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Review Article

Review of the Perches of Iran (Family Percidae)

Brian W. Coad

Canadian Museum of Nature, Ottawa, Ontario, K1P 6P4 Canada.

Abstract: The systematics, morphology, distribution, biology, economic importance and conservation of the perches of Iran are described, the species are illustrated, and a bibliography on these fishes in Iran is provided. There are three species, *Perca fluviatilis*, *Sander lucioperca* and *S. marinus*, found naturally in the Caspian Sea basin, with *S. lucioperca* translocated.

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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 for one family, while the relevant section of that website is now closed down. Other families will also being addressed in a similar fashion.

The perches, darters, pike-perches and their relatives comprise a family, the Percidae, of mostly freshwater species found across the Northern Hemisphere. There are about 10-11 genera and about 226 species (Nelson, 2006; Eschmeyer and Fong, 2011) with estimations up to 275 species (Kestemont et al., 2015). There are three species in two genera in Iran. Maximum size approaches 1 m but many species (the darters particularly) are small.

They are characterised by ctenoid scales; a dorsal fin with an anterior spiny portion and a soft rayed posterior portion; an anal fin with 1-2 spines (rather than 3 as in related families) and a few soft rays; pelvic fins thoracic in position, with 1 spine and 5 soft rays; branchiostegal membranes not attached to the isthmus; branchiostegal rays 5-8; teeth on the jaws, vomer and palatines in patches, sometimes with canine teeth; and the operculum has a sharp spine.

Perches are found in warm southern waters to subarctic ones, in both flowing and still water. Some larger species are commercially important while smaller species make attractive aquarium fishes. The small darters of North America rival coral reef fishes for colour in their breeding condition. Perches have a variety of reproductive strategies which include broadcasting, stranding, burying, attaching, clumping and clustering. During the breeding season tubercles develop, particularly on the male. These may be on the body, fins or head and are used to maintain contact and enhance grip between males and females during the spawning act.

Genus *Perca* Linnaeus, 1758

This genus comprises two species, one found in North American and one in Eurasian, fresh waters.

The body is compressed, scales are small and ctenoid, cheeks and gill covers are scaled, the opercular bone carries a single flat spine, the preopercle is serrated posteriorly and has spikes ventrally, there are no canine teeth, branchiostegal rays 7, the lateral line does not continue onto the

* Corresponding author: Brian W. Coad
E-mail address: bcoad@mus-nature.ca

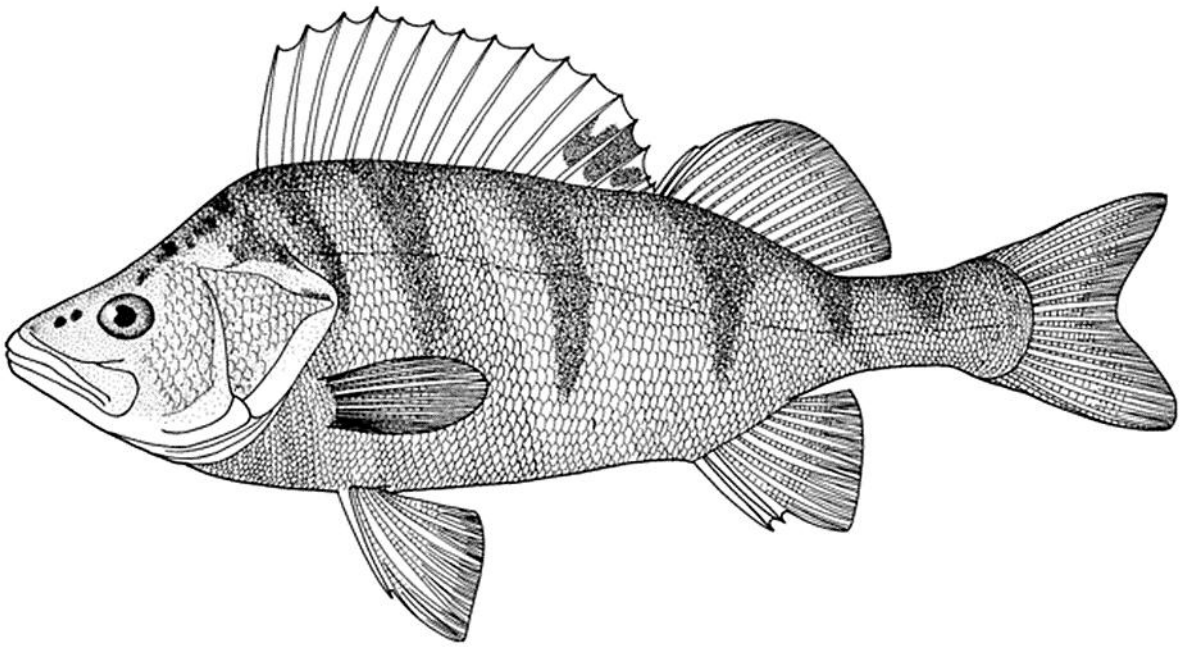

Figure 1. *Perca fluviatilis*, line drawing by S. Laurie-Bourque.

Figure 2. *Perca fluviatilis*, Anzali Wetland June 2012, courtesy of K. Abbasi

caudal fin, and the body usually has strong bars.

Perca fluviatilis Linnaeus, 1758
(Figs. 1-2)

Common names: Mahi-ye khardar, bacheh suf (=baby suf), mahi suf rudkhanehi Astrakhan (=Astrakhan river suf fish, presumably an old name at this Russian locality, suf-e Haji Tarkhan (=Astrakhan suf, an old name no longer in use), suf-e rudkhaneh'i (=river suf), hashtarkhan suf. [xanibaligi in Azerbaijan; okun' in Russian; perch, European perch, Eurasian perch, river perch].

Systematics: *Perca fluviatilis* was originally described from Europe. A syntype (BM(NH) 1853.11.12.3) is a right half-skin. Collette and Bănărescu (1977) refute earlier workers who maintain that this species and the North American yellow perch (*Perca flavescens* (Mitchill, 1814)) were the same or at best subspecies, e.g., see Svetovidov and Dorofeeva (1963) and Čihar (1975) for opposing views. .Collette and Bănărescu (1977) base their conclusion on the observation that the predorsal bone is anterior to the first neural spine in *fluviatilis* rather than extending between the first and second neural spines as in *flavescens*. Other characters also exist to separate the two species. Data on the North American perch cannot therefore be used uncritically as a summary of biology for the

Iranian perch.

Systematics: No major synonyms.

Key characters: Characters of the genus serve to identify the single, distinctive species in Iran.

Morphology: Lateral line scales 40-78; scale rows above lateral line 7-10; rows below lateral line 12-22; and predorsal scales 10-21. Scales have very fine circuli, few anterior radii, a posterior focus and a markedly incised anterior margin where about 5-7 radii terminate. The exposed part of the scale is coarse and is the base for ctenii, best developed on the margin. Dorsal fin spines 12-18; dorsal soft rays 8-17, usually 12-15, after 0-5, usually 2-3 spines; anal fin soft rays 6-11 after 1-3 spines; pectoral rays 9-17; and pelvic rays 4-6, usually 5 after 1 spine. Gill rakers 23-25, reaching between the third and fourth rakers below when appressed usually, but variable in length with diet, shortest when feeding on fish, longer when food is zooplankton. The gut is s-shaped with a large anterior loop and there are 3 pyloric caeca. Vertebrae 38-44, and gill rakers 14-29. The chromosome number is 2n=48 (Klinkhardt et al. 1995).

Meristic values for Iranian specimens are: lateral line scales 59(4), 60(2), 61(2); scale rows above lateral line 9(7); rows below lateral line 17(4), 18(2), 19(1); scales between lateral line and pelvic fin 6(2), 7(5); predorsal scales 10(1), 11(2), 12(1), 13(2), 14(1); and caudal peduncle scales 24(1), 25(1), 26(1), 27(3), 28(1); dorsal fin spines 13(1), 14(2), 15(1), 16(4); dorsal soft rays 13(3), 14(5) after 2 spines; anal fin soft rays 8(3), 9(3), 10(1) after 2 spines; pectoral rays 11(2), 12(2), 13(3), 14(1); pelvic rays 5(8) after 1 spine; vertebrae 40(2), 41(3), 42(1).

Sexual dimorphism: Males have longer paired fins than females and are brighter in colour. Females are larger than males of the same age.

Colour: Colour can be affected by diet, especially in the fins which are reddest when feeding on certain crustaceans, and by habitat depth but generally the colour is stable. Fish from along the shore in weedy habitats are greenest, those in open water a pale yellow, and at depth are darker. The body is an overall greenish-yellow with 5-9 black bars on the flanks although in some fish bars are very faint. The first dorsal fin is grey with black markings on the membranes. The first spine is often black and deep black membranes are evident between spines 1 and 2 and the last 4 to 5 spines. The second dorsal fin is greenish-yellow with melanophores on the rays and membranes, the pectoral fin yellowish and other fins pinkish to yellow to silvery-white. Paired and caudal fins have much sparser melanophores than the second dorsal fin. The lower part of the caudal fin is orange to red. The peritoneum is silvery and speckled with melanophores.

Size: 68.0 cm and 7.0 kg, possibly 10.4 kg but most are much smaller than this (Machacek, (1983-2012), accessed 27 July 2012).

Distribution: Found from the British Isles across northern Eurasia to eastern Siberia. Their presence in the Caspian Sea basin of Iran is their most southerly natural distribution. Also introduced to South Africa, Australia and New Zealand.

In Iran, it has been reported from the Aras Dam, the Hendeh Khaleh swamp in Gilan, Anzali Wetland (= Mordab or Talab) and its outlets, Ab Kenar and Siah Keshim Protected Region in the Anzali Talab, at Bandar Anzali, Bandar Anzali beach, the lower Safid River, the Amirkelayeh Wetland, and the Golshan, Pesikan, Shahrud and Sheikan rivers (Derzhavin, 1934; Holčík and Oláh, 1992; Riazi, 1996; Karimpour, 1998; Abbasi et al., 1999; Abdoli, 2000; Abdoli and Naderi, 2009; Hamzei et al., 2013; Esmaeili et al., 2014). Jolodar and Abdoli (2004) restrict its presence to the Anzali Wetland and rivers draining into it. Anderson (1880) reports perch to be abundant in the Lar River near Tehran, but this is probably a misunderstanding at this early date.

Zoogeography: Its closest relative is found in North America and they were once thought to be the same species on both continents.

Habitat: Distribution is limited by an inability to survive a temperature of 31°C for more than a few hours, by an inability to tolerate salinities above about 10-12‰ and by avoidance of waters with an oxygen level of less than 3ml L^{-1}. The upper lethal

temperature is 33.5°C (Collette et al., 1977). Fresh water is required for spawning. Riazi (1996) reports that this species is native (resident) to the Siah Keshim Protected Region of the Anzali Wetland and it is also reported from swamps near Hendeh Khaleh in Gilan.

Optimal conditions are large, weed-free, moderately deep, mesotrophic waters with food fish such as *Rutilus rutilus* readily available. Turbidity is a limiting factor for this species which depends on sight to feed. It is found only in the lower reaches of rivers along the Iranian shore and does not penetrate upstream (Berg, 1948-1949). Nevertheless it can be found in both running and still water and in both small and large water bodies.

Perch are a schooling fish, arranged by size and age. Schools form in the morning and disperse as dusk falls. Schools usually number about 50-200 fish but schools in the thousands are reported. There is a nocturnal resting area and perch move from it to a diurnal active area. The perch may move short distances within a lake and in large water bodies over 90 km but show strong homing tendencies. Seasonal movements are between feeding, spawning and overwintering areas.

Different morphs are found in some areas, depending on habitats: one small, slow-growing, dark and gregarious, feeding on small crustaceans, and found in reed beds, the other large, fast-growing, light and solitary, feeding on fish, and found in open waters.

Populations in the Safid River were supposedly increased after construction of the dam which reduced water flow and raised temperatures.

Age and growth: Maturity in males is usually attained in the second year of life (at only 5-12 cm long) with females maturing 1-2 years later (at 12-18 cm or larger). However some males may mature during their first year or as late as their third. Females grow slightly faster than males after the first 1-2 years. Eutrophication may reduce the age of first maturity because of increased growth rates. Perch in different habitats within the same water body, e.g., weeds beds as opposed to open water, will show different growth rates and body forms. Growth over the whole range of the species varies markedly. Generally fish at age 2 which are greater than 20 cm total length are characterised as having very good growth, moderate growth would be fish at age 3 greater than 16 cm total length while a very poor growth would be evidenced by all fish in the population being less than 16 cm total length. Life span is up to at least 21 years and under artificial conditions up to 27 years, perhaps even 50 years. A maximum age of 11 years is given for a Volga delta population examined by Makarova (1986).

Nezami et al. (2004) found fish in the Amirkelayeh Lagoon or Wetland on the Caspian coast of Iran were in age groups 1^+ to 6^+, had a total length of 9.5-33.5 cm and a weight of 10.5-350.0 g. Heydarnejad (2009) gave the length-weight relationship for an Iranian sample as $W=0.0145TL^{3.011}$. Saemi et al. (2012) determined growth rate and maximum length for Anzali Wetland fish were 0.31 and 21.17 cm in males and 0.33 and 21.0 cm in females, there was no sex ratio variation throughout a year although some months fluctuated, and length-weight relationships were $W=0.011 FL^{3.055}$ for males and $W = 0.024FL^{2.82}$ for females. Differences with perch from other geographical regions were attributed to lack of appropriate food and the degraded environment in the Anzali Wetland. Vafajooy Dianati et al. (2013) examined 265 fish from the Amirkelayeh Wetland and found fish were age 2^+ to 6^+ years, age groups 2^+ to 3^+ with average instantaneous growth rate of 0.461 grew fastest while age 5^+ to 6^+ with 0.231 grew slowest, males outnumbered females, females had the highest condition factor (2.49) and males the lowest (1.06), and growth rates were almost isometric with a tendency to positive allometric for males, females and all fish. In the Anzali Wetland, Ashja et al. (2010) found females (63%) outnumbered males (37%). Vafajo Dyanti et al. (2013) found fish in the Amirkelayeh and Anzali wetlands matured at age 2-3 years and fish up to 5 years were caught, males having an average total length of 22.5 cm, 158 g and gonad weight 7.15 g. There was no significant

difference in gonadosomatic index between male broods. Komsari et al. (2015) determined the von Bertalanffy growth functions for 286 Anzali Wetland fish were $L_t=21.0(1-e^{-0.33(t-0.9)})$ for females and $L_t= 21.17(1-e^{-0.31(t-0.8)})$ for males, the length-weight relationship was $W=0.011TL^{3.1}$ for males and $W=0.024TL^{2.8}$ for females, positive and negative allometry, respectively, there were no differences in sex ratio throughout the year although there was in some months attributed to gathering of spawning males and post-spawning feeding behavior of females, age was 2 to 7 years with a median of 4.6 for females and 4.8 years for males.

Food: Food for small perch is zooplankton such as rotifers, switching to insect larvae, crustaceans, molluscs and leeches with growth (larger than about 20 mm). Growth is enhanced if fish and crayfish are available. Fish predominate in the diet at a range of sizes between 10 and 25 cm. In the Caspian basin, *Rutilus rutilus*, *Blicca bjoerkna*, *Pungitius platygaster* and gobies (Gobiidae) are eaten (Makarova, 1986). Some slow-growing perch may feed on plankton until 2-3 years old. Cannibalism is common. Maximum feeding levels occur in summer and, by autumn, has fallen to a maintenance level (Collette et al., 1977; Popova and Sytina, 1977). Feeding is a daylight and highly visual activity. Feeding is more effective in shoals as the perch attempts to seize other fish by the head and, if an individual perch misses, then other members of the shoal have an opportunity to seize the prey. Large perch lie in wait for passing prey items and then dart out to seize them. Unlike northern pike, perch will pursue a prey item if it tries to escape.

In the Amirkelayeh Lagoon or Wetland diet varied according to age, season and sex, and comprised a wide variety of organisms such as water bugs, odonates, gammarids, plant materials, chironomids, *Tinca tinca*, hemipterans, *Perca fluviatilis*, snails, *Syngnathus caspius*, *Gambusia holbrooki*, *Pungitius platygaster*, dipterans, branchiopods, trichopterans, tubifex, frogs and shrimps. The species is an omnivore here and a cannibal (Nezami et al., 2004).

Reproduction: Spawning occurs in the spring in shallow water, 0.5-3.0 m deep, end of March to early June in the Volga Delta (Makarova, 1986). In Dagestan, spawning is from the end of March to the beginning of April and lasts 10-15 days (Shikhshabekov, 1978), elsewhere only 2-3 days. Water temperatures are around 11°C on the Volga (Lönnberg, 1900) and above 8°C in Dagestan (Shikhshabekov, 1978) but can occur under ice at 4°C. Up to 80% of the spawning population in the Volga Delta is female (Makarova, 1986). There is a spawning migration from deepwater resting areas to shallow spawning areas. Males precede females onto the spawning ground by days or weeks and remain behind after spawning. Brackish-water populations migrate into fresh water. Spawning itself can occur by day or by night.

Absolute fecundity in the Anzali Wetland reached 35,942.93 eggs and egg diameter reached 42.25 µ (sic) based on 254 fish (Ashja et al., 2010) or 18,312.6 for 5-year-old fish from a 60 fish sample (Hayatbakhsh et al., 2010). The latter study found maximum average relative fecundity at 122.9 and gonadosomatic index at 16.11 was for three-year-old fish. Komsari et al. (2014) looked at the reproduction of 324 Anzali Wetland fish and found a long vitellogenic process (October to February) and a short spawning season (January and February, about two weeks long), maximum gonadosomatic index was in January for females (15.57) and minimum was in August (0.2) and for males maximum was in January (6.84) and minimum in June (0.04), group-synchronous ovarian development occurred, ovarian development occurred in only one clutch of oocytes (700-900 µm) with no maturation of any subsequent clutch, the average realized fecundity was 16,177 eggs in the late vitellogenic stage, lower than potential fecundity at 17,188 eggs, and mean relative fecundity was 141.12 eggs/g.

Although temperature is the major factor affecting the timing of spawning, the occurrence of spring floods is significant in some populations as it gives access to inundation zones of large rivers. Eggs are twisted around plants, roots and logs in an egg-

strand, a cylindrical, hollow, twisted structure up to 3.75 m long, 3.8 cm thick and 8 cm wide. This structure offers protection from predators, fungal infections, desiccation, mechanical damage and smothering in the mud. Egg diameters reach 2.5 mm and fecundity 300,000 eggs. Fecundity increases with age and depends on food supply as in most fish species. As many as 15-25 males queue up to fertilize the egg-strand, following the female as she twists around the logs and plants, rubbing against the plants to void the eggs. The female drives the males away from the egg-strand after fertilisation and may guard the egg-strand for some hours.

Parasites and predators: Mokhayer (1976) records the protozoan *Trypanosoma percae* from this species in the Caspian Sea basin, the nematode larva *Eustrongylides excisus* and the annelid *Piscicola geometra*. Khara et al. (2006) record the eye fluke *Diplostomum spathaceum* for this fish in the Amirkelayeh Wetland in Gilan. Sattari et al. (2002) and Sattari (2004) records the presence of the nematode, *Eustrongylides excisus*. This parasite can damage muscles in commercial species and render them unsuitable for sale. Sattari et al. (2006; 2007) surveyed this species in the Anzali and Amirkelayeh wetlands, recording *Raphidascaris acus*, *Eustrongyloides excisus* and *Camallanus lacustris*. Khara et al. (2005) examined this species in the Amirkelayeh Wetland and found its diversity of parasites to be less than other predatory species such as *Esox lucius*. Parasites recorded were *Camallanus lacustris*, *Diplostomum spathaceum*, *Lernaea* sp., *Argulus* sp., and *Dactylogyrus* sp.. Sattari et al. (2007) record the nematode *Eustrongylides excisus* and the digenean *Diplostomum spathaceum* in this species in the Anzali Wetland of the Caspian shore. Barzegar et al. (2008) record the digenean eye parasite *Diplostomum spathaceum* from this fish. Barzegar and Jalali (2009) reviewed crustacean parasites in Iran and found *Achtheres percarum* on this species.

Anvarian et al. (2012) and Hamzei et al. (2013) isolated the bacteria *Lactobacillus fermentum* and *L. plantarum* from Aras Dam fish intestines using molecular techniques. These bacteria play an important role in producing antimicrobial substances, immune response enhancement and increasing nutrient availability. Anvarian et al. (2014) characterised the human pathogen *Aeromonas hydrophila*, which causes gastro-enteritis, on the skin and in the intestine of 35% of fish sampled from the Aras Dam, presumably from sewage contamination.

Sander lucioperca, *Esox lucius* and *Lota lota* are predators on perch in the Caspian basin and doubtless other large fishes and birds take this species. Ashoori et al. (2012) found that grey herons (*Ardea cinerea*) in the Siah Keshim Protected Area of the Anzali Wetland ate this species. Cannibalism begins as early as the fry stage when fish only 2.1 cm long eat smaller fry.

Economic importance: Holčík and Oláh (1992) report a catch of only 15 kg in the Anzali Wetland in 1990. This species has been studied for aquaculture in Iran.

Rahbar et al. (2011) and Hayatbakhsh et al. (2014) surveyed the haematology of Anzali Wetland perch, useful in assessing, for example, stress levels when handled. Rustaiyan et al. (2012) found that muscle tissue of male and female perch is rich in the omega-3 fatty acid docosohexanaenoic acid, important in the human diet, as well as other significant fatty acids. Salimi and Esmaeili (2012) fed larval perch experimental diets with various protein levels and found growth performance and feed conversion increased with protein level from 246 to 550 g/kg, protein efficiency ratio declined linearly with increased protein, survival was not affected by dietary composition and the protein requirement ranged between 489 and 530 g/kg.

Ashja Ardalan et al. (2009) found differences between fish from the Abkenar and Sheyjan areas of the Anzali Wetland in heavy metal content (copper, lead, mercury and zinc) in muscle and liver tissues, indicative of environmental pollution loads at the two localities. Baramaki Yazdi et al. (2012) found metal concentrations in this species from the Anzali Wetland in descending order were Zn, Cu, Pb, Cr

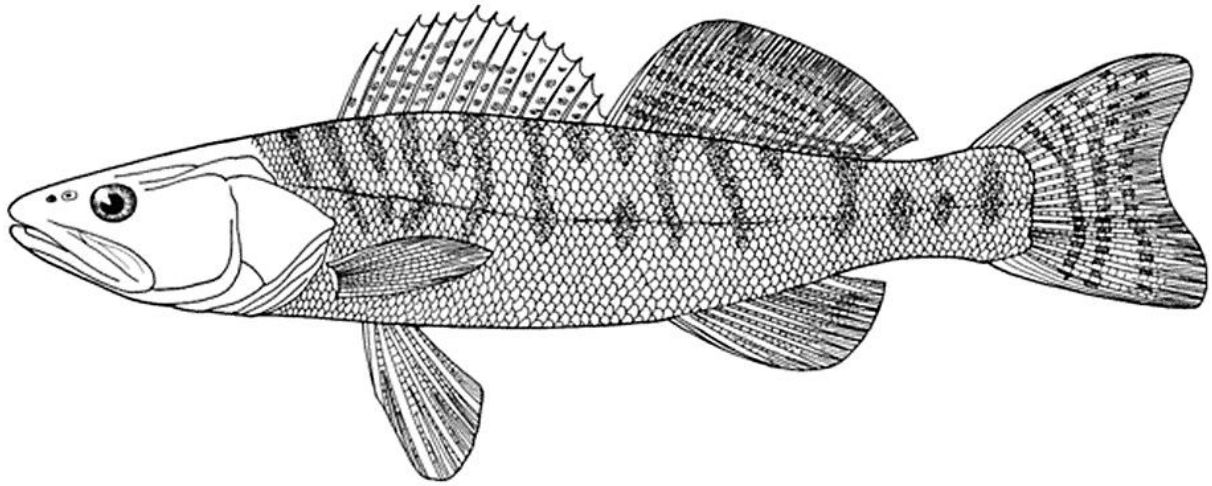

Figure 3. Line drawing of *Sander lucioperca* by S. Laurie-Bourque.

and Cd and all except Cr are below levels of concern for humans.

Robins et al. (1991) list this species as important to North Americans. Importance is based on its use in aquaria and aquaculture, as food, in sport, in textbooks, in experiments and because it has been widely introduced outside its natural range. It has been implicated in ichthyootoxism (Coad, 1979).

Conservation: Illegal fishing and non-standard nets threaten stocks of this species (Annual Report, 1995-1996, Iranian Fisheries Research and Training Organization, Tehran, p. 55, 1997). Kiabi et al. (1999) consider this species to be vulnerable in the south Caspian Sea basin according to IUCN criteria. Criteria include commercial fishing, sport fishing, medium numbers, habitat destruction, limited range (less than 25% of water bodies), absent in other water bodies in Iran, and present outside the Caspian Sea basin. Shapoori and Gholami (2005) found the fishery not to have changed despite millions of fry being stocked. The IUCN Red List of Threatened Species (2015) lists this species as of Least Concern.

Sources: General biology is based on Thorpe (1977) and Craig (1987), and there is extensive European angling literature on this species. Further details on collections examined can be found in the museum catalogues.

Iranian material: CMNFI 1970-0510, 1, 156.8 mm standard length, Gilan, Golshan River (37º26'N, 49º40'E); CMNFI 1979-0685, 1, 71.5 mm standard length, Gilan, Safid River around Mohsenabad below Dehcha (no other locality data); CMNFI 1980-0123, 1, 68.9 mm standard length, Gilan, Safid River around Dehcha above Mohsenabad (no other locality data); CMNFI 1980-0127, 1, 152.8 mm standard length, Gilan, Caspian Sea near Hasan Kiadeh (37º24'N, 49º58'E); CMNFI 1980-0148, 2, 118.2-142.1 mm standard length, Gilan, Pir Bazar Roga (37º21'N, 49º33'E); CMNFI 2008-0110, 1, 89.9 mm standard length, Gilan, swamp near Hendeh Khaleh (37º23'N, 49º28'E).

Genus *Sander* Oken, 1817

This genus is found in both North America and Eurasia and contains five species. There are three species in the Caspian Sea basin, two of which are reported from Iran. The Shahid Beheshti hatchery on the Safid River breeds the third species, *S. volgense* (Gmelin, 1789), a northern Caspian Sea species, according to Raymakers (2002) but it is unclear if these have been released and have established populations in the southern Caspian Sea.

The genera *Stizostedion* Rafinesque, 1820 and *Lucioperca* Schinz in Cuvier, 1822 are junior synonyms of *Sander* (see Kottelat 1997). The pike-perches are elongate and compressed, have large jaws reaching back beyond mid-eye level, canine teeth on the jaws and palatines, the preopercle is

Figure 4. *Sander lucioperca*, Aras Reservoir, March 2012, courtesy of K. Abbasi.

serrated posteriorly and has spines ventrally, the opercle has a weak, flat spine at its postero-dorsal corner, cheeks are naked or scaled only dorsally, there are 7-8 branchiostegal rays, adult gill rakers are densely denticulated tubercles, in young denticulated rods, and the lateral line continues onto the caudal fin with accessory lateral lines on the upper and lower caudal lobes. Divergence between North American and Eurasian members of this genus may have occurred in the middle to late Miocene or in the Pliocene (Billington et al., 1990, 1991; Faber and Stepien, 1998).

Sander lucioperca (Linnaeus, 1758)

(Figs. 3-4.)

Common names: Suf, suf-e ma'muli or soof-e-maamooli, meaning common suf, sibey(ak) in Gilaki, ? sevideh. This may be the fish referred to as sevideh from the Langarud Mordab (=Wetland) by Holmes (1845). However, the word may be sepideh which means "the white one" and may in fact refer to *Rutilus kutum*, the safid mahi. [sif, caysifi or quaysifi in Azerbaijanian; adaty silebalyk in Turkmenian; sudak in Russian; pike-perch, European pikeperch, zander].

Systematics: *Perca Lucioperca* was originally described from European lakes, no types are known.

Akbarzadeh et al. (2007, 2009, 2009) identified three distinct populations in the southern Caspian Sea and Aras Dam using a truss analysis with morphometric characters (body heights and caudal peduncle measures) showing better discrimination than meristic characters. Gharibkhani et al. (2009, 2014) examined the population genetic structure of fish from the Talesh coast, Anzali Wetland, Aras Dam and Chaboksar coast and found them to be genetically differentiated in spite of low genetic variation, with consequences for conservation. The greatest genetic distance was between Anzali and Aras populations. Gharibkhani et al. (2011) used microsatellite markers to study the genetic diversity of fish from the Anzali Wetland and found it to be low, attributing this to artificial propagation of the species. Mirza Ahamdi et al. (2015) used microsatellite markers to examine genetic structure and variation in fish from Aras Dam Lake and the Anzali Wetland, finding significant genetic differentiation.

Key characters: This species is separated from *S. marinum* by the dorsal fins being close together, obviously much less than the eye diameter apart, the anal fin spines are not closely joined to the soft rays, the interorbital width is less than, or equal to, the vertical eye diameter in adults, the upper jaw extends rearwards on a level behind the posterior eye margin in adults (under the rear of the eye in young), there are usually more than 18 soft rays in the dorsal fin, and the spiny dorsal fin bears large spots.

Morphology: Lateral line scales 75-150 (this wide range from various literature sources presumably includes counts of scales in the lateral line, and other counts which are of smaller scales to one side of the lateral line; Berg (1948-1949) gives a count of 80-97

for example, which is inherently more reasonable). Scales above the lateral line 12-17 and scales below the lateral line 16-24. Scales are incised on the anterior margin where about 6-9 radii terminate, although not as incised as in *Perca fluviatilis*. The focus is posterior. Ctenii are well-developed. First dorsal fin spines 11-17; second dorsal spines 1-4 and soft rays 16-27, usually 19-24. Anal fin spines 1-3, soft rays 9-14. Pectoral fin branched rays 11-18 and pelvic fin branched rays 5. Stubby, spinulose gill rakers number 10-17 and vertebrae 40-48, usually 45-48, mode 46. There are 4-9 pyloric caeca. The gut is relatively short but has a long anterior loop. The chromosome number is 2n=48 (Klinkhardt et al., 1995; Miri Nargesi et al., 2007) although the latter authors found a different karyotype formula in Iranian fish compared to other populations (2n=1m+13sm+4st+6a).

Meristic values for Iranian specimens are:- lateral line scales 82(1), 86(1), 89(1), 90(1), 91(3); scales above the lateral line 13(1), 14(4), 15(1); scales below the lateral line 21(2), 22(1), 24(2), 25(1); caudal peduncle scales 33(3), 34(3); first dorsal fin spines 13(3), 14(4); second dorsal soft rays 20(2), 21(2), 22(1), 23(2); anal fin soft rays 11(4), 12(1) 13(2); pectoral fin branched rays 13(2), 14(2), 15(3); pelvic fin branched rays 5(7); and vertebrae 45(3) or 46(3).

Sexual dimorphism: Females have a much lighter, whitish belly than that of males which is marbled blueish in the spawning season. The genital papilla of females protrudes.

Colour: The back and flanks are green to blue-grey to brown-black, the belly is white to bluish and fins are yellow-grey. The dorsal and caudal fins have rows of black spots on the membranes, largest and most distinctive on the spiny dorsal fin. Other fins are pale yellow. The eye is silvery because of reflection from the tapetum lucidum. Young have 8-13 brown to blackish-brown bars but these usually fade with maturity. The peritoneum is silvery to brownish in preserved fish.

Size: Up to 1.5 m and 20.0 kg. The Iranian commercial catch in the 1950s was 24-60 cm long and weighed 1.6-2.7 kg, declining to 0.6 kg (Farid-Pak, no date).

Distribution: Found in the basins of the Baltic, Aegean, Black, Caspian and Aral seas. In Iran, reported in the Aras River (and Aras Dam Lake) and along the whole Caspian coastal plain from Astara to the Atrak River including the Talesh and Chaboksar coasts, Amirkelayeh Wetland near Lahijan, Gomishan Marshes or Wetland, Gorgan Bay, Anzali Wetland and Siah Keshim Protected Region, the Babol, Gorgan, Haraz, Harisak, Langarud, Marbureh, Nek, Qareh Su, Rasteh, Safid and Shahrud rivers, as well as in the southeast Caspian Sea, southwest Caspian Sea and south-central Caspian Sea (Nedoshivin and Iljin, 1929; Derzhavin, 1934; Kozhin, 1957; Griffiths et al., 1972; Holčík and Oláh, 1992; Nejatsanatee, 1994; Riazi, 1996; Karimpour, 1998; Abbasi et al., 1999; Kiabi et al., 1999; Abdoli, 2000; Ghasempouri and Esmaili Sari, 2002; Jolodar and Abdoli, 2004; Abdoli and Naderi, 2009; Gharibkhani et al., 2009, 2014; Tabatabaie et al., 2011; Esmaeili et al., 2014).

This species has also been stocked in the Zarreinerud, 70 km upstream of Miandoab in 1971 (Griffiths et al., 1972) and in the Talkheh River, both in the Lake Urmia basin, in the Valasht Lake near Marzanabad, Evan Lake northeast of Qazvin, Ghorigol Lake near Tabriz, Marivan Lake in Kordestan, the Chamzarivar River in the Tigris River basin, and the Haft Barm Lakes west of Shiraz (Anonymous, 1977). Teimori et al. (2010) record it as introduced in the Kor River basin of Fars. Although this species has been introduced to the Manjil Reservoir on the Safid River (Nümann, 1966; Griffiths et al., 1972), this reservoir is drained to remove excess silt and no fishery exists (J. Holčík, pers. comm. 1992). Nümann (1966) recommended introduction of *S. lucioperca* to the Dez Dam and the Karaj Reservoir. However, introductions to reservoirs in Khuzestan did not survive (M. Al-Mukhtar, pers. comm. 1995). CIRSPE (2006) lists *S. lucioperca* as being present in Sistan but this may be an error.

It is also found in the Karakum Canal and

Kopetdag Reservoir of Turkmenistan (Sal'nikov, 1995) and may eventually reach the Iranian Tedzhen (=Hari) River basin.

Zoogeography: The relationships of this species are discussed under the genus.

Habitat: Generally this species is found in small schools near sandy and stony bottoms in deeper water of rivers. Ideally there should be some concealment. It can also live in reservoirs. This species has both freshwater and semi-anadromous forms in the Caspian Sea basin. It has a limited migratory behaviour such that morphologically distinct stocks may exist in larger water bodies. The population of the Anzali Wetland represents a separate stock (Hydrorybproject, 1965). Riazi (1996) and Karimpour (1998) report that this species migrates into the Siah Keshim Protected Region of the Anzali Wetland and is also resident there. Most movements of this species are within 10-20 km although distances up to 300 km have been recorded in the Volga River. Suf show strong homing tendencies. The upper lethal temperature is 35°C. High turbidity levels are preferred. During the day, suf shelter from strong light by descending in the water column (Collette et al., 1977; Marshall, 1977). Knipovich (1921) reports this species from depths of 11.0-11.9 m, possibly deeper, in the Iranian Caspian Sea. In Dagestan, this species prefers areas where there is flowing water well-supplied with oxygen (Shikhshabekov, 1978) and avoids vegetation and therefore competition with *Esox lucius*. Suf will tolerate low salinities and can be found around river mouths in the Caspian Sea basin but the sea itself is too saline. Ahmadnezhad et al. (2012) found that 1 g fingerlings can tolerate up to 12‰ salinity after a 10 day acclimation period. Ahmadnezhad et al. (2014) showed development of an osmoregulatory function in the larval gill is not complete until the eleventh day and skin ionocytes are responsible for this function until then, useful data for optimising release of larvae in stocking. Ahmadnezhad et al. (2014) found 2 g fingerlings tolerated salinity better than 1 g fingerlings but even the latter survived 12‰ Caspian Sea water and could be used for restocking.

Abstraction of water for irrigation (60% of water use) has severely reduced water levels and runoff rates necessary for reproduction of fishes along the Caspian shore. Estuarine habitats have been degraded inhibiting the survival of eggs, larvae and juveniles of anadromous and semi-anadromous fishes (the latter are species which spawn in the lower stretches and deltas of rivers where salinity is optimal at 8 g L^{-1} for many commercial species such as the suf). Over 90% of coastal streams along the Caspian shore are dry in July in Iran because of irrigation demands. As a result larvae of spring spawners are flushed into fields where they die, and nursery and reproductive areas are confined because of their low tolerance to salinities above 7-8‰. Without an adequate runoff, the sea encroaches on the estuary.

Age and growth: Males mature at 2-6 years (32 cm) and females at 3-6 years (42-44 cm). Life span may exceed 19 years, although in Lake Eğirdir, Turkey only 7 age groups were recorded (Becer and İkiz 1999a). Optimum growth occurs at 28-30°C (Marshall, 1977).

During 1932-1933 in the Anzali Wetland, 5-7 year old fish dominated in catches and weighed 2.6-7.4 kg but by the 1960s this had declined to 2-5 years and 1.6-2.7 kg (Hydrorybproject, 1965). Catches in 1971/72 in the commercial fishery of Iran were 3-7 years old, 33.0-55.0 cm long and weighed 370-2,100 g (Razivi et al., 1972). Abdolmalaki (2005) found age groups in the Iranian Caspian to be 2-5 years with 2-3 year olds forming 78.5% of the catch. The von Bertalanffy growth equation was L_t=52.5*[1-exp-0.158*(t+1.852)]. The instantaneous rate of total, natural and fishing mortality was 0.95 $year^{-1}$, 0.31 $year^{-1}$ and 0.64 $year^{-1}$, respectively. The calculated exploitation ratio was 0.67, the estimated biomass was 31.56 tons, the minimum sustainable yield was 13.89 tons (lower than the total catch), and the fishery return coefficient was 2.87%. Abdolmalaki and Psuty (2007) report 6 age groups for coastal waters of the southern Caspian Sea, the length-weight relationship was $W=-0.020606L^{2.85}$, and the von Bertalanffy parameters were L_∞=55.05

cm fork length (substantially less than in the Volga River delta at 79.0 cm and Aras Lake in Iran at 73.3 cm), K=0.15, t_0=-2.59 and M=0.31. More than 90% of the beach-seine caught fish were smaller than the minimum legal length. These authors also provide details of recruitment and fishing mortality for this population which is enhanced by introduction of fingerlings. Rahimibashar et al. (2008) found that the fish in the Aras Dam Lake had allometric growth and age classes caught with cast nets and gill nets were 2^+ to 5^+ years.

Food: The suf is an ambush-pursuit predator. Feeding on fish begins at a length of 5-10 cm (2-3 months of age) depending on the relative abundance of zooplankton, invertebrates and forage fish. In the Volga Delta, spawning *Rutilus rutilus* (presumably *R. caspicus*) in April-May is the most important food, up to 80% of the annual ration. In the 1960s and 1970s when the population of suf was 7 million fish, they ate 53,000 tonnes of *Rutilus rutilus* (presumably *R. caspicus*) (Caspian Sea Biodiversity Database, www.caspianenvironment.org). Adults are solitary but young fish feed in schools on nauplii, copepods and some rotifers. Some adults are cannibals (Collette et al., 1977; Marshall, 1977; Popova and Sytina, 1977) and Balik (1999) reports that in Lake Beyşehir, Turkey, a suf can eat its own species with a mean size of 35.9% of its length. Apparently many prey fish are seized and swallowed tail first. One Iranian specimen contained a *Neogobius melanostomus* and gobies are an important food item generally in the Caspian Sea, 17.8% of the diet compared to 59.9% for *Rutilus rutilus* (presumably *R. caspicus*).

Rahimibashar et al. (2008) found that the fish in the Aras Dam Lake were carnivorous, almost gluttonous, feeding principally on bony fishes (92% food preference) with some crab larvae and aquatic insects.

Reproduction: The spawning migration begins in late March-early April in Dagestan with spawning in early to mid-April (Shikhshabekov, 1978). In Eğirdir Lake, Turkey spawning took place from April to June and Becer and İkiz (1999b) give details of fecundity, egg diameters, and the relationships between length, weight and gonad weight and fecundity for fish that mature as young as ages 1-2. The spawning season over the range of this species is late February to late July, usually April-May at 12°C (range 6-22°C) as deep as 17 m. There are distinct spawning stocks.

In the Anzali Wetland, the main spawning area in the southern Caspian, the spawning run usually starts in the first 10 days of March at water temperatures of 8.0-9.5°C, ending at 12-14°C (Hydrorybproject, 1965; Razivi et al., 1972). Apparently, natural spawning has stopped completely in the wetland and this lagoon is stocked with fingerlings from spawners held at Aras, a border reservoir lying between Iran and Azerbaijan (Abdolmalaki and Psuty, 2007). Males build nests in depths of 30 cm to several metres on hard bottoms usually in turbid water. Each nest is a flat pit edged by gravel or shell. Plant roots are often exposed as a spawning substrate on which eggs are laid individually. The nest is guarded by the male and eggs are fanned. The female is driven away after spawning. Male suf are so devoted to protecting the nest that they will remain on site even if water levels fall and their backs stick out of the water. In addition they will try to bite humans if they approach the nest. Spawning is intermittent over several days and usually takes place at dawn. Maximum fecundity is 2.5 million eggs and egg diameters are up to 1.5 mm. Hatching occurs from 4 to 26.5 days, depending on temperature (Collette et al., 1977; Marshall, 1977). Females descend to the sea first from the Anzali Wetland after spawning and fry there are 19-33 mm long by the end of May (Hydrorybproject, 1965).

Parasites and predators: Eslami and Mokhayer (1977) examined 100 specimens of suf and found 20% to be infested with larvae of the nematode Anisakis. Ataee and Eslami (1999, www.mondialve-t99.com accessed 31 May 2000) report the helminth *Anisakis* from the gastro-intestinal tract of fish from the Anzali Wetland. This parasite can infest man if fish is eaten smoked, salted or fried at temperatures below 50°C. Mokhayer (1976) records the

acanthocephalan *Corynosoma caspicum*. Jalali and Molnár (1990) record the monogenean *Ancyrocephalus paradoxus* from this species in the Safid River. Masoumian et al. (2005) recorded the protozoan parasite *Trichodina perforata* from this species in the Aras Dam in West Azarbayjan. Pazooki et al. (2007) and Rasouli (2013) recorded various parasites from localities in West Azarbayjan Province, including *Diplostomum spathaceum* and *Argulus foliaceus* from this species. Barzegar et al. (2008) record the digenean eye parasite *Diplostomum spathaceum* from this fish. Barzegar and Jalali (2009) reviewed crustacean parasites in Iran and found *Achtheres percarum* on this species. Movahed et al. (2009, 2012, 2014, 2015) examined fish from the Anzali Wetland and found *Eustrongylides excisus* (nematode), *Achtheres percarum*, *Dactylogyrus* sp. and *Diplostomum spathaceum* (platyhelminths) and *Trichodina* sp. (ciliophore). White blood cell and lymphocyte counts increased in parasitised fish, a defense mechanism.

The bacterium *Clostridium botulinum* is present in fish from coastal areas of northern Iran and is a potential food hazard (botulism) if preservation is inadequate. Contamination rate was 10% in (Tavakoli and Razavilar, 2003; Tavakoli and Tabatabei, 2005). The bacterium *Listeria monocytogenes* and other *Listeria* species were isolated from 9.7% of suf obtained in Urmia fish markets, the lowest prevalence of seven species examined. Nonetheless, listeriosis is a foodborne disease with a high fatality rate in humans.

The Caspian seal, *Pusa caspica*, is a significant predator on this species (Krylov, 1984) as are predatory fishes such as *Esox lucius*, *Perca fluviatilis* and *Silurus glanis*. Adult suf have few predators.

Economic importance: There is some opportunity for sport fishing for this species in the Anzali Wetland and potentially in various lakes around the country where it has been introduced (Anonymous, 1977). It is a very popular food fish in Iran (Razivi et al. 1972) and one of the most important commercial bony fishes (Karimpour et al., 2013) although this has declined over the 1927-2013 period (Fazli, 2013; Fazli et al., 2013). It has also been studied in Iran as a control species for undesirable fishes (Annual Report, 1995-1996, Iranian Fisheries Research and Training Organization, Tehran, p. 80, 1997).

Nevraev (1929) reports on catches in various regions of Iran in the early years of the twentieth century. There were no evident trends of increase or decrease. In the Astara region from 1901-1902 to 1913-1914, the catch varied irregularly from 154 to 31,931 fish, in the Anzali region from 1901-1902 to 1918-1919, the catch varied from 608,300 to 3,367,000 fish, in the Safid River region from 1899-1900 to 1917-1918, the catch varied from 9,983 to 125,182 fish, and in the Astrabad region from 1900-1901 to 1912-1913, the catch varied from 1,400 to 22,900 fish.

Stocks of this species are known to fluctuate in Iran, as obviously do the catch statistics. Most fish are caught in beach seines, although some are caught in gillnets, both legally and illegally (see below). The main fishing ground is coastal waters in the Anzali region. Catches in the 1920s were at 3,000-4,000 tonnes for the coastal zone of the southern Caspian Sea but declined drastically afterward (Razavi, 1999). The commercial catch in Iran from 1956/1957 to 1961/1962 varied from 206 kg to 20,945 kg (Vladykov, 1964; RaLonde and Walczak, 1972), from 1965/66 to 1968/69 it varied from 7 to 77 tonnes (Andersskog, 1970) and from 1963 to 1967 ranged from 0 to 14.6 t (RaLonde and Walczak, 1970). In the 6 years from 1980 to 1985 catches were recorded by the Food and Agriculture Organization, Rome as respectively 0, 0, 0, 12, 13 and 10 t. Catches in 1990 were about 5-10 t and in 1996 about 35-40 t (Bartley and Rana, 1998b). In 2000-2001, the catch was 18 t or 11% of the total commercial catch in the Iranian Caspian Sea basin. Twelve tonnes were caught by beach seine along the coast, 3 t were taken in the Anzali Wetland and the rest was an estimated amount of unlicensed captures (Abdolmalaki, 2005). In 2003-2004, the catch was 38 t, a decrease in comparison to the previous year, with 15 t of this from beach seine cooperatives. Most fish were

Table 1. Summaries of catches of *Sander lucioperca* in the coastal southern Caspian Sea (Abdolmalaki and Psuty, 2007).

Catch and frequency	1927-1936	1937-1946	1947-1956	1957-1966	1967-1976	1977-1986	1987-1996	1997-2003
Total recorded catch (t)	8,959	7,224	4,986	3,262	5,547	5,384	16,903	16,201
Sander lucioperca (%)	29.7	1.7	1.0	0.2	0.4	0.1	0.1	0.2

Table 2. Recent catches of *Sander lucioperca* in the coastal southern Caspian Sea (Abdolmalaki and Psuty, 2007).

Year	Total catch (t)	Catch by beach seine (t)	Number of beach seine cooperatives	Beach seine efforts (hauls)	Number of illegal gillnets confiscated
1990	4.0	4.0	68	20,975	No data
1991	12.3	12.3	81	27,200	104,828
1992	10.0	8.7	88	30,239	109,446
1993	12.3	7.3	93	33,986	138,026
1994	40.2	22.6	91	27,868	215,381
1995	10.1	4.0	101	34,055	204,831
1996	8.0	2.8	109	42,847	270,727
1997	8.1	2.9	111	45,263	205,999
1998	95.0	54.8	125	52,574	222,897
1999	17.5	11.5	139	50,953	130,849
2000	18.0	12.0	147	56,913	82,678
2001	26.0	21.5	150	60,006	113,729
2002	30.0	20.3	150	57,310	141,506
2003	23.8	15.0	151	53,846	179,656
2004	22.5	14.4	151	49,809	261,875

immature and undersized and the catch was based on release of fingerlings (Abdolmalaki, 2006). There are minimum sizes for fish retention, e.g., 34 cm fork length for *Sander lucioperca*, but fisheries do retain smaller ones for home consumption or even marketing (Abdolmalaki and Psuty, 2007).

The Caspian Sea off the Atrak River was an important fishery economic zone and included *Sander marinum*. However, by 1972 the catch of commercially important species had declined to 1.5% and the less desirable kilkas (*Clupeonella* spp.) had increased to 98.3% of the catch. The causes were reduction in the Atrak runoff through irrigation withdrawals, pollution from agriculture, overfishing in the sea and the drop in sea level. Flows of the Atrak did not reach the sea in 1984, 1986, 1990 and 1991 and spawning of species using the lower reaches did not occur (Caspian Environmental Programme, 2000).

Summaries of catches of this species in the coastal southern Caspian Sea over 8 decadal periods is given in Abdolmalaki and Psuty (2007) (Table 1). In addition, recent catches of this species is shown in Table 2 (Abdolmalaki and Psuty, 2007). In the period from 1933/34 to 1961/62 in the Bandar-e Anzali region catches varied from about 3,483 t at the earlier date to 33 kg at the later one, with large variations between years. Holčík and Oláh (1992) report a catch of only 22 kg in the Anzali Wetland in 1990, and from 1932-1964 reported catches varied from 1 to 2,581 t annually.

Hedayatifard and Jamali (2008) showed that this fish is a good source of polyunsaturated fatty acids and one of the best sources for omega-3 fatty acids, useful in preventing cardiovascular disease.

Khaval (2007) investigated polyculture of this species with silver, bighead, grass and common carp at the Safidrud Fisheries Research Station. Carp density was 3,000 fish per hectare with 60% silver carp, 20% grass carp and 10% each for common and bighead carp. Suf weighed 2.1 g and were stocked at 250 fish per hectare. Survival rates were 93.33% for the suf and 83.77% for the Chinese carps. Over the period April to November, suf fingerlings reached 54.4 g on average and production was 4,446.66 kg per hectare compared to 3,212.8 kg without polyculture.

Robins et al. (1991) list this species as important to North Americans. Importance is based on its use in aquaria and aquaculture, as food, in sport, in textbooks, and because it has been widely introduced outside its natural range. The suf or pike-perch is

also fish-farmed in Europe for stocking purposes as eggs or young.

Conservation: The decline in catches from about 3,000-4,000 tonnes to about 30 t noted above has never been adequately explained. Overfishing, degradation of spawning grounds, fluctuating water levels and salinity variations in coastal waters, the volume of freshwater input, oxygen concentrations and input of organic material to estuaries and the sea, are all possible factors (Abdolmalaki and Psuty, 2007). Hydrocarbon pollution occurs in the Gomishan Marsh (Ghasempouri and Esmaili Sari, 2002). The stocks of this species in Iranian waters also declined in the 1960s (Walczak and RaLonde, 1970; RaLonde and Walczak, 1972). Causes were reduction in estuarine habitat needed for spawning, man-made habitat changes and overfishing of the younger age classes and first year spawners. The catch declined from 125 tonnes annually in the 1940s to 14.6 t in 1967. Vladykov (1964) considered stocks all along the Iranian shore to be at dangerously low levels. Griffiths et al. (1972) suggested that stocks in Iran were on the verge of extinction and recommended a three-year ban on catching this species. Artificial raising of this species is difficult but more than 6 million fingerlings were raised and released into the Anzali Wetland in the Iranian year 1991-1992, a 100% increase over the previous year (Abzeeyan 4(2): VI, 1993). Fingerling production rose from 0.12 million in 1990, to 1.50 million in 1991 and 2.50 million in 1992 (Emadi, 1993) (note that Matinfar and Nikouyan (1995) give 1.63 and 2.44 million fingerlings for 1991 and 1992). Fingerling production in 1995 was 2.269 million, in 1996 2.4 million and for 1996-1997 8 million (Bartley and Rana, 1998a; 1998b). The Sturgeon International Research Institute, which opened in 1994 near Rasht, released 5-8 million fry in 1996-1997 (Bartley and Rana, 1998b). The Caspian Environment Programme (1998) gives annual production (in thousands) of cultured suf in government and private hatcheries as follows: 118 (1990), 1,630 (1991), 2,443 (1992), 1,160 (1993), 2,888 (1994), 2,270 (1995) and 2,414 (1996). Karimpour et al. (2013) give production of fish fry and fingerlings in millions as 2.4 (in 1997), 3.8 (1998), 3.6 (1999), 4.3 (2000), 3.9 (2001), 7.4 (2002), 5.6 (2003), 11.0 (2004), 7.5 (2005), 13.5 (2006), 12.9 (2007) and 16.0 (2008). There is some variation in statistics from different sources. The release in 1999 numbered 5 million "juveniles" (I.F.R.O. Newsletter, 23:4, 2000). Billard and Cosson (2002) cite an annual production of 5-10 million, mostly released in the Anzali Wetland and Moghaddam (2006) gives a figure of 5.13 million fingerlings for 2002. The highest number of fingerlings released in the Anzali Wetland was 6,604,000 in 2003 with the lowest being 1,160,000 in 1993 for the period 1991-2003 according to Abdolmalaki and Psuty (2007). The latter authors also note that the beach seines used in Iran do not protect young fish. There is a heavy mortality of discarded fish even when legal landing size is enforced and resources are inadequate to manage the fishery effectively. The minimum mesh size of the cod-end of the seines should be increased and its use monitored.

Ramin (1996) has studied semi-artificial propagation and rearing of fry of this species in Iran. Broodstock spawning occurs in March-April at 12-14°C on artificial nests of green wool bunches on wooden frames placed in ponds at 5 m intervals. Nests close to the bottom are preferred and eggs are dropped on them with an average fertilization of 30-90%. The nests with eggs on them are kept in a mist chamber and the eggs collected and placed in jars. Eyed eggs appear on day 3 or 4 of incubation. Yolk-sac absorption lasts 9-13 days and exogenous feeding fry measure 4-6 mm.

Golmoradizadeh et al. (2011) and Ershad Langeroudi et al. (2012) injected fish with the hormones CPE (carp pituitary extract), hCG (human chorionic gonadotropin), LHRHa2 (Luteinizng Hormone-Releasing Hormone analogue) and saline as a control, recommending the first two in induction of artificial reproduction in this species, with different dosages for males and females.

Ghafouri Salah et al. (2008) studied physiological

stress in this species and its effects on cortisol and muscle compounds. Falahatkar et al. (2012) and Sarameh et al. (2013) showed this species to be sensitive to stress during transportation as indicated by blood parameters. Long-term exposure to stressors led to the fish becoming adapted to stressful conditions. Sarameh et al. (2012) found that broodstock spawning performance could be improved considerably by using an effective photoperiod (24h light:0h darkness spawned earlier for example), and handling stress can lead to poor reproductive performance and inhibition of spawning. Falahatkar et al. (2013) tracked changes in biochemistry, sex steroids and haematology pre- and post-spawning, relating them to stress and reproduction.

Movahed et al. (2011) described haematological parameters of fish caught on the Bandar Anzali coast, noting no differences between age groups. Haematology parameters are useful in assessing stress when the fish are handled and the effects of pollutants and parasites.

Azimirad et al. (2012) investigated the best levels of the amino acid betaine supplementation in the diet of larvae and found no effect on growth or survival rate. Zakipour Rahimabadi et al. (2012) examined the effects of different levels of dietary betaine and found that it can increase palatability and acceptability of food and thus could be used to wean fingerlings to an artificial diet. A treatment of 2% betaine with biomar (a fish feed) showed the highest increment in body weight, specific growth rate and food efficiency but a decrease in food conversion ratio and greatest cannibalism compared to other treatments, and the highest survival rate was with biomar and no betaine. Mansouri Taee et al. (2012, 2012) studied the optimal transition from live to artificial food of larvae. The best growth and highest survival rate were in larvae fed live food (zooplankton and *Artemia* larvae) only for 34 days post-hatching, although fish weaned at 28 days post-hatching had noticeable growth performance. Rasooli Karegar et al. (2014) examined density and food regime in larval culture, finding fish fed with *Daphnia* at a density of 25 L^{-1} had the highest survival rate, for example, and a larger food size (*Daphnia* rather than *Artemia*) and a mixture of the two with a density of 50 L^{-1} from the third week of culture led to better growth.

Sharifpour et al. (2011) detailed damage to various organs in fish from the Caspian Sea of Iran, suspected to be due to long-term exposure to toxic materials and considered the fish unsuitable for human consumption. Tabatabaie et al. (2011) found mercury levels in muscle tissue of 0.06 µg/g in Anzali Wetland fish and 0.15 µg/g in Gomishan Wetland fish, less than in *Cyprinus carpio*. Nabavi et al. (2012) showed that Caspian Sea samples had levels of cadmium, lead and nickel above acceptable limits while essential metals (copper, iron, manganese and zinc) were below those limits.

Ehsani et al. (2012) examined biogenic amines (which cause food intoxication) and bacteria in ungutted fish during 2 days prestorage icing and 90 days frozen storage at -24ºC, finding all values were within acceptable limits. Sahari et al. (2014) found losses in vitamins A, C, D, E and K during cold storage (-24ºC).

Lelek (1987) classifies this species as intermediate to vulnerable in Europe. Kiabi et al. (1999) consider this species to be vulnerable in the south Caspian Sea basin according to IUCN criteria. Criteria include commercial fishing, sport fishing, few in numbers, limited range (less than 25% of water bodies), absent in other water bodies in Iran, and present outside the Caspian Sea basin. Nezami et al. (2000) consider this species to be endangered because of overfishing, habitat destruction and spawning ground degradation. The IUCN Red List of Threatened Species (2015) lists this species as of Least Concern.

Sources: Deelder and Willemsen (1964) reviewed the biology of this species as did Craig (1987). Robins (1970) gave a bibliography of the genus *Stizostedion* (=*Sander*). Further details on collections examined can be found in the museum catalogues.

Iranian material: CMNFI 1970-0532, 1, 209.3 mm

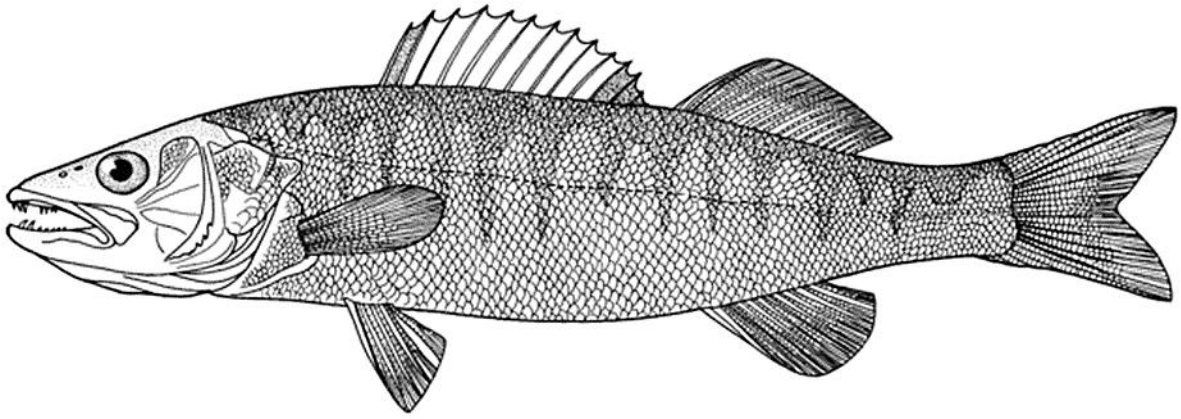

Figure 5. Line drawing of *Sander marinus* by S. Laurie-Bourque.

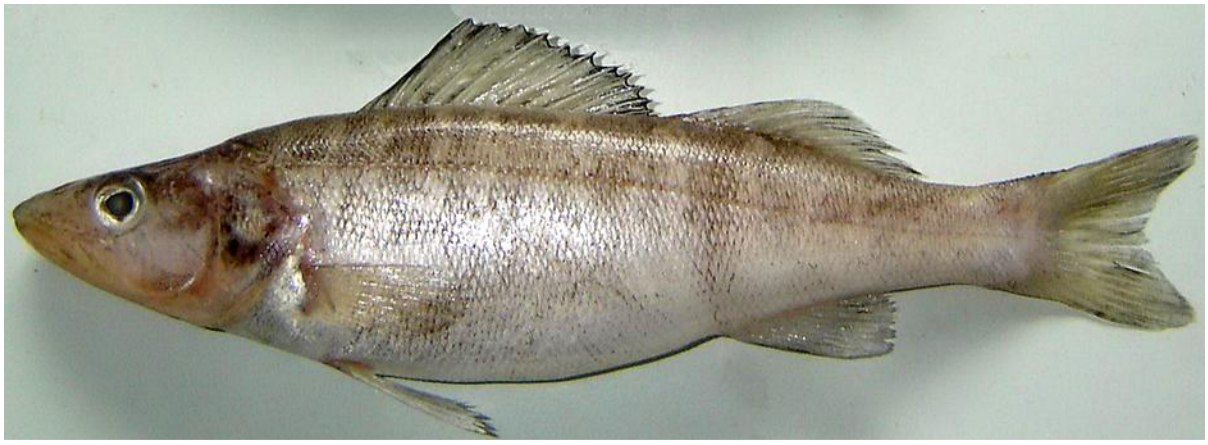

Figure 6. *Sander marinus*, Anzali Shore, May 2006, courtesy of K. Abbasi.

standard length, Gilan, Caspian Sea near Bandar-e Anzali (37º28'N, 49º27'E); CMNFI 1979-0431, 2, 211.5-241.0 mm standard length, Mazandaran, Now Shahr fish bazaar (no other locality data); CMNFI 1979-0455, 1, 68.5 mm standard length, Markazi, Manjil Dam (36º45'N, 49º17'E); CMNFI 1980-0127, 1, 266.1 mm standard length, Gilan, Caspian Sea near Hasan Kiadeh (37º24'N, 49º58'E); CMNFI 1980-0130, 1, 197.4 mm standard length, Mazandaran, river near Iz Deh (36º36'N, 52º07'E); CMNFI 1980-0150, 1, 280.8 mm standard length, Gilan, Caspian Sea at Safid River estuary (37º24'N, 49º58'E).

Sander marinus (Cuvier, 1828)
(Figs. 5-6)

Common names: Suf-e daryai (=sea suf), souf-e-daryaee. [daniz sifi in Azerbaijan; morskoi sudak or sea pike-perch, erroneously bërsh by fishermen in the Caspian Sea, both in Russian; sea zander, estuarine perch].

Systematics: *Lucioperca marina* was originally described from the Black Sea at Feodosiya. No types are known (Eschmeyer et al., 1996).

Key characters: This species is distinguished from *S. lucioperca* by the dorsal fins being well-separated, but by a distance less than eye diameter, anal fin spines are weak and closely joined to the soft rays, interorbital width in adults is much greater than eye diameter, the upper jaw extends back level with the posterior pupil edge or almost to the posterior eye edge in adults, the dorsal fin soft rays are 18 or less, and the spiny dorsal fin lacks large spots.

Morphology: First dorsal fin spines 12-14, second dorsal fin spines 1-4 followed by 12-18 soft rays, anal fin spines 2-4 followed by 9-12 soft rays, pectoral fin with 1 spine and usually 15 soft rays, and pelvic fin with 1 spine and 5 soft rays. Lateral line

scales 75-88, scales above the lateral line 9-13 and caudal peduncle scales 34-36. Scales have few anterior radii, a crenulate anterior margin and a posterior focus. Gill rakers on the upper arch number 12-20, on the lower arch 11-17, reaching the second raker below when appressed, elongate and spinulose. Vertebrae number 38-44. There are 5-7 pyloric caeca. Cheeks are scaleless or almost scaleless. There are canines on the jaws and palatines. These counts are combined for several literature sources and include eastern and western populations of the southern Caspian Sea which show evident differences indicating distinct stocks. The gut is short and s-shaped.

Meristic values for Iranian specimens are:- first dorsal fin spines 13(2) or 14(1), second dorsal fin spines 2 (3), soft rays 16 (3); anal fin spines 2(3), soft rays 12(3); soft pectoral rays 15(3), pelvic fin with 1(3) spine and 5(3) soft rays, lateral line scales 79(2) or 82(1), scales above lateral line 10(1), 12(1) or 13(1), caudal peduncle scales 34(2) or 36(1); and total gill rakers 12(1), 13(1) or 15(1).

Sexual dimorphism: Unknown.

Colour: The back is light grey and the flanks have 12-15 dark bars, which are sometimes indistinct and may be absent, e.g., in females from the eastern Caspian which had small, irregular, dark-brownish speckles. Some fish are almost black and lack bars. The first dorsal fin lacks the strong spots seen in *Sander lucioperca* and is dark grey to black with patches of concentrated melanophores and clearer areas forming irregular and incomplete stripes, or darkly fringed and with a dark spot at the posterior base. The second dorsal fin and the caudal are finely spotted. Other fins are grey with some melanophores on rays. Eyes are silvery due to the tapetum lucidum. The peritoneum is brownish.

Size: Attains 62.0 cm (65.0 cm total length in Jolodar and Abdoli (2004)) and 2.2 kg.

Distribution: Found only in the northwestern Black Sea and the Caspian Sea. Reported from near Gasan-kuli in Turkmenistan (Berg, 1948-1949) and from the southeast Caspian Sea in Iran (Kiabi et al., 1999). Jolodar and Abdoli (2004) and Abdoli and Naderi (2009) record it from the central, southwestern and southeastern regions of the Caspian Sea including in Astara. K. Abbasi records it from the Anzali Shore (see photograph above). An old record from the Anzali Wetland is cited below under Habitat.

Zoogeography: The relationships of this species are discussed under the genus.

Habitat: This species lives in the Caspian Sea proper and rarely enters rivers. De Filippi (1865), however, did record "Un molto bello e grosso individuo....in un canale di Murdab, ove l'aqua era del pari sensibilmente dolce". It favours areas with rocky bottoms and does not migrate. In winter, part of the population moves into deeper water at depths of 30 m, rarely 100 m, while another part remains near the shore. The major concentration of this pike-perch is found near the shores of Turkmenistan, and secondly of Azerbaijan.

The Caspian Sea off the Atrak River is an important fishery economic zone. Gasan-kuli or Hasan Kuli is a town in Turkmenistan near the Iranian border referred to in fishery reports from this area. The catch of *Rutilus caspicus*, *Cyprinus carpio* and *Sander marinum* was nearly 1.44×10^4 tonnes with only 1.9% being accounted for by *Clupeonella cultriventris* (= *caspia*). However by 1972 the catch of the commercially important species had declined to 1.5% and the less desirable *Clupeonella* had increased to 5.73×10^4 t or 98.3% of the catch. The causes were reduction in the Atrak runoff through irrigation withdrawals, pollution from agriculture, overfishing in the sea and the drop in sea level. Flows of the Atrak did not reach the sea in 1984, 1986, 1990 and 1991 and spawning of species using the lower reaches did not occur (Caspian Environmental Programme, 2000).

Age and growth: Sexual maturity is attained at 3-4 years for most fish with a few fish maturing at 2 years (Guseva, 1975). Life span is at least 12 years. Growth is slightly faster in females up to age 5, evens out later and males become larger (Kuliyev, 1981). Males on the spawning grounds average 41.2 cm and females 42.9 cm, with an average weight of 0.94 kg (Berg, 1948-1949).

Food: The principal foods are gobies (Gobiidae), young herring and tyulkas (Clupeidae), silversides (Atherinidae), and crayfish.

Reproduction: The male prepares a nest site and protects the eggs. Spawning takes place at 3-12 m on open, stony bottoms or in "nest-caves" and eggs are laid in a continuous layer. The male constructs and guards the nest. Spawning usually begins in the second half of April and ends in mid-May at temperatures of 10-17°C, and is most intense at 13-15°C (Guseva, 1974a). Up to 126,000 adhesive eggs are laid (Guseva, 1974a, 1975; Kuliyev, 1981) and are larger than in *S. lucioperca*. Fertilised eggs are 2.6-3.8 mm and at water temperatures of 14.7°C, incubation takes 12-17 days (Gusev, 1974a).

Parasites and predators: None reported from Iran.

Economic importance: The sea pike-perch was commercially fished off the Turkmenistan coast in the 1930s and 1940s with catches of 19 thousand centners (1 centner=100 kg) or 2,271,000 fish. In 1927-1929 the annual average on the shores of Azerbaijan was 7,000 centners and in 1930-1932 10,300 centners. In 1930, the catch for the whole Caspian Sea was 909 thousand centners (Zenkevitch, 1963). The development of offshore oil deposits has drastically reduced stocks throughout the Caspian Sea (Guseva, 1974b, 1975; Kuliyev, 1981).

Robins et al. (1991) list this species as important to North Americans. Importance is based on its use in textbooks.

Conservation: This species has been proposed for inclusion in the "Red Book of the U.S.S.R." which forms the basis for measures to protect species (Pavlov et al., 1985). Kiabi et al. (1999) consider this species to be data deficient in the south Caspian Sea basin according to IUCN criteria. Criteria include possibly few in numbers, limited range (less than 25% of water bodies), absent in other water bodies in Iran, and present outside the Caspian Sea basin. The IUCN Red List of Threatened Species (2015) lists this species as Data Deficient.

Sources: Morphology based in part on Svetovidov and Dorofeeva (1963) and Kuliyev (1981). Further details on collections examined can be found in the museum catalogues.

Iranian material: CMNFI 1970-0532, 3, 156.3-165.5 mm standard length, Gilan, Caspian Sea near Bandar Anzali (37º28'N, 49º27'E).

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