

Review Article

Review of the bitterlings of Iran (Family Acheilognathidae)

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Abstract: The systematics, morphology, distribution, biology and economic importance of the bitterlings of Iran are described, the species is illustrated, and a bibliography on this fish in Iran is provided. There is a single species, *Rhodeus amarus*, found in the Caspian Sea basin and introduced to the Lake Urmia and Tigris River basins.

Keywords: Biology, Morphology, *Rhodeus*.

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Introduction

The freshwater ichthyofauna of Iran comprises a diverse set of about 297 species in 109 genera, 30 families, 24 orders and 3 classes (Esmaeili et al., 2018). These form important elements of the aquatic ecosystem and a number of species are of commercial or other significance. The literature on these fishes is widely scattered, both in time and place. Summaries of the morphology and biology of these species were given in a website (www.briancoad.com) which is updated here for one family, while the relevant section of that website is now closed down. Other families will also be addressed in a similar fashion.

Family Acheilognathidae

The bitterlings are found in Eurasia and the family has about 76 species in five genera (Catalog of Fishes, downloaded 5 October 2018). There is one species in Iran. The family is characterised by an ovipositor in females, usually used to lay eggs in the mantle cavity of unionid bivalve molluscs, males have tubercle-bearing plates on the snout, a deep and compressed body, the uroneural bones in the caudal region are absent, and the foramen in the coracoid

bone of the pectoral fin is reduced or absent.

The family Acheilognathidae was formerly placed as a subfamily within the family Cyprinidae but is distinguished on the basis of molecular data (Chang et al. 2014; Stout et al. 2016). There is evidently a strong possibility of exotic species from Turkmenistan entering Iranian waters. Fishes, including exotics, are farmed along the basin of the Karakum Canal, a 1,372km long diversion from the Amu Darya. Some of these exotics can be expected to enter the Hari River basin of Iran via its delta and eventually the Caspian Sea basin via the Atrak River through runoff and collector canals (Sal'nikov 1995, 1998). A potential exotic is the rosy bitterling, *Rhodeus ocellatus* (Kner, 1866), a species originally from China.

Genus *Rhodeus* Agassiz, 1832

The bitterlings comprise about 23 species in Europe, Asia Minor, the Caspian Sea basin, China, Japan and Korea with one species in Iran. The monophyly of *Rhodeus* was poorly supported in a molecular study of Acheilognathinae by Kawamura et al. (2014). The two major clades diverged in the Middle Miocene and a *Tanakia-Rhodeus* clade expanded westward



Fig.1. *Rhodeus ocellatus*, Hamamatsu, Shizuoka, Japan (Wikimedia Commons).

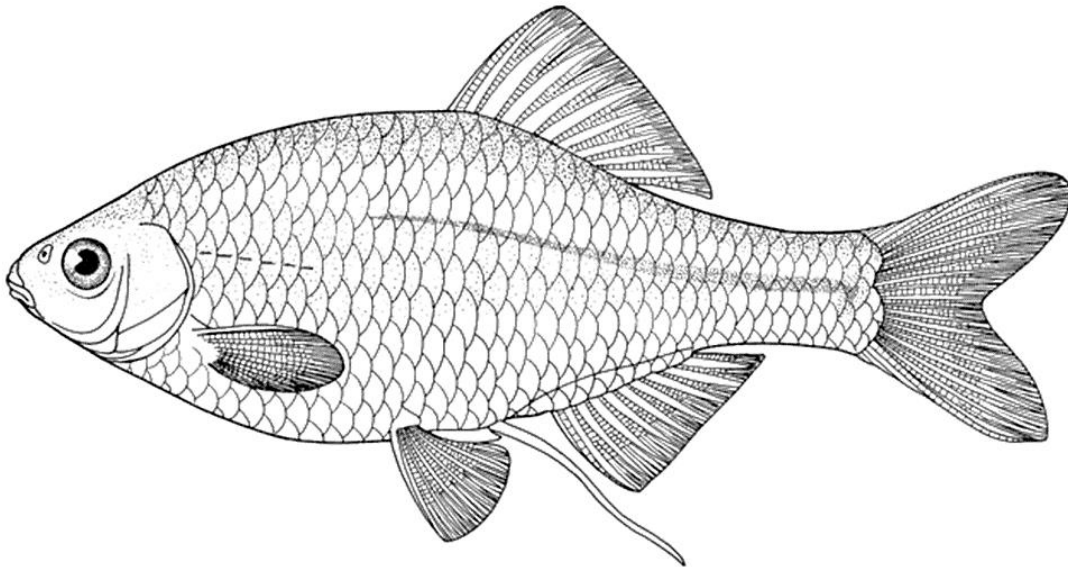


Fig.2. *Rhodeus amarus*, line drawing, S. Laurie-Bourque.

from the Far East, eventually reaching Europe. Most extant species appeared by the end of the Pliocene. A *Rhodeus sericeus* lineage including *R. amarus* diverged in Eastern Europe and the Caucasus in the Pleistocene when repeated glaciations facilitated isolation and speciation.

These are small fishes with deep, compressed bodies, an incomplete lateral line (about 11 pored scales or less), large to moderate-sized scales, females with an ovipositor, males larger than females (unusual in cyprinoid fishes), brightly coloured and

tuberculate when spawning, pharyngeal teeth in one row and not or only slightly serrated, mouth small, oblique and subterminal, no barbels, dorsal fin short to moderately long and spineless, anal fin of similar length, gill rakers short, intestine long and spirally coiled, and peritoneum black.

Rhodeus amarus (Bloch, 1782)

(Figs. 2-3)

Common names: Mahi-e-makhraj loolei or mahi-ye makhraj lulehi (= tube-like vent fish), rodeus [Karka



Fig.3. *Rhodeus amarus*, Anzali Wetland, November 2007, K. Abbasi.

in Azerbaijan; gorchak in Russian; bitterling, European bitterling].

Systematics: Holčík & Duyvené de Wit (1964) reviewed the systematic status of *Rhodeus sericeus* (Pallas, 1776) in Europe and western Asia (but not Iran) in comparison to the Chinese populations of this species. They referred European and western Asian populations to *Rhodeus sericeus amarus* (Bloch, 1782) and Iranian populations were long regarded as this subspecies. *Cyprinus sericeus* was described from the Onon River, Dauriya, Russia, no types known, and *Cyprinus amarus* was described from the Elbe basin, Germany (see below) (Eschmeyer et al. 1996). Later, Holčík & Jedlička (1994) considered subspecies not to be warranted as the key characters used in distinguishing them (pored lateral line scales, scales in lateral series, gill rakers) showed clinal variation with longitude and the number of segments was also related to latitude, elevation, mean annual air temperature, and fish size. Bohlen et al. (2006) stated that *Rhodeus* from the Vistula to the Volga belong to the *R. amarus* eastern clade based on cytochrome *b* sequences.

Kottelat (1997) considered *Rhodeus amarus* to be a distinct species since it is diagnosable (although differences with *Rhodeus sericeus* are slight and largely overlap), and it is separated by 2-4 million years in time and 4,000km in space. However, he did admit that the immense distributional gap may be a

source of bias. Holčík in Bănărescu (1999) considered *amarus* to be synonymous with *sericeus*. Bogutskaya & Komlev (2001) found no characters to clearly confirm the specific status of *R. amarus*. The name *amarus* is retained here as an indication that the taxa are geographically isolated. Van Damme et al. (2007) referred the Caspian bitterling to a species as yet undescribed and Naseka & Bogutskaya (2009) referred to Caspian Sea fish as *Rhodeus* sp.. Bektaş et al. (2013) examined Turkish populations using cytochrome *b* and found a monophyletic unit.

Jafari & Rahmani (2015a) found significant differences in body pattern of fish from the Tajan and Babol rivers, presumably a result of habitat separation. Jafari Kenari et al. (2015) found some morphometric differences between lagoon (Anzali) and riverine (Babol, Siah, Tajan) populations, but there was a large overlap.

This species was described from Lake Müggelsee near Köpenik, Berlin, Germany and three syntypes are in the Museum für Naturkunde, Humboldt-Universität zu Berlin (or Zoologisches Museum Berlin, ZMB 3393).

Key characters: The presence of an ovipositor in females, the flank stripe and few pored scales are distinctive among Iranian cyprinoid fishes.

Morphology: Body form can be seen in the illustrations. Dorsal fin with 2-4, usually 3, unbranched and 7-11, usually 9, branched rays, anal

fin with 2-4, usually 3, unbranched and 6-12, usually 9, branched rays, pectoral fin branched rays 10-13, and pelvic fin branched rays 4-8, usually 6-7. Pored lateral line scales 0-11, usually 4-6, scales along the flank 28-45, usually about 30-32 in some reports but 32-38 in Abdurakhmanov (1962), 37-40 in Holčík & Jedlička (1994), 30-38 in Pipoyan (1996) and 35-40 in Holčík in Bănărescu (1999). Gill rakers 9-16, usually 10-14, reaching the raker below when appressed. Vertebrae 33-39. Pharyngeal teeth 5-5, rarely 5-4, 4-5 or 4-4. Teeth are elongate and narrowly compressed with a slight to strong hook at the tip and a very long, narrow and concave grinding surface below the tip. The gut has numerous coils. The chromosome number is $2n=48$ (Klinkhardt et al. 1995, Arai 2011).

Meristic values for Iranian specimens are:- dorsal fin branched rays 8(4), 9(52), 10(1) or 11(1), anal fin branched rays 8(18), 9(39) or 10(1), pectoral fin branched rays 10(3), 11(24), 12(29) or 13(2), pelvic fin branched rays 4(1), 6(3), 7(53) or 8(1), scales in lateral series 32(1), 33(2), 34(22), 35(29) or 36(4), pored lateral line scales 3(1), 4(7), 5(37), 6(11) or 7(2), total gill rakers 10(3), 11(14), 12(27), 13(10) or 14(4), pharyngeal teeth 5-5(20), and total vertebrae 34(9), 35(36), 36(12) or 38(1). Holčík & Jedlička (1994) gave ranges in their Iranian sample of 33-41 for lateral series scales, 0-6 pored scales and 9-14 for gill rakers, in general agreement with data here.

Sexual dimorphism: Males develop a triangular or crescent-shaped patch of 7-20 tubercles on each side of the snout and small tubercles are found above the eyes. The female develops an ovipositor near the genital opening and it may be longer than the body. The flank stripe is longer and about one half wider in males compared to females, and male colouration is distinctive. Males are generally larger than females. Valizade et al. (2016) found morphometric data overlapped in males and females and they could not be distinguished on this basis.

Colour: Males are particularly colourful in the spawning season: the top of the head and back are olive to bright green, reddish or dark violet, the iris is

bright red, flanks are iridescent with violet and steel-blue colours most evident, the throat and belly are orange to blood-red, dorsal and anal fins are bright red and margined with black, the caudal fin is green at the base and yellow distally, and pectoral and pelvic fins are yellowish. Females are more yellowish and less iridescent than males in the spawning season. Outside the breeding season both sexes are similar in colour with a grey-green back, silvery flanks and yellowish belly. A grey-green to greenish-blue stripe originates under the dorsal fin and extends back to the tail base, broadening posteriorly. The dorsal fin is blackish and other fins reddish to yellowish. The dorsal, and sometimes the anal fin, has a dark interrupted stripe. The iris is silvery or yellowish. The peritoneum is dark. **Size:** Reaches a reputed 18.0cm but usually not more than 7.0-9.0cm. Patimar et al. (2010) found a maximum size of 8.4cm total length for Siah River fish.

Distribution: Found from Western Europe north of the Pyrenees and Alps to the Caspian Sea basin. Probably in the Aras River of Armenia (Pipoyan 1996). In Iran, it is recorded from Astara to the Gorgan River including the Anzali Talab and Hendeh Khaleh swamp, and the Astara, Babol, Chapak, Fereydun Kenar, Golshan, Gorgan, Haraz, Haviq, Karkan, Kelarud, Kiarud, Langarud, Lashtenesha (= Lasht Neshah), Molahadi, Nahang Roga, Nerissi, Pir Bazar Roga, Rasteh, Sardab, Sefid, Shafa, Shahrud, Shalman, Sheikan, Shesh Deh, Shirud, Siah, Siah Darvishan and Tajan rivers (Derzhavin 1934; Holčík & Oláh 1992; Karimpour 1998; Abbasi et al. 1999; Kiabi et al. 1999; Abdoli 2000; Abbasi et al. 2017; Banagar et al. 2008; Abdoli & Naderi, 2009; Piri et al. 2009; Abdoli et al. 2014; Gholizadeh et al. 2014). It is introduced to the Bitas, Geravand, Mahabad, Qader, Simineh and Zarrineh rivers and the Mahabad Dam of the Lake Urmia basin (Abbasi et al. 2005; Moradi & Eagderi 2014, photographs by Saber Shiri (pers. comm. 14 June 2008), Ghasemi et al. 2015; Eagderi & Moradi 2017). Introduced also near Garavand on the Qareh Su in Kermanshah (Eagderi

& Nasri 2012; Valizade et al. 2016).

Zoogeography: Bohlen et al. (2006) assumed a continuous distribution of *Rhodeus* from Europe through Siberia to East Asia during the Pliocene, loss of the Siberian population in the late Pliocene or early Pleistocene, subsequent isolation, and later post-glacial expansion from several refugia in the Euro-mediterranean zoogeographic subregion. The Caspian Sea populations were not examined but seem to belong to *R. amarus* although the authors suggested a revisionary study is required for European bitterlings. Van Damme et al. (2007) considered this species was restricted to Ponto-Caspian and Aegean regions and its presence in western and central Europe is associated with the spread of *Cyprinus carpio* cultivation, and more recently, anthropogenic alterations to habitats and temperature changes. The study by Bektaş et al. (2013) supports a hypothesis that the European bitterling survived in several glacial refugia in the Black Sea region. See also under the genus above.

Habitat: This species favours heavily vegetated areas of small lakes, ponds and slow-moving rivers, rarely in faster water. It is found in the lower reaches of rivers on the Caspian coast of Iran (Jolodar & Abdoli 2004). The bottom is usually fine sand or a thin layer of mud. Swan mussels (*Anodonta*) and freshwater clams (*Unio*) share this kind of habitat and are necessary for reproduction. Other genera of clams include *Pseudanodonta*, *Cristaria*, *Margaritifera* and *Dahurinaia* (Smith et al. 2004). Spawning occurs at water temperatures of 12-24°C, although 15-21°C is optimal (Holčík in Bănărescu 1999), Van Damme et al. (2007) giving 23°C as optimal. Its distribution is limited by the 16°C July isotherm (Van Damme et al. 2007).

Age and growth: Patimar et al. (2010) examined 272 fish from the Siahrud (= Siah River) and found length-weight relationships $W = 0.0074TL^{3.4546}$ for males, $W = 0.0133TL^{3.055}$ for females, positively allometric for both, von Bertalanffy parameters were $L_t = 94.16(1 - e^{-0.31(t + 0.321)})$ for males, $L_t = 92.33(1 - e^{-0.32(t + 0.488)})$ for females, the oldest fish were 5+ years

in both sexes, males were longer and heavier than females, unusual in cyprinids, and sex ratio was equal (1:1.05). Norouzi Elahbaksh Mahalle et al. (2014) examined 538 fish from the Anzali Lagoon and the Siyahrud (= Siah River) finding fish up to age 8+ years with the largest fish being males from the Siah River at 75.4mm and 6.67g, and positive allometric growth in both sexes and localities (combined *b* value 3.32 for in the Siah River and 3.24 in the Anzali Lagoon), and a higher condition factor in males for both localities. Norouzi & Abbasi (2015) examined Sefid River fish and also found the condition factor was higher in males and growth was positively allometric for both sexes. Fish attained age 9 years. Jafari & Rahmani (2015b) found significant differences in length and weight between fish from the Babol, Siah and Tajan rivers, population growth was isometric and the condition factor (K) was 31.48, 20.15 and 22.075, respectively.

Maximum life span is 5-8 years, the higher values being uncertain (Holčík in Bănărescu 1999) but see above. Maturity is attained during the second or third year, the life span of most individuals. Rarely some fish may mature as early as before the age of 1 year or as late as the fourth year. Growth is faster in ponds than in rivers. Males outnumber females at a ratio of 1.2-1.5:1, especially in spawning areas, although females apparently outlive males (Holčík in Bănărescu 1999) but see above.

Food: Food consists of diatoms and detritus with aquatic insects and crustaceans being mostly accidental inclusions. They also take eggs of *Rutilus rutilus* (= *lacustris*), *C. carpio* and *Rutilus frisii* (= *R. kutum*), and also their own eggs which fail to be deposited in the clam or mussel. Most gut contents in Iranian fish examined were plant fragments, filamentous algae, detritus and sand grains.

Reproduction: Reproduction takes place mainly in April and May, but can run from the end of February (in Azerbaijan) to August. The female develops an ovipositor from the genital opening, up to 6cm long. In Iranian fish examined by me, the best developed ovipositor was seen in a fish collected on 12 May

when it extended back two-thirds along the caudal fin length. Eggs in this fish were 2.2mm. Fish taken in September, October, November and January had short ovipositors progressively increasing in length with time. A fish taken on 4 July had an ovipositor extending only half way along the anal fin but no large eggs. Spring spawning is indicated but an ovipositor can be seen in varying degrees of development year round in adult females.

Holčík in Bănărescu (1999) reported ovipositor length up to 126.5% of standard length in the Anzali Talab in April. Patimar et al. (2010) examined fish from the Siah River and found a reproductive season extending from March to June, peaking in April, two kinds of eggs - small ones up to 0.91mm, mean 0.57mm, and large, yolk-filled ones up to 2.2mm, mean 1.49mm, average absolute fecundity was 329.74 eggs, average relative fecundity was 187.4 eggs/g, and large, yolk-filled eggs numbered 13-211, mean 78. Norouzi & Abbasi (2015) examined Sefid River fish and found the average number of eggs was 78.8.

The ovipositor lays eggs inside freshwater clams and mussels, using the excurrent siphon as the entry route. Apparently the flow of water, and a high oxygen content, out of this siphon encourage egg laying. Before egg laying, the female nudges the clam repeatedly to accustom the mollusc to stimulus so that it does not close up its shell. In the absence of clams, the bitterling does not become sexually mature. Clams and mussels with high numbers of bitterling larvae or filled with glochidia are avoided, as is *Anodonta cygnaea*, a mussel which is able to eject eggs and larvae and has low oxygen levels in its excurrent siphon (Kottelat & Freyhof 2007). Males select and defend a particular clam against other males. They may head-butt each other or strike flanks, dislodging scales. Sneaking occurs despite this. The female deposits eggs 1-2 at a time and the male sheds sperm which are sucked into the clam on its feeding current. This process may be repeated with the same or different females. The female deposits about 40-100 eggs at each spawning and can

spawn at least five times a day. The movement of the ovoid eggs through the ovipositor can be clearly seen as they are somewhat larger than the distensible ovipositor. Spawning bouts last 1-3 days with intervals of 5-7 days, variable with feeding conditions and temperature (Smith et al. 2004). Fecundity is up to 22,136 eggs and maximum egg diameter to 3.1mm with width up to 1.52mm. Eggs hatch 2-5 weeks later and the young leave the clam after two days when the yolk sac has been absorbed. Young fish leave the clam singly or in pairs. The fish gain the advantage that the eggs and young are protected inside the clam, even should the shore area dry out since the clam will move to deeper water. The clam is unharmed and is able to disperse its own young or glochidia by their attachment to the fins of the adult fish. Bitterlings seem, however, to have an immunological response to glochidia, having far fewer than other fishes that are less intimately associated with clams. Circumstantial evidence laid out by Smith et al. (2004) involving inhibition of free water circulation by the fish embryos, damage the clam gills, and increased consumption of oxygen by clams, indicate the relationship is a parasitic rather than a commensal one.

Smith et al. (2004) gave a detailed account of reproduction, behaviour and development in this species, and showed that male colouration predicts spermatozoa numbers and colour, as a sign of male fertility, may be under direct selection through female mate choice.

Parasites and predators: Mirhashemi Nasab et al. (2017) found *Diplostomum spathaceum* in fish from the Anzali Wetland with a prevalence of 18.18% and a range of 1-4 worms per fish.

Economic importance: Robins et al. (1991) listed this species as important to North Americans. Importance is based on its use in textbooks and aquaria and because it has been introduced outside its natural range. The species is used as a model in behavioural studies. Van Damme et al. (2007) regarded it as a parasite on freshwater mussel populations in western and central Europe outside its native range, escaping

glochidia infection and having low egg ejection rates.

Experimental studies: None.

Conservation: Lelek (1987) classified this species as rare to vulnerable in Europe and Fricke et al. (2007) as vulnerable in Turkey. Kiabi et al. (1999) considered this species to be of least concern in the south Caspian Sea basin according to IUCN criteria. Criteria include medium in numbers, widespread range (75% of water bodies), absent in other water bodies in Iran, and present outside the Caspian Sea basin. Listed as of Least Concern by the IUCN (2015, <https://newredlist.iucnredlist.org/>, downloaded 15 October 2018).

Sources: Iranian material:- CMNFI 1970-0506, 30, not kept, Gilan, Shalman River (37°08'N, 50°15'E); CMNFI 1970-0510, 21, 34.5-47.5mm standard length, Gilan, Golshan River (37°26'N, 49°40'E); CMNFI 1970-0512, 25, 26.6-43.9mm standard length, Gilan, Shalman River (37°08'N, 50°15'E); CMNFI 1970-0514, 2, 36.6-38.3mm standard length, Gilan, Shafa River estuary (37°35'N, 49°09'E); CMNFI 1970-0515, 1, 39.9mm standard length, Gilan, Shafa River estuary (37°35'N, 49°09'E); CMNFI 1970-0520, 7, 28.9-45.0mm standard length, Gilan, Astara River (ca. 38°25'N, ca. 48°52'E); CMNFI 1970-0522, 1, 36.1mm standard length, Gilan, Sefid River at Astaneh Bridge (37°16'30"N, 49°56'E); CMNFI 1970-0526, 4, 30.7-43.2mm standard length, Gilan, Sefid River below Astaneh Bridge (37°19'N, 49°57'30"E); CMNFI 1970-0542, 3, not kept, Gilan, Old Sefid River estuary (37°23'N, 50°11'E); CMNFI 1970-0567, 15, 19.7-28.8mm standard length, Gilan, Pir Bazar Roga River (37°21'N, 49°33'E); CMNFI 1970-0566, 40, not kept, Gilan, Old Sefid River estuary (37°23'N, 50°11'E); CMNFI 1970-0577, 1, not kept, Gilan, Caspian Sea at Astara (ca. 38°26'N, ca. 48°53'E); CMNFI 1970-0579, 8, 32.6-49.0mm standard length, Gilan, Old Sefid River estuary (37°23'N, 50°11'E); CMNFI 1970-0580, 6, 35.8-53.8mm standard length, Mazandaran, river near Iz Deh (36°36'N, 52°07'E); CMNFI 1970-0581, 11, 25.6-41.0mm standard length, Gilan, Caspian Sea near Hasan Kiadeh

(37°24'N, 49°58'E); CMNFI 1970-0583, 2, 34.6-35.7mm standard length, Gilan, Nahang Roga River (37°28'N, 49°28'E); CMNFI 1970-0590, 41, 37.9-53.3mm standard length, Mazandaran, Shesh Deh River near Babol Sar (ca. 36°43'N, ca. 52°39'E); CMNFI 1971-0343, 1, 29.2mm standard length, Gilan, Langarud at Chamkhaleh (37°13'N, 50°16'E); CMNFI 1979-0265, 9, 16.1-47.4mm standard length, Gilan, head of Anzali Talab at Abkenar (37°28'N, 49°20'E); CMNFI 1979-0472, 6, 37.7-47.7mm standard length, Mazandaran, stream 7km west of Mahmudabad (36°37'N, 52°12'E); CMNFI 1980-0117, 3, 42.2-47.8mm standard length, Gilan, Golshan River (37°26'N, 49°40'E); CMNFI 1980-0127, 9, 32.6-43.0mm standard length, Gilan, Caspian Sea near Hasan Kiadeh (37°24'N, 49°58'E); CMNFI 1980-0130, 1, 30.5mm standard length, Mazandaran, Iz Deh near Shilat Post (36°36'N, 52°07'E); CMNFI 1980-0131, 1, 37.3mm standard length, Iran, Caspian Sea basin (no other locality data); CMNFI 1980-0132, 1, 26.3mm standard length, Gilan, Sefid River at Kisom (37°12'N, 49°54'E); CMNFI 1980-0136, 1, 31.5mm standard length, Mazandaran, Fereydun Kenar River estuary (36°41'N, 52°29'E); CMNFI 1980-0140, 9, not kept, Gilan, Astara Talab close to sea (ca. 38°26'N, ca. 48°53'E); CMNFI 1980-0147, 3, 25.9-31.6mm standard length, Gilan, Lashtenesha (= Lasht Nesha') River (37°21'N, 49°52'E); CMNFI 1980-0149, 8, not kept, Gilan, Chapak River (37°21'N, 49°50'E); CMNFI 1980-0417, 5, 20.1-24.6mm standard length, Iran, Caspian Sea basin (no other locality data); CMNFI 1993-0135, 1, 40.1mm standard length, Mazandaran, Siah River, Qa'emshahr (36°46'06"N, 52°57'48"E); CMNFI 2008-0111, 2, 26.1-35.9mm standard length, Gilan, Caspian coast near Hendeh Khaleh (37°23'N, 49°28'E); CMNFI 2008-0112, 1, 49.7mm standard length, Gilan, swamp near Hendeh Khaleh (37°23'N, 49°28'E); CMNFI 1980-0122, 5, 31.1-40.8mm standard length, Mazandaran, Nerissi River (36°38'N, 52°16'E).

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مقاله مروری

مروری بر ماهیان مخرج لوله‌ای ایران (خانواده *Acheilognathidae*)

برایان کد

موزه تاریخ طبیعی کانادا، اتاوا، انتاریو، K1P 6P4، کانادا.

چکیده: در این مقاله مروری، سیستماتیک، ریخت‌شناسی، پراکنش، زیست‌شناسی و اهمیت اقتصادی ماهی مخرج لوله‌ای ایران شرح داده شده، تصاویری از آن ارائه گردیده و فهرستی از منابع موجود درباره این گونه لیست شده است. تنها یک گونه *Rhodeus amarus* در ایران وجود دارد که در حوضه دریای خزر یافت شده و به حوضه‌های دریاچه ارومیه و رودخانه تیگره نیز معرفی شده است. کلمات کلیدی: زیست‌شناسی، ریخت‌شناسی، ماهی مخرج لوله‌ای.