This effort has made rapid progress over the past decade in the study of freshwater fishes. Freshwater fishes are more and less confined to drainage systems and cannot disperse without connections of the freshwater systems. They provide relatively conservative system for examining zoogeographical patterns. These features make them one of the most zoogeographically important groups of animals (Berra 2007). Changes in river systems and evolution...
of the fishes might be affecting on heterogeneity in the geographic distribution of the strict freshwater fishes (Watanabe 1998). In other word, zoogeographic patterns form strong evidence of evolution (Berra 2007). However, anthropogenic effects have played a significant role in changing distribution pattern of freshwater fishes especially in the past few decades (Esmaeili et al. 2010b, 2012, 2014c–d) which can be well-understood in the case of some of the freshwater fish species distributed in different endorheic and exorheic basins of Iran.

Iran occupies a significant portion of the Middle East, in terms of land and water area and in terms of zoogeography. The freshwater fish fauna of Iran stands out from its neighboring counterpart in terms of species richness and level of endemism (see Esmaeili et al. 2010a, 2014a–c; Coad, 2014). Geographical isolation, together with the climatic conditions and watershed fragmentation experienced by Iranian plateau over geological time, has led to differentiation of the freshwater ichthyofauna into several independent and isolated populations promoting speciation.

A) Fish origin: The country contains elements of both Ethiopian and Oriental ichthyofauna, although it is predominantly a part of the Palearctic Realm (Coad 1985). This zoogeographical situation, coupled with the past geological history, vicariance events and recent anthropogenic effects have played a significant role on the ichthyodiversity of Iran in different endorheic and exorheic drainage systems including the Makran and Mashkid basins. Southern Iran is the main route for movement of animals, especially fish, between the Oriental and Ethiopian biogeographical regions; therefore the southern and southeastern ichthyofauna of Iran especially Makran and Mashkid basins is a combination of the Oriental, Ethiopian and western Palearctic ichthyofauna due to its geographic situation. The origin and distribution of fish taxa in the Makran and Mashkid basins could be attributed to several events e.g. the drainage captures, marine penetrations, exotic introductions and also endemicity. The fish origins are:

I) Ethiopian (African): Ethiopian region, also called Afrotropical Region, is one of the major land areas of the world defined on the basis of its characteristic animal life. The Makran basin has some genera (e.g., Iranocichla) with Ethiopian affinities.

II) Palearctic: The Palearctic or Palearctic is one of Earth’s eight ecozones. This region is the largest ecozone on Earth. It includes the regions of Europe, Asia (north of the Himalayan foothills), northern Africa, and the northern and central regions of the Arabian Peninsula. There are few west Palaeartect fish elements (e.g., C. saadii, C. carpio and P. parva) in these basins.

### Table 2. Endemic and exotic fishes of the Makran and Mashkid basins. En= endemic; Ex=exotic; *=established; NC=not confirmed.

<table>
<thead>
<tr>
<th>Order</th>
<th>Family</th>
<th>Specie</th>
<th>Status</th>
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</thead>
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<td>Cypriniformes</td>
<td>Cyprinidae</td>
<td>Capoeta saadii</td>
<td>En</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ctenopharyngodon idella</td>
<td>Ex, NC</td>
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<tr>
<td></td>
<td></td>
<td>Cyprinus carpio</td>
<td>Ex, NC</td>
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<td></td>
<td></td>
<td>Pseudorasbora parva</td>
<td>Ex*</td>
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<td></td>
<td>Nemacheilidae</td>
<td>Garra persica</td>
<td>En</td>
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<td>En</td>
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<td></td>
<td>Poeciliidae</td>
<td>Gambusia holbrooki</td>
<td>Ex*</td>
</tr>
<tr>
<td>Perciformes</td>
<td>Cichlidae</td>
<td>Iranocichla hormuzensis</td>
<td>En</td>
</tr>
</tbody>
</table>

124
III) Oriental: The Makran and Mashkid basins contain many element from the Oriental region, for example, *Bangana* (Cyprinidae), *Cabdio* (Cyprinidae), *Cyprinion* (Cyprinidae), *Garra* (Cyprinidae), *Channa* (Channidae), *Glossogobius* (Gobiidae), and *Boleophthalmus* (Gobiidae).

B) Attributed events

I) Marine penetrations: The distribution of certain families and species in southern Iran are the results of marine migrations by freshwaters which are known to have a wide tolerance of salinities (Coad, 1987). These marine penetrators into rivers of the Makran and Mashkid basins include *C. chanos* (Chanidae), *A. dispar* (Cyprinodontidae), *M. cephalus* (Mugilidae), *B. dussumieri*, *P. waltoni*, and *S. tenuis* (Gobiidae).

II) Exotics: Exotics comprise five fish species in two families introducing to the Makran and Mashkid basins for different purpose. *C. carpio, C. idella, C. auratus, P. parva* (all Cyprinidae) and *G. holbrooki* (Poeciliidae) are alien species in these basins. Diversity, environmental impacts and management of alien and invasive freshwater fish species in Iran have been discussed by Esmaeili et al. (2014c).

III) Endemics: There is a degree of endemism in the Makran and Mashkid basins. Here, endemic taxa include those fishes which are restricted to Makran and Mashkid basins of Iran and there is no record of them in other neighboring countries. These are: *C. saadii, G. persica* (Cyprinidae), *P. bampurensis, P. kessleri, P. sargadensis* (Nemacheilidae), *A. furcatus* (Cyprinodontidae) and *I. hormuzensis* (Cichlidae). These endemic fishes probably reflects a history of transgressions, isolation and speciation. The use of molecular markers will provide addition data on the molecular ichthyogeography of fish taxa in Makran and Mashkid and related basins.

C) Other grouping of the Makran and Mashkid basins fishes

The fish taxa listed from the Makran and Mashkid might be classified to the following major groups based on ecoregions and ecological parameters:

I) Ecoregion grouping: A new map depicting the global biogeographical regionalisation of Earth’s freshwater systems was published (Abell et al. 2008). This map of freshwater ecoregions is based on the distributions and compositions of freshwater fish species and incorporates major ecological and evolutionary patterns. In this new classification, the Makran and Mashkid basins lies in the Baluchistan region. Baluchistan (or Balochistan) comprises Iranian and Pakistani Baluchistan, delimited by the Arabian Sea to the south, the Sulaiman Mountains to the east, the Chagai and Toba Kakar ranges in the north, and the Hazaran massif in the west. It is bordered by the Northern Hormuz drainages.
ecoregion to the west, Lower and Middle Indus to the east, and Hilmand-Sistan and Kavir & Lut Deserts to the north. This ecoregion drains to the Arabian Sea and Gulf of Oman (Sea of Oman), as well as several endorheic basins in the northern part of the ecoregion. The Baluchistan ecoregion falls within a hot desert climate, with summer temperatures that exceed 44°C. Winters are very cold in the highlands, but mild along the Makran coastal plain where temperatures remain above 0°C. The mean annual temperature of the ecoregion is 22°C, and mean annual precipitation is 117mm. All streams in this ecoregion are small, many are intermittent, and some dry out completely. Small dams, springs, and qanats are also important habitats. In the west is the Hamun-e Jaz Murian, which is a marshy lake that is dry for most of the year, but fills with fresh water in winter. It is fed by the Halil and Bampur rivers. The rivers and streams of the Makran coastal plain drain to the sea at the Straits of Hormuz and the Gulf of Oman. Most streams of the Makran, however, have little running water and regularly dry up along much of their length.

There are around 130 species, some of which are marine entrants into coastal rivers (clupeids, mugilids, and gobiids). Some fish taxa classified in this category which found in the Makran and Mashkid basins *G. diplocheilus* (Cyprinidae) and *C. gachua* (Channidae). This ecoregion is a transitional zone between the Palaearctic and Oriental realms, with species such as *Capoeta* and *Cyprinion* from the former and *Labeo*, *Puntius*, and *Channa* from the latter.

2) **Ecological Grouping:** We followed classification introduced by Kessler (1877) and also Naseka & Bogutskaya (2009) for Ponto-Caspian fishes which is based on criteria of physical habitats and the presence/absence of migrations between them. However, some fish taxa may be classified in more than one category (Table 2).

1) **Fluvial:** fluvial, `of various waters` {"raznovodnyye"} species are those which rarely met in the Sea occurring only in deltas and freshened coastal shallows. Freshwater and fluvial belong to 6 families (Cyprinidae, Nemacheilidae, Cyprinodontidae, Poeciliidae, Channidae, and Cichlidae). Examples are: *B. dero, C. morar, C. saadii, C. auratus, C. idella, C. microphthalmum, C. milesi, C. carpio, G. persica, G. rossica, G. diplocheilus, P. parva, P. bampurensis, P. kessleri, P. sargadensis, A. dispar, A. furcatus, G. hollbrooki, C. gachua, I. hormuzensis and B. dussumieri*. As indicated in Table 2, most of the fluvial freshwater species mentioned above belong to the families Cyprinidae followed by Nemacheilidae which are primary division families sensu Myers (1938, 1951)
(i.e. those families whose members are strictly intolerant of salt water, both currently and historically).

II) **Aanadromous:** Anadromous species comprise those taxa that spawn in rivers, often much farther upstream than semi-anadromous fishes, and forage all over the Sea under-taking long-distance migrations (Naseka & Bogutskaya 2009). No species lists in this category.

II) **Semi-anadromous:** Semi-anadromous fishes keep spawning in fresh water (limnetic waters, 0.5ppt and less) but forage in oligohaline water (around 0.5-5ppt). Only one species, *C. carpio* (fluvial, semi-anadromous) (Cyprinidae) is classified as semi-anadromous (Table 2).

III) **Estuarine:** Species that are classified as ‘estuarine’ mostly inhabiting deltaic areas and adjacent coastal shallows, some of them being distributed also in lower reaches of rivers and/or open marine habitats. Most species belong to the family Gobiidae followed by the families Chanidae, Cyprinodontidae and Cichlidae. Examples are: *C. chanos, A. dispar, I. hormuzensis, B. dussumieri, G. giuris, P. waltoni* and *S. tenuis.*

IV) **Marine:** Strictly ‘marine” or almost marine species are mostly inhabiting the open Sea, benthic or pelagic waters. Most species belong to the family Gobiidae, followed by the family Chanidae. Examples are: *C. chanos* (fluvial and semi-anadromous), *B. dussumieri, G. giuris, P. waltoni* and *S. tenuis* (Table 2).

**Threats:** Similar to threats observed in other countries, habitat modifications (Figs. 13, 14), pollution, water extraction, eutrophication resulting from urban sewage and agricultural runoff, dam construction (which limits sediment and nutrient flow downstream to deltas) (Figs. 13, 14), drainage for irrigation and drinking water, droughts (Fig. 15), human population growth, introduction of exotic aquatic species (Fig. 16), and illegal fishing are the main threats to fish diversity in the Makran and Mashkid basins (see Esmaeili et al. 2014c). Other major threats to future fish survival include intrinsic factors such as restricted range and limited dispersal, and increasing number of invasive species from aquaculture industry.

**Conservation and management:** River basins are complex, open systems with ill-defined boundaries. They fulfil many important functions ranging from the supply of water to households and agriculture to the provision of transport routes. They also provide habitat for many different species which in turn
provide a valuable resource to people through activities such as fishing and recreation (Smith & Darwall 2006). It is essential that there is sufficient water of the right quality in the right place at the right time. To guarantee the continued social, environmental and economic services provided by freshwater systems, these systems must be adequately protected and sensitively developed (Smith & Darwall 2006).

Iran is one of the arid regions of the world on basis of various definitions of climatic conditions, vegetation types or potential for food production. Due to their high ecological value, monitoring of arid regions is necessary and priority should be given to conservation and management of freshwater ecosystems located in these area. To protect critical services such as flood control and valuable economic and livelihood benefits, all users of freshwater including biodiversity need to be taken into consideration when managing water resources.

There are over 28 fish species and many other species of aquatic vertebrates and invertebrates in the Makran and Mashkid basins. Several fish species, including natives, have declined in abundance. Due to the degradation of river systems and the loss of aquatic habitat, aquatic biodiversity has been declining. A number of fish species, populations and ecological communities might be listed as threatened in near future. The main causes of decline in freshwater fishes include: habitat degradation due to various forms of water pollution, catchment development and land use-related activities, changes to water flow regimes, barriers to fish passage, the introduction of alien fish species, introduction of parasites and diseases (see Esmaeili et al. 2014; Malekzehi et al. 2014) and historical overfishing. The aquatic systems in both basins also are predicted to experience: further drying and increased occurrence of drought, higher water temperatures, diminished water flows that will produce low oxygen levels and increased salinity which affect whole life cycle of fishes.

Efforts to conserve and protect existing habitat, as well as efforts to rehabilitate degraded habitats, monitoring of exotic fishes, monitoring of parasites and disease, drawings maps of conservation hot spots based on a combination of characters (e.g., fish diversity, population density, ecological requirements, threats), predicting potential distribution of fish species especially key or/and endangered species might be considered as the main topics in conservation management strategies. The information collected and presented here should be prepared readily available for policy makers and environmental planners in a format that can easily be employed for integration within the development planning process.

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