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Review Article

Review of the Herrings of Iran (Family Clupeidae)

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Abstract: The systematics, morphology, distribution, biology, economic importance and conservation of the herrings (kilkas and shads) of Iran are described, the species are illustrated, and a bibliography on these fishes in Iran is provided. There are 9 native species in the genera *Clupeonella*, *Alosa* and *Tenualosa* in the Caspian Sea and rivers of southern Iran.

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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.

Family Clupeidae

Herrings, shads, sardines, sprats, pilchards and menhadens are moderate-sized fishes, usually less than 25 cm long, found in warmer marine waters with some species anadromous or permanent freshwater residents. There are about 64 genera and about 218 species world-wide (Nelson et al., 2016), with 8 species in the Caspian Sea and one commonly found in Persian Gulf drainages. Some other, primarily marine, species are known to enter rivers in southern Iran (e.g. *Nematalosa nasus* (Bloch, 1795) and *Sardinella sindensis* (Day, 1878)) but are not dealt with here (Hashemi and Ansary, 2012; Jouladeh-Roudbar et al., 2015). The diversity of this family in the Caspian Sea is seen in the number of subspecies which have been described, rather than in genera. At the species level these are Caspian Sea endemics. A study by Pourrafei et al. (2016) based on the nuclear gene RAG1 did not support the monophyly of Clupeidae but, as an abstract, details are lacking. These fishes are dealt with as a single family here.

Curiously, the species and subspecies in the Caspian Sea are generally of larger size than their relatives in the Black Sea basin. These observations are attributed to the variable environment in the Caspian Sea over time, with repeated changes in salinity and temperature which the fish could not avoid. Black, Mediterranean and Atlantic species lived under more stable conditions and could, in any case, retreat from lowered temperatures for example. In addition, the Caspian Sea clupeids lacked the competitors which entered the Black Sea from the Mediterranean and Atlantic and some (*Clupeonella* spp., *Alosa caspia*) could occupy the pelagic, planktivore niche taken up by other species in the Black Sea. There are no other pelagic fish but these herrings in the stable salinity areas of the Caspian Sea.

These fishes usually have modified scales on the belly forming abdominal scutes with a saw-like

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edge. Most species have two, long, rod-like postcleithra. The lateral line is usually absent or on only a few scales. Silvery cycloid scales are easily detached and are found only on the body. The mouth is usually terminal with jaws about equal in length. Teeth are small or absent but gill rakers are long and numerous for sieving plankton. Fins lack spines and there are no barbels. There is no adipose fin. The pectoral and pelvic fins have a large axillary scale. The caudal fin is deeply forked. The eye is partly covered by an adipose eyelid. The flesh is particularly oily and is highly nutritional.

Members of this family often form immense schools in surface waters of the ocean and the Caspian Sea where they feed on plankton. Schooling is an anti-predator device making it difficult for a predator to pick out an individual from a tight mass of fish. There is also a "sentry effect" where awareness is increased by the presence of many fish. The school is maintained by a balance between visual attraction and lateral line stimulus repulsion. Herring can feed on the smaller plankton, less than 300-400 µm, at night by filter-feeding but during the day can also use particulate feeding. In the latter, they select larger plankton using the area temporalis, a specialised ventro-posterior region of the retina which improves vision as herring approach food items from slightly below.

Herring are easily caught and are extremely valuable to commercial fisheries. They are the most important fishes economically, both as food for man and also for many other commercial fish species. Wars have been fought over fisheries for herrings. In one year, members of the herring family made up 37.3% of all fish caught in the world. Some are used for fish meal, as fertiliser and as an oil source. The 1994-1995 catch of clupeids in the Iranian Caspian was 98.3 tonnes by beach seine and 671.5 tonnes by gill nets, a decrease of 200 tonnes in total over the previous year's catch (Iranian Fisheries Research and Training Organization Newsletter 10: 4-5, 1995) (but see below where the catch is much higher – sources tend to vary). The Caspian Sea shads accounted for about 35% of total inland production in Iran which was 117,300 tonnes in 1995 (Bartley and Rana, 1998). These fish are used in a high value form as frozen whole consumer packs, as fish meal for poultry and in aquaculture, and in canning (Food and Agriculture Organization, Fisheries Department 1996).

Catches in the Caspian Sea for 1991 and 1992 were respectively 13,817 and 21,527 tonnes of kilka (*Clupeonella* spp.) compared with 3,036 tonnes and 2,692 tonnes of sturgeons and 18,571 and 16,873 tonnes of bony fishes. The catch reached 51,000 tonnes in 1994 from none 10 years previously (Food and Agriculture Organization, Fisheries Department, 1996). The kilka catch in Gilan Province in 1997 was 36,077 tonnes (total catch 39,154 tonnes for the province) and in Mazandaran in 1998 was 31,583 tonnes (total catch 48,027 tonnes).

The Caspian Environment Programme (1998) gives the following catches in tonnes for the Iranian Caspian Sea for kilka (*Clupeonella* spp.) and for *Alosa pontica* (= *kessleri*), respectively as 1,013 and 2 (1973), 1,170 and 2 (1974), 1,286 and 4.5 (1975), 900 and 5.5 (1976), 1,261 and 2 (1977), 771 and 0 (1978), 836 and 0 (1979), 619 and 0.1 (1980), 1,341 and 0.4 (1981), 798 and 10.4 (1982), 621 and 1.6 (1983), 1,517 and 20.3 (1984), 1,828 and 34.8 (1985), 2,450 and 71.9 (1986), 4,389 and 13 (1987), 4,700 and 16 (1988), 7,902 and 30 (1989), 8,814 and 30 (1990), 13,817 and 35 (1991), 21,527 and 35 (1992), 28,730 and 893 (1993), 51,000 and 720 (1994), 41,000 and 490 (1995) and 57,000 and 330 (1996). Abdolmalaki and Psuty (2007) give figures over a wide range of years for Iranian coastal catches in the southern Caspian Sea with selected comparative species as presented in Table 1.

Overfishing of clupeids in the Caspian Sea and stock collapses caused by the invasive ctenophore *Mnemiopsis leidyi* have also had deleterious effects on the Caspian seal (*Pusa caspica*) which fed on these fishes (Harkonen et al., 2012).

A major source for the biology and systematics of Caspian clupeids remains Svetovidov (1952), now inevitably dated but not yet updated. Whitehead (1985), Hoestlandt (1991), Coad (1997) and Coad et

Table 1. Iranian coastal catches in the southern Caspian Sea with selected comparative species (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
Sturgeon meat + caviar (%)	13.4	8.8	16.3	50.9	40.9	34.2	9.4	5.0
Rutilus kutum (%)	12.2	43.0	24.9	25.8	17.8	19.8	53.2	45.4
Rutilus rutilus (%)	20.7	25.5	18.8	0.7	0.8	2.3	5.8	6.1
Alosa spp. (%)	1.9	6.2	14.7	2.9	0.3	0.2	3.2	3.9

al. (2003) gave brief overviews of Iranian herrings. There has been no recent, careful systematic and taxonomic study of these species in the Caspian Sea basin as a whole and extensive new material was not available for examination here.

Key to Clupeidae: Caspian Sea species have numerous nominal subspecies and keys to these may be found in Berg (1948-1949) and Svetovidov (1952).

1a. Upper jaw without a median notch, rounded when viewed from in front; last two anal fin rays enlarged; lower jaw articulation with skull below or anterior to posterior eye margin; Caspian Sea species; *Clupeonella* spp. 2

1b. Upper jaw with a median notch; last two anal fin rays not enlarged; lower jaw articulation with skull behind posterior eye margin; Caspian Sea and Persian Gulf; *Alosa* and *Tenualosa* spp. 4

2a. Pectoral fins rounded at tips; head large and narrow (interorbital width 15.5% or less of head length)..............................*Clupeonella grimmi*

2b. Pectoral fins pointed at tips; head short and wide (interorbital width 16% or more of head length).....3

3a. Body and belly compressed (body depth about 21-27% of standard length); keeled belly scales evident ....*Clupeonella caspia*

3b. Body cylindrical and belly rounded (body depth 16-19% of standard length); keeled belly scales weakly developed.........*Clupeonella engrauliformis*

4a. Branched pelvic fin rays 7; upper gill rakers not overlapping lower gill rakers at angle of first arch; Persian Gulf basin..................... *Tenualosa ilisha*

4b. Branched pelvic fin rays 8; upper gill rakers overlap lower gill rakers at angle of first arch; Caspian Sea species; *Alosa* spp. 5

5a. Body deep and compressed; head large and deep, wedge-shaped in anterior view; caudal peduncle short; pectoral fins long................................6

5b. Body not deep and not compressed; head not large and deep, not wedge-shaped in anterior view; caudal peduncle not short; pectoral fins short.......8

6a. Gill rakers on first arch 50 or more, thin and long, much longer than gill filaments; teeth weakly developed…...............................*Alosa caspia*

6b. Gill rakers on first arch 48 or less, shorter, equal to or somewhat longer than gill filaments; teeth well developed 7

7a. Upper and lower profiles of head straight; lower jaw protruding and its upper edge straight ....*Alosa saposchnikowii*

7b. Upper and lower profiles of head rounded; jaws equal in length and lower jaw has a crescentic upper edge............................. *Alosa sphaerocephala*

8a. Gill rakers 49 or less, thick and coarse............................. *Alosa braschnikowii*

8b. Gill rakers 57 or more, may be thin and long but can be coarse and short................. *Alosa kessleri*

Genus *Alosa* Linck, 1790

The Caspian Sea species of *Alosa* were formerly placed in the genus *Caspialosa* Berg, 1915. Svetovidov (1952) synonymised *Caspialosa* with *Alosa*. There are 5 species in Iranian waters and the Caspian Sea as a whole but numerous subspecies have been described. *Alosa* species are also found in the Black Sea, Mediterranean Sea and Atlantic Ocean.

Often distinguished by gill raker counts which in any case overlap, the various subspecies are difficult to identify. Morphometric characters are of little help and Zamakhaev (1944) points out that some named taxa are merely different age groups.

Alosa species are distinguished from sympatric *Clupeonella* species by larger size (up to 75 cm total

Table 2. Distinguishing characters of *Alosa* species from Mazandaran and Golestan provinces, southern Caspian Sea (Afraei Bandpyi et al., 2004).

Species	Gill rakers	Ratio of eye diameter to total length (%)
A. braschnikowii	20-40, mean 30.93	2.9-5.82, mean 4.72
A. caspia	110-125, mean 118.3	5.73-7.46, mean 6.21
A. pontica (= *kessleri*)	60-73, mean 66.82	4.27-6.48, mean 5.46
A. saposchnikowii	20-48, mean 32.83	6.0-9.33, mean 7.3

Table 3. Distinguishing characters of *Alosa* species from Gilan Province, southern Caspian Sea (Hosseini et al., 20114).

Species	Gill rakers	Ratio of eye diameter to head length (%)
A. braschnikowii	22-49, mean 36.6	15.91-21.88, mean 18.53
A. caspia	74-128, mean 106.3	19.36-24.3, mean 22.48
A. kessleri	49-73, mean 58.5	17.75-22.4, mean 20.88

length compared to 20 cm), a large mouth, a black spot on the flank behind the operculum and sometimes a row of such spots, an elongate scale or ala at the upper and lower base of the caudal fin, a notch at the mid-line of the upper jaw and by the last two anal fin rays not being elongated.

Caspian Sea species have a laterally compressed belly with 29-36 spiny scutes running from the throat to the anal fin, the dorsal fin origin is closer to the snout tip than the caudal fin base, the dorsal fin lies in a groove formed by enlarged scales, scales are easily detached, the pelvic fin origin lies below or slightly posterior to the dorsal fin origin, teeth are usually present on the jaws, roof of the mouth (on the palatine bone and always on the vomer bone), and on the tongue, the opercular bone is distinctly striated, eggs are demersal, semi-pelagic, and lack an oil globule, gill rakers highly variable in shape and number (18-180), dorsal fin branched rays 11-16, anal fin branched rays 10-21, scales in lateral series 49-60, and vertebrae 43-55.

Afraei Bandpyi et al. (2004) examined 336 specimens *Alosa* species from Mazandaran and Golestan provinces and found the distinguishing characters presented in Table 2. In addition, Hosseini et al. (2011) examined 132 specimens of *Alosa* species from Gilan Province and found the distinguishing characters presented in Table 3. The two characters used in combination distinguish the species.

The general Farsi name for these fishes is shag mahi or zalun (both in Gilaki). *Alosa volgensis* (Berg, 1913) was recorded from Iranian waters by Kottelat and Freyhof (2007) but presence needs confirmation by specimens. *Alosa curensis* (Suvorov, 1907) is poorly known and described from Kyzylagach Bay of Azerbaijan. It may eventually be recorded from Iranian waters. These herrings migrate from the north Caspian Sea to overwinter in the central and southern parts, returning north in the spring.

Alosa braschnikowii (Borodin, 1904)
(Fig. 1)

Common names: Shagmahi, shagmahi-ye Khazari. [Dolkii siyanayn, Agraxan siyanayi, Sara siyanayi, irikoz siyanak, hasangulu siyanayi, agbas siyanak, all in Azerbaijan; Caspian marine shad, Kurinskaya sel'd or Kura herring, poloschataya sel'd or striped herring, Agrakhanskaya sel'd or Agrakhan herring, bol'sheglazaya sel'd or bigeye herring, dolginskaya sel'd or dolginka herring, belogolovaya sel'd or whitehead herring, Astrabadskaya sel'd or Astrabad herring, sel'd-gonets or driver, zheltospinka or yellow-back, Gasankulinskaya sel'd or Gasan-Kuli herring, kiselevichevskaya sel'd or Kiselevitch herring, Krasnovodskaya sel'd or Krasnovodsk herring, vostochnaya sel'd or eastern herring, obzhorka or glutton, Sarinskaya sel'd or Sara herring, maiskaya sel'd or May herring, Brashnikovskaya sel'd or Brashhnikov's shad, all in Russian].

Systematics: Originally described as *Clupea caspio-pontica* var. *Braschnikowii*. Reshetnikov et al. (1997) revert to the original double "i" ending to the

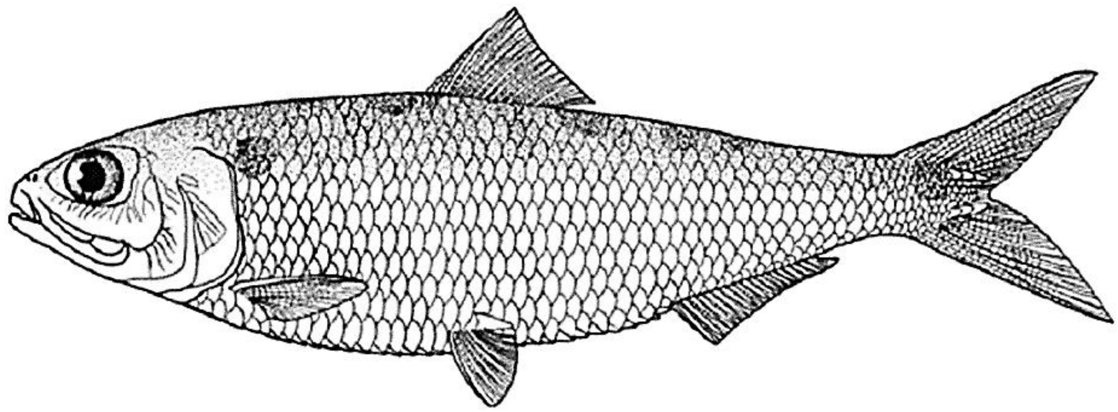

Figure 1. Line drawing of *Alosa braschnikowii.*

specific name although the Catalog of Fishes (downloaded 13 January 2017) has a single "i" ending. A lectotype from Fort Shevchenko (Aleksandrovsk) is in the Zoological Institute, St. Petersburg (ZISP 13051) and paralectotypes were designated by Svetovidov (1952) (ZISP 13051). *Clupea caspio-pontica* is an unneeded new name according to Eschmeyer et al. (1996).

Alosa braschnikowii was regarded as a subspecies of *Alosa caspia* by some authors. *Clupeonella leucocephala* Berg, 1913 from Sumgait and Gyurgenchai, Azerbaijan is a synonym (as *Caspialosa brashnikovi leucocephalia* (*sic*). it is listed as a synonym of *C. b. grimmi* in Mikhailovsky (1941)), as is *Caspialosa caspia nigra* Kisselevitsh, 1923 from the Caspian Sea opposite Dzambai (the material also included specimens of *Alosa saposchnikowii*) (Whitehead 1985, Eschmeyer et al. 1996).

Alosa braschnikowii has several subspecies in the Caspian Sea, namely *agrachanica* (Mikhailovsky, 1941) (author also spelt Mikhaylovsky or Mikhailovskaya; dated 1940 in Eschmeyer et al. (1996) but 1941 in the online Catalog of Fishes and 1941 on the paper itself and in Svetovidov (1952) and Berg (1948-1949); species also spelt *agrakhanika* in Berg (1948-1949); *Caspialosa brashnikovi* morpha *elata* is a synonym according to Mikhailovsky (1941)), the Agrakhan herring; *autumnalis* (Berg, 1915), the bigeye herring; *braschnikowii* (Borodin, 1904) (also spelt *brashnikovi* in Svetovidov (1952) and Berg (1948-1949)), the dolginka herring; *grimmi* (Borodin, 1904), the whitehead or Astrabad herring, driver or yellow-back; *kisselevitschi* (Bulgakov, 1926) (spelt *kisselevitschi* on the plate in Bulgakov (1926), *kisselevitschi* in Mikhailovsky (1941), *kisselevitshi* in Svetovidov (1952) and Whitehead (1985) and *kisselewitschi* in Berg (1948-1949)), the Gasan-Kuli or Kiselevitch herring; *nirchi* (Morosov, 1928) (author also spelt Morosow in Mikhailovsky (1941) and Morozov in Eschmeyer et al. (1996)) (with *Caspialosa brashnikovi kenderlensis* Budamshin, 1938 from Kendyrli Bay as a synonym in Svetovidov (1952) and Berg (1948-1949)), the Krasnovodsk herring; *orientalis* (Mikhailovsky, 1941), the eastern herring or glutton; and *sarensis* (Mikhailovsky, 1941), the Sara or May herring. *Caspialosa brashnikovi derzhavini* Tarasevich, 1946 described from the Caspian Sea near the Apsheron Peninsula, Azerbaijan may be another subspecies. *Caspialosa kiselevitschi* morpha *elata* Morozov, 1928 from the Caspian Sea, Krasnovodsk Bay, Turkmenistan is an infrasubspecific taxon and its availability and validity as a taxon have not been examined (Eschmeyer et al., 1996).

This high number of subspecies is an indication of the populational variation of this shad and not all subspecies may be valid. A modern revision is required to assess this problem. In light of this uncertainty and the lack of adequate sample sizes to determine which of the subspecies occurs in Iranian waters or which taxa are valid, reference is made here mostly to the species level. Additionally, it should be noted that hybrids between the various subspecies, and between this species and other species, do occur to complicate matters even further.

Jaafari et al. (2013) compared fish from Anzali and Sari morphologically and found standard length, postorbital length and anal fin base length were significantly different. Jafari et al. (2014) used microsatellite data to study fish from Golestan Province between Gomishan and Miankaleh. Low genetic differentiation between the two populations could be due to natural migration, genetic diversity within populations was only 1% and among populations was 99%, and it was considered possible that a genetic bottleneck could arise in the future. Paknejad et al. (2014) examined morphological variation between 6 localities along the whole Iranian coast and found populations to be distinct, particularly the Tonekabon region. Head shape, eye diameter and predorsal, prepelvic and preanal lengths were the main characters. Heidari et al. (2015a) examined fish from the Miankaleh Gulf for morphometric and meristic characters and suggest, in this brief abstract, that morphological variations should be taken into account in fisheries management and stock enhancement.

The neotype of *Caspialosa brashnikovi agrachanica* was designated by Svetovidov (1952) as the specimen described by Berg as *Caspialosa brashnikovi* m. *elata* taken in front of the Sulak River mouth, Agrakhan Bay and housed in the Zoological Institute, St. Petersburg under ZISP 7334. However, this neotype was not validly designated because qualifying conditions 75.3.1, 75.3.4 and 75.3.5 of the International Code on Zoological Nomenclature were not met (N.G. Bogutskaya, pers. comm. 23 January 2013). This also applies to the following 6 taxa.

The neotype of *Caspialosa braschnikovi autumnalis* was designated by Svetovidov (1952) as a specimen 26.9 cm long from the eastern shore of the Caspian Sea at Gasan-Kuli (just north of the Iranian border in Turkmenistan) caught on 8 April 1948 and housed under ZISP 31749.

The neotype of *Caspialosa kisselevitschi* is also from Gasan-Kuli caught on 30 June-1 July 1926 and was housed in the Faculty of Zoology, Central-Asian State University (Sredne-Aziatskogo Gosudarstvennogo Universiteta), Tashkent.

The neotype of *Clupea caspio-pontica* var. *grimmi* was designated by Svetovidov (1952) as a specimen 34.0 cm long found at Ashur-ade (= Ashuradeh) near Astrabad Bay (= Gorgan Bay or Khalij-e Gorgan) on 23 April 1903 is under ZISP 13045.

The neotype of *Caspialosa nirchi* as designated by Svetovidov (1952) is from the southern part of the Caspian Sea opposite North Cheleken Spit and is under ZISP 31780.

The neotype of *Caspialosa brashnikovi orientalis* as designated by Svetovidov (1952) is from the southern part of the Caspian Sea opposite Kara-Ashly and is under ZISP 32187.

The neotype of *Caspialosa brashnikovi sarensis* from Sara Island is under ZISP 32184 as established by Svetovidov (1952).

Key characters: Characterised by a relatively elongate and rounded body likened to a "herring" shape, not as deep as in some related species which are likened to a "shad" shape. Total gill rakers 18-49 and short (about equal to gill filaments in length, sometimes shorter). Teeth are well-developed in both jaws.

Morphology: Dorsal fin with 3-5 unbranched and 12-15, mostly 14, branched rays, anal fin with 2-4, usually 3, unbranched rays and 10-20, mostly 18, branched rays. Scales in lateral series 51-54. Teeth are well-developed on the jaws, tongue and roof of the mouth. Ghotbi Jokandan et al. (2014) briefly distinguish this species from *A. saposchnikowii* on morphometric characters in Gilan. The distance between the posterior end of the dorsal fin to the anterior caudal peduncle, distance between origins of pelvic and anal fins, head length, pectoral fin height and ratio of anal fin height to standard length were greater than in *A. saposchnikowii*. Alavi-Yeganeh and Razavi (2016a, 2016b) found 26-47 gill rakers in 50 specimens 15-45 cm long from Iran and number increased with total length, although only fish 15-20

Table 4. Characters of the subspecies in *Alosa braschnikowii* based on Svetovidov (1952) and Mikhailovsky (1941).

Character / Subspecies	Gill rakers (mostly)	Pectoral fins as % body length	Head as % of body length	Vertebrae
agrachanica	20-46 (28-33)	13.1-15.6	22.6-25.2	47-54
autumnalis	21-37 (28-30)	16.4-19.9	26.0-29.2	45-53
braschnikowii	24-47 (30-33)	14.3-16.7	23.5-26.6	48-55
grimmi	18-28 (20-22)	12.9-15.2	22.9-26.4	45-52
kisselevitschi	29-49 (36-40)	13.9-16.8	24.2-26.9	43-53
nirchi	20-31 (23-26)	10.9-14.7	23.4-26.3	48-52
orientalis	20-35 (27-32)	13.5-18.0	25.0-27.8	45-53
sarensis	20-33 (24-27)	14.1-16.2	23.8-26.6	45-53

cm and 40-45 cm long had significantly different counts. Gill raker length, length/width ratio and ratio of raker to filament length decreased with increase of total length. Equal lengths of rakers and filaments were found in fish greater than 25 cm. Evidently, some *Alosa* species may overlap in counts depending on size.

The accompanying table (Table 4) summarises characters of the subspecies and is taken from Svetovidov (1952) and Mikhailovsky (1941) but identification to subspecies should be done with the keys from these works. Some of the characters used in the keys are not in the table as they do show individual variation and are difficult to summarise. An example is the nature of the gill raker (thin, thick, blunt, pointed, bent, straight, curved, branched, broken off, forked, swollen at the tip, etc.); another is the degree of protrusion of the lower jaw.

The subspecies *grimmi* is quite specialised in association with its benthic mode of life, feeding mostly on gobies (Gobiidae). It has a unique character in the well-developed callus on the tip of the lower jaw which adults acquire from rubbing the jaw on the sea bed while feeding, gill rakers are low in number as fine food is not taken, and the tips are broken off, broadened, and split owing to abrasion, and the rakers on the lower arch are reduced in number so the first raker is far from the tongue base. The subspecies *nirchi* is similar. In contrast, the subspecies *kisselevitschi* has a high gill raker count, rakers are pointed and not split at the tips, and the first raker is close to the tongue base. This species lives in surface waters feeding on *Clupeonella*, *Atherina*, shrimps, gammarids, and gobies (Gobiidae).

Sexual dimorphism: None reported.

Colour: The back and top of the head are dark with a green or blue tint and may be grey-green. Some subspecies are paler in colour with a grey or grass-green back and pale flanks, *nirchi* has a whitish blue-green head, light grey back with a slight greenish tint, and lower jaw and pectoral fins light, while *grimmi* is also quite pale with a grey-blue back and top of the head and whitish anterior head and pectoral fins. There is a dark spot behind the operculum but no series of spots along the flank in most subspecies, except in rare cases when there may be up to 7, occasionally 12-13. The subspecies *grimmi* regularly has a row of diffused, grey spots almost merging into a stripe, and *nirchi* occasionally. Pectoral fins are dark on some subspecies (*braschnikowii*, *sarensis*, and *kisselevitschi*), pale or whitish on the others, although there is confusion in the literature over this, perhaps indicative of individual variation (cf. *sarensis* in Mikhailovsky (1941)). The back and upper part of the head may become a deep black at spawning. The flanks and belly are silvery.

Size: Attains 50.0 cm standard length but average lengths are about 27-34 cm.

Distribution: All the Caspian subspecies are found widely distributed in the sea but chiefly in the south in winter, moving north to spawn in spring. The subspecies *sarensis* is reported from the Lenkoran coast and from southwest of Gasan-Kuli (in Turkmenistan just north of the Iranian border), the subspecies *orientalis* from Gorgan or Astrabad Bay, *autumnalis* from coastal waters at Gasan-Kuli, *kisselevitschi* from Astara and Gasan-Kuli, and *grimmi* from Astara and Gorgan Bay. Esmaeili et al. (2014) record it from the Anzali Wetland or Talab.

Zoogeography: This species is endemic to the Caspian Sea.

Habitat: In winter, this species moves into deeper water towards the Iranian coast. In March, it approaches coastal waters (Vetchanin, 1984) including brackish waters but does not enter fresh water. It never enters rivers in the south of the Caspian Sea (Jolodar and Abdoli, 2004). Salinities up to 47.6‰ are survived by this species. Spawning and feeding grounds are in the north Caspian for some populations but others live permanently in the south Caspian Sea and are of smaller size. The subspecies *kisselevitschi*, for example, lives off Gasan-Kuli in winter at depths below 25 m, not migrating or feeding. In March, they move north to feed and then return south to spawn but live almost entirely as a pelagic species in the southern Caspian Sea. Knipovich (1921) reports this species from depths of 80-98 m in Iranian waters. The density of this species increased from east to west in a 1999-2001 study in Iranian waters (Afraei et al., 2006). Abdoli and Naderi (2009) list it as from the southwest, southeast and south-central Caspian Sea in Iranian waters.

Age and growth: Maturity is attained at age 2-5 and life span is up to 10 years, although this varies with the subspecies. Most south Caspian forms apparently mature at age 2 according to Svetovidov (1952). Growth rates also vary between subspecies, *orientalis* being one of the slowest growing herrings in the Caspian Sea and reaching 10 years of age. The catch near Astara of *sarensis*, for example, is mainly 4-5 year olds but this too varies with the subspecies and also with the year-class strength. Vetchanin (1992) reported on *grimmi* catches from the southeastern Caspian where the average length was 27.8-28.6 cm and the average weight 294-313 g. There is a tendency for length and weight to fall in catches as the summer progresses, from April to July. Length and weight are less in southern, compared to northern waters. Afraei et al. (2006) found this species to be the largest *Alosa* in Iranian waters on average at 395 mm and 760.3 g. Males predominate at 55.8% in Mazandaran and 69.4% in Golestan catches. Six age classes were present (1^+ to 6^+) with the 2^+ class being the most common at 28.9% and 6^+ the rarest at 8.9%. Alavi-Yeganeh et al. (2013) found Mazandaran fish were 1-6 years old and had a *b* value of 3.693 showing positive allometric growth. Ghotbi-Jokandan et al. (2015) examined 147 fish from Anzali, Noor and Torkeman and found a *b* value of 3.1. Mousavi-Sabet et al. (2016) gave a *b* value of 3.24 for Iranian fish from 6 fishing areas from Astara to Miankaleh.

Food: Diet in the southeastern Caspian Sea in winter comprises 85% *Clupeonella engrauliformis* with some gobies (*Neogobius*) and shrimps (Vetchanin, 1984). From March to November the diet is dominated by *Clupeonella caspia, Atherina boyeri* (= *caspia*) and shrimps. Juvenile *Liza saliens*, *Syngnathus caspius*, molluscs, crabs and higher aquatic plants are also recorded along with foreign objects such as rice husks, pieces of wood, foil, polyethylene, etc. This species is a cannibal. The more southerly populations examined favour *Atherina boyeri* (= *caspia*) and *Neogobius* species and some of these populations favour benthic invertebrates. The subspecies *grimmi* is the most benthic one and takes primarily gobies with some molluscs as well as *Clupeonella*. Feeding intensity rises sharply after spawning. While some herrings, like *Alosa pontica* (= *kessleri*), feed poorly on their migration, this species feeds intensively on its spring migration. Azizov et al. (2015) examined fish from the western Caspian Sea north of Iranian Astara in Azerbaijan waters and found the main foods were kilkas, gobies and shrimps with some zoobenthos. Intensive feeding took place in spring (March-April) before spawning and in July after spawning.

The feeding regime altered after the invasion of the ctenophore, *Mnemiopsis leidyi*. A shift was observed from 85% *Clupeonella engrauliformis* to 65% *Atherina boyeri* (= *caspia*). Other fishes were also eaten including *Clupeonella grimmi*, *C. caspia*, *Cyprinus carpio*, *Liza saliens*, as well as *Palaemon* spp. (Iranian Fisheries Research Organization Newsletter 49: 2, 2006). Afraei Bandpei et al. (2012) examined 357 fish from beach seines in the south-central Caspian Sea and found the diet was dominated by *Atherina boyeri* (= *caspia*) at 58% with Gobiidae (26%), Clupeidae (11%), Cyprinidae (3%) and Mugilidae (1%). *Atherina boyeri* (= *caspia*) was the most frequent prey at 78.6% index of relative importance, followed by *Neogobius fluviatilis* (= *pallasii*) at 18.2%. A wider variety of items was fed on in November, December and February with lowest feeding in October and January. There were also differences in diet related to fish size. Increases in the gastrosomatic index in February and March coincide with the spawning season and energy preservation for gonadal development.

Reproduction: Vetchanin (1984) reports spawning of this species in the southeastern Caspian Sea north of Iranian waters to begin in early May, continuing to July as it is intermittent. The subspecies *sarensis* spawns along the Lenkoran coast from mid-April to the end of June. The subspecies *orientalis* spawns in Gorgan Bay from the end of March to the beginning of April, spawning schools forming at 17-18°C or higher. The subspecies *autumnalis* spawns at the same time off Gasan-Kuli near the Iranian border with Turkmenistan. The subspecies *grimmi* spawns in May-June in Gorgan Bay. The subspecies *kisselevitschi* has the latest spawning date, June to July and even in August off Gasan-Kuli when temperatures exceed 25°C. Spawning takes place in shallow water (1.8-5.8 m) in the sea over sand or silt bottoms at 15-18°C (some subspecies and populations at 20-22°C, others beginning as low as 11°C), and a salinity of 8-13‰. Fecundity is up to 178,400 eggs, average 66,000 per fish. There is no feeding while spawning. Early maturers, like the south Caspian populations, can reproduce up to 7 times in their life.

Parasites and predators: The Caspian seal, *Pusa caspica*, is a predator on this species (Krylov, 1984).

Economic importance: The catch for all species of "*Caspialosa*" in Iran varied between 5,337 kg and 419,518 kg for the years 1956/1957 to 1961/1962 (Vladykov, 1964). In the Anzali region, the catch for the years 1933/1934 to 1961/1962 varied from 1,553 kg to 539,710 kg (Vladykov, 1964). The catch has been as high as 126,900 centners or 12,690 t in the sea as a whole for the type subspecies alone (1 centner=100 kg (Svetovidov, 1952)), taken chiefly in spring. Other subspecies were not fished for as extensively although *kisselevitschi* was the most numerous of the south Caspian forms of *Alosa braschnikowii*, forming 70% of the drift net catch.

Conservation: Reputedly depleted in Iranian waters. Kiabi et al. (1999) consider this species to be data deficient in the south Caspian Sea basin according to IUCN criteria. Criteria include medium numbers, medium range (25-75% of water bodies), absent in other water bodies in Iran, and present outside the Caspian Sea basin. Afraei Bandpei et al. (2012) noted that fishing is forbidden in the southern Caspian Sea from May to September.

Sources: Iranian material: CMNFI 1970-0581, 5, 226.0-245.0 mm standard length, Gilan, Caspian Sea near Hasan Kiadeh (37º24'N, 49º58'E); CMNFI 1979-0431, 1, 297.2 mm standard length, Mazandaran, bazaar at Now Shahr (no other locality data); CMNFI 1980-0126, 1, 245.8 mm standard length Gilan, Caspian Sea near Bandar-e Anzali (37º28'N, 49º27'E); CMNFI 1980-0150, 1, 222.4 mm standard length, Gilan, Safid River estuary (37º24'N, 49º58'E).

Comparative material: BM(NH) 1938.8.2:1, 1, 245.9 mm standard length, Kazakhstan, Caspian Sea, Kaidak Bay (no other locality data); BM(NH) 1938.8.2:2, 1, ca. 337.5 mm standard length, Kazakhstan, Caspian Sea, Kaidak Bay (no other locality data); BM(NH) 1939.2.21:17-18, 2, 285.0-305.2 mm standard length, Caspian Sea (no other locality data); BM(NH) 1939.2.21:19-20, 2, 222.9-273.4 mm standard length, Caspian Sea (no other locality data).

Alosa caspia (Eichwald, 1838)
(Figs. 2, 3)

Common names: Shagmahi-ye shekambozorg (= big belly herring fish), shagmahi-ye chekameh dar,

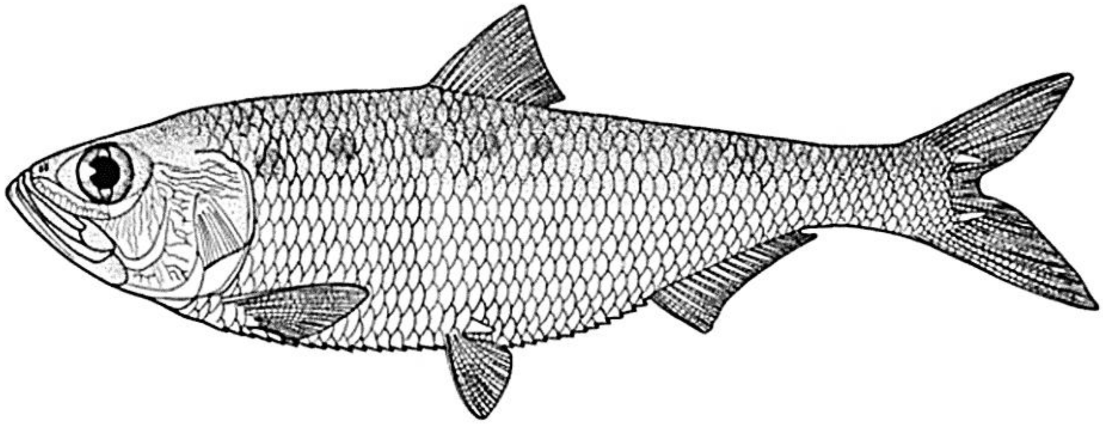

Figure 2. Line drawing of *Alosa caspia*.

Figure 3. *Alosa caspia* courtesy of A. Abdoli.

shagmahi-ye darya-ye khazar (= Caspian Sea herring fish), shah mahi (= king fish), zalun (in Gilaki), puzanok. [Xazar sisgarini, sara sisgarini in Azerbaijan; Kaspiiskii puzanok or Caspian shad, severokaspiiskii puzanok or North Caspian shad, srednekaspiiskii puzanok or Central Caspian shad, il'mennyi puzanok or il'men shad, Enzeliiskii puzanok or Enzeli (= Anzali) shad, Sarinskii puzanok or Sara shad, Bakinskii puzanok or Baku shad, Astrabadskii puzanok or Astrabad shad, all in Russian].

Systematics: *Clupea caspia* was originally described in Latin from "Hab. in Caspio mari, meridiem versus" (Caspian Sea, towards the south). *Alosa caspia* has 3 subspecies in the Caspian Sea basin, namely *caspia* (Eichwald, 1838) (= North Caspian, Central Caspian, Caspian or il'men shad); *knipowitschi* (Iljin, 1927) with natio *knipowitschi* (Iljin, 1927) (= Enzeli or Anzali shad) and natio *saraica* (Berg, 1948) (= Sara or Baku shad); and *persica* (Iljin, 1927) (= Astrabad shad). The differences between natio *knipowitschi* and natio *saraica* are small (e.g. gill rakers 122-166 versus 140-150, both averaging 145; vertebrae 43-49 versus 45-51, both with mostly 47 or 48; growth differences are known, the former grows faster in the first 2 years of life but the latter reaches a greater size) and they probably have no taxonomic significance being simply separate breeding populations. The differences between *Alosa caspia caspia* natio *caspia* (the North or Central Caspian shad) and natio *aestuarina* Berg, 1932 (the il'men shad) were found to be based on geography and growth rate (Svetovidov, 1952).

Alosa rossica Kessler, 1870 described from the Volga River is a *nomen nudum* and is this species. Other taxa now considered as synonyms of *Alosa caspia* are *Caspialosa caspia salina* Svetovidov, 1936 from Mertvyi Kultuk and Kaidak bays in the northeast Caspian Sea and *Caspialosa caspia kaidakensis* Kazancheev, 1936 (spelt *kajdakensis* in Svetovidov (1952)) from Kaidak, the latter being in any case a synonym of the former subspecies. *C. caspia* m. *elongata* Berg, 1913 is also a synonym. *Alosa caspica* Yakovlev, 1871 is presumably a misspelling.

Table 5. Characters of the subspecies in *Alosa caspia* based on Svetovidov (1952) and Hoestlandt (1991).

Characters / Subspecies	Head length as % of body length	Pectoral length as % of body length	Vertebrae (mostly)	Gill rakers (mostly)
caspia	25.5-28.1	15.5-18.1	45-52 (49-51)	68-150 (100-140)
knipowitschi	18.3-24.1*	16.0-19.1	43-51 (47-48)	120-180 (130-160)
persica	25.6-27.1	16.5-17.7	45-51 (47-49)	50-120 (60-90)

* The numbers cited in Svetovidov (1952: 256 in the English version) and Hoestlandt (1991: 128) in the keys to subspecies do not agree with the numbers on p. 148 and p. 265 respectively in the species descriptions.

Knipovich (1921) records a species, *Caspialosa enzeliensis* Iljin, from the southern Caspian Sea which he places as a subspecies of *caspia*. I have been unable to locate the original description of this taxon, which presumably is found in the Anzali Mordab (= Talab) of Iran. It is probably an unused manuscript name for what Iljin later described as *knipowitschi*. As of 15 July 2007, this scientific name returned no hits on Google and as of 12 December 2016 the only hit was for www.briancoad.com.

The lectotype of *Caspialosa knipowitschi* is a specimen 21.2 cm long from Anzali in Iran caught on 15 April 1915 and housed in the Zoological Institute, St. Petersburg (ZISP 31892). The lectotype of *Caspialosa caspia* var. *persica* is a specimen 147.5 mm long from the Caspian Sea Bay of Asterabad (= Gorgan Bay or Khalij-e Gorgan) north of Ashur-ade (= Ashuradeh) at 36°53'N, 53°55'E caught on 25 April 1904 on the Caspian Expedition of 1904 and housed in the Zoological Institute, St. Petersburg (ZISP 16413). The lectotype of *Caspialosa caspia knipowitschi* n. *saraica* is from near Sara Island and is under ZISP 32183. The lectotype of *Caspialosa caspia salina* is from Mertvyi Kultuk Bay, 10 km west of Cape Kizil-kair and is under ZISP 25813. These taxa were designated by Svetovidov (1952) as none were before or material was not preserved.

Key characters: Characterised by a relatively deep and compressed body likened to a "shad" shape, not as elongate and rounded as in some related species which are likened to a "herring" shape. Total gill rakers 50-180, variously reported as thin or thick, long (obviously longer than the gill filaments), and forming a convex outline on the lower arch. Teeth are poorly developed in both jaws.

Morphology: Dorsal fin with 3-4 unbranched and 12-15 branched rays, anal fin with 3-4, usually 3, unbranched and 15-20 branched rays. Scales in lateral series 49-54. The characters distinguishing subspecies all overlap widely and are given in Table 5 after Svetovidov (1952) and Hoestlandt (1991).

Sexual dimorphism: Females are longer and weigh more than males of the same age.

Colour: The back is blue-green to dark and the flanks silvery. There is a black spot on the flank behind the upper operculum margin and sometimes up to 7 spots extending along the upper flank to a level of the rear of the dorsal fin.

Size: Reaches 28.0 cm standard length for *caspia*, to 29.6 cm for *knipowitschi*, and to 33.8 cm for *persica*.

Distribution: Found in the Caspian Sea. The subspecies *caspia* is found mostly in the western half of the Caspian Sea basin but is the most widely distributed subspecies, found throughout almost the whole sea. The subspecies *knipowitschi* is found in the south near Anzali, Astara and the Baku Archipelago, near the northern shore of the Apsheron Peninsula in autumn with a few reaching the Gorgan Bay in fall and winter; natio *saraica* is found north of Astara and spawns near Sara Island, natio *knipowitschi* spawns in the Anzali Wetland. The subspecies *persica* is found in the southeast, near Gorgan or Astrabad Bay. Holčík and Oláh (1992) report *persica* from the western basin of the Anzali Wetland and this species is reported from the Safid River and Anzali Wetland as subspecies *persica* and from the Anzali Wetland as *knipowitschi* (Abbasi et al., 1999). Abdoli and Naderi (2009) list it as from the southwest, southeast and south-central Caspian Sea, the Anzali Wetland and Gorgan Bay in Iranian waters for both *knipowitschi* and *persica*. Reported from the Siahdarvishan River as *A. caspia caspia* (Abbasi et al., 2007). Esmaeili et al. (2014) record *A. knipowitschi* and *A. persica* as species from the Anzali Wetland but these natio are listed as *A. caspia* in the Catalog of Fishes (downloaded 15 December 2016).

Zoogeography: This species is a Caspian Sea endemic.

Habitat: The type subspecies prefers open waters. Caspian shad winter at depths of 30-40 m or more and prefer temperatures not less than 8-11°C. They rise to surface waters in spring, moving north along the western shore of the Caspian Sea in waters of about 9-11°C according to Kushnarenko (1986) while Heckman in Hoestlandt (1991) states that this shad begins to migrate at the end of March at 5-6°C water temperature with a peak at 9-14°C in mid to late-April, ending in early May. Males migrate in large numbers at the beginning and end of the migration, females in the middle (Pushbarnek, 1987) while Heckman in Hoestlandt (1991) states that two waves of migration occur, one usually in late April at 7.6-10.2°C comprised of over 80% males and the second in the first half of May at 10.8-14.0°C comprised of over 70% females. The young, which hatch in the spring, leave the summer feeding grounds before the adults and migrate south before October-November. Adults follow as temperatures fall. Some populations do not migrate north and spend their whole life in the southern Caspian Sea. This subspecies will enter fresh waters to spawn in addition to spawning in the open Caspian Sea. The subspecies *knipowitschi* prefers water warmer than that of all other Caspian Sea clupeids except for *Alosa caspia persica*. Its sea movements are not well known but spawning fish favour waters with freshwater input and some fish enter rivers so it is classified as semi-anadromous. This subspecies was common in the Anzali Wetland but is now replaced by *persica* (Holčík and Oláh, 1992). The rise in Caspian Sea level since 1977 is gradually returning the Wetland to its supposed, natural brackish state and may improve the fisheries situation which had declined over the last 50 years. Emergent and submergent aquatic macrophytes were decreasing and *Alosa caspia* were increasing in numbers since 1989 (Mandych, 1995). However, the fishery will require extensive engineering and management innovations to recover.

It is also reported westwards to Astara and eastwards to Gorgan Bay. The winter habitat of *persica* is unknown. It is semi-anadromous and remains in the southern Caspian Sea near the shore. From spring to fall this subspecies moves northward along the eastern Caspian shore towards Krasnovodsk Bay and westwards to the Anzali Talab.

Age and growth: Pushbarnek (1987) found shad of the type subspecies up to 7 years of age on the western coast of the middle Caspian Sea. In the spawning population, the predominant sizes and weights for males were 16-21 cm and 60-130 g and for females 18-23 cm and 70-140 g. Males and females usually mature at 2-3 years although most spawn for the first time at 3 years. Females grow faster than males. Shad may spawn up to four times as the period of sexual maturation may continue for 2-5 years. The age composition of the spawning population is dependent on year-class strength. First spawners constitute 75.9% of 3-year-olds, 41.7% of 4-year-olds and 23.5% of 5-year-olds. The Caspian shad is a slow-growing species compared to *A. braschnikowii* and *A. saposchnikowii*, its mean length being 21.2 cm compared to 32.2 cm and 25.6 cm for the two other species respectively (Shubina, 1981).

Dmitriev (1947) briefly examined the Anzali, Iran population and found 6 age groups but life span is noted by Heckman in Hoestlandt (1991) to be up to 9 years. Maturity is attained as early as 2 years although most fish appear to mature later as most spawners are 4-5 years old. The subspecies *persica* is the slowest growing of the shad species in the Caspian Sea, sexually mature fish being 13-21 cm long. Some fish become mature at 2 years of age. Life span is up to 8 years. The populations of both *knipowitschi* and *persica* are small compared to *caspia*. Abbasi and Sabkara (2004) studied 180 fish from the southeast Caspian Sea coast of Iran and found fork length to be 103-232 mm, mean 158.8 mm, weight 16-130 g, mean 52.2 g and age 2-5 years, mean 2.64 years. Afraei et al. (2006) found this species to be the smallest *Alosa* in Iranian waters on average at 110 mm and 109 g. Patimar et al. (2011) found Iranian fish to reach age 5^+ years, with positive allometric growth in the southeast Caspian, and negative allometric growth in the central and southwest Caspian. Females had a *b* value larger than males. von Bertalanffy growth functions were variable, different between males and females of each area and between sexes from different areas. The largest L_∞ was in the southeast for males and in the central area for females. The highest *K* value was for males and the lowest for females in the southeast area. t_0 was negative in all areas with lowest value for females (-0.531) in the southeast and the highest for males (-0.145) in the central area. Alavi-Yeganeh et al. (2013) found Mazandaran fish were 2-5 years old and had a *b* value of 3.022. Ghotbi-Jokandan et al. (2015) examined 113 fish from Anzali, Noor and Torkeman and found a *b* value of 2.98. Mousavi-Sabet et al. (2016) gave a *b* value of 3.12 for Iranian fish from 6 fishing areas from Astara to Miankaleh.

Food: The most intensive feeding period occurs after reproduction, beginning in June and the highest condition factor is found at the end of this summer feeding period. Little food is eaten in winter. Temperature (affecting metabolic rate) and zooplankton biomass (decreases engender competition with *C. engrauliformis* and other planktivores) are important factors governing catches of this species (Shubina 1981). Food is chiefly copepods, more than 70%, with mysids at 20%, but some phytoplankton and small fishes are taken. Food in rivers after spawning is mostly cladocerans and other crustaceans. The above refers to the type subspecies; food of the other two subspecies is assumed to be similar.

The southeast Caspian Sea fish studied by Abbasi and Sabkara (2004) fed on phytoplankton (*Rhizosolenia* and *Spprirogyra*) at 4.5%, zooplankton (Foraminifera, Copepoda, Cirripedia, Bivalvia larvae) at 95.0%, and bony fish larvae and eggs at 0.5%. The presence of the ctenophore, *Mnemiopsis leidyi*, a food competitor reduced the index of fullness and fish growth was reduced. Abdollapour Bereya et al. (2007) studied diet in fish from beach seines and gill nets in Gilan. 98.0% of the stomach contents were zooplankton (ostracods, rhizopods, cladocerans, rotatarians, copepods, cirripedes, mysids, bivalve larvae and bony fish larvae and eggs), 1.8% was phytoplankton (notably *Rhizosolenia* and *Spirogyra*), and 0.2% was benthic items (foraminiferans, sponges, cumaceans, amphipods, insect larvae and palaemonids). *Acartia* spp. (copepods) at 83.1%, and *Balanus* (cypris larvae of the cirripede) at 12.9% were the most abundant. The zooplankton have declined drastically from predation by *M. leidyi*, the invasive ctenophore, and the fish have shown a great reduction in the index of fullness and in growth recently.

Reproduction: Most spawning of the type subspecies occurs in the north Caspian Sea near the outflow of the major rivers, particularly the Volga, and the fish overwinter in the south Caspian, migrating between the two areas (Shubina, 1981). This subspecies spawns successively, 3 times within a week. Some fish enter fresh water to spawn. Spawning takes place at the favoured water temperature of 13.8-24.1°C, with mass spawning at 18-22°C, beginning as early as late April or as late as mid-May and continuing to mid- or late June. Most eggs are released in the upper 3m of the water column. Fecundity reaches 41,000 eggs. The eggs are 1.11-1.38mm when ripe but unfertilised and 1.92-2.91 mm in diameter when fertilised, and are semi-pelagic to demersal. The subspecies *knipowitschi* spawns in the Anzali Talab (and probably the Chemkhaleh River to the east of the Safid River) in May and June after a spring migration from the sea, leaving in the fall. Spawning of the subspecies *persica* takes place in Gorgan Bay and Holčík and Oláh (1992) suspect from catches of mature and spent fish that it also occurs in the Anzali Talab.

Parasites and predators: Naem et al. (2002) found the monogenean trematode *Mazocraes alosae* on the gills of this species in the western branch of the Safid River. Barzegar et al. (2008) record the digenean eye parasite *Diplostomum spathaceum* from this fish. Youssefi et al. (2011) report the digenean *Pronoprymna ventricosa* from fish in the Babol River. Barzegar et al. (2012) found *Mazocraes alosae*, *D. spathaceum*, *P. ventricosa* (digenean), and *Hysterothylacium* sp. (anisakid).

The Caspian seal, *Pusa caspica*, is a predator on this species (Krylov, 1984) and it forms a substantial part of the diet of *Silurus glanis* in the Anzali Talab (Holčík and Oláh, 1992). Ashoori et al. (2012) found that grey herons (*Ardea cinerea*) in the Siahkeshim Protected Area of the Anzali Wetland or Talab ate this species.

Economic importance: The type subspecies was the most important subspecies in the herring family in the Caspian Sea. It was caught off the coasts of Dagestan and Azerbaijan for research purposes and comprises 85% of the clupeid catch (Pushbarnek, 1987), and 80-90% of the Caspian commercial catch (Kushnarenko, 1986). During the 1970s, it was only 2% of the total Caspian fishery production. These herrings dominated the commercial catch in the Caspian Sea until the 1960s when commercial fishing was banned except on the western coast of the central Caspian. Many young of other commercial species were being killed in the herring fishery, entangled in the gill nets used. Soviet catches have weighed as much as 75,000 t. This fish is fattier than other Caspian Clupeidae, except for *A. kessleri*, up to 18.1% of the body weight. The fat content decreases on the spring migration. The catch of the subspecies *knipowitschi* is of minor economic importance and had been little exploited when Svetovidov (1952) summarised biology, as the age of captured fish indicated. About 420 tons (*sic*, possibly tonnes) were caught in the Anzali Talab in 1933 and 1934, but this may be an error in the report by Vladykov (1964) according to Holčík and Oláh (1992) although Berg (1948-1949) reports 4,200 centners for the same period. The fishing season in the talab began in mid-April and ended in mid-June when spent fish appeared. There appears to be no fishery data on the subspecies *persica* in the sea. Holčík and Oláh (1992) report catches of *persica*, which replaced *knipowitschi*, in the Anzali Talab from the end of April to the beginning of June but in 1990 this comprised only 5 kg. It is regarded as of inferior quality in Iran. The Caspian shad is the dominant fish catch in the Iranian Caspian, comprising 51,000t in 1994 rising from nothing a decade earlier (Food and Agriculture Organization, Fisheries Department, 1996). Robins et al. (1991) list this species as important to North Americans. Importance is based on its use as food.

Ershad Langroudi (2004) investigated the durability of polycyclic aromatic hydrocarbons (PAH), a carcinogen, in cold smoked fish and found relatively large amounts in the skin and flesh of this fatty shad compared to cyprinids. The PAH density declined with storage time. Nemati et al. (2012) determined that the protein hydrolysate produced from by-products (head, skin, viscera) using the enzyme alcalase was the best, with high nutritional value and was useful as a protein source in fish food. Soleimani et al. (2012) found the amounts of fat, protein, ash and dry matter were higher in this species than in *C. engrauliformis* and it was a rich source of omega-3 fatty acid. Salting and drying methods were compared.

Najm et al. (2014) determined the concentration of the heavy metals cadmium, chromium and lead in fish from the Babol Sar coast and found cadmium levels exceeded international standards for human consumption although a risk assessment concluded the fish were safe for consumers. Sadeghi Bajgiran et al. (2016) assessed this species for muscle content of nickel, vanadium and zinc and found levels not to be dangerous to consumers.

Conservation: The stocks of this species in the Anzali Talab are likely to increase if the lagoon becomes more saline (Holčík and Oláh 1992). Kiabi et al. (1999) consider this species to be of least concern in the south Caspian Sea basin according to IUCN criteria. Criteria include abundant in numbers, widespread range (75% of water bodies), absent in other water bodies in Iran, and absent outside the

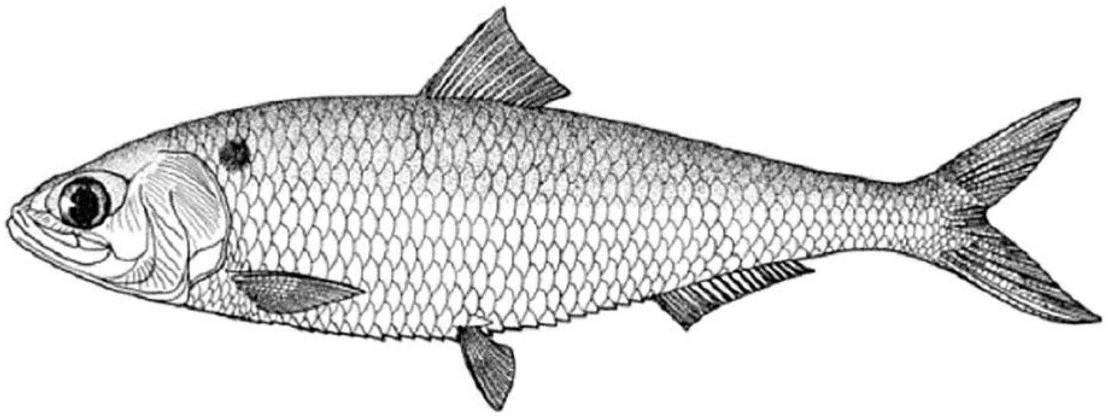

Figure 4. Line drawing of *Alosa kessleri*.

Caspian Sea basin.

Sources: Iranian material: CMNFI 1970-0524, 11, 58.7-88.9 mm standard length, Gilan, Caspian Sea at Bandar-e Anzali (37º28'N, 49º27'E); CMNFI 1970-0532, 1, 113.0 mm standard length, Gilan, Caspian Sea near Bandar-e Anzali (37º28'N, 49º27'E); CMNFI 1970-0543A, 1, 85.9 mm standard length, Gilan, Caspian Sea at Hasan Kiadeh (37º24'N, 49º58'E); CMNFI 1970-0586, 1, 77.5 mm standard length, Mazandaran, Gorgan Talab at Ashuradeh-ye Kuchak (36º50'N, 53º56'E); CMNFI 1970-0587, 2, 107.4-108.6 mm standard length, Mazandaran, Babol Sar (36º43'N, 52º39'E); CMNFI 1971-0343, 1, 95.5mm standard length, Gilan, Langarud at Chamkhaleh (37º13'N, 50º16'E); CMNFI 1979-0430, 1, 118.0 mm standard length, Mazandaran, river east of Now Shahr (36º39'N, 51º31'E); CMNFI 1979-0431, 7, 120.8-155.1 mm standard length, Mazandaran, Now Shahr bazaar (no other locality data); CMNFI 1979-0686, 2, 119.7-126.9 mm standard length, Gilan, Safid River (37º24'N, 49º58'E); CMNFI 1980-0146, 2, 106.9-171.8 mm standard length, Mazandaran, Gorgan Talab at Ashuradeh-ye Kuchak (36º50'N, 53º56'E).

Comparative material: BM(NH) 1938.8.2:3, 1, 203.8 mm standard length, Caspian Sea (no other locality data); BM(NH) 1939.2.21:22-23, 2, 175.6-179.2 mm standard length, Caspian Sea (no other locality data); BM(NH) 1954.6.24:5-7, 3, 164.1-189.1 mm standard length, Caspian Sea (no other locality data).

Alosa kessleri (Grimm, 1887)
(Figs. 4, 5)

Common names: Shagmahi-ye poshtsiah, shagmahi darya-ye siah, shagmahi-ye moohajer or shagmahi-e-mohajer, zalun (in Gilaki), puzanok. [Volga siyanayi, garabel siyanak in Azerbaijan; arkasy gara takgas in Turkmenistan; blackback, Caspian anadromous shad; chernospinka or black-spined herring, chernonosik or blacknose, beshenka, zalom, poluzalom, zheleznitsa, veselka, Volzhskaya mnogotychinkovaya sel'd or Volga many-rakered herring, Volzhskaya sel'd or Volga herring, Astrakhanskaya sel'd or Astrakhan herring, all in Russian].

Systematics: *Clupea kessleri* was originally described from the Volga River delta, Astrakhan. *Clupea pontica* (Eichwald, 1838) was originally described in Latin from "Hab. in Ponte Euxino prope Odessam" (= Black Sea near Odessa). *Alosa kessleri* was formerly considered as a subspecies of *A. pontica*. *Alosa pontica* then had two subspecies in the Caspian Sea, namely *kessleri* (Grimm, 1887) (chernospinka or black-spined herring, chernonosik or blacknose, beshenka, zalom, poluzalom, zheleznitsa, veselka, blackback), and *volgensis* (Berg, 1913) (Volzhskaya mnogotychinkovaya sel'd or Volga many-rakered herring, Volzhskaya sel'd or Volga herring, Astrakhanskaya sel'd or Astrakhan herring, zheleznitsa, beshenka, veselka). Kottelat and Freyhof (2007), Abdoli and Naderi (2009) and

Figure 5. *Alosa kessleri* courtesy of A. Abdoli.

Naseka and Bogutskaya (2009) consider *Alosa kessleri* and *A. volgensis* to be valid species.

A lectotype of *kessleri*, 40.1 cm long, was designated from the Volga Delta by L. S. Berg under ZISP 15925 (in the Zoological Institute, St. Petersburg). A lectotype of *volgensis*, 34.8 cm long, is under ZISP 15926 and is from the Volga River at Chernyi Yar (Svetovidov, 1952). A paralectotype of *kessleri* is under ZISP 15922.

Caspialosa volgensis bergi Tanasiichuk, 1938 described from the Volga Delta is a synonym of *Alosa kessleri* (Heckman in Hoestlandt, 1991). Eschmeyer et al. (1996) give author and date for *Alosa volgensis bergi* as Tanassiychuk, 1940, the variation probably being due to transliteration of a Russian name and to year of actual publication rather than year on the journal.

Caspialosa kessleri infraspecies *volgensis imitans* Berg, 1948 from the Caspian Sea (see Berg (1948-1949) for further details) is not available because of its infrasubspecific rank (Eschmeyer et al., 1996). *Clupea caspio-pontica* Borodin, 1904 is an unneeded new name (Eschmeyer et al., 1996).

Key characters: Characterised by a relatively elongate and rounded body likened to a "herring" shape, not as deep and compressed as in some related species which are likened to a "shad" shape. Total gill rakers 49-158 in the Caspian Sea, with ranges about 57-95 in *kessleri* and 87-158 in *volgensis*. Rakers are usually longer than the gill filaments in *volgensis*, shorter in adult *kessleri*. Teeth are well developed in both jaws in *kessleri* and can be felt with a finger, poorly developed in *volgensis* such that they sometimes cannot be felt.

Morphology: Dorsal fin with 3-5 unbranched and 12-16 branched rays, anal fin with 2-4, usually 3, unbranched and 15-21 branched rays. Vertebrae 47-50 in *kessleri* (also a report of 50-54, both in Svetovidov (1952)), 48-54 in *volgensis*. Pyloric caeca 21-62. Scales in lateral series 53-56. Gill rakers in adults are thick and often broken off at the tip or near the base in *kessleri*, unbroken in *volgensis*. The tips of the gill rakers may be swollen and they are arranged in a straight line. Young fish have long and thin gill rakers with strong lateral spines. Spines are lost with age.

Sexual dimorphism: None reported.

Colour: The overall coloration is dark with a black back which has a violet tinge in spring in *kessleri*, light olive-green in *volgensis*. There is dark, sometimes vague, spot on the flank behind the operculum and sometimes a series of spots in *kessleri*, but these are absent in *volgensis*. The pectoral fin is black on top. Spawning *kessleri* become grey or grey-green on the back and flanks with bronze spots on the operculum and flanks. A greenish-yellow circle forms around the eye after spawning.

Size: Reaches 52.0 cm total length and 2.0 kg for *kessleri*, 40.0 cm for *volgensis*.

Distribution: Found in the Caspian Sea, entering northern rivers to spawn. Abdoli and Naderi (2009) list it as from the southwest, southeast and south-central Caspian Sea in Iranian waters. Esmaeili et al. (2014) list this species from the Anzali Wetland or Talab.

Zoogeography: This species is a Caspian Sea endemic.

Habitat: Both subspecies are found in the open sea but *kessleri* ascends rivers much higher than *volgensis* which spawns in the delta region. Both subspecies overwinter in the southern Caspian Sea off the Iranian coast and then migrate north to enter the Volga and other northern rivers to spawn. The subspecies *volgensis* is absent from the southern Caspian in summer. The subspecies *kessleri* shows a greater affinity than *volgensis* for cold water.

The subspecies *kessleri* begins to migrate northward in March and April mostly along the western shore of the Caspian Sea, beginning to arrive in northern waters when temperatures are still below 5°C, most arriving when temperatures are 6-8°C compared to 10-13°C for *volgensis*. A mass migration into the lower Volga takes place in late April or early May for both subspecies when water temperature reaches 9°C and the peak run begins at 12-15°C, ending at 22°C. The run of *volgensis* is about 10 days later than that of *kessleri* and spawning takes place earlier as they do not travel as far upriver. Speed is up to 70 km/day for *kessleri* and depends on temperature. This fish used to run 2,000 km up the Volga River. Sexually immature fish remain in the south and do not migrate. Knipovich (1921) reports *kessleri* as deep as 235-300 m in Iranian waters. Temperatures up to 25ºC are tolerated.

Age and growth: Males are sexually mature at 3 years and females at 4 years, other reports give 4-5 years for both sexes in *kessleri*. Many fish die after spawning but some survive to spawn two or three times. Four and five-year-olds dominate on *kessleri* spawning runs with some older fish also present. Females predominate in older fish making the spawning run. Life span is between 7 and 8 years.

Growth of the *volgensis* subspecies is slower than in *kessleri*, which apparently grows faster than any other Caspian clupeid. Life span in *volgensis* is 7-8 years with females living longer than males. Most spawners are 3-4 years old although in some years, 5 year old fish are abundant. Males may mature at 2 years, females later. Most fish spawn again the next year after their first time but some may miss a year. An individual may spawn up to four times during its life.

Heidari et al. (2015b) examined fish from the Tonekabon fishing area and found *b* values of 3.687 and 3.571 for total and standard length, indicating positive allometric growth. Alavi-Yeganeh et al. (2013) found Mazandaran fish were 2-5 years old and had a *b* value of 2.993. Ghotbi-Jokandan et al. (2015) examined 103 fish from Anzali, Noor and Torkeman and found a *b* value of 2.88. Mousavi-Sabet et al. (2016) gave a *b* value of 3.13 for Iranian fish from 6 fishing areas from Astara to Miankaleh.

Food: Cladocerans are the main food item of young *kessleri* which have a feeding peak at 1800-2200 hours and another at about 0800 hours. Adults in the sea take fishes such as *Clupeonella* and *Atherina* with some crustaceans and insect larvae. *Clupeonella caspia* makes up 92% of the diet of *kessleri* in the northern Caspian in May, with *Sander lucioperca* at 6.6% and gammarids at 1.0%. There is said to be little feeding on the spawning run although some fish sampled contained cladocerans, copepods, insects, bryozoans and fish fry.

The food of *volgensis* is similar to the other subspecies, taking copepods when young and larger items with growth. The main items are copepods, mysids, cumaceans, amphipods and small fishes. This subspecies feeds on the spawning migration.

Reproduction: Spawning in *kessleri* occurs in rivers from mid-May to mid-August, either the delta or lower reaches when entering in a ripe condition, or as much as 500 km upriver when entering in an unripe condition. Larger fish have spawning grounds further upriver than smaller fish and predominate earlier in the run. The spawning grounds in the Volga River cover a considerable stretch. Spawning usually occurs at 18-20°C between 0300 and 0600 hours or from 1600 hours to sunset. Spawning occurs in the main channel, over shallow sand banks, or in backwaters. Batches of eggs are laid at intervals of several days. Eggs are pelagic as in other Caspian *Alosa* and develop as they drift downriver near the bottom. At 22.7°C incubation takes about 40 hours. The young fish descend in late summer and early fall. Fecundity in *kessleri* reaches 344,000 eggs and egg diameter 1.51 mm. Shed eggs are up to 4.1 m in diameter. Some fish may return to spawn in total three times.

Spawning of the first batch of eggs in *volgensis* may occur in the sea with the subsequent 2 batches at 7-10 day intervals in the delta and river. This takes place from mid-May to the beginning of August. Up to 281,000 eggs are shed. Peak spawning occurs at 15-19°C and ends at 25-27°C. Most spawning takes place in the evening between the 1600 and 2200 hours. The young appear in the pre-estuarine area of the Volga River in July and towards October begin to migrate south.

Parasites and predators: The Caspian seal, *Pusa caspica*, is a predator on this species (Krylov, 1984), larval shad are fed on by other fishes and by various invertebrates, and adults by various fishes and birds.

Economic importance: The subspecies *kessleri* and *volgensis* were caught on the spawning run with as much as 5,750 t being taken annually pre-World War II. It is the biggest shad in the Caspian Sea. The subspecies *kessleri* was the most important and valuable herring in the Caspian Sea. Early spring catches were mostly *kessleri* but as the run of *volgensis* built up it formed an increasingly significant part of the catch, forming as much as 92% of the total. The catch of *volgensis* has declined from this period until the 1970s when the fish taken were mostly *kessleri*. The catch of *Alosa pontica* (= *kessleri*) on the North Caspian fishing grounds in 1965-1972 has declined to 2-4% of the 1938-1943 catch. The subspecies *volgensis* was one of the most important Caspian herrings, 23-29% of the total catch from 1936-1939, as high as 69,100t in 1939.

The subspecies *kessleri* is said to be the tastiest Caspian clupeid because of its high fat content, averaging 18.9% of weight along the coast of Azerbaijan, while in *volgensis* it was 9.6%. Post-spawners of *kessleri* may have a fat content as low as 0.5%. Catches are processed as canned, salted and pickled fish. Beach seines are used to catch this fish.

Akhondzadeh Basti et al. (2006) found the bacterial pathogen *Vibrio haemolyticus* in fresh and smoked *Alosa kessleri*. Tavakoli et al. (2012) found a frequent contamination rate with *Staphylococcus aureus* and *Vibrio parahaemolyticus*, human pathogens, in fresh and smoked shad and they may cause health problems. Robins et al. (1991) list this species as important to North Americans. Importance is based on its use as food.

Conservation: Stocks in Iranian waters are said to be depleted. The subspecies *volgensis* was in Category I on the "Red List" of the Russian Republic (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 commercial fishing, numbers unknown, range unknown absent in other water bodies in Iran, absent outside the Caspian Sea basin.

Sources: Iranian material: None available.

Comparative material: BM(NH) 1879.11.14:22-23, 2, 255.9-259.1 mm standard length, Caspian Sea (no other locality data); BM(NH) 1939.2.21:21, 1, 388.6 mm standard length, Caspian Sea (no other locality data).

Alosa saposchnikowii (Grimm, 1885)
(Figs. 6, 7)

Common names: Shagmahi-ye cheshmdorosht, shagmahi, kilka (incorrectly), herring. [Irikoz sisgarin in Azerbaijan; bol'sheglazyi puzanok or bigeye shad, Sapozhnikovskii puzanok or Saposhnikovi shad, all in Russian].

Systematics: The lectotype of *Clupea saposchnikowii* from the Volga Delta is in the Zoological Institute, St. Petersburg under ZISP 15921 (Berg 1948-1949; Eschmeyer et al. 1996). The name is often spelt *saposchnikovi*, in error, or with a single terminal "i"; Reshetnikov et al. (1997) revert to the original spelling of the specific name.

Caspialosa caspia nigra Kisselevitsh, 1923, in part, from the Caspian Sea opposite Dzambai is a synonym with a lectotype in the Zoological Institute, St. Petersburg (ZISP 15938) (Kisselevitsh is also transliterated Kiselevich and Kisselevitz). The material also included specimens of *Alosa braschnikowii* (Whitehead, 1985; Eschmeyer et al., 1996).

Key characters: Characterised by a relatively deep and compressed body likened to a "shad" shape, not

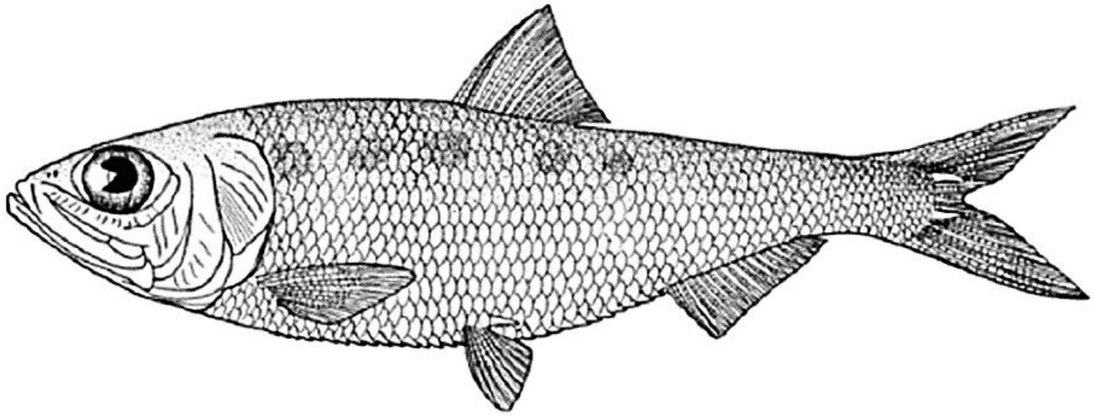

Figure 6. Line drawing of *Alosa saposchnikowii.*

Figure 7. *Alosa saposchnikowii* courtesy of A. Abdoli.

as elongate and rounded as in some related species which are likened to a "herring" shape. The upper and lower head profiles are straight. The upper edge of the lower jaw is straight. Total gill rakers 20-48, short (obviously shorter than the gill filaments), and thick. Teeth are well developed in both jaws.

Morphology: Dorsal fin with 3-5, usually 4, unbranched rays and 12-15, mostly 13, branched rays, anal fin with 2-4, usually 3, unbranched rays and 15-21, mostly 18, branched rays. Lateral series scales 52-55. Vertebrae 47-53. Pyloric caeca 36-59.

Sexual dimorphism: None reported.

Colour: Fish from the southern Caspian Sea are more intensively coloured than those from the north. The back is violet with a green sheen and the flank has 4 dark stripes which merge with the dark on the back. There is a spot posterior to the operculum, which may be absent.

Size: Reaches 36.0 cm total length and 650 g.

Distribution: Found mainly in the north Caspian Sea and the coast of Dagestan but entering Iranian waters. Abdoli and Naderi (2009) list it as from the southwest, southeast and south-central Caspian Sea in Iranian waters and see below under Sources for some specific localities.

Zoogeography: This species is endemic to the Caspian Sea.

Habitat: This species spends its whole life in the Caspian Sea and never enters rivers. It favours colder water and is one of the first clupeid species to migrate north in spring, principally along the western coast. Large fish migrate first. Fish first approach the shore of Azerbaijan in mid-March with a mass approach from late March to mid-April. It is less frequently encountered in the southern part of the Caspian Sea, overwintering in the central Caspian and only moving south if winters are cold. A Caspian Sea Biodiversity Database (from www.caspian environment.org) has it at 400-600 m in the southern Caspian in cold winters but later states it keeps at 15-

32 m. Winter temperatures at which this species is found are 6-7°C. Depths are 25-32 m in winter, more shallow in summer but below 9 m. Knipovich (1921) reports this species in a depth range of 52-77 m in Iranian waters. It tolerates a range of 3-25°C and spawns at salinities of 0.7-11.0‰, although preferring 4.0-7.5‰. The Caspian Sea Biodiversity Database (from www.caspian environment.org) estimates a population of 1.1125 billion fish.

Age and growth: Life span is about 9 years and female lengths and weights exceed those of males throughout life. On average, males weigh less than half the weight of females since females carry a heavy egg load. Growth is most intensive in the first two years of life and slows thereafter (Chang, 1972). Males mature at age 2 and females at age 3. Ghotbi-Jokandan et al. (2015) examined 40 fish from Anzali, Noor and Torkeman and found a *b* value of 3.14. Mousavi-Sabet et al. (2016) gave a *b* value of 2.99 for Iranian fish from 6 fishing areas from Astara to Miankaleh.

Food: A rapacious fish which takes young herrings and kilka, *Atherina* and even *Benthophilus* (Lönnberg, 1900) as well as large crustaceans such as mysids and gammarids. It is a cannibal. This shad overwinters and feeds in the south Caspian Sea (Chang, 1972).

Reproduction: The spring spawning migration (end of April to end of May) enters the north Caspian Sea and fish are mostly 15-25 cm in body length. Males mature at a younger age than females as evidenced by fish 3-4 years old predominating among females and fish 2-4 years old among males in the north Caspian catch. Spawning takes place in May (peaking in the first 10 days) and most fish are returning for the second time. Spawning temperatures are lower than in *Alosa caspia*, being only 13-14°C although the peak is at 19-20°C. Spawning occurs in il'mens, the sea where there is a freshwater discharge such as near the Volga River mouth, and in the northeastern sea. Females may spawn up to 6 times and males up to 5 times (Chang 1972). Spawning takes place in shallow water at 1-6m depths. Fecundity is up to 318,852 eggs. The young migrate southwards.

Parasites and predators: Mazandarani et al. (2016) found a trematode (*Pronoprymna ventricosa*) and two nematodes (*Anisakis simplex* and *Eustrongylides* sp.) in the abdominal cavity of fish from Behshahr, Mazandaran Province. The latter two are pathogenic to humans. The Caspian seal, *Pusa caspica*, is a predator on this species (Krylov 1984).

Economic importance: An important commercial species in the central and northern Caspian, taken on their way to, and on, the spawning grounds. The fishery in Azerbaijan during 1937 caught fish on average 17cm long and 62g in weight, most fish being 2-3 years old. The Caspian catch in the period 1936-1939 reached a peak of 8,800t annually. Fish are caught with beach seines, stationary nets and drift nets.

Conservation: Stocks in Iranian waters are reputed to be depleted. Kiabi et al. (1999) consider this species to be data deficient in the south Caspian Sea basin according to IUCN criteria. Criteria include numbers unknown, range unknown, absent in other water bodies in Iran, absent outside the Caspian Sea basin.

Sources: Iranian material: CMNFI 1970-0531, 15, 49.9-108.7mm standard length, Mazandaran, Larim River (36º46'N, 52º58'E); CMNFI 1970-0532, 1, 137.4mm standard length, Gilan, Caspian Sea near Bandar-e Anzali (37º28'N, 49º27'E); CMNFI 1970-0543A, 2, 78.8-80.2mm standard length, Gilan, Caspian Sea at Hasan Kiadeh (37º24'N, 49º58'E); CMNFI 1970-0581, 1, 102.1mm standard length, Gilan, Caspian Sea near Hasan Kiadeh (37º24'N, 49º58'E); CMNFI 1979-0788, 3, 96.0-114.9mm standard length, Mazandaran at Khadje Nafas (37º00'N, 54º07'E); CMNFI 1980-0136, 3, 107.3-127.6mm standard length, Mazandaran, Fereydun Kenar River (36º41'N, 52º29'E); CMNFI 1980-0157, 2, 96.6-101.1mm standard length, Mazandaran, Gorgan River estuary (36º59'N, 53º59'30"E); CMNFI 1980-0908, 1, 77.9mm standard length, Gilan, Safid River estuary (ca. 37º28'N, ca. 49º54'E).

Comparative material: BM(NH) 1954.6.24:8-10, 3, 150.5-177.0mm standard length, Caspian Sea (no

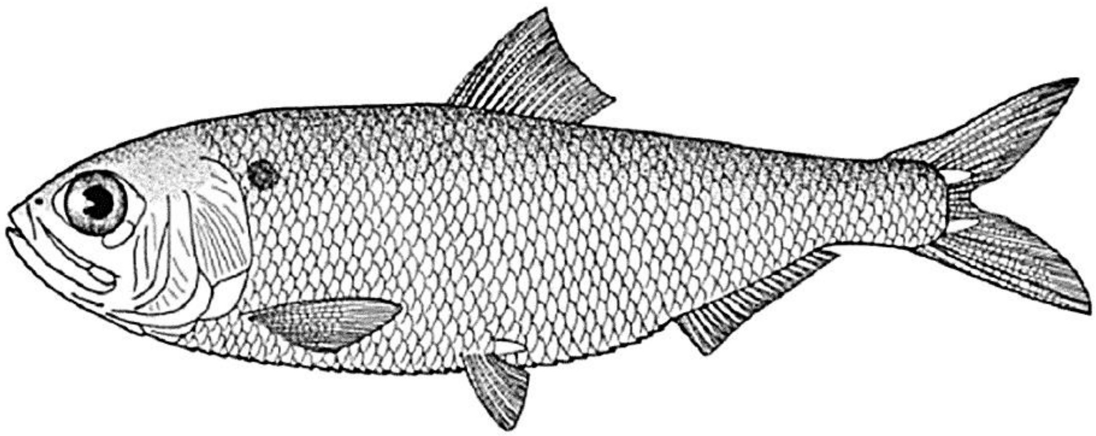

Figure 8. Line drawing of *Alosa sphaerocephala.*

other locality data).

Alosa sphaerocephala (Berg, 1913)
(Fig. 8)

Common names: Shagmahi-ye Agrakhan. [Kruglogolovyi puzanok or roundheaded shad, Agrakhanskii puzanok or Agrakhan shad, both in Russian].

Systematics: The holotype of *Clupeonella sphaerocephala* from Agrakhan Bay, at Tyulenii Island, Turali in the northern part of the Caspian Sea is in the Zoological Institute, St. Petersburg under ZISP 15928 with more than 30 paratypes (Eschmeyer et al., 1996).

Key characters: Characterised by a relatively deep and compressed body likened to a "shad" shape, not as elongate and rounded as in some related species which are likened to a "herring" shape. The upper and lower head profiles are obviously rounded. The upper edge of the lower jaw is crescent-shaped. Total gill rakers 25-45, long (equal to or longer than the gill filaments), and thin. Teeth are well developed in both jaws.

Morphology: Dorsal fin with 3-4, usually 4, unbranched rays and 13-15 branched rays, anal fin with 3-4, usually 3, unbranched rays and 17-20 branched rays. Vertebrae 47-51.

Sexual dimorphism: None reported.

Colour: The back is dark with an olive tint, the tip of the snout is occasionally black and the pectoral fins are dark. There is a black spot behind the operculum and occasionally a row of such spots.

Size: Reaches 25.0 cm standard length.

Distribution: Found in the Caspian Sea including Iranian waters.

Zoogeography: This species is endemic to the Caspian Sea.

Habitat: This species does not enter fresh waters. It is most common along the eastern shore of the northern part of the sea in spring where spawning occurs and along the northern shore of the northern part of the sea in summer. Knipovich (1921) reports this species from Iranian waters in a depth range of 52-77 m.

Age and growth: Unknown.

Food: Unknown, although presumably similar to other shads.

Reproduction: Spawning takes place in the northeastern Caspian from mid-May to the end of June peaking at 18-20°C, most frequently in a salinity of 8-11‰ and in depths around 3-8 m. The young move south in late autumn, as late as November, the last clupeids to leave this area. Fecundity is about 20,000 eggs.

Parasites and predators: The Caspian seal, *Pusa caspica*, is a predator on this species (Krylov, 1984).

Economic importance: This species is caught only in small numbers.

Conservation: The status of this species is unknown.

Sources: Iranian material: None available.

Comparative material: BM(NH) 1954.6.24:11-13, 3, 145.6-162.1 mm standard length, Caspian Sea (no other locality data).

Genus *Clupeonella* Kessler, 1877

This genus is found in the Black and Caspian seas basins with 5 species, 3 of which are in the Caspian Sea and in Iranian waters. *Clupeonella* species are distinguished from sympatric *Alosa* species by smaller size, a small and toothless mouth, adipose eyelids are small or rudimentary, no spots on the flank, no elongate scales (ala) at the base of the caudal fin, no vomerine teeth, the lack of a notch at the mid-line of the upper jaw, and by the last two anal fin rays being elongated.

Species in this genus live entirely in the sea, or in fresh water, or migrate between the two. Eggs are pelagic and have a large oil globule. The general Farsi name for these fishes is kilka or kelka, i.e. "sprat", although sprat is erroneous according to Berg (1948-1949) who uses tyulka for these fishes).

The three *Clupeonella* species have been fished in modern Iran since December 1971 but the commercial catch did not exceed 15,000 tonnes. Earlier catches date back only to 1939, with an annual catch of about 100t in 1943-1949, exported in a marinated form to the Soviet Union (Alam, no date). Curiously, the abundance of kilka has long been known as Kinneir (1813) records "and herrings are in such abundance, that after a storm, the shores of *Ghilan* and *Mazanderaun* are nearly covered with them". Caddy (1984) refers to the kilka fisheries of the Iranian Caspian by the scientific name *Sprattus sprattus* but this is an error.

Caddy (1984) indicated that there were problems in marketing and utilizing these fishes in Iran even though up to 50,000 t could be caught annually (200,000 t elsewhere in the same article). Their best use was probably as food for predators such as *Sander lucioperca, Esox lucius* and *Salmo caspius*. A study by Razavi Sayad (1993) suggested a ceiling of 100,000 t was possible. The Caspian Sea resources of kilka are estimated at 800,000 t from which 340,000 t can be exploited (Abzeeyan, Tehran, 6(8): IV, 1995).

The catch reached 51,000 t in 1994 from none 10 years previously (Food and Agriculture Organization, Fisheries Department, 1996) and was 36,000 t in 1997-1998 (Irna, 31 March 1998) and 85,000 t in 1998-1999 (Fazli and Roohi, 2002a). The catch for the first 6 months of the Iranian year was 17,000 t, taken by 70 trawlers and a 10% increase over the previous year (Irna, 20 October 1998). Fishermen in Gilan caught 50,000t annually in the late 1990s (Tehran Times, 5 September 1999). A reported catch of 56,000 t was made in 1999-2000, a 13% increase over the previous year (Irna, 27 March 2000). A later estimate expects the kilka catch to reach 66,000 t by the year 2000 (Abzeeyan, Tehran, 5(9): IV, 1995).

Fazli (2006) records that kilka fishing ships discharge their catches at three ports, Babol-Sar and Amirabad in Mazandaran and Anzali in Gilan. The catch decreased from 28,000 t to 19,600 t in Mazandaran and from 57,000 to 42,600 t in Gilan from 1999 to 2000. The catch per unit effort also decreased from 3,900 kg to 2,500 kg over the two years. Anchovy kilka dominated the catch but the frequency fell from 85-90% to 76% of the catch and common kilka sharply increased. Common kilka had been caught in spring and summer but in 2000 they were taken in all months. The average length of anchovy kilka declined from 96.3 mm in 1997 to 87.3 mm in 2000 and this was also reflected in the age structure, 5^+ and 6^+ fish being rare.

The presence of the ctenophore, *M. leidyi*, was thought to be damaging stocks (Fazli and Roohi 2002a; Ahmadpour et al., 2012). Darvishi et al. (2004) studied dietary overlap between the ctenophore and the anchovy kilka (see below). Barati (2009) found that the diet of chicks of the Great Cormorant, *Phalacrocorax carbo*, at Ramsar comprised only 2% Clupeidae by frequency, perhaps a result of the decline in *Clupeonella* stocks.

Fazli (2002) studied kilka catches off Mazandaran in 1996-2000. Fishing occurred at night and lasted 7.78-8.22 hours. The maximum catch at 42.8% was taken in October, November and December with a minimum catch in June. The least annual catch per vessel occurred in 1999-2000 (499,401 kg).

A study utilizing an echo-sounder and a pelagic trawler concludes that the maximum biomasses for the three *Clupeonella* species in the southern Caspian Sea were in winter (422,300 t) and autumn (326,900 t) while in summer and spring values were lower at 275,100 t and 260,800 t, respectively. The population consisted of 66.1% anchovy kilka (*C. engrauliformis*), 18.9% bigeye kilka (*C. grimmi*) and 15% common kilka (*C. caspia*) (Iranian Fisheries Research and Training Organization Newsletter, 14: 6, 1996). Note that later, the Iranian Fisheries Research and Training Organization Newsletter (17: 3, 1997) gives kilka biomass in the southern Caspian Sea as winter 22,300 t, autumn 26,900 t, summer 75,100 t and spring 60,800 t, presumably lacking the initial digit, and the percentages of kilka species in the biomass are also wrong. This is corrected in a subsequent newsletter (Iranian Fisheries Research and Training Organization Newsletter, (18: 43, 1997) but the corrected percentage biomasses are given as 66% for *C. engrauliformis*, 19% for *C. caspia* (as *C. delicatula*) and 15% for *C. grimmi*. It is unclear whether *grimmi* or *caspia* is the second most important kilka species. Poorgholam et al. (1996) gave a stock assessment for kilkas in 1995-1995 using the hydro-acoustic method.

Clupeonella engrauliformis dominated the catch in Iran at 91.8%, followed by *C. grimmi* at 6.84% and by *C. caspia* at only 1.35% (Coad 1997). The 2^+ and 3^+ year classes accounted for 69.95% of *C. engrauliformis*, 81.06% of *C. grimmi* and 80.88% of *C. caspia* catches. Catch rates of kilka on the top ranking 17 fishing grounds of 56 studied range from 800 to 1,200 kg per unit effort per hour while traditional grounds have rates of 400-800 kg per unit effort per hour. The kilka are caught by attraction to lights and netting or pumping the catch into specially constructed ships (Fig. 9).

The kilka fishing fleet of Iran expanded in the 1980s and 1990s. There were 30 active vessels in Mazandaran in 1994, each with a capacity up to 30tons (*sic*, probably tonnes here and elsewhere for modern catches) (Abzeeyan, Tehran, 4(10): IV, 1994). The Mazandaran Kilka Cooperative Companies Union had 75 boats in 2000 (Tehran Times, 31 December 2000). Gilan planned to construct 12 fish meal factories each with an annual capacity of 1,000 t and 10 kilka canneries also with 1,000t capacities (Abzeeyan, Tehran, 4(4): III, 1993). Catches off Gilan alone from April 1994 to January 1995 increased 59% compared to the same period in 1993-1994, exceeding 20,000 t (Abzeeyan, Tehran, 6(1): II, 1995). The catch off Mazandaran from March 1994 to March 1995 was 15,400t, an increase of 10% over the previous year. About 1,000 t were processed for human consumption and the rest for fishmeal production (Abzeeyan, Tehran, 6(2): V, 1995). The total kilka catch for Iran has increased to 45,000 t annually and efforts were being made to increase it to 110,000 t (Abzeeyan, Tehran 4(5): IV, 1993). The catch in 1995 was 32,000 t with 64.7% from Mazandaran and 35.3% from Gilan, with the maximum catch occurring in April (Abzeeyan, Tehran, 7(6): II, 1996). Catches declined from 95,000 t in 1999 to 15,497 t in 2003 (Sayyad Bourani et al., 2008). Annual Soviet catches reached 37,000 t in 1956 but this declined to 300-1,500 t by the end of the 1970s or 0.2-0.8% of all kinds of tyulka or kilka in the Caspian Sea. Turkmenistan harvested 7,660 and 8,500 t in 1995 and 1996 although previously almost 45,000t valued at $22.5 million had been taken before equipment deteriorated (http://bisnis.doc.gov/isnis/isa/9805fish.htm, downloaded 14 March 2000). Stocks remained large even though kilka were heavily fished. Kohani et al. (2012)

Figure 9. Conical lift net or kilka net after www.farsnews.com.

Table 6. The catch records for the total kilka catch in Mazandaran in tonnes is courtesy of F. Darvishi (pers. comm. 2003).

Months/Years	**1998 (1377)**	**1999 (1378)**	**2000 (1379)**	**2001 (1380)**	**2002 (1381)**	**Mean**
March-April (Farvardin)	2,848	2,703	4,644	1,217	876	2,458
April-May (Ordibehesht)	1,116	607	972	1,422	195	862
May-June (Khordad)	370	763	1,819	125	158	647
June-July (Tir)	1,392	919	194	425	444	675
July-August (Mordad)	2,152	2,306	433	614	249	1,151
August-September (Shahrivar)	3,117	2,010	581	528	336	1,314
September-October (Mehr)	3,103	6,184	1,785	432	575	2,416
October-November (Aban)	4,120	3,468	2,305	3,051	1196	2,828
November-December Azar)	3,835	3,410	2,655	993	-	2,723* (2,179)
December-January (Dey)	2,754	1,735	620	1,082	-	1,548* (1,238)
January-February (Bahman)	3,968	1,262	2,146	1,586	-	2,241* (1,792)
February-March (Esfand)	2,815	1,667	1,192	1,903	-	1,894* (1,515)
Total	31,590	28,034	19,648	13,378	4,029	

* = averaged over 4 and (5) years.

reviewed fishing in Gilan and noted the number of vessels used increased from 9 in 1989 to 110 in 1999, resulting in the highest catch at 55,900 t. Mis-management, the invasive ctenophore, pollution and temperature changes caused a decline in catches to 4,603 t in 2009.

The kilka fisheries were threatened by the comb jelly (a ctenophore, *M. leidyi*), which arrived in the Caspian Sea in 1995 in the ballast water of ships and spread through the entire sea by the year 2000, feeding voraciously on zooplankton. It is now known as the "Caspian monster" despite its small size of 5cm (J. Muir 2001, http://news.bbc.co.uk/2/hi/middle_east/1453117.stm). It doubles in size in one day, reaches maturity in two weeks and then produces 8,000 young each day. The fisheries collapsed by 50% in a few months, catches by one fisherman falling from being 3-6 t a night to half a tonne. Bilio and Niermann (2004) review the interplay of overfishing, pollution and the ctenophore invasion on the kilka fisheries of the Black and Caspian seas, Kideys et al. (2005) gave an overview of ctenophore impacts on fisheries, and Roohi et al. (2010) compared the effects on phytoplankton, zooplankton, zoobenthos and kilka. Ghadirnejad (2003) reported that *C. engrauliformis* originally dominated the kilka catch at 85-90% but has dropped to 55% through the impact of the comb jelly which has up to 2,285 individuals per cubic metre in the southwest Caspian Sea. Roohi et al. (2010) stated that Iranian landings of kilka dropped about 70% from 69,070 t in 1995-2000 to 23,430 t in 2001-2006, a loss of at least U.S. $125 million. Parafkandeh (2006) gave similar figures for declines in catches.

Fazli et al. (2009a) describe a multi-species approach for stock management, allowing for the decline of *C. engrauliformis* and increase in *C. caspia* in Iranian waters through competition with the ctenophore. The fisheries may recover somewhat after the comb jelly population collapses (Tidwell, 2001) or if a predator, *Beroe ovata,* is introduced and can survive in the less saline waters of the Caspian Sea (J. Muir 2001, http://news.bbc.co.uk/2/hi/middle_east/1453117.stm). Studies indicate it can survive the brackish Caspian Sea water, feed on the comb jelly and not feed on other plankton (Iranian Fisheries Research Organization Newsletter, 36: 35, 2003). The catch records for the total kilka catch in Mazandaran in tonnes is courtesy of F. Darvishi (pers. comm. 2003) (Table 6) and shows the drastic decline caused by the ctenophore, as well as monthly variations in catches.

The species composition of kilkas changed after the introduction of the comb jelly - comparing the year 2000 and before with the year 2002 - the common kilka changed from about 1-5% to about 30%, the bigeye from about 10-15% to 0.2% and the anchovy kilka from about 85-90% to about 70% (Iranian Fisheries Research Organization

Table 7. The catch after after the introduction of the ctenophore (after Fazli, 2011).

Year	*C. caspia* catch (t, %)	*C. caspia* CPUE*	*C. engrauliformis* catch (t, %)	*C. engrauliformis* CPUE*	*C. grimmi* catch (t, %)	*C. grimmi* CPUE*
1997	52,246, 86.5	3.35	6,704, 11.1	0.5	1,450, 2.4	0.09
1998	61,880, 72.8	2.92	18,445, 21.7	0.87	4,675, 5.5	0.22
1999	67,450, 71.0	3.12	14,535, 15.3	0.67	13,015, 13.7	0.6
2000	57,486, 73.7	2.26	9,828, 12.6	0.39	10,686, 13.7	0.42
2001	37,590, 83.2	1.31	2,801, 6.2	0.1	4,789, 10.6	0.17
2002	17,358, 69.5	0.75	25, 0.1	0	7,592, 30.4	0.33
2003	7,530, 50.5	0.57	89, 0.6	0.01	7,291, 48.9	0.55
2004	5,089, 26.9	0.4	227, 1.2	0.02	13,602, 71.9	1.06
2005	4,249, 18.8	0.31	542, 2.4	0.04	17,808, 78.8	1.3
2006	1,896, 8.5	0.15	1,048, 4.7	0.08	19,356, 86.8	1.51
2007	910, 6.0	0.1	379, 2.5	0.04	13,881, 91.5	1.49
2008	440, 2.7	0.06	277, 1.7	0.04	15,573, 95.6	2.13
2009	454, 1.8	0.06	302, 1.2	0.04	24,444, 97.0	3.35

*CPUE = catch-per-unit-effort (tonnes per vessel per night)

Newsletter, 36: 2, 2003). The catch per unit effort (catch per vessel per fishing night) fell from 4 t to 1 t. The catch during 1997-1999 of anchovy kilka fell from 51,300 t to 491 t and bigeye kilka from 7,600 t to 309 t while common kilka rose from 1,500 t to 24,600 t (Iranian Fisheries Research Organization Newsletter, 65: 4, 2011). Parafkandeh Haghighi and Kaymaram (2012) found, for the years 2006-2007, that the common kilka was the dominant species (89.7%) while the anchovy kilka was at only 8.7% after previously being the dominant species. This was attributed to the comb jelly which occupied the anchovy kilka habitat at depths greater than 50 m. The total catch of kilkas fell from 95,000 t in 1999 to less than 20,000 t in 2007. The fishery moved to areas with depths less than 50m, the main reason for the change in species composition.

In 2004, more than 200 fishing boats had been forced to stop operations. The kilka stock has been reduced from 400,000 t to 80,000t over the past 4 years and the catch fell by 34,000 t (www. iranmania.com, downloaded 4 October 2004). Mamedov (2006) gives details of the biology and decline of kilkas in Azerbaijan waters.

The Caspian seal was once a major predator on kilkas but the number of seals has declined on the Kazakhstan and Iranian coasts from 300,000 to 5,000 in recent years through DDT pollution, viral infections and food shortages (Hashemi, 2001).

Fazli (2011) evaluated changes in species composition, catch and catch-per-unit-effort from 1961 to 2009. He found a negative correlation between long-term sea level changes and total catch which significantly declined in 1995 when sea level increased to its highest level. The catch-per-unit-effort before the ctenophore invasion (1996-1999) and after (2000-2009) showed significant declines in *C. caspia* and *C. engrauliformis* while *C. grimmi* increased significantly. Overfishing and environmental factors after the introduction of the ctenophore were the major factors in species composition changes. Catches are presented in Table 7.

Fazli et al. (2013) also examined the stock status of Iranian kilkas. The anchovy kilka and all three species together showed no overfishing from 1991 to 2000 but in 2000 the catch-per-unit-effort neared an "in danger" region and from 2001 to 2007 stocks were overfished. During 2008-2010 the biomass increased and the stocks became non-overfished. The anchovy kilka fishery generally reduced since 1998 and collapsed to the lowest level in 2010. For the anchovy stock to recover, the catch of all three species would have to be restricted during the spawning period and an international effort made to manage stocks.

The Food and Agriculture Organization (www.fao.org/fishery/facp/IRN/en, downloaded 16 January 2017) summarised catches in the south Caspian Sea (Table 8), showing the relative

Table 8. The summarised catches in the south Caspian Sea (Food and Agriculture Organization, 2017)

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Bony fish	16,573	15,665	21,845	23,802	23,538	20,045.5	18,665	16,601	17,034	16,160	17,146	16,733
Sturgeon	463	500	416	330	225	178.5	131	94	80	68	56	41
Kilka	15,497	19,610	22,626	22,303	15,411	16,743	25,483	27,110	20,717	24,086	23,221	22,873
Total	32,533	35,775	44,887	46,435	39,174	36,967	44,279	43,805	37,831	40,314	40,423	39,647

importance of kilka.

The by-catch from the kilka fishery on the grounds at Anzali comprised 0.2% of the catch (Moradinasab et al., 2015). This low by-catch was attributed to the use of lantern nets and the positive phototropism of kilkas. By-catch species were *A. caspia*, the mullet *Mugil cephalus*, the cyprinids *Alburnus chalcoides*, *Cyprinus carpio* and *Rutilus kutum*, and the catfish *Silurus glanis*.

Kilka are smoked, salted, canned in sauce and oil and marinated according to a traditional recipe and seasoned with fruits, herbs and vegetables in Iran (Keivany and Nasrollahzadeh, 1990; www.netiran.com/business.html, downloaded 31 October 2003). Moini and Koochekian (2003) gave details of fish sauce production from kilkas using traditional, microbial and enzymatic methods, along with taste tests. Vacuum packaging of fresh, smoked and salted kilka has been investigated in Iran (Annual Report, 1995-1996, Iranian Fisheries Research and Training Organization, Tehran, p. 45-46, 1997) and studies on processing kilkas as fish balls have also been carried out (Annual Report, 1994-1995, Iranian Fisheries Research and Training Organization, Tehran, p. 40, 1996). Koochekian Sabour and Moini (2009) described investigations on using Iranian kilkas to produce a fermented fish sauce for marketing in Southeast Asian countries. One company markets kilka in a clear package which gives the product a bright and colourful appearance. Kilka have even been made into crackers (Iranian Fisheries Research and Training Organization Newsletter, 18: 6, 1997, Shojaei 1998). Kilka have also been made into oil as a by-product of the fish meal industry (Iranian Fisheries Research and Training Organization Newsletter, 27: 3, 2001). Omega-3 fatty acids have been extracted from kilka oil under laboratory conditions (Salmani Joloudar et al. 2009). M. Shivazad, H. John Mohammady, A.A. Yousef Hakimi and H. Fazaely (http://iman.ut.ac.ir/news/agr.htm, downloaded 12 December 2004) discuss the use of *C. engrauliformis* as fish meal in animal nutrition and analyse the protein quality and Faeed et al. (2006) studied spoilage in kilka meal from bacteria and fungi. Nassiri Moghaddam et al. (2007) studied commercial samples of kilka fish meal and found differences in protein efficiency ratio and net protein ratio, attributed to the species used, conditions and length of storage and processing methods. Agh et al. (2012) showed that replacing kilka fish oil with vegetable oil in the diet of rainbow trout (*Oncorhynchus mykiss*) broodstock significantly reduced total fecundity and hatching rate, and increased larval mortality and deformed larvae rate. Jalili et al. (2012) compared diets with *Clupeonella* fish meal and plant protein in various proportions on growth of rainbow trout fry and found, for example, replacing 50% of the fish meal with plant protein did not affect growth nor did a complete replacement with poultry by-product and plant proteins.

The Iranian Fisheries Research and Training Organization Newsletter (20: 4, 1998) and Rezaei et al. (2003) report on methods of transporting kilka in cold water and crushed ice to processing factories which were better than traditional methods. Salmani et al. (2001) recommended chilled sea water for preservation for human consumption. Motamedzadegan et al. (2009) found that partial hydrolysis of fish myofibrillar proteins using papain improves its functionality. Motalebi et al. (2010) investigated the use of whey protein coating on quality and shelf life of kilkas; it can enhance quality and increase frozen shelf life in fish stored for up to 4 months. Khanedan

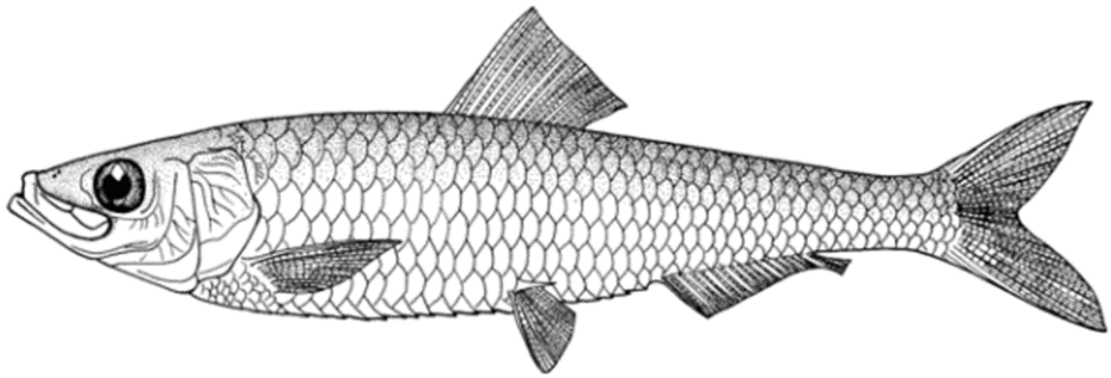

Figure 10. Line drawing of *Clupeonella caspia*.

et al. (2011) found that an edible film of sodium alginate on dressed kilka increased shelf life. Seyfzadeh et al. (2013) used an edible film of whey protein and sodium alginate to coat gutted kilka, enhancing quality and shelf life for up to 6 months in frozen storage.

Valipour Meri et al. (2011) showed that *Bacillus licheniformis* can decrease significantly the aflotoxins in kilka fishmeal. Khoshkoo (2008) and Khoshkoo et al. (2010, 2012) studied deterioration of fish protein concentrate made from kilkas caught near Anzali in different packaging and temperatures, stored in light and darkness. Vacuum packaging and storage in darkness at lower temperatures was the best method to avoid deterioration. Ebadi and Shokrzadeh (2006) examined *Clupeonella* species in Mazandaran for the organochlorine pesticide lindane and found levels in muscle tissues to be less than FAO and WHO recommended permissible intake and so were not a public concern.

An account on the biology and identification of Caspian kilka in Farsi is given by Emadi (1991) and Fazli (1990). Fazli and Besharat (1998) and Poorgholam et al. (1996) give accounts of biology and catches in Iran in Farsi.

Clupeonella caspia Svetovidov, 1941
(Figs. 10, 11)

Common names: Rizeh keraye, rizeh kuli, kilka-ye ma'muli or kilka-e-maamooli (= common shad). [Xazar kilkasi in Azerbaijan; adaty kulke balyk in Turkmenistan; Kaspiiskaya tyul'ka or kil'ka (i.e. Caspian tyulka or kilka), tyulka, obyknovennaya tyul'ka (i.e. common tyulka), all in Russian; common kilka, common Caspian kilka, sardelle, Caspian sprat].

Systematics: Formerly identified as *Clupeonella cultriventris* (Nordmann, 1840), originally described from the northern shore of the Black Sea. *Clupeonella delicatula* (Nordmann, 1840), described from Odessa market on the Black Sea, is a synonym of *C. cultriventris* and a lectotype is in the Zoological Museum St. Petersburg under ZISP 2254 with paralectotypes also under ZISP 2254, as designated by Svetovidov (1952). *Clupeonella delicatula caspia* Svetovidov, 1941 was considered to be a synonym and was described as from the "Caspian Sea, where it is met with almost everywhere, from very saline parts (Kaydak Bay) to quite fresh. Enters the mouths of the Volga and Ural rivers, ascending sometimes very far upstream". The holotype is from the Volga Delta and is under ZISP 15883 (Svetovidov, 1952). Kottelat and Freyhof (2007) considered this subspecies to be a distinct species found in the Caspian Sea with *cultriventris* restricted to the Black Sea. Reshetnikov et al. (1997) considered recognition of this subspecies as questionable. The Caspian Sea taxon, *Clupeonella caspia*, has a lectotype, 152 mm long, designated by Svetovidov (1952) in the Zoological Institute, St. Petersburg (ZISP 15883).

Clupea cultriventris is spelled *cultiventris* in some parts of Eschmeyer et al. (1996), apparently in error. Three syntypes of *Clupea cultriventris* may be in the Muséum National d'Histoire Naturelle, Paris under MNHN 3681 (Svetovidov, 1952; Eschmeyer et al.,

Figure 11. *Clupeonella caspia* courtesy of A. Abdoli.

1996).

Clupea cultriventris var. *tscharchalensis* Borodin, 1896 from Lake Charkhal in the Ural River basin is variously listed as a variety, morpha or a distinct species (see Svetovidov (1952); Kottelat and Freyhof (2007)). mtDNA studies of fish from Mazandaran and from Gilan showed statistically significant differences in haplotype frequencies, indicating genetically different populations (Lalouei et al., 2006). Norouzi et al. (2012, 2013) examined microsatellite markers in fish from Anzali collected in spring and summer and found evidence for two differentiated populations in the southwest Caspian Sea. Norouzi et al. (2014) also sampled spring and summer populations at Anzali and also at Babol-Sar and found significant genetic differentiation among seasons and regions.

Key characters: This species has a moderately deep body (21-27% of standard length), a short and wide head (interorbital width 16% or more of head length), a sharply keeled belly, and pointed pectoral fin tips.

Morphology: The dorsal fin has 3-4 unbranched rays, usually 3, followed by 11-14 branched rays and the anal fin has 1-3 unbranched rays, usually 3, and 14-19 branched rays. Scales in lateral series 42-55. There are 24-30 belly scutes and 41-62 (rarely to 64), usually 51 or more, gill rakers. Vertebrae 40-44 (rarely to 45) compared to 44-47 in the anchovy kilka and usually 46-48 in the bigeye kilka, probably as a result of higher water temperatures during development compared to other kilka species (Prikhod'ko, 1979b).

Sexual dimorphism: Sexual dimorphism is only evident during egg development when the belly of females is swollen.

Colour: The back is blue-green or light-green, the flanks silvery and the belly silvery-white or golden-yellow. Fins are hyaline except the dorsal fin which has a central dark but faint stripe and the caudal fin which is darkish at the base. The iris is black.

Size: Reaches 14.5 cm standard length and 19.0 g.

Distribution: Found in the Caspian Sea, tributary rivers and some adjacent lakes. In Iran, it is reported from sea and also the confluence of the Pasikhan and Pir Bazar rivers of the Anzali Talab and the Anzali Talab and its outlets by Holčík and Oláh (1992), and from the Safid River and Anzali Talab by Abbasi et al. (1999). Abdoli and Naderi (2009) list it as from the southwest, southeast and south-central Caspian Sea in Iranian waters. Esmaeili et al. (2014) recently list it from the Anzali Wetland or Talab. Also in Gorgan Bay.

Zoogeography: This species is a Caspian Sea endemic.

Habitat: The habitat of this species in the Caspian Sea is the coastal zone of the sea at depths less than 100m, more usually less than 50-70 m, over a wide range of temperatures (2.6-27.6°C for adults, higher for larvae, and possibly lower temperatures since they are found under ice and probably over 28°C according to some reports), and in fresh and hypersaline waters (to 36‰). The young can develop in water at 16‰. Southern populations live in a more saline habitat than northern and central Caspian populations which are mostly in fresh water. This tyulka may not migrate far but does move between summer-winter feeding and spring-early summer spawning grounds. Large schools are found 0.5-2.0 km from shore at depths of 20-25 m on the eastern coast of the Caspian Sea, descending deeper if water temperatures rise and coming up to about 8 m in autumn as temperatures fall. In winter this species is found at about 30-40 m deep where the temperature range is 7-10°C, warmer than surface waters. Larvae and young remain in shallow coastal areas. Knipovich (1921) reports a fish from a depth range of 235-300 m in Iranian waters but populations at these depths are small (Iranian Fisheries Research and Training Organization Newsletter, 14: 6, 1996). The Caspian Sea Biodiversity Database (from www.caspianenvironment.org) states that the largest concentrations are found at 3-7‰ with most intensive spawning at 2-4‰.

It is the most widely distributed kilka and with the other kilka species the most abundant fish in the Caspian Sea (Prikhod'ko, 1979b). Large schools can be found by day but these disperse at night. It overwinters in the southern Caspian Sea and some individuals move north to spawn and feed in April. The Caspian Sea Biodiversity Database (from www.caspianenvironment.org) estimates the population to number 224 billion fish, with 96 billion fish in the south Caspian. The south and north Caspian Sea stocks are about equal in number after a decline in copepod biomass in the north. The relative frequency of this species compared to other kilkas increased after the invasion of *M. leidyi*, by more than 10% (Fazli et al., 2006).

The rise in Caspian Sea level since 1977 is gradually returning the Anzali Talab to its supposed, natural brackish state and may improve the fisheries situation which had declined over the last 50 years. Emergent and submergent aquatic macrophytes were decreasing and such fish as *C. cultriventris* (= *caspia*) were increasing in numbers since 1989 (Mandych, 1995). However the fishery will require extensive engineering and management innovations to recover.

Age and growth: Osipov and Kiyashko (2008) found that using otoliths gave more reliable estimates than using scales for ageing. This Caspian species grows faster than its Black Sea relative. Together with the sturgeons, this species comprises 82.1% of the fish biomass in the Caspian Sea. Condition in this species is better in winter because of the summer-autumn feeding period after spring spawning compared to *C. engrauliformis* in the Big Kizil-Agach (= Bol'shoy Kyzylagach or Imeni Kirova) Bay of Azerbaijan (Badalov, 1972). Local populations have differing growth regimes depending on the productivity of these areas (Prikhod'ko, 1979b) and there are great variations on a yearly basis too. Southern populations grow faster than northern ones in their first year. Females grow somewhat faster than males (9.0 g versus 7.3 g average weight along the Dagestan coast for example), and life span is about 6 years. This species is mature there at 1 year and average life span is about 3 years.

Females dominated the population in Iran and sexual maturity was attained usually at age 2 and 2-4 year olds dominated catches but life span is up to 8 years (Iranian Fisheries Research and Training Organization Newsletter, 14: 6, 1996; Abtahi et al., 2002). Fazli et al. (2006) found age classes 0^+ to 5^+ in Iranian waters with 0^+ to 3^+ making up 95% of the fish in 1997-1999. In 2000, age classes 0^+ and 1^+ were reduced in numbers and 2^+ to 4^+ fish comprised 93.8%. Parafkandeh Haghighi (2010) examined Iranian populations in 2006-2007 and found a mean length of 102.4 mm, negative allometric growth, a mean age of 3.6 years, a male:female sex ratio of 0.6:1, the growth coefficient (K) was the highest of the three species at 0.321, total mortality (Z) was 1.28/yr, natural mortality (M) was 0.622/yr, fishing mortality (F) was 0.658, exploitation rate (E) was 0.514, and the maximum constant yield for the kilka fishery was 14,100 t. Fazli et al. (2013) studied the status of stocks in Iranian waters from 1996 to 2011. The length range with optimum yield was 80-100 mm, mega-spawners were larger than 105 mm, the percentage of mature fish increased, optimum size declined since 2005, the percentage of mature fish decreased from 100% to 58% in 1999 and increased to 90% in 2001, and this kilka stock was in better condition than the other two species.

Fazli et al. (2017) found that the biomass of this species increased from 22,000 t in 1997 to 112,000 t in 2009 and declined to 83,300 t in 2013. Over this time span the instantaneous coefficient of fishing mortality varied between 0.246/yr and 1.64/yr and exploitation rates were 0.327 and 0.764. The reference points at $F_{0.1}$ and $F_{40\%}$ were estimated at 0.92 and 0.8/yr, respectively. The maximum sustainable yield (MSY) and f_{MSY} were estimated at 22,670t and 8,690 vessel x nights (a unit of effort). The acceptable biological catch should be restricted to 17,500 t.

Abtahi et al. (2004) examined fish from the conical net and light catch at Babol-Sar, Mazandaran and found average fork lengths were 69.82 mm, 83.56 mm, 88.38 mm and 88.43 mm while weights were 2.2 g, 4.18 g, 4.77 g and 5.06 g for fishes at maturity stages I, II, II and IV. Fazli (2007) and Fazli et al. (2007) studied this species from 1995 to 2004 in Iranian waters, sampled at landing sites at Amirabad and Babol-Sar in Mazandaran and Anzali in Gilan. Growth parameters were L_∞=132 mm, K=0.259/yr. t_0=-1.285/yr. The instantaneous coefficient of natural mortality was 0.506/yr, the instantaneous coefficient of total mortality (Z) was 1.62/yr and the instantaneous coefficient of fishing mortality varied over 10 years from 0.125/yr to 1.487/yr. Annual survival rate (S) was 0.2/yr. The exploitation rate was 0.092-0.64 and the acceptable biological catch was 7,450 t. Age at first capture was 2.8 years. Ages ranged from 1 to 7 years with age groups 2, 3 and 4 dominating at different periods. Mean fork lengths were 59.3, 77.5, 87.4, 97.2, 104.5, 111.9 and 116.8 mm. Females dominated in each month except April, averaging 0.47:1, possibly due to differing attraction to lights used in the fishery. Biomass increased from 16,000 t in 1995 to more than 41,000 t in 2002, declining to less than 28,000 t in 2004. The increase was simultaneous with a sharp decline in anchovy kilka, changes in zooplankton composition and abundance, and especially an increase in zooplankton species favoured by this kilka. This kilka was overfished. Janbaz and Abdolmalaki (2009) found this species comprised over 86% of the total catch at Babol-Sar and Amirabad in Mazandaran, and age groups were 1^+ to 6^+ with age class 4 predominating at 35.3%. von Bertalanffy growth parameters were L_∞=114.92mm, K=0.339/yr, t_0=-1.878/yr, $L_t=114.92(1-e^{0.339(t+1.878)})$, total mortality (Z)=0.84/yr, natural mortality (M)=0.41/yr, fishing mortality (F)=0.44/yr and exploitation rate (E)=0.51. Karimzadeh et al. (2010) and Karimzadeh (2011a) examined fish from the Babol-Sar region and calculated growth parameters as L_∞=143.5mm, K=0.30/yr^{-1} and t_0=-1.02/yr, instantaneous coefficient of natural mortality was 0.671 yr^{-1}, fishing mortality was 0.849 yr^{-1}, and the current exploitation rate was estimated as 0.55 and this species is now overfished. Akbari Miarkolae et al. (2014) examined 175 fish from Babol-Sar and found a *b* value of 2.71 and an average condition factor of 2.33 with maximum and minimum values in January and June respectively. Condition factors were significantly different in all months studied and greater in winter than spring. An increased mean length and decreased mean weight in recent years was attributed to the ctenophore invasion limiting access to zooplankton.

Aliasghari et al. (2012) examined 3,774 fish from Mazandaran and found a *b* value of 2.92, growth parameters were L_∞=128.7 mm, K=0.41/yr, t_0=-0.59/yr, age groups were 1-6 years, average age was 3.27 years, 3-year-old fish dominated (45.24%) of the catch), male:female sex ratio was 1:0.779, survival rate was 0.239/yr, natural mortality was 0.448/yr, fishing mortality 0.983/yr, and exploitation rate was 0.687 indicating overfishing. The mean length and weight of fish had increased but mean age had decreased in recent years.

Moradinasab et al. (2012) studied fish caught in lift nets in Gilan and found *b* values of 2.37 in males and 2.57 in females (both negatively allometric growth) with variations between sexes and seasons.

Khedmati Bazkiaei et al. (2013) studied 547 fish from the Gilan coast and found most fish were 4-5 years old, older fish dominated and fewer younger fish were being caught, the growth equation was $L_t=142.1(1-\exp^{-0.248(t+1.63)})$, natural mortality (M) was 0.506/yr, fishing mortality (F) was 0.994/yr and total mortality (Z) was 1.5/yr.

Food: Plankton is the main food and copepods predominate but diet also includes Cladocera, *Balanus* larvae and clam larvae. The dominant food item is the copepod *Eurytemora grimmi*, particularly in winter when plankton biomass is lowered in the Bol'shoy Kyzylagach Bay of Azerbaijan. The food of the common kilka is more varied than the other kilka species simply because of its habitat in shallow coastal areas (Badalov, 1972; Prikhod'ko, 1979b). Older fish take larger and faster crustaceans and consume less food in proportion to body size as they grow. The most intensive feeding is in summer and autumn, decreasing in winter and during reproduction. Food is taken during the day.

Roushan Tabari et al. (2009) examined fish from fishing vessels of Mazandaran and found highest feeding activity in April with 280±153 prey items per fish weighing 2.9±1.6 mg. *Balanus* nauplii and cypris larvae comprised 93% and *Acartia* 7% at this time with increasing spring temperatures and reproduction, but the copepod *Acartia* biomass dominated from October to February. Khedmati Bazkiaei et al. (2014) found fish from the Anzali shore had copepods, *Balanus* cypris and larvae, cladocerans, and *Azolla* in their gut, dominated by copepods at 94.5% in number.

Reproduction: Spawning occurs in January-February in the southern Caspian, later in the north, mainly in depths less than 10m and where salinity is low to average for the Caspian Sea (Badalov, 1972; Prikhod'ko, 1979b). The largest southern Caspian population spawns near the mouths of the Volga and Ural rivers (Kozlovsky in Hoestlandt, 1991). Spawning is most intensive at 11°C, but occurs at 10-20°C. Spawning is intermittent and lasts from mid-April to July.

Peak spawning in Iranian waters of Mazandaran Province is April-May with an average fecundity of 28,240 eggs (Abtahi et al., 2002). Fazli et al. (2006) recorded mass spawning in Iranian waters in April, continuing on until August. Eggs are released in water 0.5-9.0 m deep at a salinity range of 0.02-15‰, perhaps as high as 29.15‰. Fecundity reaches 60,000 eggs and egg diameter 1.0 mm, 0.48-1.46 mm for fertilised eggs. Relative fertility is 4-13 times greater than in *Alosa* species. Holčík and Oláh (1992) consider that it may spawn in rivers entering the Anzali Talab.

The studies of Fazli et al. (2006, 2007) showed that reproduction started in March, peaked in May and finished at the end of August. Half the females were mature at 84.3 mm fork length. Aliasghari et al. (2012) found from gonadosomatic indices and sexual maturity stages that spawning in Iran began in February and peaked in May and June. Karimi et al. (2013) examined 800 fish from the Anzali coast and found batch spawning with group-synchronous oocyte development. Maximum gonadosomatic indices were found in March-April and May in different years suggesting temporal variation in spawning. Estimated relative batch fecundity was 6,718 eggs/g, with a range from 3,646 to 10,198 eggs. A low level of atresia (4.7%) during spawning showed that this species was in optimal condition. Female common kilka were in better condition in 2008 than in 1994-1996. The invasive ctenophore *M. leidyi* did not appear to affect competitively the somatic condition of this kilka and overfishing is the probable cause of decline in numbers caught. Khedmati Bazkiaei et al. (2013) studied fish from the Gilan coast and found the highest gonadosomatic indices in April-May and the lowest in November-December.

Aliasghari and Parafkandeh Haghighi (2013) examined 3,774 fish caught in 2010 from Mazandaran and found a male:female sex ratio of 1:0.779, the sex ratio varied between months (females appear to be less attracted to fishing lights with development of gonads as they cease feeding), and spawning began in March and ended in July with a peak in May.

Parasites and predators: Samples of this species from Babol Sar and Bandar Anzali contained the digenean parasites *P. symmetrica* (probably *P. ventricosa* after Youssefi et al. (2011)) and *B. cingulata*, the acanthocephalan *C. strumosum*, metacercariae of a *Bucephalus* species, and larvae of a *Contracaecum* and an *Anisakis* species (Iranian Fisheries Research and Training Organization Newsletter, 11: 4-5, 1996, Annual Report, 1995-1996; Iranian Fisheries Research and Training Organization, p. 28, 1997; Shamsi and Dalimi, 1996; Shamsi et al., 1998). Ghayoumi (2009) used the helminth parasites *C. strumosum* and *P. ventricosa* as bioindicators of the heavy metals lead and cadmium. Ghayoumi et al. (2009) found that fish from Babol-Sar harbour contained the intestinal helminths *C. strumosum*, *P. ventricosa*, *Contracaecum* sp. larvae and *Raphidascaris* sp. larvae, diet being the main factor affecting diversity of the parasites. Varshoie et al. (2010) record the helminths *Pseudopentagramma symmetrica* (see above), *B. cingulata*, *Mazocreas alosae*, *C. strumosum*, *Contracaecum* sp. and *Anisakis* sp. in this species from Iranian waters.

Clupeonella species are an important food fish for sturgeons (59.4% by weight of *Acipenser stellatus* diet in the Middle Caspian), *Sander*, herrings (Clupeidae) and the Caspian seal (Badalov, 1972; Krylov, 1984) as well as *Salmo caspius* and *Stenodus leucichthys* (Kosarev and Yablonskaya, 1994).

Economic importance: It is caught by attraction to underwater electrical lights (Prikhod'ko, 1979b) and in school seines in spring and purse seines in summer. In Gilan, fish are caught at 12-43 m depths by lift nets equipped with underwater lights (Moradinasab et al., 2012). In Iranian waters, this species formed only a small proportion (1.35%) of the total kilka catch in a study by Razavi Sayad (1993) and Fazli et al. (2006) gives values of 1.34%, 2.5% and 5.5% for the years 1990-91, 1997-98 and 1998-99, respectively. However, as the anchovy kilka catch declined, this species increased from 13.7% of the total catch in 1999 to 48.9% in 2003 (Sayyad Bourani et al., 2008).

Jorjani et al. (2014) detailed the chemical composition and fatty acid profile of this species from specimens landed at Anzali. This species was rich in essential unsaturated fatty acids of the omega-3 family especially docosahexanoid acid which is nutritionally attractive for humans. Catches should be used for human consumption rather than as fish meal.

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*, *C. carpio* and *Sander marinum* was nearly 1.44 x 10^4 tonnes with only 1.9% being accounted for by *C. 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 x 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 1991and spawning of species using the lower reaches did not occur (Caspian Environmental Programme, 2000).

Ebadi and Shokrzadeh (2006) examined *C. delicatula* (= *caspia*) for lindane at Chalus, Babol Sar, Khazarabad and Miankaleh but levels detected were less than the FAO/WHO recommended permissible intake and were no cause for public concern. Similar studies on D.D.T. and D.D.E. and on chlorobenzilate from the same sites found levels were also less than the permissible intake (Shokrzadeh and Ebadi, 2005, 2006). Shokrazadeh et al. (2009) also found that levels of Lindane in dorsal muscle of kilka species were less than FAO/WHO recommended intake. Shokrzadeh Lamuki et al. (2012) evaluated residues of D.D.T. and D.D.A. in fish from localities in Mazandaran and found values (0.017-0.025 mg/kg D.D.T. and 0.019-0.026 mg/kg D.D.A.) in the middle of the range of other species, cyprinids and a mullet, and varying between localities. Iraj et al. (2014) examined concentrations of chromium, copper, nickel and zinc in fish from the southern Caspian Sea and found levels of chromium and zinc exceeded international standards. Najm et al. (2014) determined the concentration of the heavy metals cadmium, chromium and lead in fish from the Babol-Sar coast and found cadmium levels exceeded international standards for human consumption although a risk assessment concluded the fish were safe for consumers.

Ojagh et al. (2004) showed that natural antioxidants beta-carotene with ascorbic acid and green tea polyphenols were useful in preservation during storage with ice powder. Naseri et al. (2005) found that a fluorescence detection method was a good technique for assessing degradation in steam-cooked kilka. Naseri et al. (2006) also used fluorescence detection to compare the quality of oil and brine filling material in canned kilka. Naseri et al. (2009) studied chilling times on quality of the canned product but deterioration was not well shown. Fluorescence detection of interaction compounds provided a good technique to assess product quality. Naseri et al. (2010) studied lipid changes in canned kilka after long-term storage. Motalebi and Seyfzadeh (2011) found that a 20% whey protein coating on kilka frozen at -18ºC maintained quality for 6 months while control samples lost their quality after 3 months. Zamani et al. (2012) found that belly bursting (enzymatic decomposition leading to unmarketable fish) can be prevented by trypsin inactivation through application of low temperature (4ºC), acidic ph, certain metals (aluminium, copper and zinc ions) and trypsin inhibitors. Dorvaj et al. (2013) showed that protein hydrolysates from this kilka can be used as an alternative substrate for the culture of microorganisms. Khanipour et al. (2014) found that the shelf life of breaded kilka with tempura batter was about 3 months at -18ºC. Navidshad (2014) used an oil supplement from this fish in combination with soybean oil in chicken food to enrich the product. Sahari et al. (2014) showed loss of certain vitamins in fish stored at -24ºC including A, D and K and significant losses in C and E vitamins. Dehbandi et al. (2015) found that encapsulated nisin z (a polycyclic antibacterial and antioxidant peptide) in liposome improved shelf life of kilka surimi. Robins et al. (1991) list this species as important to North Americans. Importance is based on its use as food and as bait.

Conservation: Stocks on the Iranian coast are said to have been depleted but its ecological specialisation on zooplankton means there is comparatively little competition with other fishes. It is probably not in any immediate danger. Kiabi et al. (1999) consider this species to be of least concern in the south Caspian Sea basin according to IUCN criteria. Criteria include commercial fishing, abundant in numbers, widespread range (75% of water bodies), absent in other water bodies in Iran, and present outside the Caspian Sea basin.

Sources: Iranian material: CMNFI 1970-0531, 14, 78.0-88.6 mm standard length, Mazandaran, Larim River (36º46'N, 52º58'E); CMNFI 1980-0146, 7, 79.9-96.2 mm standard length, Mazandaran, Gorgan Bay at Ashuradeh-ye Kuchak (36º50'N, 53º56'E); CMNFI 1993-0146, 3, 80.2-98.2 mm standard length, Mazandaran, Gorgan Bay (no other locality data); CMNFI 1993-0167, 1, 96.6 mm standard length, Mazandaran, Caspian Sea, 10 km offshore (ca. 36º49'N, ca. 52º39'E); CMNFI 1993-0168, 3, 84.9-88.0 mm standard length, Mazandaran, Caspian Sea, 10 km offshore (ca. 36º49'N, ca. 52º39'E).

Clupeonella engrauliformis (Borodin, 1904)
(Fig. 12)

Common names: Rizeh keraye, kilka-ye anchovy or kilka-e-anchovi. [Ancousabanzar kilka in Azerbaijan; ancous sekilli kulke balyk in Turkmenistan; anchousovidnaya tyul'ka or anchovy-like tyulka, sardelle or sardel'ka, "sardinka" but incorrectly, all in Russian; anchovy kilka, anchovy sprat].

Systematics: No major synonyms. Originally described from Buinak, central part of the Caspian Sea. The lectotype is in the Zoological Institute, St. Petersburg (ZISP 13860) with paralectotypes as established by Svetovidov (1952) (Eschmeyer et al., 1996). Eschmeyer et al. (1996) gave the date as 1906 but Reshetnikov et al. (1997) and the online Catalog

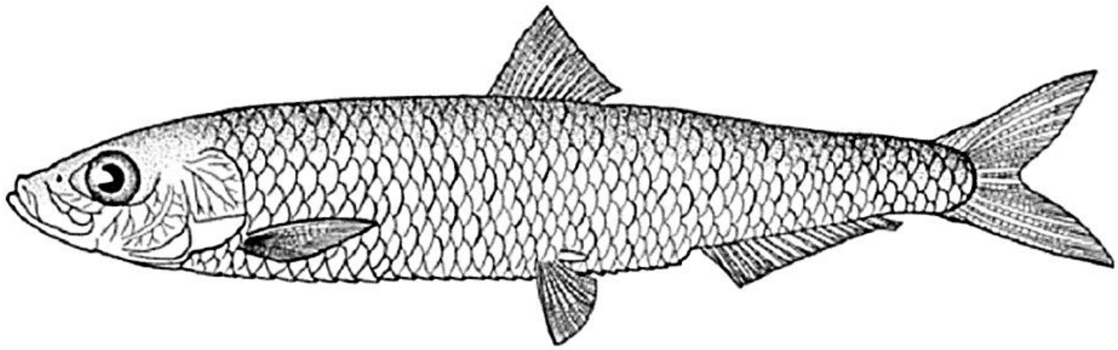

Figure 12. Line drawing of *Clupeonella engrauliformis*.

of Fishes give 1904.

Key characters: This species has a slender body (body depth 16-19% of standard length), a short and wide head (interorbital width 16.0-18.5% of head length), a rounded belly with keel scales weakly developed, and pointed pectoral fin tips.

Morphology: Dorsal fin with 3 unbranched and 12-14 branched rays, anal fin with 3 unbranched and 15-19 branched rays. Scales in lateral series 45-49. Vertebrae 44-47, rarely to 48 compared to 40-45 in the common kilka (*C. caspia*). Gill rakers number 56-67. Belly scutes 23-31.

Sexual dimorphism: None reported.

Colour: The back and head are dark blue with violet, green or olive tints. These colours become brighter or turn black in dead fish. The fins are hyaline except the caudal fin which has a black base and the dorsal fin which has a central dark stripe.

Size: Attains 15.5 cm standard length.

Distribution: Found in the central and southern Caspian Sea, and in Iranian waters the southeast Caspian Sea, southwest Caspian Sea and the south-central Caspian Sea (Kiabi et al., 1999) as well as the Anzali Talab, Babol-Sar Beach and Gorgan Bay (Armantrout, 1980; Abdoli and Naderi, 2009).

Zoogeography: This species is endemic to the Caspian Sea.

Habitat: The anchovy kilka, along with other kilkas, is the most abundant fish in the Caspian Sea forming large concentrations in the central and southern Caspian wherever water depth exceeds 30m. The anchovy kilka is estimated to be the most numerous kilka at about 77% (Ivanov and Katunin, 2001; Daskalov and Mamedov, 2007). It is generally found in the upper water layers but may descend to 120 m. Nearshore areas, inlets and water of salinity below 8‰ are avoided. They can tolerate a salinity range of 8-14‰ but the main part of the population is found at 10-12‰ (Fazli et al., 2007). Overwintering takes place in the southern Caspian and the southern part of the central Caspian Sea at 8.5-9.0°C and up to 13.5°C. Schools extend their range into the central and northern Caspian in spring to feed (Prikhod'ko, 1979b). This species has a hibernation period in the south Caspian Sea, a spring migration of part of the population to the central Caspian, a feeding period in the central and south Caspian and an autumn prespawning migration to the south Caspian (Sedov and Rychagova, 1983).

In Iran, larvae are found mostly in surface layers at 5-20 m while adults are found in deeper zones. Males dominate in winter while females dominate in other seasons. The maximum juvenile density (fish <75 mm), comprising 36% of the population, is seen in the summer (Iranian Fisheries Research and Training Organization Newsletter, 20: 7, 1998). Jolodar and Abdoli (2004) state it is most abundant at 100-150 m. Zare et al. (2017) investigated acoustic target strength in Iranian waters for calculating biomass, stock assessment and management strategies. Mean target strength was correlated with indices of female maturity status and depth of fish occupancy, but not size. There was a high variability in mean target strength estimates despite a small range in fish size (3.2 cm). Biological characteristics other than size were important drivers of this variation.

Age and growth: Abundance of young anchovy kilka, and hence future year-class strengths, depends on water temperature in autumn (October-November). Falling water temperatures, in the eastern Caspian for example, are caused by upwelling which brings nutrients to surface waters and promotes growth of plankton on which the kilka larvae feed (Prikhod'ko, 1979a). Females are somewhat larger than males in the spawning areas. Sexual maturity is attained usually at age 2 and 2-4 year olds dominate catches but life span is up to 8 years (Iranian Fisheries Research and Training Organization Newsletter, 14: 6, 1996). This species shows the fastest rate of growth in the genus. Of the 8 age classes, 0^+, 1^+, 2^+ and 3^+ form 99.91% of the whole population (Iranian Fisheries Research and Training Organization Newsletter, 20: 7, 1998). The same study showed that 18.6% of the population matures in the first year of life while 81% matures in the second. The mean age in coastal areas is 2.9 years, slightly higher than that in deep zones below 200 m where 0+ fish are more abundant. The Caspian Sea Biodiversity Database (from www.caspian environment.org) gives a population of up to 293 billion fish in the Caspian Sea.

Fazli et al. (2007) and Sayyad Bourani et al. (2008) studied these kilkas from catches with conical liftnets carrying underwater lights in the fisheries of Gilan and Mazandaran in the 1995-2004 period. Fish were aged using the sagittal otoliths. Length and weight ranges were 40-140 mm and 0.4-18.4 g with averages of 94.0 mm and 5.7 g (89.2-100.4 mm from 1999 to 2003 in Sayyad Bourani et al. 2008). The age range was 1-7 years (rarely to 8^+ years in Parafkandeh Haghighi and Kaymaram (2012)). The dominant age group varied from age 2 to age 4, making up 40.6% to 57.7% of the catch (Fazli et al., 2007) or 5^+ years with 4^+-5^+ making up 84.6% for 1999-2003 (Sayyad Bourani et al., 2008). Growth was high for the first year of life and then gradually decreased. The von Bertalanffy growth equation was $L_t=148(1-e^{-0.238(t+1.340)})$ (Fazli et al., 2007, and following data). The sex ratio varied with season and was significantly different from equal at male:female=0.78:1 for adults. Females were more abundant from January to June and males predominated from September to November. Condition factors differed significantly between years, increasing from 1995 to 1996, being lowest in 1998 and then increasing to 2004, and between months, being lowest in January and February and then increasing in March. 50% of fish were mature at 84.5 mm fork length. Annual survival rate was estimated at 0.32, the instantaneous coefficient of total mortality (Z) was 1.14/year, and natural mortality was 0.473/year. Age at first capture was estimated as 2.92 years. The total biomass declined from 186,000 t in 1996 to less than 12,000 t in 2004 and the exploitation rate for 1995-2004 varied between 0.34 and 0.815.

Fazli (2007) examining fish for the 10-year period 1995-2004 gave slightly different figures: estimated survival rate (S) was 0.174, fishing mortality was 0.65-2.93/yr, biomass declined from 185,000 t in 1996 to 8,320 t in 2004, exploitation rate was 0.39-0.83, maximum sustainable yield (MSY) and f_{MSY} were 44,652 t and 18,609 vessel x nights (a unit of effort), and the acceptable biological catch was 2,190 t. Sayyad Bourani et al. (2008) give a *K* value of 0.598/year and a L_∞ of 110.13 mm. Natural, fishing and total mortality coefficients were 0.69, 0.31 and 1 per year respectively and the sex ratio was female:male=68.2:31.8. These latter results for the 1999-2003 period show how values can change when subsets of data are used.

Karimzadeh et al. (2010) examined fish from the Babol-Sar region off Mazandaran and calculated growth parameters as L_∞=151.9 mm, K=0.28/yr^{-1} and t_0=-1.12/yr, instantaneous coefficient of natural mortality was 0.633/yr^{-1} and the current exploitation rate was estimated as 0.41. Parafkandeh Haghighi (2010) and Parafkandeh Haghighi and Kaymaram (2010) studied fish from Anzali and Babol-Sar in 2006-2007 and found the mean length was 117.8 mm, mean age was 4.5 (or 4.6) years, a male:female sex ratio of 0.52:1, and 80% of fish were in the 4 and 5 years old age classes. Growth parameters were

L_∞=147.45 mm and t_0=-1.73/yr, *b*=2.56 (negative allometric growth), K=0.245/yr, Z=1.067/yr, M=0.503/yr and F=0.564/yr and E=0.528/yr. Aliasghari et al. (2011) estimated growth parameters for fish from Babol-Sar and found an increase in mean length and weight over previous years attributed to weak stock construction consequent on the ctenophore invasion, L_∞=160.5 mm, K=0.25/yr^{-1} and t_0=-0.92/yr for males and L_∞=138.7 mm, K=0.55/yr^{-1} and t_0=-0.42/yr for females, *b* values for both sexes were 2.5, males had age groups 1-7 years and females 2-7 years, mean age of males was 3.86 years and 4.58 for females, and four-year-old fish predominated at 26.55%.

Fatemi et al. (2009) examined fish taken from commercial vessels in 2007 using lift nets and lights. Age structure ranged from 2 to 7 years and was dominated by the third year class (38.6%). Back-calculation methods were validated using otoliths to determine lengths. Janbaz et al. (2012) gave values for Iran from 2005 to 2007 of K=0.375/year, L_∞=131.7 mm, instantaneous coefficient of natural mortality was 0.49/year, fishing mortality was 0.51/year and total mortality 1.0/year, and exploitation rate was 0.51. Abundance declined over the three years from 18.8% to 8.5% and to 6%, catch per unit effort declined from 0.3 to 0.1 t, and the condition factor declined. Overfishing and the competitive ctenophore were the main causes of the decline. Fazli et al. (2013) studied the status of stocks in Iranian waters from 1996 to 2011. The length range with optimum yield was 85-105 mm, mega-spawners were larger than 100mm, the percentage of mature fish increased, optimum size declined since 2004, the percentage of mature fish were more than 78% (often more than 95%), and the length structure of this kilka stock is a matter for concern.

Food: Plankton is the main food and copepods predominate but diet also includes Cladocera, *Balanus* larvae and clam larvae. The dominant food item is the copepod *Eurytemora grimmi*, particularly in winter when plankton biomass is lowered (Badalov, 1972). It can make up over 70% of its food. This copepod is more characteristic of the diet of this kilka compared to the other two species and the daily vertical migrations and seasonal movements of the copepod are mirrored by the kilka. The most abundant fish species in the Caspian depends on the most abundant member of the crustacean zooplankton (Prikhod'ko, 1979b). This species feeds in winter, unlike *C. caspia*. Intensive feeding begins in spring as a preparation for spawning (Sedov and Rychagova, 1983). Spawning males show a positive response to light and so feed during the spawning season, while females do not.

F. Darvishi (pers. comm. 2003) has demonstrated that the this species has a similar feeding niche as the exotic ctenophore *M. leidyi* in Iran and Esmaili Sari et al. (2002) also determined that there is a similar diet suggesting that a decline in stocks of the fish is the result of competition. Darvishi (2003) and Darvishi et al. (2004) studied catches of the anchovy kilka and the ctenophore in the southern Caspian Sea from August 2001 to October 2002. Dietary overlap was >89 in Babol-Sar samples and >84 in Nowshahr samples using the Schoener Index (presumably 0.89 and 0.84 where 0 is no dietary overlap and 1 is an identical diet). The ctenophore was also feeding on fish eggs but the effect of this was less than competition for food. Rahimi Bashar and Alipour (2009) listed a wide range of phytoplankton and zooplankton species in the diet of fish from the southwest Caspian Sea.

Reproduction: Spawning ends in late autumn and winter food requirements are higher than in spring-spawning *C. caspia* (Badalov, 1972). Areas for spawning in this species are extensive. Spawning is most intensive in July when temperatures are 13-24°C and salinity 8-13‰ although the Caspian Sea Biodiversity Database (from www.caspian environment.org) gives peak spawning (70%) as in October-November. Fazli (2006) gives spawning in Iran as spring and autumn but mass spawning takes place in in autumn. Spawning takes place in the central and southern Caspian along both eastern and western shores both in coastal regions and the open sea from late April to November. Mass spawning takes place at depths of 50-200 m and as a result eggs and larvae are carried over a wide area by the Caspian gyral current at these depths (Prikhod'ko, 1979b). Young hatch mainly in autumn and reach 4.5-8.0 cm at an age of 8-10 months (Prikhod'ko, 1979a). Eggs are up to 1.82 mm in diameter and fecundity reaches 39,900 eggs.

In Iran, 80% of the population spawns in autumn and the remainder in spring. Accordingly the fishery should be closed in October and November (Iranian Fisheries Research and Training Organization Newsletter, 19: 5, 1998). The subsequent Iranian Fisheries Research and Training Organization Newsletter (20: 7, 1998) states that 89% of the population spawns in autumn with September, at 68.3%, the major month. Fazli et al. (2007) found reproduction to start in June, peaking in October and then declining. Janbaz et al. (2012) found an absolute fecundity of 12,625 eggs in Iranian waters, more than 50% of fish were mature when length exceeded 92.5 mm, and spawning was in autumn but overfishing and the ctenophore invasion pushed the kilka to spawn in winter which caused stocks to collapse. Year-round spawning occurred as a strategy to mitigate these problems. Aliasghari and Parafkandeh Haghighi (2013) examined 1,659 fish caught in 2010 from Mazandaran and found a male:female sex ratio of 0.569:1, the sex ratio varied between months (females appear to be less attracted to fishing lights with development of gonads as they cease feeding), and spawning was from April to November with a peak in November.

Parasites and predators: Samples of this species from Babol Sar and Bandar Anzali contain the digenean trematode parasites *P. symmetrica* (probably *P. ventricosa* after Youssefi et al. (2011)) and *B. cingulata*, the acanthocephalan *C. strumosum* and larvae of the nematode *Contracaecum* sp. (Iranian Fisheries Research and Training Organization Newsletter, 11: 4-5, 1996; Shamsi et al., 1996b; Annual Report, 1995-1996; Iranian Fisheries Research and Training Organization, p. 28, 1997; Shamsi and Dalimi, 1996; Shamsi et al., 1998a, 1998b). Ghayoumi (2009) used the helminth parasites *C. strumosum* and *P. ventricosa* as bioindicators of the heavy metals lead and cadmium. Ghayoumi et al. (2009) found that fish from Babol-Sar harbour contained the intestinal helminths *C. strumosum*, *P. ventricosa*, *Contracaecum* sp. larvae and *Raphidascaris* sp. larvae, diet being the main factor affecting diversity of the parasites. Varshoie et al. (2010) record the helminths *P. symmetrica* (see above), *B. cingulata*, *Mazocreas alosae*, *C. strumosum* and *Contracaecum* sp. in this species from Iranian waters.

Clupeonella species are an important food fish for sturgeons (59.4% by weight of sevryuga diet in the Middle Caspian), *Sander* (Percidae) and herrings and the Caspian seal (Badalov, 1972; Krylov, 1984) as well as other fishes.

Economic importance: This species forms 80-90% of the catches of kilkas in former Soviet waters (Sedov and Rychagova, 1983) and, as noted above, 91.8% of catches in an Iranian study (Razavi Sayad, 1993; Rezaei et al., 2003). High catches are related to the larger spawning and foraging range of this species compared to other kilkas and to its habitat in the Caspian gyre, an area of increased biological productivity (Prikhod'ko, 1979b). It is caught in former Soviet waters by attraction to underwater electrical lights attached to the middle of the mouth of a fine-mesh conical net or the sides of a fish pump (Ben-Yami, 1976). Fishing is suspended at full moons as the fish are dispersed. Both large and small individuals are taken by these non-selective methods (Prikhod'ko, 1981). Incidental catches include Mugilidae (common), and *Alosa* spp., Atherinidae and the cyprinid *Pelecus cultratus* (all occasional) (Ben-Yami, 1976). The catch per unit effort for funnel nets and midwater trawls is 2,321 and 1,014 respectively (Iranian Fisheries Research and Training Organization Newsletter, 20: 7, 1998).

Fazli et al. (2009c) estimated the maximum sustainable yield at 44,652 t and 18,609 vessel x nights (as a unit of effort). The acceptable biological catch was estimated at 2,190 t in 2004 but in 2005 it was 4,300 t. In 2008, the catch declined to 220 t through overfishing combined with sea level changes, invasive species and pollution. In 1999, the catch was 67,450 t in Iranian waters. Janbaz et al. (2012) recorded a decline in catches from 4,250 t in 2005 to 924 t in 2007.

It is regarded as a valuable and cheap food resource in Iran where it is canned, made into sausages and surimi, and processed as fish meal (Shamsi et al., 1996; Moeini, 2002; Shabanpour et al., 2002, 2006). Ovissipour et al. (2103) showed that protein hydrolysates from this fish had high antioxidant activity and amino acid content and low heavy metal concentrations. This species has a high potential for use in animal and human diets.

Various studies on its preparation and storage as food have been carried out, e.g. Rezaei et al. (2002, 2003), Rezaeian et al. (2002), Rezaie et al. (2007) and Moeini et al. (2009). Shelf life in cold storage at -18ºC was 60 days for packed and 30 days for unpacked fish and at -30ºC lipid quality was higher. Moeeni et al. (2006) determined the proper formulation of soup powder and found that shelf life of the product was about 60 days. Sarhadi et al. (2012) and Sarhaddi et al. (2015) studied the proximate composition, amino acid profile, fatty acid and mineral composition of this species and found it to have good nutritional quality such that powdered bone may be used as an additive in food industries. Robins et al. (1991) list this species as important to North Americans. Importance is based on its use as food and as bait.

Conservation: Prikhod'ko (1981) recommends fishing in deeper waters where larger fish are concentrated to avoid an excessive take of young fish which favour the upper water layers. Stocks in the southern Caspian Sea are said to be depleted. Kiabi et al. (1999) consider this species to be of least concern in the south Caspian Sea basin according to IUCN criteria. Criteria include commercial fishing, abundant in numbers, widespread range (75% of water bodies), absent in other water bodies in Iran, absent outside the Caspian Sea basin. Daskalov and Mamedov (2007) studied commercial catch data in the Caspian Sea generally and found a period of high catches from 1991 to 2000 with high spawning-stock biomass and relatively good recruitment. Catches peaked at 271,400 t, fishing mortality reached $1.8y^{-1}$ in 1999 and overfishing occurred. From 2001 to 2004, the stock collapsed, recruitment failed in 2001 and catches fell to 54,300 t in 2005, of which the Iranian fishery was about 8%. This was attributed to the spread of the ctenophore *M. leidyi*, with contributions from overfishing. Fazli et al. (2007) also concur that both overfishing and the invasive ctenophore caused the collapse of stocks. The catch in Iran declined from 71% of the total kilka catch in 1999 to 52.5% in 2003 (Sayyad Bourani et al., 2008). Janbaz et al. (2012) give figures for the collapse in Iran from 4,250 t in 2005 to 924 t in 2007.

Sources: Iranian material: CMNFI 1993-0167, 1, 99.5 mm standard length, Mazandaran, Caspian Sea (ca. 36º49'N, ca. 52º39'E); CMNFI 1993-0168, 4, 89.3-107.6 mm standard length, Mazandaran, Caspian Sea (ca. 36º49'N, ca. 52º39'E).

Clupeonella grimmi Kessler, 1877
(Fig. 13)

Common names: Kilka-ye cheshmdorosht (= bigeye kilka). [Irikoz kilka in Azerbaijan; sardelle or sardel'ka, bol'sheglazaya tyul'ka or bigeye tyulka, bol'sheglazaya kil'ka or bigeye kilka, all in Russian; bigeye kilka, southern Caspian sprat].

Systematics: *Clupeonella Grimmi* was originally described from the central part of the Caspian Sea. The lectotype is in the Zoological Institute, St. Petersburg under ZISP 10934 as designated by Svetovidov (1952). *Harengula macrophthalma* Knipovich, 1921 is a synonym. Four syntypes are in the Natural History Museum, London under BM(NH) 1897.7.5:41-44 (when examined were numbered 42-44, 3 fish, 29.9-33.5 mm standard length in poor condition, September 2007), with many others apparently in the Zoological Institute, St. Petersburg (Eschmeyer et al., 1996).

Key characters: This species has a moderately slender body (17-22% of standard length), a long and narrow head (interorbital width 13.0-15.5% of head length), a sharply keeled belly, and rounded pectoral fin tips.

Morphology: Dorsal fin unbranched rays 3-4,

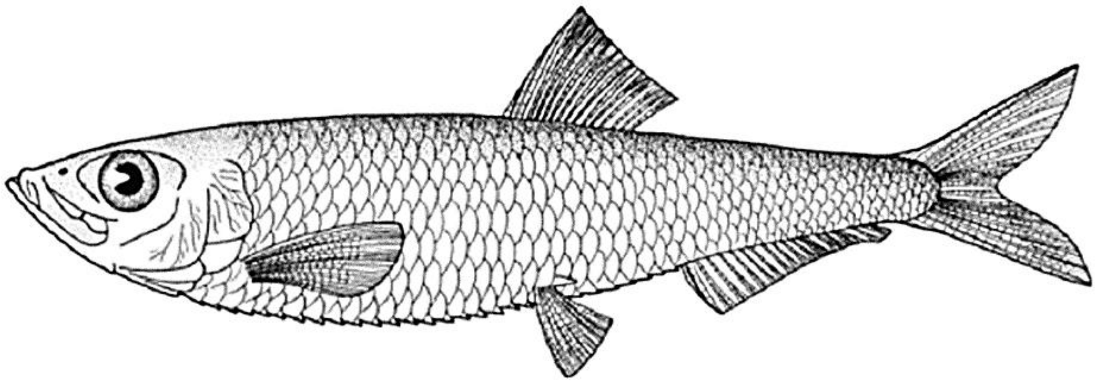

Figure 13. Line drawing of *Clupeonella grimmi*.

usually 3, branched rays 13-15, and anal fin unbranched rays 3, branched rays 14-21. There are 44-49, usually 46-48, vertebrae, more than in the other two kilka species and probably a consequence of the low water temperature larvae develop in. Belly with 26-32 scutes. Gill rakers 42-51.

The bigeye kilka is adapted to life in deeper water having, as its name indicates, big eyes with more rod cells and a weaker retina but also more transparent body tissues than other kilkas.

Sexual dimorphism: None reported except size.

Colour: The back and top of the head are dark.

Size: Reaches 14.5 cm standard length and 15.2 cm fork length (Karimzadeh, 2011b).

Distribution: Found in the Caspian Sea and concentrated in the south including Iranian waters. Abdoli and Naderi (2009) list it as from the southwest, southeast and south-central Caspian Sea in Iranian waters.

Zoogeography: This species is endemic to the Caspian Sea.

Habitat: The bigeye kilka is found further away from the coast than the anchovy kilka at depths over 50-70 m, down to 450 m, with large schools down to 130m. It does not enter fresh water or low salinity areas, staying well away from the shore. There is a daily vertical migration, avoiding sunlight, and following food items. Larvae live in water temperatures of 5°C. Overwintering occurs in the southern Caspian at temperatures of 9-11°C, a migration to the central Caspian takes place in spring, with a return south in autumn (Prikhod'ko, 1979b).

Age and growth: Sexual maturity is attained usually at age 2, and 2-4 year olds dominate catches, but life span is up to 8 years (Iranian Fisheries Research and Training Organization Newsletter, 14: 6, 1996). The female is larger than the male at the same age. Growth is slower than in *C. engrauliformis*. Males dominate the population (Iranian Fisheries Research and Training Organization Newsletter, 14: 6, 1996; Fazli et al., 2005) but this study may have sampled spawning fish (see below).

Fazli et al. (2005) examined fish from the main landing ports (Babol-Sar, Amirabad and Anzali) and found the mean fork length of fish increased from 95.87 mm in 1997 to 105.0 mm in 2000 but then decreased to 102.3 mm afterwards. Over this time period, fork length range became wider with specimens in the upper length classes representing most of the catch. Six age classes were present, 1^+ to 6^+ years. During 1998-1999, age classes 1^+ to 3^+ comprised more than 90% of the catch. In 2000, there was a decrease in age classes 1+ and 2+ and an increase in 3^+ to 5^+ classes. In 2001, age classes 3+ and 4+ decreased and classes 5^+ and 6^+ increased. The relative frequency of the bigeye kilka has decreased in recent years as a result of the introduction of the ctenophore, *M. leidyi*, a food competitor and predator on kilka eggs and young.

Janbaz et al. (2016) examined 262 fish from Babol-Sar, Amirabad and Anzali stations caught between May 2006 and April 2007. The largest length-groups were found from December to

February and the lowest in April, coinciding with spawning and feeding during wintering respectively. The male:female sex ratio was 0.33:1 which differed significantly from the expected ratio of 1:1. The length-weight regression was W= 0.0000744 $FL^{3.14}$ for females and W=0.0000341$FL^{3.16}$ for males, indicating isometric growth. Age based on otolith readings showed that the population was composed of age groups from 2 to 7 years old with rapid growth during the second year. Four-year-olds with a mean fork length and weight 115.5 mm and 11.9 g were the most abundant at 40.1%. The condition factor was 0.7-0.8 which varied in different months and coincided to the gonad development. The *K* value and L_∞ of females was more than that of males. This was a rapidly-growing species in the southern parts of the Caspian Sea.

Khorashadizadeh et al. (2006) found fish in the Babol-Sar area off Mazandaran to have 5 age classes, dominated by the 4^+ class. Karimzadeh et al. (2010a) examined fish from Babol-Sar and calculated growth parameters as L_∞=148.6 mm, K=0.46/yr^{-1} and t_0=-0.18/yr, instantaneous coefficient of natural mortality was 0.881/yr^{-1} and the current exploitation rate was estimated as 0.26. Karimzadeh (2011b) determined mortalities for these Babol-Sar fish as natural and fishing mortality 0.881 and 0.309/yr respectively, annual survival rate 0.304/yr, instantaneous coefficient of total mortality 1.19/yr and exploitation rate 0.26/yr. Age groups were 2-6 years with ages 3 and 4 comprising 72% of the catch. Average age of females was 4.194 years and males 3.347 years. Catches decreased from overfishing, predators and ecological disturbances. Aliasghari et al. (2011) also examined fish from Babol-Sar numbering 1,043 specimens. Growth parameters were L_∞=149.7 mm, K=0.32/yr^{-1} and t_0=-1.2/yr for females and L_∞=136.5mm, K=0.65/yr^{-1} and t_0=-0.24/yr for males. *b* values were 3.043 in females and 3.079 in males, both positively allometric. The fish were aged at 2-7 years with mean age 4.09 for females and 3.61 for males. Four-year-old females dominated at 33.34% and three-year-olds in males at 47.45%. The male:female sex ratio was 0.656:1. This kilka had not been affected by pelagic changes in the Caspian Sea since it inhabits deeper waters. In recent years the population became older and length and weight increased as Karimzadeh (2011b) noted also. This was attributed to use of nets with a standard mesh, overfishing and change in living depth.

Fazli (2007) examining fish for the 10-year period1995-2004 gave von Bertalanffy parameters L_∞=144 mm, K=0.265/yr, t_0=-1.422/yr, estimated survival rate (S) was 0.298, natural mortality (M) was 0.46/yr, fishing mortality was 0.46-0.98/yr, biomass increased from 36,000 t in 1995 to more than 52,000 t in 1998 and declined to less than 5,900t in 2001, exploitation rate was 0.3-0.52, and the acceptable biological catch was 2,210 t. Fazli et al. (2009) examined changes in the population biology of this kilka over the period 1995 to 2001, attributed to the invasive ctenophore. The overall sex ratio was 1.65:1 in favour of males, length-weight regressions were W=0.00922$L^{2.851}$ for females and W=0.008021 $L^{2.907}$ for males, indicating a negative growth for both sexes, growth parameters were L_∞=142 mm, K=0.28 $year^{-1}$, and t_0=-1.39 years, the instantaneous coefficient of natural mortality was 0.460 $year^{-1}$, and the instantaneous coefficient of fishing mortality varied between 0.469 and 0.980 $year^{-1}$. Biomass increased from 36,900 t in 1995 to more than 53,500 t in 1998 but declined to less than 5,900t in 2001. This was attributed to overfishing and the appearance of the ctenophore, a competitor for zooplankton food.

Parafkandeh Haghighi (2010) studied fish in 2006-2007 and found the mean length was 119.5 mm, mean age was 4.6 years, a male:female sex ratio of 1.6:1, growth was negative allometric, K=0.267/yr, Z=1.015/yr, M=0.537/yr and F=0.478/yr and E=0.471/yr.

Fazli et al. (2013) studied the status of stocks in Iranian waters from 1996 to 2011. The length range with optimum yield was 90-110 mm, mega-spawners were larger than 110 mm, the percentage of mature fish increased, optimum size declined since 2002, the percentage of mature fish were more than 78% (often more than 95%), and the length structure of this kilka stock is a matter for concern.

Food: Migratory mysids often predominate in the planktonic diet of this species. Fish fry are also eaten. Its foods are less diverse than that of other kilkas because the variety is less in the deeper waters this fish inhabits during the day. The three kilkas share the available habitat and its foods, the common kilka in shallow, coastal waters, the anchovy kilka in the upper layers of the open sea and the bigeye kilka in deeper water of the open sea (Badalov, 1972; Prikhod'ko, 1979b).

Reproduction: Spawning is extended, from January through to September but is most intense in spring and autumn (Prikhod'ko, 1979b). Males predominate in the spawning areas, remaining there while females leave immediately after spawning. Males are mainly at 10-20 m and females at 20-25 m during the spawning season. Water temperatures are at 6-13°C and salinity 12.6-13.0‰. Fecundity is 28,300 eggs. In Iranian waters, mature fish ready to spawn are always present in catches in winter and early spring (Fazli et al., 2005). Khorashadizadeh et al. (2006) found fish in the Babol-Sar area of the Iranian coast to have peak spawning in early January. Aliasghari and Parafkandeh Haghighi (2013) examined 1,034 fish caught in 2010 from Mazandaran and found a male:female sex ratio of 0.656:1, the sex ratio varied between months (females appear to be less attracted to fishing lights with development of gonads as they cease feeding), and spawning occurred year round with a peak in October.

Parasites and predators: Samples of this species from Babol Sar and Bandar Anzali contain the digenean parasites *P. symmetrica* (probably *P. ventricosa* after Youssefi et al. (2011)), *B. cingulata*, the acanthocephalan *C. strumosum*, *Eustrongylides excisus*, and larvae of a *Contracaecum* and an *Anisakis* species (Iranian Fisheries Research and Training Organization Newsletter, 11: 4-5, 1996, Annual Report, 1995-1996; Iranian Fisheries Research and Training Organization, p. 28, 1997; Shamsi and Dalimi, 1996; Shamsi et al., 1998, 1998a). Ghayoumi (2009) used the helminth parasites *C. strumosum* and *P. ventricosa* as bioindicators of the heavy metals lead and cadmium. Ghayoumi et al. (2009) found that fish from Babol-Sar harbour contained the intestinal helminths *C. strumosum*, *P. ventricosa*, *Contracaecum* sp. larvae and *Anisakis* sp. larvae, diet being the main factor affecting diversity of the parasites. Varshoie et al. (2010) record the helminths *P. symmetrica* (see above), *B. cingulata*, *Mazocreas alosae*, *C. strumosum*, *Contracaecum* sp. and *Anisakis* sp.in this species from Iranian waters.

Clupeonella species are an important food fish for sturgeons (59.4% by weight of sevryuga (*Acipenser stellatus*) diet in the Middle Caspian), *Sander* (Percidae) and herrings and the Caspian seal. Predators consume 590 million kg of the three kilka species which themselves are the main consumers of zooplankton. Kilkas are a very important element in the life of the Caspian Sea (Badalov, 1972; Prikhod'ko, 1979b; Krylov, 1984). This species is taken to a lesser extent than other *Clupeonella* species because it is relatively sparse.

Economic importance: The bigeye kilka catch amounts to about 70 million kg a year in former Soviet waters of the Caspian by means of electric light. All three kilka species are caught by using underwater electric lights and fish pumps (Nikonorov, 1964) but in the case of the bigeye the effect is avoidance used to drive it to the bottom where it can be caught. Other kilkas are attracted to the light but the bigeye is a vertical migrator, avoiding sunlight (Prikhod'ko, 1979b). Light-assisted catches of kilkas damages young shad (*Alosa*) stocks which are an incidental catch (Zakharyan and Teruni, 1979). Catches in Iranian waters are only 6.84% of the total kilka take (Razavi Sayad, 1993). The relative frequency of the bigeye kilka in Iranian catches was ranked second after anchovy kilka in 1990-1991 at 6.84%, increasing to 12.6% and 21.7% in 1997 and 1998 and then decreasing. The catch in 2008 was 490.8 t with maximum catch-per-unit-effort 0.19 t per vessel per night in February and minimum 0.03 t in January.

Omega-3 fatty acids from fish oil of this species have been tested as a dietary supplement and were

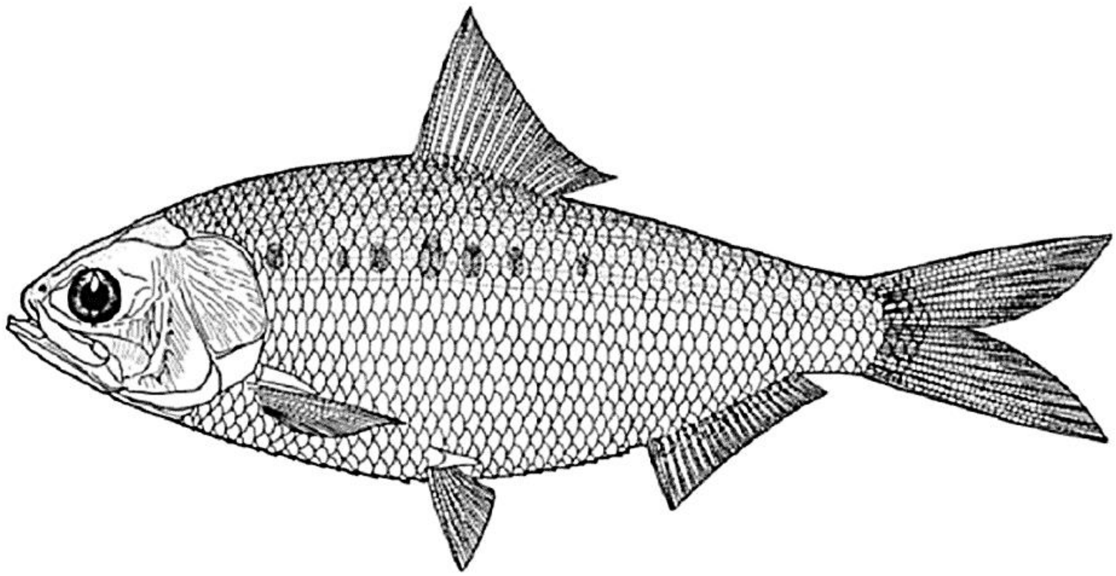

Figure 14. Line drawing of *Tenualosa ilisha*.

found to relieve symptoms of dysmenorrhoea (Moghadamnia et al., 2010).

Conservation: Stocks in Iranian waters are said to be depleted. Kiabi et al. (1999) consider this species to be of least concern in the south Caspian Sea basin according to IUCN criteria. Criteria include commercial fishing, abundant in numbers, widespread range (75% of water bodies), absent in other water bodies in Iran, and absent outside the Caspian Sea basin.

Sources: Iranian material: CMNFI 1993-0167, 1, 93.0 mm standard length, Mazandaran, Caspian Sea (ca. 36º49'N, ca. 52º39'E); CMNFI 1993-0168, 2, 91.8-94.0 mm standard length, Mazandaran, Caspian Sea (ca. 36º49'N, ca. 52º39'E).

Genus *Tenualosa* Fowler, 1934

This genus comprises 5 species found from the Indian Ocean to Indonesia and China. A single species enters rivers of southern Iran. The genus is defined by a series of characters listed below under

Key characters: These fishes form part of local, artisanal fisheries throughout their range.

Tenualosa ilisha (Hamilton, 1822)

(Figs. 14, 15)

Common names: Sobour, soboor, sobur, sabur, zobur, zabur, zamur or zomur, all variants of the same word), bari, barak; mahi-ye khor kuchiku (= small bone fish, at Abadan from www.abadan.com/abadanhistory.html, downloaded 15 March 1998). [Zoboor, soboor, sbour in Arabic; hilsa, Indian shad or river shad; palo, palla or pulla and tikki-palwar in Pakistan].

Systematics: *Clupanodon ilisha* was originally described from the Ganges estuaries in India. Formerly placed in the genus *Hilsa* Regan, 1917. Al-Hassan (1982), citing a personal communication from a Mr. Al-Abaychi in 1973, suggests that Shatt al Arab fish are distinct from those in Pakistan on morphometric and meristic grounds but no data have been published. Milton and Chenery (2001) used genetic and otolith chemistry data that provided strong evidence for a distinct stock in Kuwait, compared with stocks from India to Sumatra. Al-Hassan (1999) mentions that people in Basrah can distinguish two kinds of sobur, based on taste. One is the tastier and pricier Shatt al-Arab form and the other is the less desirable estuarine/sea form. This has not been confirmed by systematic studies. Jorfi et al. (2008, 2009) found differences between populations in Iran and Iraq using molecular techniques.

Key characters: This species is distinguished from other Indian Ocean clupeids by the upper jaw with a median notch, the anal fin ray count being less than

Figure 15. *Tenualosa ilisha* from Kuwait by J. E. Randall after FishBase.

30 rays, a terminal mouth (lower jaw not prominent nor flared at the corners), scales in lateral series are not perforated posteriorly, last dorsal fin ray not filamentous, weakly developed lines (the fronto-parietal striae) on top of the head (usually covered by skin and not visible), gill rakers on inner arches straight not curled, a long head 28-32% of standard length, and 30-33 ventral scutes forming a keel along the belly, 15-18 being prepelvic and 11-15 postpelvic (Al-Nasiri and Al-Mukhtar, 1988a, 1988b; Marammazi et al., 1995).

Morphology: Dorsal fin with 4-5 unbranched rays followed by 14-16 branched rays, anal fin with 2-3 unbranched rays followed by 16-20 branched rays, pectoral fin branched rays 12-15 and pelvic fin branched rays 7. Lateral series scales 44-51. Gill rakers are fine and numerous, up to about 275 on the lower arch.

Iranian fish examined by Marammazi et al. (1995) from the Bahmanshir River in Khuzestan have 30-32 total scutes along the belly, 16-18 prepelvic scutes, 13-15 postpelvic scutes, 19-21 dorsal fin rays, 19-24 anal fin rays, 13-15 pectoral fin rays, 8 pelvic fin rays and 44-51 scales.

Sexual dimorphism: None reported.

Colour: The back is grey-blue, bluish to green and the sides are silvery with golden, purplish or pink highlights. The dorsal fin is grey, the caudal fin grey-blue with a silvery tinge and darkened margin, and the anal fin is light blue with some silvery tinges. Paired fins are hyaline. The area behind the gill cover in young fish and many adults have a dark blotch followed by a series of spots or blotches running along the upper flank, for a total of 6-7. The blotches may take the form of bars. The eye is yellow to red. Young have a bronze back, silvery flanks and a caudal fin margined in black.

Size: Attains 60.6 cm total length and 2.49 kg for females and 43.0 cm and 0.68 kg for males. A sample of 233 moribund fish from the Ashar Canal, a branch of the Shatt al Arab, Iraq examined by Al-Nasiri and Al-Mukhtar (1988a, 1988b) had a total length range of 70-152 mm. Hussain et al. (1994) record fish migrating to the Shatt al Arab for breeding at 21-38 cm for males and 33-43 cm for females. Mature females in the Shatt al Arab weighed about 0.5-1.1 kg (Jabir and Faris, 1989). Fishes from Kuwait attained 57.0 cm (Al-Baz and Grove, 1995). Fishes from the Arvand, Bahmanshir, Karun and Dez rivers of Iran were 12-50 cm long (Marammazi et al., 1998; Ghafleh Marammazi et al., 2004). Nasri Tajan (2009) gave a maximum length and weight for 344 fish from the Bushehr coast as 45.1 cm and 953 g.

Distribution: Reportedly found from the Red Sea and Persian Gulf through the Indian subcontinent to the Malayan Archipelago in some general works, or more narrowly from the Persian Gulf to Myanmar. It enters the Shatt al Arab and Tigris River, once as far north as Baghdad (Kanazawa, 1955), but the northernmost distribution today in Iraq is the Hawr al Hammar. Before the construction of dams on the Euphrates the migration was up to Yaou and Meshkhab and up to Qal`at Salih (31°31'N, 47°16'E) in the Tigris of Iraq (van den Eelaart, 1954).

The lower reaches of the Tigris and Euphrates rivers were connected by a channel to the Khor Al-Zubair in Iraq during 1983. As a consequence the Khor became oligohaline (at less than 10‰) rather than hypersaline (at more than 40‰), becoming an estuary with heavy reed growth. The catch of sobour in the Khor by 1997 exceeded that in the Shatt al Arab and may involve diversion of stocks from the original habitat of the Shatt (Hussain, 1997).

In Iran, it is recorded as far north as the Gargar Shoteit on the Dez River (Marammazi, 1994). Hussain, Jabir and Yousif (in litt. 1995) record this species from the Shatt al Arab in Iraq and the Bahmanshir, Hilleh, Jarrahi and Zohreh rivers in Iran. Marammazi (1994), Najafpour (1997), Marammazi et al. (1998) and Ghafleh Marammazi et al. (2004) report this species from the Arvand, Bahmanshir, Dez, Karun and Zohreh rivers. It may be found in the Hormuz basin but this has not been verified with specimens. Esmaeili et al. (2014) record it from the Shadegan Wetland and Esmaeili et al. (2015) from the Persis basin. Hashemi et al. (2014) caught a single specimen from the Shadegan Wetland in a year-long survey. Hashemi et al. (2015) listed this species as an exotic in the Shadegan Wetland but in the sense of a migrant from the sea. In the sea, they are found from Bushehr around to Kuwait in coastal waters (Blegvad and Løppenthin, 1944; Hussain et al., in litt. 1995).

Zoogeography: Al-Hassan (1982) mentions a study comparing a population of this species from Basrah, Iraq with one from Pakistan and finding significant meristic and morphometric differences, perhaps indicative of distinct stocks.

Habitat: Sobour enter the Shatt al Arab in February and March during high tides and feed there until the fall according to a study by Al-Nasiri and Al-Mukhtar (1988a, 1988b) working on fish taken from the Ashar Canal, Basrah, Iraq. van den Eelaart (1954) reported that most fish entered the Shatt al Arab in April during the last and first phase of the moon and anecdotal reports indicate the end of March to be the peak period of entry. They ascended into the Hawr al Hammar and from there into the Euphrates as well as into the Tigris (van den Eelaart 1954). Significant numbers were recording as entering the recovering Hawr al Hammar in 2005-2006 (Hussain et al., 2006). Small specimens (50-100 mm) were observed in the east Hawr al Hammar in June 2005 and July 2006 (www.iraqmarshes.org, downloaded 29 August 2005, N.A. Hussain in litt. 2006). In mid-April sobour were found below the Yaou and Meshkhab regulators which formed the limit of their migration on the Euphrates in the early 1950s. The limit in the Tigris was beyond Amara. The main spawning grounds in the Euphrates were probably somewhere between Shinafiya and Samawa and in the Tigris between Amara and Qalat Saleh.

The last ones leave the Shatt in July and fry are found in the rivers of Iraq at the end of the June. Hussain et al. (1994) recorded sobour ascending the Shatt al Arab during March with a continuing migration upstream through April to July for spawning and a return migration to the sea during August to October. Al-Hassan (1993) notes that local people believe that sobour ascend the Shatt al Arab during spring to marshes north of Basrah for spawning, suggesting that they are the fluvial anadromous type. Al-Hassan (1999) considers they migrate to the sea in September-November, when they are landed in Kuwait, and they then migrate to the Iranian coast during December-January. Males and females move upriver in separate groups according to Iraqi fishermen (Al-Hassan, 1999).

Jorfi et al. (2008) suggest, based on molecular studies, that a population in the Persian Gulf chooses the Karun River for spawning and migrates via the Bahmanshir River, while others migrate up the Tigris and Euphrates rivers in Iraq via both the Bahmanshir and the Arvand rivers.

Blegvad and Løppenthin (1944) mention this species on sale at Khorramshahr on 28-29 April. The spawning migration in Iran occurs in spring

(Sharifpour, in litt. 1991). It is only found in the Zohreh River in spring and summer (Marammazi, 1994). Ghobeishavi et al. (2016) found a depression is some haematological and immunological parameters during the upstream migration in the Karun River, possibly a result of hormonal and environmental effects. Dastan et al. (2017) described gill and kidney tissue changes on the migration into the Bahmanshir and Karun rivers, chloride cells decreasing in number and area for example.

They may be found in deep water, over 18 m, or in shallows, on their spawning migration. Large concentrations of sobour occur below dams blocking their migration. Young occur in side branches of the Shatt al Arab near food, shelter and the spawning grounds (Hussain et al., in litt. 1995).

This species occurs in river estuaries and coastal waters and appears to be restricted to the northern end of the Persian Gulf because this is the only part with large spawning rivers (Hussain et al., in litt. 1995). These authors also suggest that an anadromous stock from the Shatt al Arab migrates to warmer waters off Bushehr during January, February and March. At the same time there is a winter decline of Kuwaiti stocks. There may also be a marine stock inhabiting coastal waters of Kuwait since larvae have been found in Kuwait Bay during June and November and catches are made in the Bay year round.

Hussain (1997) notes the changing conditions in the Khawr az Zubayr, which became oligohaline from hypersaline after it was connected to the Tigris-Euphrates basin by the Shatt al Basrah Canal. In 1994, fishermen began catching sobour in the Khawr az Zubayr and by 1997 the numbers caught exceeded the catch in the Shatt al Arab.

Migrations in the Indus River of Pakistan (Islam and Talbot, 1968) may last over 7 months and the migration up the Ganges River extends over 1,287 km. Fish may move as much as 70.8 km in one day and may jump out of the water on the migration.

Age and growth: In the Bahmanshir River, Iran most fish are 4-5 years old. The minimum total length and age at maturity are 26.2 cm, 200 g and 2 years for males and 32.18 cm, 450 g and 3 years for females. von Bertalanffy growth parameters in Iranian females are L_∞=57.78 cm and K=0.282 and in males 46.37 cm and 0.252 (Marammazi, 1995; Iranian Fisheries Research and Training Organization Newsletter, 12: 5, 1996, Annual Report, 1995-1996; Iranian Fisheries Research and Training Organization, p. 53-54, 1997). Nasri Tajan (2009) found Bushehr coast fish were 2-4 years old with most 2^+ years.

Hashemi et al. (2009) studied fish landed at Hendijan and Abadan and recorded L_∞ as 42.81 cm, K was 0.9, M was 1.37, F was 2.41, Z was 3.78 and E was 0.64. Y'/R was 0.048 and B'/R was 0.19, exploitation rate (U) was 0.61, annual stock at the beginning of the year (P) was 7,615 t, annual standing stock (b) was 1,927 t and MSY was 3,642 t. The stock was overfished. Hashemi et al. (2009), also studying fish at Hendijan and Abadan, recorded L_∞ as 54.6 cm, K was 0.96, M was 1.34, F was 2.8, Z was 4.2, E was 0.68 and t_0 was -0.14, and the stock was overfished. Hashemi et al. (2010) studied 9,317 fish from the landings at Abadan and Hendijan. Size range was 20-39 cm. The von Bertalanffy growth parameters were L_∞=43.32 cm, K=0.78yr^{-1}, Φ' was 3.16 and t_0 was -0.18. Mortality rates were M=1.29 and Z=4.53, and fishing mortality (F) was 3.24yr^{-1}. The exploitation rate (E) was 0.72 and the stock was overfished. Values of the sizes where the probability of capture was 50% (L_{50}) and 100% (L_{100}) were 22.3 and 28.5 cm total length respectively. Fish were recruited to the fishery at a mean size of L_{100}=22.3 cm. The relative yield per recruit (Y'/R) was 0.062, relative biomass per recruit (B'/R) was 0.12 and exploitation rate (U) was 0.76. The values for annual catch, total annual stock, standing stock and maximum sustainable yield were 4,645t, 6,635.71 t, 1,433.64 t and 3,274.19 t, respectively. The fishing pressure must be reduced from 3.24yr^{-1} to about 0.97yr^{-1}for this population to be adequately managed. Another study apparently based on the same or similar samples (Hashemi Seyed et al., 2010) found slightly different parameters: L_∞=42.81 cm, K=0.0yr^{-1}, t_0=-0.25, Z=3.78, M=1.37, F=2.41, E=0.64 and the values for annual catch, annual average standing stock and maximum sustainable yield were 7,615 t, 1,927 t, and 3,624 t, respectively. Hashemi et al. (2010) assessed production in the Shadegan Wetland, Khuzestan as 0.73 kg/ha/year.

Roomiani and Jamili (2011) examined fish landed in Iran from a northern Persian Gulf fishery. Growth was isometric. Maximum total length was 43 cm and weight 949 g. von Bertalanffy growth parameters were L_∞=42.74 cm total length, K=0.77 and t_0=-0.21 years^{-1}. Total mortality (Z) was 2.55 years^{-1}, natural mortality (M) was 0.75 years^{-1}, fishing mortality (F) was 1.8 years^{-1}, and exploitation rate (E) was 0.7 years^{-1}, and parameters indicate overfishing. Maximum sustainable yield was calculated to be 2,653t. Roomiani et al. (2012), presumably working with a partially similar dataset, found L_∞=42.8 cm, K=0.7, Z=3.45, M=1.24, F=2.21 and E=0.64.

Al-Nasiri and Al-Mukhtar (1988a, 1988b) give a length-weight relationship of W=3.9 x $^{10-6}$ $L^{3.16}$ or logW=3.16 logL-5.4 for fish aged at 0^+ from the Ashar Canal at Basrah. The mean condition factor was 0.87. Fishes in the Shatt al Arab are in age groups 5 to 6 for the period May to August (Hussain et al., 1991). In contrast, a later study on the Shatt al Arab fish showed there are 5 age groups and the second and third age groups dominate in catches (Hussain et al., 1994). In this latter study, Shatt al Arab fish mature at 25 cm for males and 33 cm for females, similar to an Iranian study (see below). The length-weight relationship was logW=-4.7074+ 3.0479 logL for females and logW=-4.5802+3.0193 logL. Condition factor gradually increased with length groups in males, peaking at 32-33 cm followed by a sharp decline while females had a nearly stable condition factor from 34 to 43cm. Mohammed et al. (2001) gave a von Bertalanffy growth equation as L_∞=60.47 cm and a condition factor of 0.32, slower growth than in Indian and Bangladesh populations and probably maturing later.

Amodeo (1956) gives lengths of 25 to 35 cm for fish caught in the Shatt al Arab on their spawning migration. Young grow rapidly, 4.3 cm in October-November. Most fish on the migration in the Indus River were in age groups 3 and 4. Life span is up to an estimated 7 years with maturity as early as 1 year. Jawad et al. (2004) found haematocrit level to increase with body length up to 40 cm after which it decreased, males showed higher levels than females, and levels were higher pre-spawning than during spawning and increased slightly post-spawning, a general correlation with fish activity in Iraqi waters.

Al-Baz and Grove (1995) studied fish taken from Kuwait fish markets. Females dominated the catch, male:female ratio being 1:2.4, perhaps because the sexes moved in different schools. The smallest mature female was 34.4 cm and 50% of the females are mature at 41.5 cm. They estimated natural mortality (M) based on von Bertalanffy growth parameters (L_∞ and K) and mean annual water temperature as logM=-0.0066 -0.279 logL_∞+0.6543 logK + 0.4634 logT. The length-weight relationship was W=0.011$L^{2.983}$ for males and W=0.007$L^{3.104}$ for females. Growth in the sexes follows different patterns. Five age groups were detected using otoliths and fish were fully recruited to the fishery at 3 years of age. von Bertalanffy growth parameters were L_∞=52.70 cm and condition factor (K)=0.28 per year while using Allen's method they were L_∞=52.50 cm and condition factor (K)=0.36 per year. Annual total mortality was estimated to be 1.2 using the K value of 0.36. A fishing mortality was calculated to be 0.8 per year.

Mohamed et al. (2001) studied 7,535 fish from landings at Fao, Iraq in 1998-1999 and found growth and mortality parameters were L_∞=60.47 cm, K=0.32, Z=1.28, M=0.62 and F=0.66. The exploitation rate (E) was 0.52, a bimodal recruitment pattern of unequal strength was observed (peaks in March at 54.65% and October at 45.35%), maximum yield per recruitment was achieved at E_{max}=0.63 and L_c=25.0 cm. They recommended fishing nets should be adjusted to capture fish over 25 cm to avoid overfishing. Mohamed and Qasim (2014a) assessed the stock in 2012-2013 in Iraqi marine waters close to Iran. They found fish were 12.2-48.0 cm total length with >93% of fish 26-44 cm. Age span was almost 6 years. The *b* value was 3.2683 (allometric growth), asymptotic growth (L_∞)=61.47 cm, growth rate (K)=0.275, annual instantaneous rate of total mortality (Z)=1.66, natural mortality (M)=0.55, fishing mortality (F)=1.11 and exploitation rate (E)=0.67. A bimodal pattern of unequal recruitment was observed with April fish being migrant breeders and July fish juveniles from the previous year recruiting to the adult stock. The maximum yield per recruitment was achieved at E_{max}=0.72 and L_c=27.8 cm. The stock was overexploited.

Food: The Ashar Canal study found them to feed on phytoplankton such as dinoflagellates and diatoms and on zooplankton, mainly copepods, as well as their own young. The sieve-like gill rakers are used to strain out planktonic organisms without selection. Presence of some sand grains indicates that feeding can occur on the river bed. Feeding intensity may decrease or cease on the spawning migration and is very high after spawning. The Bahmanshir fish feed principally on copepods and diatoms. Shatt al Arab juveniles feed mostly on filamentous algae and diatoms with some organic matter, fish eggs and zooplankton while adults have empty stomachs on the spawning migration (Hussain et al., in litt. 1995). In the Indus River, the newly hatched larvae and juveniles graze for five to six months in fresh waters before they migrate to the sea (www.jang-group.com/thenews/feb2003-daily/18-02-2003/busi ness/b2.htm, downloaded 18 February 2003). The prime food in the sea off the Iranian coast at Deylam, Bushehr is phytoplankton, principally Bacilliario-phyta followed by Pyrrophyta. Zooplankton was also taken (Nasri Tajan et al., 2008; Nasri Tajan, 2009).

Reproduction: The spawning migration depends on the flood regime of the rivers. Turbid water and fast current are probably stimulants to egg deposition. The sobour depends on river-edge vegetation for egg deposition. Spawning grounds in Iraq are probably located near the beginning of the side branches of the northern sector of the Shatt al Arab, 120 km from the sea (Hussain et al., 1994). This species is gonochoristic (Blaber et al., 1997). Males may ascend the river before females but females become dominant in Indian populations. Males dominate in March in the Shatt al Arab and the sex ratio reaches equilibrium in the spawning months of May-July (elsewhere in the same communication spawning is given as June to August) (Hussain et al., 1994; Jawad et al., 2004). Spawning may occur more than once in a season in India. This has not been demonstrated for Iran but could occur. The gonadosomatic index for fishes in the Iraqi Shatt al Arab indicates peaks in March-May and July-August, suggesting two spawnings (Hussain et al., 1991) although a later report (Hussain et al., 1994) gives spawning as June to July and July to August as evidenced by two modes of juveniles found in September. Sex ratio is equal during this period. All females entering the Shatt al Arab were mature with smallest female being 33.0cm long. Males less than 25.0 cm were immature, the population reaching 100% maturity at 31-32cm (Hussain et al., 1994). The Kuwait fish studied by Al-Baz and Grove (1995) indicated spawning between May and July with a peak in June.

Fecundity in the Indus River population was estimated to be up to 2,917,000 eggs per female, egg diameters reached 0.89mm, and the hatching takes place in about 23 to 26 hours (www.jang-group.com/thenews/feb2003-daily/18-02-2003/busi ness/b2.htm, downloaded 18 February 2003). Estimates for the Hooghly River of India reach 13,230,500 eggs per female (Al-Hassan, 1993). Fecundity in the Shatt al Arab ranges between 444,960 and 1,616,560 eggs for fish 33.0-41.5 cm total length although 2 fish 37.3 and 2 fish 39.0 cm total length had a range in egg numbers of 109,000-233,840, showing that great variations in fecundity occur between individuals; possibly some fish had partially spawned before capture (Jabir and Faris, 1989). This latter study gave a relationship between absolute fecundity and total length as $F=1.3699\ L^{3.6681}$ and $\log F=0.1367 + 3.6681 \log L$ and between fecundity and weight $F=302.8214\ W^{1.2087}$ and $\log F=2.4812 + 1.2087 \log W$. Fecundity increased significantly with body weight, ovary weight and total length. Relative fecundity (ova/gramme body weight) varied from 737 to 1,721, mean 1,216.

Hatching can occur within one day at an average temperature of 23°C. Eggs, larvae and young are found on the spawning grounds but with growth the young move into estuarine and foreshore areas during winter months. Hussain et al. (1994) record the appearance of juveniles from the northern Shatt al Arab from June to November. Adults return to their original habitat in the sea after spawning. There is some evidence for freshwater resident populations in India which migrate upriver to spawn but do not descend to the sea.

The Bahmanshir fish are thought to spawn from April to July. Only adults enter the Bahmanshir (Iranian Fisheries Research and Training Organization Newsletter, 12: 5, 1996). Absolute fecundity of fish from the Arvand, Bahmanshir, Dez and Karun rivers ranges from 374,892 to 1,954,144 eggs for total lengths of 380 to 500 mm, respectively and is related to age. Ova with diameters 0.64-0.795 mm were released spontaneously in a study of this fish in Khuzestan Province, in several batches along its migration route (Ghafleh Marammazi et al., 2004). Spawning begins on entry to the Bahmanshir and Arvand rivers in Khuzestan in April, continuing to September and the end of their migration at the cities of Shushtar and Dezful higher upriver. Males enter these rivers first in March, followed by females in April (Ghafleh Marammazi et al., 2004). Nasri Tajan (2009) found Bushehr coast fish were batch spawners in April-May.

Parasites and predators: None reported from Iran other than nematode larvae by Ebrahimzadeh and Nabawi (1975) for fish from the Karun River. Bannai and Muhammad (2016) studied the parasite fauna of this shad as it immigrated to Iraqi waters from Fao in the estuary of the Shatt al Arab to the Al Hammar Marshes. They concluded that these fish do not come from the Indian Ocean and are endemic to the Persian Gulf (unless parasites are lost on the migration from the Indian Ocean).

Economic importance: The Ashar Canal study cites 996,308 kg reaching the Ashar fish market from October 1975 to June 1977 (see also Sharma (1980)). The catch landed at Fao on the Shatt al Arab estuary of Iraq was 6,576 t in 1990-1991 (L.A.J. Al-Hassan in litt. 1995; however this seems much too high although the estimate is from the Food and Agriculture Organization). This species forms the most important commercial fishery in the Basrah region of southern Iraq, average catches being 491.086, 319.661 and 267.988 t in 1977, 1978 and 1979 respectively (*sic*, Jabir and Faris, 1989). There is a drift-net and stake-net ("hadra") fishery in the sea by Kuwait in Kuwait Bay and around Falaikah Island (Al-Baz and Grove, 1995).

The fishing season on the Tigris-Euphrates is March to August with a peak in April, or late April to early June (Jabir and Faris, 1989) or to November (Ali et al., 1998). van den Eelaart (1954) gave the fishing season for this species as March-August (peaking in April) in rivers, and March-May (peaking in April) in Hawr al Hammar, Iraq. Fish are caught at the mouth of the Shatt al Arab as they enter the river with stationary gill nets, drifting gill nets, and in "mailan" and "odda" traps from March to August. The catch averaged 150-180 kg per ten odda and in March 1953 the total catch at the mouth of the Shatt al Arab was about 25,000 kg (Amodeo, 1956). Large fish are only caught in the summer (Al-Hassan, 1999).

The catch at Abadan in Iran from February to November in 1943 was about 401.42 t and from January to June about 336.67 t (Pillay and Rosa, 1963). This species is seen on markets at Ahvaz, Khuzestan in November but these are sea-caught fish. Marjan Iran Company was selling 600-800 g fish for U.S.$1.40/kg, 800-1,000 g fish for U.S.$1.60/kg, 1,000-1,200 g fish for U.S.$1.70/kg, and 1,200 g and larger fish for U.S.$1.80/kg in August 2003 (http://groups.yahoo.com/groups /hilsa/message/25). The catch in Khuzestan Province in 2000 was 2,688 t (Ghafleh Marammazi et al., 2004) and in 2006 was 4,989.83 t (about 15% of Khuzestan's total commercial fish landing) (Roomiani and Jamili, 2011). The catch in Khuzestan Province in 2008 was 4,645 t (Hashemi et al., 2010).

These fish are caught with traps, weirs, gill nets and other devices in rivers on the spawning migration. They are excellent eating until spawning occurs after which they lose their flavour. However this species has been implicated in clupeotoxic poisoning. Hindi et al. (1996a) give the chemical composition of flesh of this species as 66.41% moisture, 12.12% fat, 18.72% protein and 1.98% ash, indicating a valuable food fish characterised as fatty. Hindi et al. (1996b) give chemical indices for assessing fish freshness according to the month of capture and marketing (pH 6.06, total volatile nitrogen bases 15.32 mgN/100g fish, thiobarbituric acid 1.35 mg, and free fatty acids 1.33%).

Biogenic and anthropogenic sources were noted for the hydrocarbons in this species from the Shatt al Arab; n-alkanes attained 31.11 μg/g and hydrocarbons 10.91 μg/g, the highest for the fish species studied (Al-Saad et al., 1997). The fat content of this shad is a factor in these high levels (Al-Saad, 1990). Salari and Sadough (2009) compared heavy metal (Cd, Pb, Cu, Co, Ni) content in muscle, liver and gill tissues of fish from the Karun River and found levels less than those considered dangerous in Iran. Sadough Niri et al. (2010) examined fish from the Arvand River and found some of the above listed heavy metals exceeded international limits however.

In Pakistan, the Indus River fishermen number between 8,000 and 9,000. Jafri (1994) reviews the Indus fishery which had yields up to 2,694mt. It is the most important Indo-Pacific shad species. The failure of the Indus River fishery in 2003 through drought resulted in Iranian fish being flown to Pakistan for marketing there at rupees150-400 per piece (www.jang-group.com/thenews/feb2003-daily /18-02-2003/business/b2.htm, downloaded 18 February 2003). Robins et al. (1991) list this species as important to North Americans. Importance is based on its use as food, in aquaculture and in textbooks.

Conservation: Hussain et al. (in litt. 1995) report a decline in catches over the previous two decades in the Shatt al Arab. Al-Nasiri and Al-Mukhtar (1988a, 1988b) mention that fish enter the polluted Ashar Canal, a side tributary of the Iraqi Shatt al Arab, during high tide when waters are diluted. A low tide in October resulted in severe oxygen depletion and fish suffocated. Das et al. (1977) found samples from the Ashar fish market in Basrah to be contaminated with hydrocarbons, emitting a kerosene smell and being unfit for human consumption. Al-Saad (1990) found petroleum hydrocarbon residues to be high in Khawr az Zubayr fish at 40.6 μg/g as this species is one that accumulates fat. Mohamed and Qasim (2014b) found Iraqi landings decreased from 90.2% of total landings in 1965-1973, to 52.9% in 1991-1994, to 41.8% in 1995-1999 and to 30.7% in 2000-2006. They recommended establishment of closed areas to protect spawning such as the Shatt al Arab for 30 days in May, catch of small fish up to 23 cm in spawning areas banned, reduction of pollution, and cooperation within Iraq and with Iran on fisheries management.

Evidently, overfishing and pollution are major factors in the conservation of this species, to which must be added variations in freshwater flow and quality from the marshes and Tigris-Euphrates through human processes.

Sources: Some aspects of the biology of this species were based on Pillay and Rosa (1963) and Al-Hassan (1993) writing mostly on Indian and Pakistani populations. Bhaumik (2015) also reviews studies on the biology of this species. Specimens on markets in Ahvaz, Khuzestan examined.

Iranian material: CMNFI 1991-0153, 1, 243.3 mm standard length, Khuzestan, Zohreh River (no other locality data).

Comparative material: BM(NH) 1875.1.14:11-13, 3, 118.8-135.8 mm standard length, Iraq, Tigris River (no other locality data); BM(NH) 1920.3.3:178-182, 6, 103.3-132.4 mm standard length, Iraq, Basra (30°30'N, 47°47'E); BM(NH) 1989.1.13:1-3, 3, 53.9-59.9 mm standard length, Iraq, Khawr az Zubayr (no other locality data); BM(NH) 1989.1.13:4-5, 2, 66.6-69.8 mm standard length, Iraq, Khawr az Zubayr (no other locality data).

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چکیده فارسی

مروری بر شگ ماهیان ایران (خانواده شگ‌ماهیان)

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

چکیده:
در این مقاله سیستماتیک، ریخت‌شناسی، پراکنش، زیست‌شناسی، اهمیت اقتصادی و وضعیت حفاظتی شگ‌ماهیان ایران توصیف می‌شود، گونه‌ها مورد بررسی قرار گرفته و یک مرور منابع در مورد این ماهیان در ایران فراهم می‌گردد. در مجموع تعداد ۹ گونه بومی از جنس‌های *Clupeonella*، *Alosa* و *Tenualosa* در دریای خزر و رودخانه‌های جنوب ایران یافت می‌شود.

کلمات کلیدی: ریخت‌شناسی، زیست‌شناسی، *Alosa*، *Clupeonella*، *Tenualosa*، کیلکا، زالون.