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Review Article

Review of the Freshwater Eels of Iran (Family Anguillidae)

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Abstract: The systematics, morphology, distribution, biology, economic importance and conservation of the freshwater eel (*Anguilla anguilla*) of Iran are described, the species is illustrated, and a bibliography on this fish in Iran is provided. The species is found in the Caspian Sea basin as an exotic.

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Introduction

The freshwater ichthyofauna of Iran comprises a diverse set of families and species. 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, while the relevant section of that website is now closed down.

Family Anguillidae

Freshwater eels are found world-wide in temperate to tropical waters except for the South Atlantic Ocean and the whole eastern Pacific Ocean. There are about 20 species in one genus (Eschmeyer and Fong, 2011) with one found in Iran.

The family is characterised by the elongate body, numerous vertebrae, small elliptical scales which are difficult to see casually, a small and elliptical gill opening just in front of the pectoral fin base, very long dorsal and anal fins confluent with a reduced caudal fin, a terminal mouth with the lower jaw projecting a little, small teeth in several rows on the jaws and palate, the dorsal fin origin well behind the pectoral fin level but in front of the anus level, no pelvic fins, and by a suite of osteological characters. The term eel-like is based on the body shape of freshwater eels and includes the muscular slipperiness associated with this fish and its mucus-producing skin.

The life cycle of Atlantic eels was unknown until Johannes Schmidt published his 1922 study based on years of collecting. Where the adults went on their seaward migration and where the elvers ascending rivers came from were a mystery. These eels are catadromous, living in fresh water but migrating to the sea to spawn and die. In the North Atlantic Ocean spawning occurs in the Sargasso Sea. The young eels or leptocephali (= thin head larvae) are distinctive, being transparent and leaf-like. A newspaper can be read through the body of a leptocephalus. In this form they drift to the shores of America and Europe, transform into elvers with the more familiar eel-shape and move into rivers and lakes to feed and grow. Some scientists believe that the European eel is not a distinct species but merely American eels (*Anguilla rostrata* (Le Sueur, 1817)) which develop in cooler areas of the Sargasso Sea and are carried by different ocean currents to the shores of Europe. Differences between the American and European eels overlap and include such characters as vertebral number which is known to vary with development

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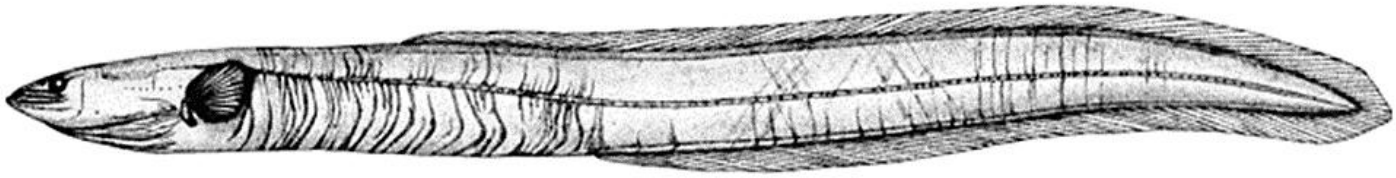

Figure 1. Line drawing of *Anguilla anguilla* by S. Laurie-Bourque.

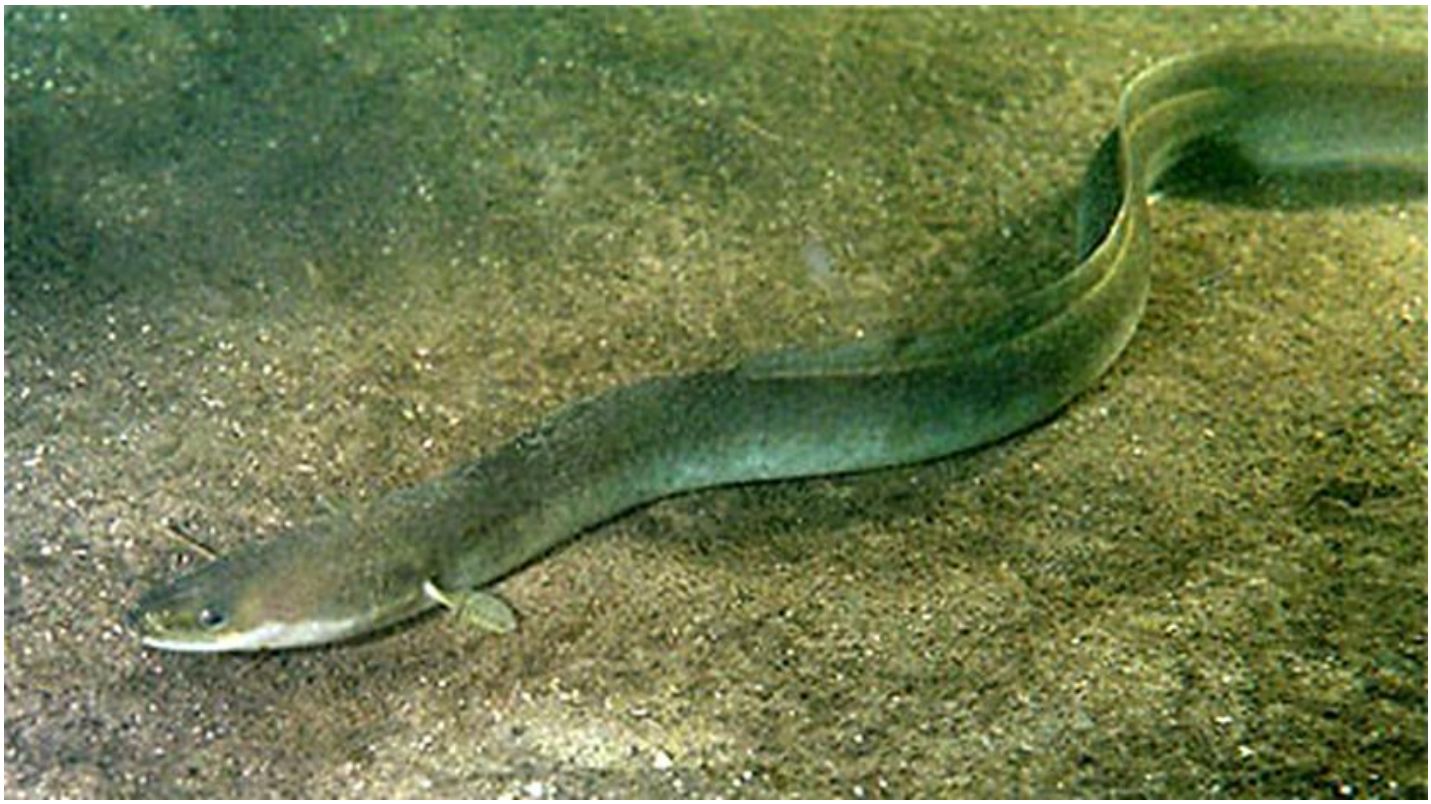

Figure 2. *Anguilla anguilla* from Wikimedia Commons.

temperature. Recent studies using mitochondrial DNA (mtDNA) showed no genetic divergence among samples of American eels along 4000 km of North American coastline reflecting a single spawning population. However, European eels had a distinct mtDNA genotype and the conclusion to be drawn is that American and European eels have separate spawning sites such that larval dispersal ends up on different continents. The mtDNA differences are marked but do not prove species distinction as this level of distinction is known to occur among fishes which are a single species (though some authorities would argue that these "single" species are themselves complexes of two or more species). However, Icelandic eels seem to be hybrids between the two putative species. All other evidence (vertebral and other counts, body proportions, biology, and electrophoresis) suggests that the American and European eels are the same species but have different spawning sites.

The biology of eels is based almost entirely on the freshwater phase of their life. Adults in fresh water develop large eyes, the gut degenerates and coloration changes in preparation for the migration to the Sargasso Sea. Adults were only caught in the deep ocean, at nearly 2000 m near the Bahamas, in 1977. The Sargasso spawning ground is deduced from collections of larvae across the Atlantic Ocean - the smallest and youngest larvae are found around the Sargasso Sea. The spawning grounds are at about

400 m, at a 17°C temperature and in saltier water than usual sea conditions according to some authors but since spawning adults have never been caught this remains dubious.

The theory advanced by D.W. Tucker in 1959 maintained that European eels lack the energy resources in their migratory, spawning phase to reach the Sargasso Sea 7000 km from Europe. They are presumed to be following an instinct to head out to sea, dating from an earlier geological age when the Atlantic Ocean was narrower before the separation caused by Continental Drift. All European eels die at sea and Europe is restocked by larvae drifting there spawned from American parents. The American populations are closer to the Sargasso and can make the journey easily. Differences between American and European eels are merely the consequence of different environmental regimes in different parts of the Sargasso. This theory has not found general acceptance but, if true, means that all European eels can be harvested for food without depleting stocks. Eels are valued as food, particularly in Europe and Japan. Hochleithner (2010) gives a review of eel biology and aquaculture.

Genus *Anguilla* Schrank, 1798

Characters of the family also serve for the genus.

Anguilla Anguilla (Linnaeus, 1758)

(Figs. 1-2)

Common names: Marmahi-ye ma'muli (= common snake fish), marmahi mohajer, meaning migrating snakefish), marmahi-ye haghighi. [rechnoi ugor' or river eel in Russian; European eel].

Systematics: No major synonyms. *Muraena anguilla* was originally described from Europe.

Key characters: The eel shape is characteristic along with the long and spineless dorsal and anal fins and the absence of pelvic fins. The Caspian lamprey, *Caspiomyzon wagneri*, has a similar shape but lacks pelvic fins, has seven gill openings in a row behind the eye, and has a round suctorial mouth.

Morphology: The scales are small, elliptical in shape and embedded in the skin. The lateral line is distinct. Some fish in any population may have a broad or a narrow head. Fish approaching sexual maturity develop very large eyes, the olfactory organs atrophy, the lateral line becomes more conspicuous, a tougher and thicker skin develops, and the colour changes as detailed below.

Dorsal fin rays 243-275, anal fin rays 175-249 and pectoral fin rays 15-21. Vertebrae number 110-120, usually 114-116. The chromosomes are 2n=38 (Klinkhardt et al., 1995).

The leptocephalus and elver stages are not found in Iranian waters and are not described here (see below under Reproduction).

Sexual dimorphism: At the silver eel stage males are 29-40 cm and females 38-130 cm long. Male adults are smaller than females.

Colour: Colour is variable but the back is usually grey-brown, olive-brown, brownish-green, yellowish or black and the belly is whitish to yellowish. The dorsal fin is dark, other fins are yellowish. The iris is yellow. This yellow or green eel stage changes to the silver or bronze eel at maturity. The mature fish is darker on the back, has silvery or bronze to coppery flanks and belly, a black pectoral fin and a clear contrasting black lateral line, as well as enlarged eyes.

Size: Attains 2.0 m, but rarely, and 12.7 kg, possibly 14.0 kg. Iranian specimens up to 1.0 m long have been caught near Bandar-e Anzali (Firouz, 2005).

Distribution: Common in Europe including the Mediterranean Sea, and east to the Black Sea although few young eels migrate naturally as far as this.

Occasionally caught in Iranian waters (P. Walczak, pers. comm. 1978; Holcík and Razavi, 1992). Holčík and Oláh (1992) report single specimens from the Anzali Mordab (= Talab) and its exit streams and near Bandar-e Anzali. Also reported generally from the southeast Caspian Sea, southwest Caspian Sea and south-central Caspian Sea (Kiabi et al., 1999). Reported from the Safid River and Anzali Talab by Abbasi et al. (1999), and also from the Sheikan River. Berra (2001) does not show the Iranian distribution because the fish are introduced.

Zoogeography: An exotic species in Iranian waters,

arriving there through the influence of mankind (Esmaeili et al., 2014, 2014). This species established itself in the Caspian Sea after the opening of the Volga-Baltic waterway and the introduction of larvae from France and England and was recorded from fresh waters in Azerbaijan by Abdurakhmanov and Kuliyev (1968).

Habitat: Eels are caught by fishermen between Bandar-e Anzali and the mouth of the Safid River in beach seines, in the Anzali Mordab and are probably present in rivers along the Caspian coast. The catch appears to be increasing (Holčík and Razavi, 1992). About 10-40 specimens are caught annually weighing up to 3 kg (Holčík and Oláh, 1992). In Europe freshwater populations show considerable migratory movements in summer and this helps explain their widening distribution in the Caspian Sea basin. However, Abbasi (2005) states that the population has decreased.

Eels will live in almost any kind of water over a wide range of temperatures (0-30°C at least); warmer waters being preferred as long as oxygen is not low. They are found at depths of 0-1000 m. They are found in small streams, large rivers, lakes and coastal waters, all connected to the sea for natural populations. Elvers flourish in sandy areas where grain size is 0.25 mm or in gravel areas where size is 2 mm or larger, the former for burrowing, the latter for insinuating between. Adults also prefer a substrate that can be burrowed into during the day, emerging at night. The burrows are usually at a 45° angle and the eel sticks its head out at this angle too. Eels show some migratory habits within fresh water, moving between summer and winter areas, over a distance of a few metres to tens of kilometres.

In Europe, eels in the silver eel stage begin to migrate to the sea in late summer and autumn on their journey to the Sargasso Sea where they arrive the following spring. They travel at about 2 km/hour, particularly at night when the moon is at or a few days after the last quarter and light levels are low. Iranian fish cannot migrate, being constrained by distance and lack of ready access to the open ocean.

Age and growth: Eels generally begin to mature only at sizes above 30 cm long. Females grow much larger than males and usually begin to mature at 54 cm or longer. Maturity is actually attained after leaving European waters en route to the Sargasso Sea. Eel larvae do not all metamorphose at the same age (this can vary from 1 to 6 years), with subsequent effects on age at the same length. In addition, growth varies widely with the habitat and available food supply. Fish of the same length often have very different weights. Average life span is usually 15-20 years. Life span is up to a reputed 88 years based on a captive specimen.

Food: Eels are principally nocturnal but feed both at night and during the day. Food includes almost any edible item and includes fish spawn, small fishes, and larger dead fish which have a mouthful of flesh torn off by a rapid rotation along the long axis of the eel body. Food includes insect larvae and algae but fishes, worms, crustaceans and molluscs are the most important items in order. In the southern Caspian, they have been reported to eat gobies (Gobiidae) and *Rutilus* sp. in November, suggesting that feeding continues late in the year in contrast to other waters where they dig into sand or silt and hibernate (Abdurakhmanov and Kuliyev, 1968). Eels will lie buried in mud or gravel with just the head projecting, seizing by a sudden strike any food item passing by. Eels will feed on commercially important species such as salmonids and crayfishes. They are reliably reported to even leave the water and enter fields, presumably to feed on slugs and worms.

Reproduction: This has not been observed in the wild but under artificial conditions eels are promiscuous and fertilisation is external. The eel is catadromous and is believed to spawn in the Sargasso Sea at 100-200 m depths off the coast of America after a long migration from Europe. Adults die after spawning. Spawning takes place at the beginning of March. Mature females contain 3 million eggs per 1 kg body weight. The ovary is a rosy-pink because of numerous blood vessels. The pelagic eggs are 1.2 mm in diameter. The eggs develop into a distinctive leptocephalus larva which has a leaf-like shape quite unlike the adult eel. During its leptocephalus phase,

the eel drifts on ocean currents and actively swims from the American side of the Atlantic, arriving in Europe in its third summer. It is now fully grown and 7.5 cm long. The larva gradually transforms into the elver at depths of 1000 m off the coast of Europe. The elver is eel-shaped and transparent and reduces in length and weight during the autumn when it does not feed. The elvers begin to migrate into rivers and lakes in Europe in winter. They are regarded as young eels once they begin to feed and are fully pigmented. The transition from a yellow to a silver eel stage lasts 6-12 years in males and 9-20 years in females.

Parasites and predators: There is a heavy toll on elvers which are taken on the migration into rivers and lakes by a wide variety of fish and birds. Adults are eaten by large fishes including larger eels and by birds such as herons and cormorants. A large variety of parasites have been reported from eels.

Economic importance: Not used in Iran for food, probably because its minute scales make it appear scaleless, and in any case the annual catch is only about 40-60 specimens (Holčík and Razavi, 1992). It is of considerable economic importance in Europe where annual catches have reached 22,000 tonnes. The 1981 catch in Turkey, for example, was 374 tonnes. This species is also farmed quite extensively. The flesh has a high fat content and the eel is often smoked for sale.

The blood of this fish is poisonous but the poison is destroyed by cooking. Fresh eel blood should never be ingested. A dog injected with eel serum died within one minute. Symptoms include diarrhoea, bloody stools, nausea, vomiting, frothing at the mouth, skin eruptions, cyanosis, apathy, irregular pulse, weakness, numbness, paralysis, respiratory distress, and death. Severe inflammations will result if the blood touches the eye or tongue.

Robins et al. (1991) list this species as important to North Americans. Importance is based on its use in aquaculture and aquaria, as food, for sport and in textbooks

Conservation: The peculiar migratory behaviour of this species prevents spawning in Iranian waters and all stocks must be replenished through migration from European waters or by artificial introductions. As a non-reproducing, exotic species, no conservation measures are required. Critically Endangered in Turkey (Fricke et al., 2007) and throughout its range (IUCN, 2014) with a suite of reasons for this status, e.g., barriers to upstream and downstream migration caused by dams and mortality by hydropower turbines, pollution, etc.

Sources: There is little information on this species in Iran because of its scarcity and general biology is taken from Bertin (1956), Tesch (1973), Sinha and Jones (1975), Deelder (1984), Hoestlandt (1991) and IUCN (2014). These works should be consulted for the extensive data on biology and economic importance of this fish.

Comparative material: CMNFI 1983-0359, 3, 63.6-180.9 mm total length, Italy, Rio Porra at Finale Ligure (no other locality data); CMNFI 1986-0458, 2, 287.5-434.0 mm total length, Germany, Danube River at Frengkofen (48º58'N, 12º18'E); CMNFI 1986-0462, 1, 209.9 mm total length, Germany, Vils River at Mettenhausen (48º32'N, 12º50'E)..

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