Sturgeon stocking programme in the Caspian Sea with emphasis on Iran

Hossein Abdolhay
Director of Fish Reproduction and Stock Enhancement
No. 250 Fatemi St., Tehran, Iran

INTRODUCTION

The sturgeons of the Caspian Sea are considered highly valuable species. The Caspian Sea has traditionally been regarded as the sea of sturgeon since it produces more than 90 percent of the world's caviar. Despite a remarkable decline of sturgeon numbers over recent years, the Caspian Sea still continues to be of considerable importance in sturgeon fisheries. In 1997, the global landing of sturgeon amounted to 6 126 million tonnes, which the Caspian Sea sturgeon catch accounted for 3 872 million tonnes (FAO, 1999).

At the turn of the last century (1900) the former Soviet Union used to produce some 29 000 million tonnes of sturgeon. The fishery decreased operation following the First World War (1921–26) resulting in dramatic decreases in catch down to 1 100 million tonnes, which in turn boosted the sturgeon stocks in these years.

Numerous sturgeon hatcheries were created as mitigation for lost spawning habitat as a result of dam construction in the former Soviet Union and the Islamic Republic of Iran. With the partial destruction of natural sturgeon spawning grounds the artificial breeding of sturgeon species and fingerling release was started in the former Soviet Union in 1955 (Ivanov and Majinic, 1997). The same trend began in Iran in 1970 through the assistance of Russian fisheries technicians (Abdolhay, 1997). The growth in sturgeon fingerling released grew to such an extent that production reached 100 million fingerlings in 1985. The production and release of sturgeon fingerling continued by the establishment of 11 sturgeon hatchery centres in USSR along with three and five hatchery centres in Azerbaijan and Iran respectively; hatcheries played a crucial role in rehabilitation and restoration of sturgeon stocks. After fingerling production, release to the sea and fisheries management the capture increased to 28 000 million tonnes in 1977. During this period, sturgeon catch in Iran ranged from 1 500–2 500 million tonnes.

In the 1990s, there was a sharp decline in sturgeon stocks due to ecological changes caused by human activities (i.e. illegal fishing). The catch of sturgeon fish plummeted from 28 126 million tonnes in 1980 to 3 872 million tonnes in 1997 (FAO, 1999).

In this article, attempts are made to briefly review the sturgeon landing in recent years as well as the production and release of sturgeon fingerlings and the role hatcheries play in the development of the sturgeon fisheries in the Caspian Sea.

The Caspian Sea

In the Caspian Sea there are more than 123 species and subspecies of fish in 17 families (Kazancheev, 1981) including five species of sturgeon *Acipenser persicus* (Persian sturgeon), *Acipenser gueldenstadti* (Russian sturgeon), *Acipenser nudiventris* (ship sturgeon), *Acipenser stellatus* (sevruga), and *Huso huso* (beluga). Their roe is processed into black roe or caviar, one of the most expensive luxury food items obtained from the aquatic environment. The trade name for caviar from the Persian sturgeon, Russian sturgeon and ship sturgeon is ossetra and the two other types of caviar are named as the sturgeon they come from, i.e. sevruga and beluga.

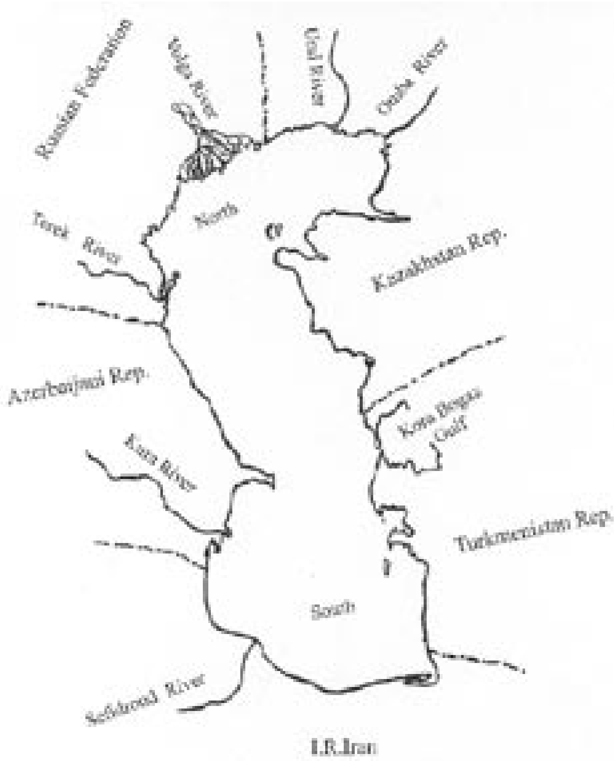
TABLE 1. Coastline of the Caspian Sea

Country	Coastal length (km)
Azerbaijan	850
Iran	992
Kazakhstan	2200
Russia	695
Turkmenistan	1642
Total	6 379

The Caspian Sea is surrounded by five countries: Azerbaijan, Iran, Kazakhstan, the Russian Federation and Turkmenistan (Figure 1). The perimeter is about 6 380 km of which 992 km is in Iran (Table 1). Total sea surface area is about 386 000 km^2, with fluctuations owing to changes in water level.

The Caspian Sea is approximately 1 200 km long and 310 km wide. It is divided into three basins. The most northerly basin is shallow, and covers an area of 80 000 km^2. The middle basin is a separate depression of some 138 000 km^2. The deepest part, 800 m, is located in the west, with a long gently rising slope to the east. The average depth is calculated to be 190 m. The southern basin, which is of particular importance to Iranian fisheries, is separated from the central part by the Absheron underwater ridge. The total area is over 168 000 km^2, which represents over 40 percent of the entire Sea. The deepest area of the depression, which lies considerably to the south of the Kura River delta off the coast of Gilan, in the west is over 1 000 m in depth. There are several ridges occurring in this area but, to the east of the depression, the sea bed is a gently rising slope and the mean depth of the basin is estimated to be 100 m (Faraji *et al.*, 1995).

FIGURE 1. The Caspian Sea and surrounding area, with its major tributaries



The southern shoreline is relatively smooth, with several safe anchorages. There are two major inlets of importance from a fisheries point of view: to the west, the Anzali lagoon and in the east of Golestan Province, the Gorgan Gulf.

The level of the Caspian Sea, which is below sea level, fluctuates considerably as a result of climate changes in the drainage basins and, to a large degree, changes of the Volga River flow. In recent years the level of the Caspian Sea has been referenced to the level of the Baltic Sea. For the first three decades of the last century the level remained around 26 m below the level of Baltic. This was followed by a period of fluctuation during which a minimum of -28.4 m was recorded. The most recent rise of level began in 1978, reaching -26.9 m by 1994. This was attributed to increased river flow, improved surface precipitation with a subsequent reduction in evaporation, and a decrease of flow into the Kora Bogaz Gulf.

The level continues to rise and low coastal areas have been inundated. Predictions are that, although the intensity may decrease, the sea level will continue to rise and may reach -26 m by 2 010 and even 1 m less some 15–20 years later. After that, a period of stability, or even decrease in levels, is predicted.

Wind-induced water surges, which may cause economic damage, are a regular feature of the Caspian Sea. Although they occur throughout the region they are particularly severe in the shallow northern reaches. Their effect in southern areas is not so serious. Sea ice appears in the northern areas in November and, during a particularly hard winter, may cover the whole area of the northern Caspian. In the middle basin, however, ice formations generally occur in December and January and are of local origin in the east, when shallow bays may be frozen over. Ice appearing in the west mostly drifts from the north. Ice is not a problem in the southern part of the Caspian. The water currents are primarily wind-generated, although in the north they are influenced strongly by river inflow. In the south, currents correlate with wind direction and are typically towards the north and north-west, or south and south-east. Localised baroclinic currents and seiches are also noted, but it is not known if these have any particular influence upon fish movements, particularly of the kilka (*Clupeonella engralliformis, C. grimmi* and *C. cultriventris*). In the north, salinity ranges from 0.1 ppt at the mouth of the River Volga and River Ural, to 10–11 ppt near the middle part of the Sea. In the south, surface salinity is around 12.6–13.5 ppt, increasing from north to south and from west to east. There is reportedly a slight increase in salinity with depth.

Water temperatures vary with latitude. In the south there is a horizontal homogeneity, with typical surface temperatures varying between 24°C and 28°C in summer. Warmer waters are to the east. In winter months these could be reduced by as much as 10°C.

The main rivers supplying the Caspian Sea are the Volga (in the Russian Federation), Kura (in Azerbaijan) and Ural (in Kazakhstan) providing 80 percent, 6 percent, and 5 percent of the inflow, respectively. Although there are many small rivers originating in Iran, they exert only a localised influence upon the hydrology of the region. Original breeding and nursery grounds for anadromous species and the environment of several rivers has been adversely affected by the construction of dams for irrigation purposes.

The Caspian Sea fisheries in Iran

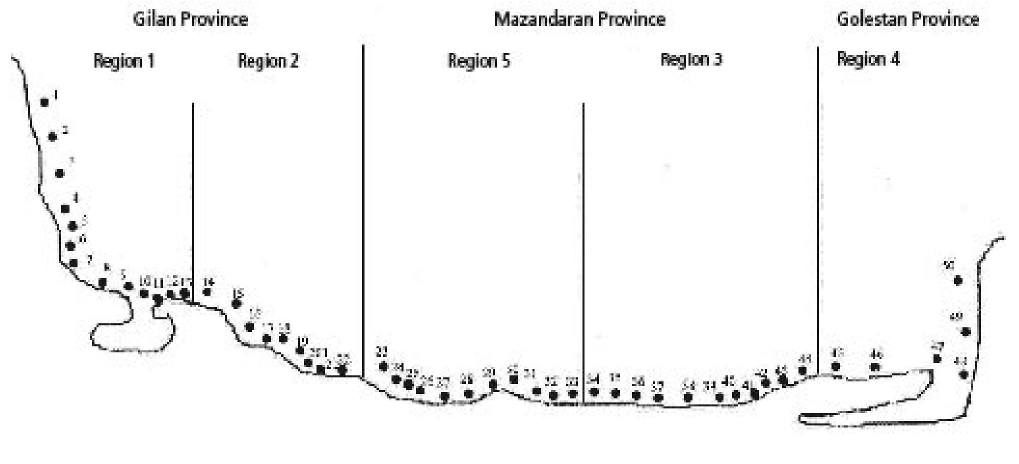
The sturgeon fishery in the Caspian Sea contributes both in food supply and providing employment in northern part of Iran. According to the Iranian fishery management plan all commercially exploitable fish in the South Caspian Sea are divided into three groups.

First group: Distant water fishery which is mainly herring (clupeidae such as *C. engralliformis, C. grimmi* and *C. cultriventris*). The herring fishery in the southern Caspian Sea started in 1939. An extensive fishery began in 1987 with total harvest of 4 170 million tonnes. The annual landing of herring increased to 82 200 million tonnes in 1998.

Second group: The coastal fishery operates mainly on six families: Cyprindae, Mugilidae, Clupeidae, Salmonidae, Percidae and Esocidae that are mainly harvested by beach sine. Average landing of these fish was 15 000 million tonnes in 1997.

Third group: Sturgeon fishery, the most valuable of the Caspian Sea, is the major economic resource and plays a significant role in the income of the Iranian south Caspian Sea fisheries.

FIGURE 2. The five SHILAT regions of the Iranian coastline, together with the 50 sturgeon stations



For administrative purposes, SHILAT (Iranian Fisheries Company) has divided the Iranian coast line of some 992 km length into five regions. From west to east, these are (Figure 2):

Gilan Province

- Region 1 - headquarters in Bandar Anzali, with 13 fishing stations.
- Region 2 - headquarters in Keyashar, with jurisdiction over nine fishing stations.

Mazandaran Province

- Region 5 - headquarters in Nowshahr, with 11 fishing stations.
- Region 3 - headquarters in Babolsar, with 11 fishing stations.

Golestan Province

- Region 4 - headquarters in Ashuradeh, with six fishing stations.

Sturgeon fishing methods in the Southern Caspian Sea

The catches of sturgeon in the sea began at the end of the last century; previously, sturgeon was caught in rivers (Barannikova, 1991). In the southern part of the Caspian Sea (Iranian side) most of the sturgeon catches are made around the rivers. As the result of legislative restrictions on gear (for protecting the sturgeon) only gillnets have been used for catching the sturgeon.

The Iranian Fisheries Company is in charge of both managing and fishing sturgeon. Three provinces, Gilan, Mazandaran and Golestan, are located in the southern part of the Caspian Sea, each with a general fisheries office and a research and training organization. Four fishing districts in these provinces were established in 1970 (districts were increased in 1987 to five) for managing and organizing sturgeon fisheries, and each district has several fishing stations from which sturgeon captured by fishermen are delivered for processing of caviar. Sturgeons are fished only by anchored gillnets, although sometimes a few may be caught by beach seine, when

TABLE 2. Standard mesh size, and length and width of gillnets used for fishing different species of sturgeon in the southern part of the Caspian Sea

Species	Mesh size (mm)	Meshes and length (m)	Width (meshes)
Acipenser stellatus	100	164 (18m)	21
Acipenser persicus	150	120 (18m)	18
Acipenser guldenstadti	150	120 (18m)	18
Huso huso	280	64 (18m)	7

fishing for teleost fishes. The standard mesh sizes (knot to knot) and length and width of gillnets used for capturing different sturgeons in the south part of the Caspian Sea are given in Table 2.

The number of nets used for capturing the sturgeon in the south Caspian depends on the fishing season and varies between the districts. Usually the number of nets used daily for each district varies between 100 to 200. The standard mesh size for Beluga until 1988 was 250 mm, but then mesh size was increased to 280 mm to prevent catches of young fish. It should be noted that, with regard to the fishery management policy fishermen have to release any immature fish caught and they are not permitted to catch ship sturgeon (*A.nudiventris*) because it is endangered. The gillnets have a length of 18 m, their lower edge rests on the sea bed during the autumn fishing season (August to October) but the nets are raised a few meters in the spring season (February to June). The sea bed is sandy over almost the whole fishing area. The sturgeon-fishing calendar for different districts is given in Table 3.

Review of fishery in the Caspian Sea

Historically the exclusive rights to fishing and other uses of the Caspian Sea belonged to the Russian Empire. In 1828, by treaty, Persian trade vessels were granted the right to navigate its waters on an equal basis with Russian ships. This was further endorsed by an exchange of letters between the two countries in 1921 and again in 1940. On both occasions it was agreed that, except for a 10-mile exclusive fishing zone, the Caspian Sea in legal terms was an area beyond the national jurisdiction of each, and where both countries had equal rights to its utilisation.

Recent history of harvest in the former Soviet Union

In the former Soviet Union, some 29 000 million tonnes per year of sturgeon were landed in 1900s but the recession in fishing operation caused by the First World War and the internal war during 1921–26 resulted in the decrease of landing down to 1 100 million tonnes which in turn improved the sturgeon stocks (Ivanov and Majinic, 1997).

In 1938 the sturgeon catch was restricted and in 1962-65 the sturgeon fishing at sea was banned in the Soviet Union, and sturgeon fishing was only allowed in the rivers. Such a ban on the fisheries could foster the migration of sturgeon species to rivers and from 1975 to 1981 the catch increased to 20 000–25 000 million tonnes (Table 4).

TABLE 3. Sturgeon fishing calendar in different fishing districts in the southern part of the Caspian Sea (Taghavi Motlagh, 1996)

Season	District	Species			
		A. stellatus	*A. persicus*	*A. guldenstadti*	*Huso huso*
Spring	1	Feb. 8 – Jun. 21	Feb. 8 – May 22	Feb. 8 – May 22	no fishing
Spring	2	Feb. 8 – Jun. 21	Feb. 8 – May 22	Feb. 8 – May 22	no fishing
Spring	3	Feb. 8 – Jun. 21	Feb. 8 – May 22	Feb. 8 – May 22	no fishing
Spring	4	Jan. 21 – May 31	Aug. 12 – May 22	Aug. 12 – May 22	Sep. 23 – Oct. 12
Spring	5	Jan. 21 – May 31	Aug. 12 – May 22	Aug. 12 – May 22	Sep. 23 – Oct. 12
Autumn	1	no fishing	Aug. 2 – Oct. 12	Aug. 2 – Oct. 12	Aug. 23 – Oct. 12
Autumn	2	no fishing	Aug. 2 – Oct. 12	Aug. 2 – Oct.12	no fishing
Autumn	3	no fishing	Aug. 2 – Oct. 12	Aug. 2 – Oct. 12	no fishing
Autumn	4	no fishing	Aug. 12 – May 22	Aug. 12 – May 22	Sep. 1 – Apr. 4
Autumn	5	no fishing	Aug. 2 – Oct. 12	Aug. 2 – Oct. 12	no fishing

The catch of sturgeons amounted to 20 000–27 000 metric tonnes during 1975–86. A decreasing trend started in 1987 and continues at present (Table 4). The collapse of the Soviet Union has further aggravated the situation to such an extent that officially reported sturgeon landing plummeted to 2 900 metric tonnes in 1995 (Ivanov and Majinic, 1997).

Recent history of harvest in Iran

In Iran, the sturgeon fishery is a government monopoly. Traditionally the fishery takes place in the estuaries of the coastal rivers based on an agreement signed between Iran and the former Soviet Union. Every year, fisherman paid by the Iranian government set out to sea on pre-planned schedule for catching sturgeon. The catch figures for sturgeon are given in Table 4. A stable trend in the fisheries is noticeable between 1975 to 1985, the highest catch was recorded in 1991, (3 036 million tonnes). After the collapse of the Soviet Union, there was a downward tendency in sturgeon landings that continued up to the present time. The capture fisheries in Iran were often between six percent to ten percent of that of Russia.

Fishing operations are carried out from small fibreglass vessels powered with 48 hp outboard engines. The only gear permitted is the gillnet with mesh that is especially suited for the targeted species (as discussed in **Sturgeon fishing methods in the Southern Caspian Sea** section). The complement of fishermen in each boat is four, except in Region 3 where there are only three.

Principal problems with fishery

Oil and industrial pollution is a serious danger to fisheries in the region. The source of pollution of the Northern Caspian Sea is oil production on the Mangyshlak Peninsula (Kazakhstan). When drilling for oil on the shore during the period of the sea level fluctuations and under the influence of winds, a large amount of oil is discharged into the sea. The discovery of new production fields in the sea and possible oil blow-outs may lead to the destruction of feeding grounds in the eastern part of the Northern Caspian Sea. Oil pollution in the Southern Caspian (Azerbaijan) is also a problem (Vlasenko, 1994).

Pollution problems notwithstanding the main troubles began after the dissolution of the Soviet Union in 1991. Instead of one government with centralised control of the catch, four independent countries (the Russian Federation, Azerbaijan, Kazakhstan and Turkmenistan) and two autonomous republics (Dagestan and Kalmykiya) began to harvest sturgeon in the Northern Caspian Sea. Despite efforts to establish regulations for sturgeon catch in the Caspian Sea basin, such an international agreement between the four former Soviet republics and Iran has not yet been signed.

Sturgeon poaching in the new states has increased dramatically. This is most damaging where sturgeon are taken illegally not only from rivers during the spawning period but also from the sea. The sea catch destroys stocks of young fish and makes no economics sense, because females caught at sea are not mature from caviar made of their roe is of very poor quality and cannot be sold officially on the international caviar market (Birstein, 1996).

According to estimates by Dieckmann & Hansen (the oldest caviar trading company in Europe) the total international market for caviar in 1995 was 450 million tonnes, whereas the legal production of caviar in the Russian Federation and Iran totalled only 228 million tonnes (Birstein, 1996). International caviar markets stimulate sturgeon poaching. Caviar lovers around the world gladly pay high prices for the delicacy.

TABLE 4. Sturgeon capture in the Caspian Sea (metric tonnes)

Year	Russia	Kazakhstan	Azerbaijan	Turkmenistan	The former Soviet Union	Iran	Total
1900	22 800.0	0	5 100	1 100	29 000.0	0	29 000.0
1905	21 600.0	0	4 500	1 100	27 200.0	0	27 200.0
1910	18 400.0	0	3 800	900	23 100.0	0	23 100.0
1915	20 100.0	0	6 100	700	26 900.0	0	26 900.0
1920	1 400.0	0	1 500	0	2900.0	0	2 900.0
1925	8 000.0	0	3 700	400	12 100.0	0	12 100.0
1930	9 700.0	0	3 600	400	13 700.0	1 100	14 800.0
1935	9 400.0	4 100	4 000	1 800	19 300.0	840	20 400.0
1940	3 600.0	1 300	2 200	400	7 500.0	550	8 050.0
1945	1 500.0	300	1 700	100	3 600.0	620	4 220.0
1950	11 000.0	100	2 400	0	13 500.0	760	14 260.0
1955	7 500.0	700	2 200	100	10 500.0	710	11 210.0
1960	7 400.0	1 600	1 100	0	10 100.0	1 500	11 600.0
1965	10 600.0	3 900	400	20	14 920.0	0	14 920.0
1970	10 700.0	5 200	170	0	16 070.0	0	16 070.0
1975	14 670.0	8 250	34	0	22 954.0	1 500	24 454.0
1976	16 897.0	9 006	360	0	26 263.0	1 500	27 763.0
1977	16 610.0	10 413	340	0	27 363.0	1 500	28 863.0
1978	14 732.0	8 480	424	0	23 636.0	1 500	25 136.0
1979	15 181.0	8 936	535	0	24 652.0	1 500	26 152.0
1980	16 705.0	8 101	323	0	25 129.0	1 500	26 629.0
1981	17 217.3	7 635	319	0	25 171.3	1 496	26 667.3
1982	16 804.5	7 107	267	0	24 178.5	1 496	25 674.5
1983	17 013.7	6 539	224	0	23 776.7	1 500	25 276.7
1984	15 895.6	6 246	223	0	22 364.6	1 330	23 694.6
1985	15 062.6	5 895	241.9	0	21 199.5	1 650	22 849.5
1986	14 283.1	5 496	232	0	20 011.1	1 690	21 701.1
1987	14 972.0	4 090	185	0	19 247.0	1 690	20 937.0
1988	15 202.4	3 177	218	0	18 597.4	1 700	20 297.4
1989	13 431.8	2 269	120	0	15 820.8	2 051	17 871.8
1990	11 664.6	1 936.1	70.37	0	13 671.1	2 645	16 316.1
1991	8 547.5	1 767	108.6	0	10 423.1	3 036	13 459.1
1992	7 508.2	1 670	119.0	0	9 297.2	2 692	11 989.2
1993	4 238.1	1 109	240.5	0	5 587.6	1 710	7 297.6
1994	3 255.4	635	63.2	0	3 953.6	1 700	5 653.6
1995	2 301.8	562	43.4	180	2 907.2	1 500	4 407.2
1996*	1 779.0	510	24.0	0	2 313	1 360	3 673.0
1997*	2 044.0	460	23.0	0	2 527	1 200	3 727.0

Hamoonpad (1999), Ivanov and Majinic (1997).

*FAO statistics.

Thirty grams of Beluga caviar in the well-known New York store “Petrossian” sell for US$65, for example wheras the price of a kilogram of caviar on the black market in Moscow is US$250, (Birstein 1996).

United States Commerce Department data show that caviar imports has increased 100 percent since 1991. Meanwhile reputable caviar suppliers in Europe are being driven out of business by illegal trade. For example, from 1992 to the present the German caviar market has been overwhelmed by poor quality caviar (Birstein 1996).

Unique features of the fishery

The Caspian Sea and its sturgeon comprise a unique fishery. Among the various renewable and non-renewable resources naturally bestowed to the littoral states of the Caspian Sea, the sturgeon stocks are known worldwide, but they are very vulnerable to overfishing. During the last centuries, Russia has always been at the lead in terms of sturgeon fisheries around the world. Sturgeon have been fished in places other than the Caspian Sea, including Sea of Azov, Black Sea, Ural Sea, and a number of rivers in Siberia as well as in the far east, the Caspian Sea has always been the most exploited in this respect.

The sturgeon species are *Acipenserid chondrostans*, a primitive stock of teleost fish that diverged 200 million years ago (Berg, 1948 cited by Doroshov, 1985). Longevity is a characteristic of most sturgeon species and the Beluga can reach an age of over 100 years (Marti 1979 cited by Doroshov 1985).

Sturgeon includes two families: *Acipenseridae* and *Polyodontidae*, *Acipenseridae* includes 25 species in four genera such as *Huso*, *Acipenser*, *Scaphirhynchus* and *Pseudoscaphirhynchus.* They live around the world especially in the Caspian Sea, Black, Azov Sea and inland water. Twelve species are on the brink of extinction (Doroshov 1985, Birstein *et al.,* 1997, FAO 1999).

Sturgeon spends their adult lives in both freshwater and saltwater environments depending on the species. All of them however, migrate upriver to spawn. A relatively small number of species are truly anadromous. The most abundant group can be defined as semi-anadromous (Russian and Persian sturgeon, beluga, sevruga and ship sturgeon).

All sturgeon require a much longer time to reach sexual maturity and to complete the gametogenic cycle than most other fish. The average age of fish at their first spawning varies 10 to 25 years in different species (see in Appendix 2). All sturgeon species are iteraparous and spawn several times during their lives. Completion of one gametogenic cycle takes longer than one year. Intervals of two to eight years were indicated for sturgeon females (Doroshov, 1985).

RATIONALE FOR SEA RANCHING PROGRAMMES

Large brackish water seas, such as the Caspian Sea, provide unique conditions for sturgeon ranching due to their isolation from the ocean and an abundant food base. The major target of sturgeon management in the Caspian Sea is the capture of adult, sexually mature fish during the spawning migration and migration around the sea. Ripe fish are harvested from rivers deltas or lower reaches of rivers during their spawning migrations and used for caviar and flesh production. More than 65 percent of total spawning stock is removed by the fishery; the remainder is passed to those spawning grounds or artificial propagation in Russia (Marti, 1979 cited by Doroshov 1985).

Rationale for sea ranching

Sturgeon ranching was an attempt to mitigate for loss of sturgeon spawning habitat in rivers surrounding the Caspian Sea. Sturgeon migrates to river from the sea to lay their eggs. In the past, fishing used relied merely on natural recruitment of the sturgeon stocks. Rivers such as Volga, Ural, Kura, Sefidroud, Tajan, Gorgan and Atrak constituted some of the major natural spawning ground for these species. Destruction of natural spawning ground is one of the causes for the decline in the natural recruitment of the sturgeon stocks at present.

Obstructing rivers to control the discharge of water for agriculture purpose may bring about irretrievable losses of natural spawning ground of sturgeon. The discharge of water during springtime reduces the spawning potential of the sturgeon in Volga River (Khoroshko, 1972) and Aktoba River (Pashkin and Paletiva, 1992). Before construction of the dam on the Volga, sturgeon spawning ground area was as large as 3600 ha. Because of the construction of Volgagrad dam in 1958-1960 and of the storage reservoirs, 85 percent of the spawning grounds have been completely lost (Vlasenko, 1994; Birstein, 1996), about 3 percent of the spawning grounds are beyond backwater areas and only 12 percent have remained in lower Volga. According to the same report, all the spawning grounds for Belugas has been removed along with 70 percent and 40 percent for Russian sturgeon and Sevruga respectively (Vlasenko, 1994). More than 160 ha of natural spawning areas for sturgeon have been lost in Kura River followed by 132 ha on Tarak River and another 201.6 on the Sulak River. The only unregulated river flowing into the Caspian Sea is the Ural with the largest area (1 400 ha) of spawning grounds for sturgeons (Vlasenko, 1994). Therefore, building dams on these rivers has not only destroyed spawning grounds but flow depletion has changed the hydrological and hydrochemical regimes of rivers and the sea and reduced their biological productivity (Barannikova, 1991).

The Sefidroud, Gorganrud and Tajan rivers in Iran have lost their capacity to provide suitable grounds for sturgeon spawning in recent years because the rivers have been dammed (the Sefidroud dammed by three dams the Manjil, Tarik and Sangar). Due to drainage regulation during the spring season, the river usually becomes very shallow followed by severe fluctuations in water temperature downstream (Fadaee, 1997). Furthermore, creating dams on the Tajan River (Laloee, 1996), which is aimed at exploiting the water for agricultural purpose, as well as Voshmgir dam in Gorgan River have substantially impoverished these rivers in terms of their ability to support sturgeon migrations. All these factors have resulted in reduced water in the rivers.

Changes in the nature and location of principal sturgeons spawning grounds can be related to:

- human intervention of the inflowing waters of the Caspian Sea through the construction dams;
- industrialisation and irrigation;
- pollution of both rivers and the Sea from industrialisation and agricultural effluents;
- eutrofication resulting from the above;
- poaching and the destruction of immature fish through the use of non-selective gear, or inappropriate open seasons;
- inadequate fisheries management.

Evaluation of other sturgeon fishery management options

Fish season closure

When ice in the Volga and Ural rivers is melting, capture of sturgeon fishes begins in the mouth of Volga, Oral, Kura, Trek, and Solak rivers. At the end of winter and beginning of spring capture of sturgeon is carried out with common and specific beach seine (plates 26–28) in a special area of the Volga delta. Sturgeon capture is allowed prior to 15 May when the fish are migrating for spawning in the main branch of Volga except captures for research purposes or to provide enough broodstock for hatcheries. Sturgeon capture in this area is allowed from 15 May to 5 June. Fishing is not allowed in the basin in summer. Aurumn fishing in the Volga delta begins on 1 September and continues until the permitted annual catch level has been reached.

Sturgeon captures in the Ural River begins after ice-melt and are permitted between 25 May and 1 August again until the permitted annual catch level is reached. According to scientific advice, sturgeon capture stops after three days of fishing so that the broodstock can migrate through the river and then capture continues after two days.

Fishing time and methods in Iran are discussed in the section **Sturgeon fishing methods in the Southern Caspian Sea**. Fish season closure is under control of research centres and these do not permit capture of immature fish. These methods apply to capture of standard size fish.

The main problem in managing sturgeon stocks in all littoral countries is illegal fishing and it is not possible to control poaching. Iran has special guards who prevent illegal fishing at sea.

Restriction of fishing area

In term of fisheries improvement of sturgeon in 1960s, the Russian government decided to ban sturgeon fishing in the sea and switched to fishing in rivers. This action combined with artificial reproduction caused sturgeon catch to double in the late 1970s and early 1980s (Hamoonpad, 1999).

After prohibition of sturgeon capture in the sea, the Russian government limited fishing time and imposed high fines for illegal fishing. In 1994 the cabinet of the Russian Federation agreed to increase fines for any illegal capture of sturgeon fish to 35 percent, 14 percent and 12 percent of an offender’s salary for beluga, ossetra, sevruga, respectively (Hamoonpad, 1999).

In an agreement between Iran and USSR in 1940, catch of sturgeon in Iran was permitted only in rivers and this was further agreed between Russian fishery committee and ministry of Jahad e Sazandegi in 1996. Iran's share of the sturgeon capture in the Caspian Sea was 10 percent of total capture and has undergone less damage.

In the mid 1970s Kazakhstan and the former USSR established a no-fishing area in the North Caspian Sea. Unfortunately, on 23 September 1993, the Kazakhstan government approved geological research activity and the extraction of hydrocarbon material from this area.

Restriction on fish gear in Iran

Sturgeon fishes were previously caught using longline method in which each vessel had 20 000-30 000 hooks with 25 hooks for every rope. This method was harmful to sturgeon stock because immature fish were trapped and killed. Therefore, capture methods changed to netting and variable mesh made from natural thread. Synthetic thread was bought from USSR in 1956 and all fishermen used these nets from 1963.

Before 1995 fin fish such as kutum (*Rutilus frisii kutum*) were caught with gillnets in the south of the Caspian Sea but studies conducted on this method have shown it was harmful to sturgeon stocks. Therefore, to preserve sturgeon stocks, in 1995 Iranian Fisheries spent US$25 000 000 purchasing all gillnet fishing permits. This fishing method was banned and not used in Iranian Fisheries (Pourkazemi and Hosseini, 1997). Iranian Fisheries decreased numbers of fishing vessels and fishermen from 430 to 343 and from 1 500 to 1 285 respectively from 1991 to 1998.

Sturgeon species inadvertently caught by cooperatives fishing for bony fish are obliged by law to report this to SHILAT officials, who are responsible for the disposal of the fish. In the 1994–1995 season, beach seine units in Gilan captured sturgeon weighing a total of just under 9 500 kg with caviar weighing 1 173 kg. In the following year the landing of sturgeon doubled to 21 800 kg to 2 259 kg of caviar.

Sturgeon fishing in the Volga River is with beach seine with a mesh size of 45 to 50 mm (knot to knot). Russia has enacted laws to decrease the accidental catch of sturgeon and encourages fishermen to return trapped fish to the sea in good condition (personal communication from KaspNIRK) .

METHODOLOGY OF SEA RANCHING

Broodstock selection and management

The season of sturgeon breeding and fingerling production is restricted to the period from March to July in the hatcheries of the south Caspian Sea. Hatchery facilities are used at least twice during the breeding and rearing seasons. The most beluga sturgeon (*H.huso*) are caught in wintertime and the broodstock are kept to a suitable time for spawning. The beluga migrates to the Sefidroud River in early spring. Persian sturgeon and sevruga spawn in late spring and their fingerlings are stocked in May. The other species such as *A.stellatus* and *A.nudiventris* migrate to Sefidroud, Tajen, and Gorganrud Rivers.

Broodstock are caught in the rivers by beach seine and some of them are also selected from the fisheries stations around the rivers by experienced hatchery personnel. Large numbers of animals have to be captured and examined to obtain sufficient numbers of mature fishes that will spawn within a few months in captivity. They are examined by sampling eggs and a check of the germinal vesicle (GV), and if they are not suitable for injection they will be returned to the fisheries station for caviar processing.

In Iran broodstock captured in the rivers or sea are transferred to the hatcheries by truck equipped with oxygen (Abdolhay, 1996; Bradran Tahori *et al.*, 1997). The broodstock are transferred to ponds (75 × 12 m called a koransky) (Kohehshari *et al.*, 1974). The ponds have three parts, the first part is for long-term storage, the second part is for temporary storage and the third part is for injection of fish (Kohnehshari, *et al.*, 1974). In new hatcheries the broodstock are kept in earthen and concrete ponds (Abdolhay 1997).

The hatcheries in the Russian Federation are usually near navigable parts of the river. The broodstock are transported with special vessels (Abdolhay, 1997; Baradaran Tahori *et al.*, 1998). These vessels, called prolis, have numerous holes for the exchange of water between the river and the vessel (Abdolhay, 1996; Baradaran Tahori *et al.*, 1998).

The scheme of the hatchery enhancement cycle is shown in Table 5. Brood fish are selected from commercial landings and transported to the hatcheries. All fish are slaughtered after spawning. Progeny are raised in tanks or ponds until early or

TABLE 5. Sturgeon ranching scheme in the Caspian Sea (Iran and Russia)

Capture (Feb.–May)	Commercial fisheries in river deltas supply food markets with flesh and caviar and supply hatcheries with ripe broodstock.
Spawning (March–May) (3–5 days)	Ripe fish are induced to spawn via hormonal treatment. Broodstocks are slaughtered.
Egg incubation (5–10 days)	Eggs are incubated in jars or in trough incubators. Newly emerged larvae are held in circular tanks.
Fingerling production (40–60 days)	Fry are stocked and raised in fertilized ponds in tanks until fingerlings reach 3–5 g mean body weight.
Release (June–July)	Fingerlings are released in river deltas.
Capture (10–20 years)	Sexually mature fish return to the rivers for spawning and capture by fisheries. Their return to the fisheries is 1–3%.

Doroshov, 1985

midsummer, when juveniles reach 1 to 3 g body weights. These fish are released into river deltas or upper estuaries. Broodstock selection is earlier in Iran and they are often collected in winter. In-depth research on sturgeon embryology conducted by Detlaff and Ginzburg (1954) contributed to major improvements in sturgeon hatchery spawning and egg incubation techniques.

Reproduction (After Doroshov 1985; see plates 1–12)

Ovulation is recognised by the palpation of the female's abdomen or by the spontaneous discharge of a few sticky ova. A reasonable prediction of spawning induction response is possible through the examination of the germinal vesicle position. A rapid method to determine gonad maturity in the sturgeon is via the location of the GV. Follicles are removed with a probe and boiled in water for 2 minutes in a test tube and then are cut with a sharp safety razor blade exactly along the axis through the animal and vegetal pole and an index of oocyte polarization is then calculated.

Ripe fish are injected with ovulation-inducing substances. Gerbilsky (1972) established methods of induced spawning via the intramuscularly administration of acetone and dried pituitary glands. Sturgeon pituitary glands are used for the induction of ovulation and spermitation in Iran and in the Russian Federation. Glands are obtained from commercial sturgeon catch and stored after dehydration in acetone. Leutenizing Releasing Hormone, LRH-a synthetic analogue has also been used to induce spawning. The dosage of hypophysis and LRH depend to the weight of fish and temperature for each species (Dettlaff *et al.*, 1993; Shafizadeh and Vahabi, 1996). The collected eggs are fertilised with semen and diluted with hatchery water to avoid polyspermy (Kohehshari *et al.*, 1974; Dettlaff *et al.*, 1993).

To be successful, hypophysation requires the use of pituitary materials from suitable donor fish. The donor should be a mature pre-spawned fish, preferably of the same species as those that are to be spawned. Pituitary can be preserved in alcohol or acetone, but acetone-dried material is easier to handle. In order to preserve the glands, they should be placed in absolute acetone, which has been refrigerated or placed on dry ice. The acetone should be changed several times over a 24-hour period to ensure that the glands have been properly dried and deflated. They are then dried on filter paper or under vacuum and stored.

PLATE 1. Broodstock transfer

PLATE 2. Hormone injection

PLATE 3. Check ripping fish

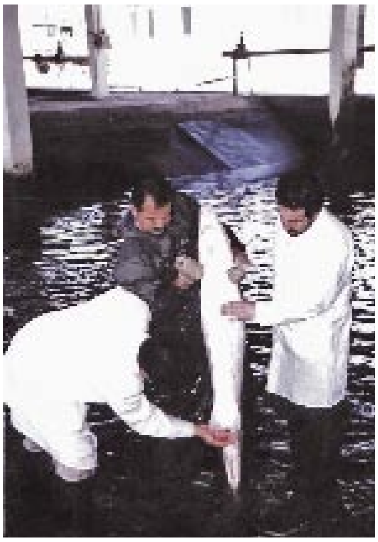


PLATE 4. Remove eggs

PLATE 5. Remove ovarian fluid

PLATE 6. De-adhesion the egg

PLATE 7. Sperm collection

PLATE 8. Sperm addition

PLATE 9. De-adhesion of the egg by mixing

PLATE 10. Water hardening eggs with silt

PLATE 11. Transfer egg to the incubator

PLATE 12. Slaughtered fish

Two consecutive injections are recommended to obtain the best ovulatory response. The total dose for the female is divided into two injections, an initial dose of 10 percent and final dose of 90 percent. Male fish receive a single injection when the female has her second injection. In females, the gland extract is injected intramuscularly (between the lateral and dorsal scutes within the area extending from the base of pectoral fin to the midsection of the fish). The time between the last injection and ovulation ranges from 15 to 40 hours and depends on species and water temperature.

The following equipment is necessary for performing insemination: dry pans for eggs, dry vessels for the sperm, enamel-coated bucket, 100 ml measuring cylinder, microscope, several glass slides, a glass rod and a pipette. Ripe sperm are collected by stripping or by catheterization of male and sperm can be kept intact at refrigerator temperature for at least 24 hours prior insemination without any noticeable decrease in fertility (Doroshov, 1985). Before the sperm is used to fertilise eggs they are examined under a microscope to determine viability. Stripping of eggs is not feasible for most sturgeon because the structure of the female oviduct allows only partial stripping of small portions of ova. The eggs should therefore be removed by opening the female abdomen.

The eggs collected are fertilised by different established methods of insemination: dry, semidry and wet methods. Comparison of the effectiveness of these three methods of insemination was carried out on the eggs of *A. stellatus*. The best results were obtained with the semidry methods (Ginsburg, 1968) where the eggs and sperm are collected in dry containers, but shortly before addition to the eggs the semen is diluted by hatchery water at ratio 1: 200 to avoid polyspermic fertilization (Doroshov, 1985) because the sturgeon have many micropyles. Eggs have to be placed in a cool place and protected from direct sunlight. Insemination should be performed without delay, preferably no later than 10 to 20 minutes after collecting eggs.

Activated eggs become highly adhesive within a few minutes after fertilisation. In USSR, Derjavin (1914) developed a simple egg de-adhesion technique using silt coating of eggs immediately after insemination. For de-adhesion, the eggs are placed immediately after insemination into a suspension of clean silt (washed, dried and sieved to particles 10–20µm) and gently stirred for 20-40 minutes. Alternatively urea, tannic acid and various salts can be used instead of silt to remove chemically the jelly layer from fertilised sturgeon eggs; a treatment of urea and sodium chloride (NaCl) or sodium sulphide (Na_2SO_3) is followed by a tannic acid wash (Conte *et al.,* 1988). The silt method is used in Iran for de-adhesion of fertilised eggs.

Determination of the percentage of fertilisation and polyspermy are of great importance to fish culture and is carried out for all incubated batches of eggs at the 2nd cell division of the eggs. If the technique of insemination was correct, usually no more than 4–6 percent of polyspermic eggs are present in a batch of good-quality eggs (Dettlaff *et al.*, 1993).

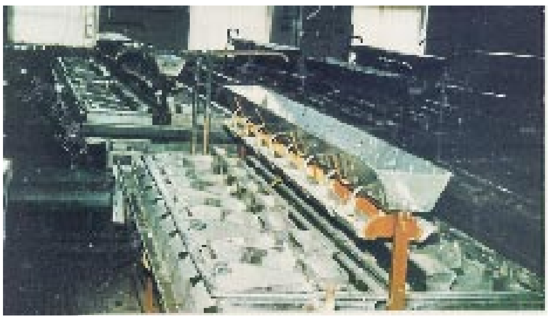
Incubation (see plates 13–14)

The Russian hatcheries use Osetr incubators for egg incubation at present and they do not use the Yuschenko system (Abdolhay, 1996; Baradaran Tahori and Abtahee, 1998). The Osetr incubator has some advantages over the Yuschenko, such as greater capacity, higher efficiency and low noise. To reduce stress larvae transfer to the tank is done by water flow without contact by hand. Water flow also removes dead and diseased eggs (eggs with saprolegnia) automatically to prevent contamination to healthy eggs (Pourasady, 1995).

The most popular egg incubator in Iran is the Yuschenko trough, which was designed by Russian experts. The Iranian experts who were trained in Russia constructed an Osetr incubator system in Iran in 1996 (Pourasady, 1996). The period of incubation depends on species and temperature and is usually 7-12 days.

PLATE 13. Yuschenko incubator

PLATE 14. Osetr incubator



Methods of larvae rearing (see plates 15–23)

Three methods of fingerling production are used in Russian and Iranian hatcheries.

- Rearing in earthen ponds from initiation of feeding to final fingerling size.
- Rearing in tanks on cultured live food up to or beyond metamorphosis, followed by additional grow-out in ponds until final size.
- Intensive tank culture.

The first method used on Volga River hatcheriesn is inexpensive and cost efficient but requires appropriate climatic conditions and pond management to produce predictable harvests. The larvae are stocked in ponds just prior to the initiation of feeding, at a density of 60 000 to 75 000 per hectare. Ponds (usually 2 ha surface and

PLATE 15. Transfer of the larvae to fibreglass tank

PLATE 16. Concrete tank for larvae

PLATE 17. Fibreglass tank for larvae

PLATE 18. Larvae rearing

PLATE 19. Larvae rearing

PLATE 20. Pond rearing

PLATE 21. Fingerling collection

PLATE 22. Fingerling counting

2 m maximal depth) are fertilised with manure prior to and after stocking. The rearing period continues for 30 to 40 days. The survival at harvest is 50-60 percent and fingerling size is 2-3 g.

The second method (used at hatcheries on Kura River and in Iran) includes initial rearing in tanks to overcome the problems associated with the possible high mortality of larvae in the ponds. Between 20 000 and 30 000 larvae are stocked in each 2 m diameter, 30 cm deep round tank. Fry are fed the white worm (*Enchytraeus albidus*), zooplankton (*Daphnia* and *Moina* sp) and the brine shrimp (*Artemia* sp), that have been cultured in the hatchery. After reaching 0.1–0.3 g body weight, fry are stocked in fertilised ponds to complete grow-out. The survival in tanks is 50–80 percent and that in the pond is 70–80 percent (Milstein, 1972, cited by Doroshov, 1985).

PLATE 23. Fingerling transfer to a river in Iran

In Iran the concrete pond (2.5 m diameter and deep with a 30 cm, capacity of 30 000–35 000 larvae) and fiberglass tank (2 × 2 × 0.5 m with a capacity of 15 000–20 000 larvae) were constructed and aeration used to increase density in new hatcheries. Stocking the larvae to the pond will be done at 70–80 mg. This method is suitable for Iran because of low production of larvae to overcome the problems associated with the possible high mortality of larvae in the ponds. The survival rate in tanks, incubator and ponds is shown in Appendix 1 (Abdolhay and Tahori, 1997).

The third method is used when the number of larvae is very low and it is necessary to keep them in the small pond to reduce mortality. Sometimes this method is used in Iran, especially in autumn propagation season.

Larval rearing in ponds

The quality of pond soil will be tested in autumn. Five million tonnes of cow manure are added to the pond and water is added 10–15 days before stocking larvae. Initially, water depth is kept at 1 m and fertiliser is put in the pond (ammonium phosphate and ammonium nitrate). After the daphnia stock is added to the pond and water depth increased to 1.5–2 m, sampling is performed during rearing of fingerling and phytoplankton, benthos condition factor, growth rate and nutrition are monitored.

Most ponds are 1–2 ha in size; the stocking density is between 70 000 and 90 000 fry per ha, dependent on species and fertility of the pond. A project was established to increase stocking density by aeration. The stocking density was increased up to 200 000 fry per ha. The survival rate was increased from 50–60 percent to 85– 90 percent and the average fingerling production was increased from 50 000 to 100 000 per ha (unpublished data). The average body weight of fingerling is about 2–3 g for 30–40 days at which point they are released to the river.

PLATE 24. Fingerling releasing directly to the river in the Russian Federation

Release strategy

Three mechanisms for releasing fish are used:

- spot planting: introducing all the fish into the receiving waters at the same time
- scatter planting: introducing fish into several sites in the same region;
- trickle planting: introducing fish into the same region over a period of time (Cowx, 1994).

Spot planting can lead to competition among stocked fish, or with natural stocks and in rivers it is often associated with considerable downstream displacement to reduce population interactions. Scatter stocking gives a wider dispersal at the outset and minimises competitive pressures. Trickle stocking similarly removes competition but is often constrained by lack of labour, finance and available stock. Evidence suggests that scatter and trickle stocking (Berg and Jorgensen, 1994) are more successful than spot stocking but the latter is generally carried out because it is easier to undertake (Cowx, 1994).

In the hatchery centres of Astrakhan (the Russian Federation) sampling is carried out by trawlnet during release of sturgeon juveniles and an estimation of the approximate number of juvenile sturgeon is maintained. However, according to Russian experts, in order to obtain a more accurate account of the actual number of produced fingerlings, a more rigorous method of counting was used during the early years of operation. Nevertheless, in order to avoid manipulation stress on juvenile sturgeon, and because of the great number of rearing ponds, estimation of the released fingerlings is statistically done through applying trawlnet. After estimation the number of fingerling in each pond, they are directed toward the outlet channels that flow into the river. In order to enhance the survival rate of fingerling some of them are transported by special vessel to the feeding ground (Vlasenko, 1994).

As the sturgeon hatchery centres in Iran are located far from the rivers, the fingerling (3–5 g) are introduced into fish collectors by gradually draining the ponds and forcing the fingerling through concrete water canals. They are then counted in a special container and their average weight is determined.

The fingerlings are then transferred to the rivers by trucks that contain oxygen tanks, and are released into the rivers. Careful monitoring is carried out in terms of timing, location and the weight of fingerling in Iran; counting of the juvenile fish is performed by fisheries research officers. The fingerlings in Iran are usually released in rivers such as Sefidroud, Tajan and Gorgan that have abundant flow of waters. Meanwhile the fisheries research centres carry out certain studies on the migration of sturgeon (Fadaee, 1997).

PLATE 25. Boat for transfer of broodstock in the Russian Federation

Genetic resource management

PLATE 26–28. Capture of broodstock in the Volga River

The first step in conserving genetic resources is to determine what genetic resources exist. This basic information is often lacking or incomplete for many aquatic species. Protein or isozyme analysis enables the genetic variability of numerous species to be examined quickly and relatively cheaply. Protein variation can provide information on geneflow, population structure, species identification, taxonomy, hybridization, and evolutionary relationships in fishes. More information is becoming available on DNA level variation in aquatic species (Cited by Bartley, 1995).

In the conditions that existed after the Volga River flow regulations, the probability of interspecific mating of sturgeon increased. Sturgeon hybrids have accounted for 0.02–3.1 percent of the total number of migrating sturgeon juveniles over all the years for which data exist (Lagunova, 1997), the proportions of the different hybrids has varied with time. Between 1964 and 1981 the hybrid Russian sturgeon × sterlet (*Acipenser ruthenus L.*) was most common and accounted for 51.3 percent of all hybrids, Russian sturgeon × sevruga accounted for 28.2 percent and sevruga × sterlet accounted for 20.5 percent (Lagunova, 1997). From 1982 to 1994 the hybrid Russian sturgeon × sevruga was prominent and its percentage nearly doubled (55.7 percent) whereas the proportions of Russian sturgeon × sevruga decreased 1.5 times (to 33.9 percent) and the proportion of the sevruga × sterlet decreased to 10.4 percent. Different sturgeon hybrids have varied in number over all the period of observations in Volga River. It seems most likely that the increasing number of Russian sturgeon × sevruga was promoted by a reduction in spawning areas, together with improved reproduction conditions for the Russia sturgeon breeding in summer as a result of stored water releases during a period of low water period (Lagunova, 1997).

At present, the preservation of all sturgeon species cannot be guaranteed. Many are in very poor condition and may disappear in the near future. Rare sturgeon species are in dire need of genetic conservation. Within framework of the Russian Federation Committee of Fisheries (Goskomrybolovstvo) a long-term programme of Sturgeon Biodiversity Conservation was begun in 1990s. Live collections of rare sturgeons coupled with of sperm cryopreservation was suggested as a means to help in gene pool conservation.

The question is whether a long-term species-group raised in captivity can be based on a limited number of live specimens and a large amount of frozen sperm (Artyukin *et al.* 1997). Currently, within the framework of the programme, several special facilities for the central collection of live sturgeon are under construction near Moscow. A sperm bank was also created in a laboratory in St. Petersburg (Artyukin *et al.* 1997).

A gene bank for frozen sperm is planned in the Sturgeon International Institute in Rasth in Iran (Alipoor *et al.,* 1998).

The maintenance of rare sturgeon stocks in captivity began in the 1980s. In particular, a small population of Sakhalin sturgeon (*Acipenser medirostris* Ayers) was begun in Konakovo experimental hatchery, Tver region. Here the males started to produce sperm at the age of 6 years. The female Sakhalin sturgeon matured in Konakovo hatchery at age 9 years. Iran is also experimenting with a live gene bank at Beheshti hatchery in Rasht and in other inland areas (personal communication, Bahmani and Kazemei, 1998).

Iranian hatchery experts try to produce high quality and healthy fingerlings but with the mass production of fish it is difficult to give consideration to some aspects of genetic management. Hatchery managers try to keep separate broodstock for each area. No hybrid fish are released to the sea (Rezvani, 1990). Some projects have sought to produce beluga-sevruga, beluga-Russian sturgeon and ship-beluga, but this research is undertaken to obtain data on best growth rate for culture.

Fish health management

In the hatchery

With regard to the release of juvenile sturgeon, the health control laboratories have responsibility for monitoring the production process in different stage of the task within the hatchery centres. Through sampling and examining, they take the required measures in identification, control, prevention and elimination of the stresses or any other causes of disease that increase mortality in broodstock, eggs, or in the developing embryos incubators and finally among the newly developed fingerlings that are in earthen ponds. Such laboratories play an effective role in improving the quantity and quality of sturgeon for release (Jalali, 1998).

Monitoring includes medical examination of the transferred broodstock to hatcheries as well as growing fingerling up to release. Some of the main medical measures are: disinfecting the broodstock ponds, disinfecting of hatchery (i.e. incubators, larvae culture ponds), inspecting the received broodstock and disinfecting skin injuries, sterilising the soil used for de-adhesion of eggs, sampling the live food consumed by the cultured larvae, disinfecting the canals and waters remaining in ponds by splashing them with lime, combating the intermediate host of many parasites, and drying and disinfecting the ponds using lime (Personal observation).

Fingerlings are disinfected at different stages until release to ensure that problems are eliminated. Sampling is performed before the actual release of the fingerling as a final check. Macroscopic and microscopic examinations of the samples in the laboratory give final assurance about the broodstock. If there is any acute form of contamination or bacterial infection, the broodstocks are not use for reproduction.

In general, only few instances of contamination have occurred because all necessary control measures have been taken. In addition, the rearing ponds are only used for two months of the year and after which they are drained and lime is splashed on the ponds for disinfecting purposes. There is also a low density of fish in the ponds (80 000- 100 000 pieces per hectare) with no utilisation of artificial feed.

In the sea

Deterioration of the ecological situation in the Caspian Sea and its flowing rivers has been responsible for the degraded physiological state of sturgeons during their marine and river periods of life, which has manifested itself in metabolic disturbance, and impaired haematological blood characteristics. Histological investigations suggest severe gameto- and gonadogenesis disturbances in the sturgeon. Many specimens at gonad maturation stage II in their marine period of life display oocyte abnormalities. More than 30 percent of females migrating into rivers have reproductive products at the initial stage of resorption. In 1988–1989, water pollution gave rise to many cases of a disease of sturgeon in the lower Volga river, characterised by lamination of the muscle tissue and the egg membrane. Complete loss of the sturgeon stock has become a real possibility (Vlasenko, 1994).

MONITORING AND EVALUATION PROGRAMMES

Enhancement goals

Considering the high value of the sturgeon resources, the decline of the sturgeon stocks triggered the establishment of hatchery centres and fingerling release programmes in 1955 in the former Soviet Union that was followed by a similar trend in Iran in 1972. In 1950s, sturgeon hatchery centres were established along the Volga River with the aim of improving sturgeon stocks. In 1954, the Koorinski hatchery started operation followed by Kizaneski hatchery in 1955 (Ivanov and Majinic, 1997).

The carrying capacity of sturgeon in the Caspian Sea has been estimated at 50 000 million tonnes, but the harvest was only 29 000 million tonnes during the 1900s. The capacity of the Caspian Sea with regards to food supply permits an increased release of juvenile sturgeon up to 150 million one-summer-old fish (Vlasenko, 1994; Ivanov *et al.*, 1997). With the emergence of hatchery centres in Russia, the capacity reached 27 000 million tonnes. There are currently 11 hatchery centres in the Russian Federation along with five and three in Iran and Azerbaijan respectively (Tables 6 and 7).

In the second development plan of Iran, the construction of hatcheries began with the aim of producing 14 million sturgeon fingerling. With the construction of new hatchery centres along with an increased expertise, and training provided by Russian fishery experts, the production rate of sturgeon fingerling which was lower than one million individuals in 1981 rose to 24.5 million individuals in 1998 (Abdolhay, 1997). The sturgeon hatchery

TABLE 6. Sturgeon hatchery programme in the Russian Federation and Azerbaijan

Reproduction hatchery	Pond area (ha)
the Russian Federation	
Kizaneski	124.5
Bertoleski	165.0
Alexanderofski	175.3
Jinefnski	129.0
Sergiofski	100.0
Libiaji	292.5
Eikrianensko	59.0
Volgagradski	117.9
Plavzavod	-
Total hatchery in Volga	1163.2
Sulakski	26.0
Treski	91.3
Total in Daghestan	117.3
Total hatchery in Russian Fed.	1280.5
Azerbaijan	
Ust koorinski	86.1
Ali bairaminski	42.0
Kora experimental reproduction hatchery	21.3
Total hatchery in Azerbaijan	149.4
Total	1429.9

Ivanov cited by Hamoonpad (1999).

TABLE 7. The sturgeon hatchery programme in Iran

Hatchery name	Total area (ha)
Beheshti	110
Siahcal	210
Marjani	45
Rajai	77
Woshmgear	300
Total hatchery in Iran	742

Abdolhay (1997).

area was 72 ha in 1981 and increased to 742 ha in 1997 (Table 7). The development programmes are still underway. Fingerling production decreased from 1981 to 1986 (less than 2 million) as a result of production of Chinese Carp and kutum (*Rutillus frissii kutum*). Fingerling sturgeon production in Siahcal began in 1988 with 134 ha ponds, in Shahid Marjani in 1988 with 30 ha and in Shahid Rajai hatchery with 40 ha in 1995. Woshmgear hatchery began in 1996 with 144 ha ponds. (Table 7).

Enhancement goals for the Iranian Fisheries Company of Iran are the production of 50 million fingerlings and an increase in weight of fingerlings (up to 30 g), with an emphasisis on Persian sturgeon. Every year several million sturgeon fingerlings are produced and then released at the rivers. Table 8 illustrates the production and release rate of fingerlings in both Iran and the former USSR. Hatchery activities began operation with an annual production of 2.6 million fingerlings in Russia in 1955. This increased in 101 million fingerlings in 1985, and since then has followed a falling trend, to such an extent that the former USSR produced only 55 million fingerling in 1996 (Artyukin *et al.*, 1997; Ivanov and Majinic, 1997; Hamoonpad, 1999).

TABLE 8. Sturgeon fingerling release to the Caspian Sea (millions)

Year	Russia	Azerbaijan	Kazakhstan	Total	Year	Iran
1955	0.84	1.73	0.02	2.59	1960	0.0
1960	2.81	5.52	0.63	8.96	1965	0.0
1965	30.15	10.91	1.21	42.27	1970	0.0
1970	39.82	15.30	0.61	55.73	1972	1.60
1975	56.87	19.87	0.54	77.28	1975	3.90
1980	65.58	19.92	–	85.50	1980	3.03
1985	82.88	17.96	0.63	101.47	1985	1.29
1990	75.88	17.55	0.76	94.19	1990	4.55
1991	72.29	9.14	–	81.43	1991	6.59
1992	75.06	2.97	–	78.03	1992	3.45
1993	62.90	2.39	–	65.29	1993	4.17
1994	68.96	1.57	–	70.53	1994	5.91
1995	55.66	1.24	–	56.90	1995	9.12
1996	51.059	4.06		55.65	1996	12.45
1997					1997	21.62
1998					1998	24.55

Ivanov and Majinic (1997), Abdolhay (1997) and SHILAT for current estimates.

Measures of success and contribution of hatchery fish to fishery

Young sturgeons of the Volga-Caspian region have been reared at hatcheries for over 40 years. However accurate evaluation of the effectiveness of sturgeon culture presents certain difficulties. Wild spawning is still greatly effected by anthropogenic "pressure". Attempts to tag hatchery-produced young fish to distinguish between them from wild fish have not been successful. Several investigations observed that some sturgeon fry had a morphological anomaly of the nasal capsule: a complete or partial absence of septum between olfactory orifices. Such fry are quite numerous among hatchery-produced fish but are uncommon among wild fish. This anatomy is retained by the fish throughout their lifetime and can be used as "a natural mark" to estimate the coefficient of commercial return. In 1985–1986 and 1988–1991 the proportion of Russian, beluga and stellate sturgeon with such "marks" among the fish reared at Astrakhan hatcheries was determined to range from 0 to 77 percent. The percentage is usually higher among stellate than Russian and beluga sturgeons (Podushka and Levin, 1993).

The Russian Federation

There was previously no effective technique available for marking sturgeon fingerlings. The survival of hatchery fish was, therefore, monitored by periodic observations of their year-class strength in the sea. Because natural mortality is low in fish older than one year and fishing mortality in the sea is absent, the survival of hatchery recruitment is determined as the proportion of fish surviving until one-year of age in the sea. These estimates are primarily for beluga because natural recruitment is either absent or can be ignored for this species. Between 1960 and 1970, Soviet hatcheries released about 17 million beluga fingerlings annually. During that time the abundance of the first three year-classes of the beluga in the Caspian Sea increased tenfold compared with the period when only natural recruitment was available (Marti 1979, cited by Doroshov, 1985).

TABLE 9. Study of natural spawning in the former Soviet Union

Year	Catch (1000 million tonnes)	Natural spawning area (ha)
1959–60	7.5	450
1961–65	6.5	440
1966–70	6.0	430
1971–75	4.8	403
1976–80	4.5	376
1981–83	3.6	350

Moghim *et al.* (1996).

Over the last 30 years there has been some change in the species composition of the catch as a result of environmental stresses. The portion of Russian sturgeon has decreased from 70.6 percent in 1962 to 66.2 percent in 1995, for the sevruga from 29.1 percent to 26.8 percent, whereas the proportion of beluga has increased from 0.3 percent to 7.0 percent. The increased relative number of beluga is a result of its rearing on fish farms because the rate of natural reproduction of the beluga is very low (Ivanov *et al.*, 1997). As an average the survival of hatchery-produced fingerlings to the commercial fisheries is estimated at 1 to 3 percent.

The natural spawning of Russian sturgeon was at a maximum before damming of the Volga river. The fisheries return has been 7 500 million tonnes. The average percentage of natural spawning has decreased from 1961 owing to destruction of natural spawning ground (Table 9). Fingerling production has increased year by year in hatcheries. The annual production increased from 0.7 million in 1951-1955 to 45.5 million in 1981-1983. Studies of the effect of releasing fingerlings have been done by trawl survey and capture one-year classes of fish. Table 10 shows the annual fingerling production and captures by trawl.

TABLE 10. Study of fingerling release in the former Soviet Union

Year	Fingerling release (millions)	No. (100 in trawl)
1948–50	0.0	37.6
1951–55	0.7	22.8
1956–60	4.9	21.6
1961–65	11.2	53.0
1966–70	13.1	37.6
1971–75	23.1	22.8
1976–80	32.3	21.6
1981–83	45.5	53.0

Moghim *et al.* (1996)

Iran

Sturgeons are caught at 50 stations in the south of the Caspian Sea in Iran with numbers varying dependent on the station. All stations record the catch composition. Thirteen thousand fish are studied every year. Factors recorded are: species, fork length, total length, weight, sex, maturation stage, caviar weight, type of caviar and fish age. The age is determined by the first hard ray pectoral fin in the laboratories. Maturation is determined as described earlier. The total catch is measured every year and reported as catch per unit effort (CPUE) (Moghim and Ganinejad, 1994). Table 11 shows the catch composition of sturgeon species and Table 12 shows the catch composition of Ossetra (*A. guldenstadti, A. persicus and A nudiventris*) in Iran.

TABLE 11. Variation in catch composition of sturgeon in Iran

Year	Catch (kg)	Sevruga (%)	Ossetra (%)	Beluga (%)
1972	2 163 132	34.0	36.3	29.7
1994	125 872	49.5	41.0	9.5
1997	905 087	35.8	54.3	9.9

Abdolhay (1997), Moghim *et al.* (1996)

In the past, many fish were marked by the cutting the first hard ray of pectoral fin; some of them have been caught but not enough to provide meaningful information. In 1999, Iranian experts implemented a project for tagging the sturgeon fish. Reportedly Russian tags have been retrieved on sturgeon taken from the Caspian Sea in Gilan Province (personal communication with Razavi Sayad in Fisheries Research centre, Bandar Anzali, Gilan province, Moghim, 1992).

TABLE 12. Variation in catch composition of sturgeon in Iran (Ossetra species percent)

	1971–72	1989	1990	1991	1992	1993	1994	1995
A. goldenstadtii	89.6	50.2	42.2	40.0	36.7	34.7	29.0	26.6
A. persicus	4.2	44.2	53.8	57.0	60.2	62.3	68.2	70.6
A. udiventris	6.2	5.6	4.2	3.0	1.0	3.0	2.8	2.8

Moghim *et al.* (1996)

Economic analysis

No recent papers concerning economic analysis on Russian stocking are available. In Iran the study of the economics of the fishery has not yet been completed. According to the finance office in Shilat the cost for each fingerling is:

Operating cost	US$0.20
Capital cost	US$0.10
Caviar as egg	US$0.15
Miscellaneous	US$0.05
Total	US$0.50

The high cost of caviar as a source is an important case for fingerling production. One female of ossetra (standard size) may have 5 kg caviar that could produce 20 000 fingerlings (3–5 g).

Export, income and production of caviar are in Table 13 from 1989 to 1999. Prices of caviar increased from US$192 per kg in 1989 to US$312 per kg in 1998, US$385 in 1999 and over US$500 in 2000. Production decreased from 209 million tonnes in 1989 to 126 million tonnes in 1998 and was about 100 million tonnes in 1999 (Hosseni, 1997, personal communication).

TABLE 13. Export of caviar and income in Iran

Year	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Income (million US$)	40	52	54	42.2	30	30	41.5	40	34	39	34
Caviarexport(tonnes)	209	251	225	169	167	156	146	100	106	126	90
Average prices (US$ per kg)	192	204	239	250	185	190	385	430	324	312	385

Interaction with natural population

Recent reviews demonstrated that many anadromous salmonoid populations are well adapted to their native habitat and that infusion of exotic genes from populations from different habitats, including hatcheries, may harm native fish (Hindar *et al.*, 1991; Waples 1991, cited by Bartley 1995). Some of the reported effects of the interaction between hatchery fish and closely related or conspecific fish are genetic erosion (loss of alleles), introduction of poorly adapted genes, introduction of disease organisms, changes in genetic subpopulation structures, changes in stock size, reductions in survival, changes in adaptive behaviour, reductions in homing accuracy, changes in migration patterns, reductions in recapture rate and increased disease susceptibility. Moreover, the effective size of an enhanced population could theoretically be reduced by the addition of hatchery fish with variable reproductive success and reduced genetic variability. The above effects are a result of direct competition, predation, and disease transmission between hatchery and wild stocks, as well as to the introgression of "hatchery" genes into the wild population (Bartley 1995).

However, the goal of many enhancement projects is for the hatchery and wild fish to mix and form a new and larger mixed population (Bartley, 1995). Therefore, trying to create fish in the hatchery that are compatible with wild stocks and the environment will be an important option for certain enhancement programs and for certain aquatic species (Bartley, 1995).

Natural reproduction of all three sturgeons species in the Volga River has been completely destroyed. Nearly all of the sturgeon migrating to the spawning grounds below the Volgagrad dam in 1995 are caught by poachers somewhere between Astrakhan and Volgagrad (Caspian Fishery Research Institute in Astrakhan, pers. comm). The hatchery in that area could not catch enough breeders for artificial reproduction of the sturgeon.

Because of the long time maturation of sturgeon, the impact of the interaction between wild and hatchery fish is difficult to assess. However, in the Caspian Sea, it appears that there are very few naturally produced sturgeon.

GENERAL CONCLUSION

General lessons

The major aim of sturgeon management in the Caspian Sea is the capture of adult, sexually mature fish during the spawning migration and migration around sea. In Iran and other littoral countries, the time from the initial stocking of fingerlings to fishery return is 10–20 years, far longer than in other aquaculture ventures. All commercial fisheries for sturgeon in the sea has been banned since the 1960 (Doroshov, 1985) and only Iran catches fish in deltas of rivers by gillnet. After the break up of the Soviet Union three new littoral countries also collect sturgeon.

Mention has been made of the introduction of sturgeon juveniles and fingerlings of other species into the Caspian Sea to enhance and safeguard the resource.

Although Iran began this practice in 1972, Shilat has undertaken a progressive stock enhancement programme since 1983 when 1.03 million juvenile sturgeons were released. Since that time the annual production and release of fingerlings has increased rapidly. In Iran, 3.46 million sturgeons alone were released into the Caspian Sea in 1992 and 24.5 million in 1998. It is possible to develop fingerling production because of good knowledge, pond area available and support of the Iranian government for investment. However, cooperation among the five littoral countries is necessary to provide management for sustainable fisheries. After dissolution of the USSR in 1991, fishing pressure increased, with substantial illegal fishing. Most natural spawning areas have been destroyed. In light of this, artificial reproduction has an important role for increasing sturgeon stocks in the Caspian Sea.

Strengths and weaknesses of the programme

Natural spawning plays a major role in the preservation of genetic structure of the population and the genetic diversity of the sturgeon stocks. Alteration at rivers, however, caused by dams creates dire ecological situations for the Caspian Sea. Fortunately, there are still some rivers that offer inviting conditions for natural spawning.

Artificial breeding and production aimed at stock rehabilitation plays a crucial part in this respect. According to KaspNIRKH (Caspian Fisheries Research Institute, Astrakhan), the contribution of stocked fish of various sturgeon species in the sturgeon fishery are 90 percent for beluga, 60 percent for ossetra, and 50 percent for sevruga (Ivanov and Majinic, 1997) whereas stocking constitutes 100 percent of Persian sturgeon recruitment (Abdolhay and Baradan Tahori, 1998). With the availability of nearly 2000 ha of ponds in the Russian Federation, Iran and Azerbaijan, along with the knowledge and expertise in those countries, it may be possible to revive the sturgeon resources through artificial breeding of these species.

During recent years overfishing has inflicted great damages to sturgeon stocks. Devastation to the natural spawning grounds has also been important. The collapse of the former Soviet Union has negatively affected the economic and social status of the newly independent republics, and coastal inhabitants in these countries have done great damage to the fishery resources. The lack of appropriate exploitation and fishing management system in the newly independent republics, the discharge of pollutants into the sea, lack of control, monitoring and surveillance on fishermen, and oil extraction operations have all together jeopardised substantially the future of the sturgeon stocks.

Some of the problems with hatchery practices are:

- lack of control and survey on the status of the released juvenile sturgeons and their return rate;
- lack of economic assessment of the artificial breeding costs and its economic impact;
- lack of knowledge about the available genetic stocks of the Caspian Sea and the difference between various species and groups in order to avoid genetic complications.

Future prospects and limitations

On the basis of many years study on the nutrition of food relationships of fishes of the Caspian Sea, Shorygin (1952) proposed the idea of converting the Caspian Sea into a predominantly sturgeon waterbody. The theoretical basis for reconstruction of the food base of sturgeons was developed in the Caspian Sea and *Syndesmia* and *Nereis* were introduced from Azov Sea into the Caspian Sea. These two species constitute about 70 percent of the reserves of variable prey organisms, whose biomass has increased more than three times (Barannikova, 1988). However, at present there are no plans for introducing or increasing the prey species into the Caspian Sea.

Currently, sturgeon broodstock are killed during egg extraction. It may be possible to remove eggs surgically without sacrificing the adults, thus allowing further reproduction (Podushka, 1997).

Given the decrease in mature sturgeon, it is necessary to reconstruct and to build facilities for long-term storage and culture of sturgeon broodstocks. At the same time, it is advisable to revise the standards of fish production towards increase of sturgeon fry weight at release up to at least 10–15 g; in particular, it should be carried out at fish farms of Dagestan, Azerbaijan, and Iran (Kokoza, 1997). Means to protect young sturgeon on feeding grounds need to be developed.

The Caspian sturgeon stock has been so devastated that sturgeon commercial fishery may be banned in the near future, with the catch of sturgeon only for research and artificial breeding purposes. Nevertheless, sturgeon conservation and restocking is still possible. A solution to this problem should be the concern of all the Caspian states (Ivanov *et al.,* 1997) because illegal fishing is still continued by some of these countries.

In 1991, after the dissolution of the USSR, the Caspian States, which include Iran, the Russian Federation, Kazakhstan, Turkmenistan, and Azerbaijan, guaranteed "the fulfilment of international obligations arising from treaties and agreements of the former USSR". In that same year, the Russian Federation proposed a multilateral programme for conservation of biological resources, which would introduce fishing quotas and mandatory fishing regulations, and include the original exclusive fishing zone. The most important step to save the Caspian sturgeon must be the immediate signature of "The agreement of the conservation and use of bioresources of the Caspian Sea" by the Russian Federation, Kazakhstan, Azerbaijan, Turkmenistan, and Iran and its implementation by each of five bordering states (Lukyanenko *et al.,* 1997). A substantial increase in sturgeon stocks is also attainable in near future, provided that the littoral states of the Caspian Sea pay due attention to the agreement prepared by experts and take the required measures to preserve the bioresources of the Caspian Sea. The agreement has been the object of permanent interstate negotiations for several years. (personal communication from international office of the Iranian Fisheries). Concern for sturgeon conservation was already expressed under the project "agreement on Caspian Bioresources Conservation and Management", which was designed by representatives of all states bordering the Caspian Sea: Azerbaijan, Kazakhstan, Iran, the Russian Federation, and Turkmenistan (Ivanov *et al.,* 1997) but this has yet to be signed.

The Caspian sturgeon conservation problems were discussed at a conference with the president of the Russian Federation B.N. Yeltsin present at the Astrakhan meeting in 31 October, 1992, when the president's Directive No 642-rp "On Measures for Caspian Sturgeon Conservation" was signed. Subsequently, the Directive No. 28-r was issued by the Prime Minister of RF VS. Tchernomyrdin on 29 January, 1993. According to these documents, a long-term programme on sturgeon reproduction, conservation and restocking was to be developed by specialists of the state Fishing Committee in collaboration with experts of the Russian Academy of Science, Ministry of Ecology and Ministry of Science, this has so far been partially implemented (Ivanov *et al.,* 1997).

Islamic Parliament of Iran proposed severe punitive measures against illegal fishing of sturgeon for the protection of marine resources. In 1992, Iran followed Russian suggestions with a proposal to establish a framework for cooperation through a regional organization. This was to regulate all aspects of the utilisation of the Caspian Sea and its resources. Such an organization was to:

- develop a database management and geographic information system to permit ease of rational control and transfer of diverse information between the Caspian States;
- establish conservation areas;
- formulate social and economic programmes to enhance conservation measures;
- encourage ways and means to promote these;
- monitor and predict sea-level fluctuations and the effect of river control upon the ecosystem;
- introduce programmes for the rehabilitation of affected endangered species and habitats;
- improve fisheries management and so safeguard this resource for the benefit of all peoples of the Caspian States.

CITES (Convention on International Trade in Endangered Species)

Following several international meetings on trade and illegal fishing in June 1997 (in Harare, Zimbabwe) the tenth meeting of CITES listed all sturgeon and paddlefish on Appendix 2 based on proposals submitted by Germany and United States. However, if the current downward trend in landing still continues, sturgeon fishing may be prohibited, which will require a collective approach by the coastal states of the Caspian Sea to prevent illegal fishing.

CITES listing will not only result in better international monitoring of the sturgeon trade but also enhance controls on the products in trade and ensure that sturgeon products, that are not traded in full compliance with provisions of the convention, can be confiscated or seized. In all major import markets of sturgeon products stiff penalties exist for CITES infraction and this has reduced illegal fishing. Anyone wishing to export caviar requires a CITES certificate and no one has been able to purchase more than 250 g of caviar from airport shops since 1998 (Hoseini, Director of Iranian Fishery Trade Company).

International Research Institute for Sturgeon

An International Research Institute for Sturgeon has been established in the grounds of Shahid Beheshti hatchery in Gilan Province in Iran. The objective of the Institute is the conservation and study of natural stocks of sturgeon in the Caspian Sea and inland waters. The Institute has departments planned for Biology, Nutrition, Reproductive Physiology, Genetics, and Fish Processing, and plans to work on Stock Assessment with other colleagues in IFRO (Iranian Fishery Research Organization). The projected complement of staff is 47, with 16 professional scientists.

The International Research Institute for Sturgeon, as the singlemost prominent fisheries body responsible for scientific investigation and research studies on sturgeon resources in Iran, began its operation in 1996. The actual research operation on various aspects of sturgeon resources started through the assistance of Russian research scientists from the KaspNIRKH institute as well as other senior experts.

The Institute currently has well-equipped laboratories and is in close cooperation with a number of research centres and universities in Iran as well as university students who are examining problems affecting sturgeon resources.

ACKNOWLEDGEMENT
Special thanks to Devin Bartley for assistance with editing this paper.

In regards to country names, the editors have used the Union of Soviet Socialist Republics for references to information prior to 1993 and used the Russian Federation after 1993 which refer to that specific former republic. With historical references it was often difficult to know which designation to use and no political statement or intent should be inferred.

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APPENDIX 1

STURGEON REPRODUCTION IN IRANIAN HATCHERIES IN 1996

	A. persicus	*A. stellatus*	*H. huso*
Broodstock capture (numbers)	644.0	236	17
Injected broodstock (numbers)	381.0	165	10
Spawning rate (%)	86.1	54	83.3
Total fecundity (numbers)	256 946.0	138 091	240 458.0
Relative fecundity (numbers)	7 882.7	9 574	2 766.0
Fertilization rate (%)	67.6	44.4	45
Survival rate in incubator (%)	63.1	32.1	38.7
Survival rate in tank (%)	72.1	72.6	74.7
Stocking density (numbers/ha)	82 860.0	99 833	72 941
Survival rate in pond (%)	58.2	54	55.6
Fingerling production (numbers)	10 779 938	316 214	346 300

(Abdolhay and Baradaran Tahori, 1998)

APPENDIX 2

GENETIC RESOURCES OF CASPIAN STURGEON

Species, subspecies and stocks

There are five species of sturgeon belonging to the genera of *Acipenser* and *Huso* in the Caspian Sea. Significant variations both within and between geographical regions were observed in different sturgeon species (Holcik, 1989).

***Beluga sturgeon* (Huso huso)**

There are a number of forms of beluga sturgeon. A series of morphological differences have been observed between the Danube and the Caspian Sea beluga sturgeon (Pavlov, 1967). The type of beluga sturgeon that was considered by Berg (1948) was *Huso huso* and was typical of the Caspian-Volga populations. However, based on antigenic studies of the blood serum protein, three subpopulations of beluga sturgeon from the Volga, Ural and Kura rivers in the Caspian Sea region have also been identified (Karataeva, Lukyanenko and Terentev, 1971). The largest of these is the beluga, which reaches a length of up to 425 cm and weight of 520 kg. For example, Pour-Qadiri (1996) reported that a 414-cm, 500-kg beluga sturgeon was caught on the east coast of the south Caspian Sea. It yielded 54 kg of high-quality caviar. In the past, individuals have reached the age of 100–120 years, but the present life span does not exceed 50–55 years. Sexual maturity is attained at the age of 11 years for males and 16 years for females. For breeding, the beluga sturgeon enters the rivers Volga, Ural, Terek and Sefidroud. They feed on gobies, shads and carp, and during their first month of life in the sea on Mysidaca. At the beginning of the twentieth century (1904–1913) the beluga sturgeon accounted for about 40 percent of the sturgeon catch. At present it accounts for no more than 10 percent (annual report of Shilat in Iran).

***Stellate and sterlet sturgeon* (Acipenser stellatus and A. ruthenus)**

There are two forms of stellate surgeon in the Volga basin, the typically resident sterlet (*A. ruthenus*) whose living area is limited to the upper and middle parts of the Volga River, and the semi-migratory stellate that enters the brackish parts of the Caspian to feed. Borozenko (1942) reported two different ecological forms of stellate surgeon in the Caspian Sea, northern and southern forms. The northern form (*A. stellatus stellatus*) has growth rate and fecundity lower than that of the southern form (*A. stellatus cyrensis*).

Immunological studies (Lukyanenko *et al*., 1972) show that the northern and southern Caspian Sea stellate sturgeon are genetically distinct from each other and have distinct spawning periods in the spring and winter (Nikolskii, 1971).

Based on analysis of the average proportion of the head and the dorsal and anal fins, a subspecies *A. stellatus donensis* from the Azov Sea was reported by Lovetsky (1834) and reconfirmed by Chugunova (1964). However, their suggestion was rejected by Holcik (1989), who argued that those characters are not reliable as they undergo a considerable change during growth and depend upon feeding conditions.

Stellate sturgeon are smaller than beluga and other sturgeons, reaching 195 cm in length and a weight of up to 25 kg, and they also have shorter life spans of 28– 30 years. Sexual maturity is reached at 6–8 years. Most of the males attain full growth after 9 years and females after 11 years. Fingerlings in the river and the sea feed on crustaceans. The proportion of stellates in Iranian sturgeon catches has gradually decreased in recent years from 45 percent to 35 percent (Moghim *et al*., 1996).

***Persian sturgeon* (Acipenser persicus)**

The Persian sturgeon (*A. persicus*) prefers warmer water than the beluga and Russian sturgeon. It forages mostly in the Middle and South Caspian Sea and also the Black Sea (Artyukhin and Zarkhua, 1986). It was considered a subspecies of Russian sturgeon (*A. gueldenstaedti persicus*) because of its morphological similarity with the Russian sturgeon. (Berg, 1933). Based on external morphological differentiation, two forms of Persian sturgeon subspecies were recognized as *A. persicus* in the Caspian Sea Basin and *A. persicus colchicus* in the Eastern Black Sea (Marti, 1940). Haematological and biochemical studies during 1984–1988 in coastal waters in Iran and isoelectric focusing clearly identified a significant difference between the Persian and Russian sturgeon (Keyvanfar and Nasrichari, 1997). A partial sequence of the mtDNA ND 5 region gene from five individuals of Persian sturgeon collected from west and east regions from the South Caspian Sea revealed a very low level of divergence. Four of these sequences were identical. The genetic distance between the two different sequences was only 1 percent. Several explanations can be put forward to explain the low levels of sequence divergence observed (Rezvani, 1997). Ovenden (1990) pointed out that it is possible that marine organisms, in general, have a slower rate of mtDNA evolution. However, other factors such as the bottleneck effect can create the low nucleotide divergence (Rezvani, 1997). Spawning grounds are predominantly in the rivers Kura and Volga rather than the Ural. Two races of Persian surgeon spawning at different times in the Sefidroud (Iranian side) were reported by Rostami (1961). The first group spawns at the end of April and in May and the second group spawns during September and October. This sturgeon belongs to the category of fish with mixed feeding habits (eating other fish and bottom invertebrates). Fingerlings in the rivers and after entering the sea feed on mysids and other crustaceans.

The maximum recorded age of Persian sturgeon in the Kura River is 48 years. An individual taken in the Volga was 38 years old. The maximum size reached by Persian sturgeon in the Caspian Sea region was 231–242 cm but at present individuals do not exceed 205–230 cm (Holcik, 1989, Razavi, 1998). The average length for males is 139 cm and for females 155 cm and the average weight is 20.1 kg and 29.9 kg, respectively (Moghim and Ganinejad, 1994). Persian sturgeon reaches sexual maturity later than Russian sturgeon. In the Kura River the males mature at age 8 years and the females at 12 years. In the Volga and Ural rivers maturity is reached at the age of 15 years for males and 18 years for the females (Holcik, 1989).

***Russian sturgeon* (Acipenser gueldenstaedti)**

The Russian sturgeon lives in the Caspian Sea, Volga and Kura rivers, Black Sea (Rioni Dnieper Rivers) and the Azov Sea (Don River). The forms in these rivers are well differentiated from each other. Different stocks of Russian sturgeon from the Volga and Kura rivers have been identified (Belyaeva, 1932, 1972; Kazancheev, 1981). Immunological analysis of all these stocks has revealed a high degree of differences between fish from different geographical regions (Umerov and Altufev, 1968; Lukyanenko, Popov and Terentev, 1968).

Several races of summer and winter migratory forms of Russian sturgeon were also reported in the Volga River (Barannikova, 1991). Marti (1940) classified two varieties of Russian sturgeon inhabiting the Black Sea as *A. gueldenstaedti* var. *tanaica* and *A. gueldenstaedti* var. *colchicus*. However, Berg (1948) called the latter a subspecies *A. guedenstaedti colchicus* (Marti). By contrast, because of a great similarity of this subspecies to Persian sturgeon, Artyukhin and Zarkua (1986) called it *A. persicus colchicus*. Russian sturgeon is representative of sturgeon species that are commercially exploited throughout the Caspian Sea. Identification of its genetic variability and stock structure will provide useful information for conservation and fishery management. Sixty-two fish samples representing two different populations from the South Caspian Sea (west and east areas) were investigated using PCR amplification of the mtDNA ND 5/6 gene regions. PCR fragments of all individuals (2400 bp) were digested with ten restriction enzymes (Rezvani, 1997). Significant differences in the distribution of haplotype frequencies were observed between populations. The average nucleotide and haplotype diversity over all populations were 0.029 and 0.95, respectively. The value of nucleotide divergence between west and east populations was only 0.052 percent but a χ^2 test based on haplotypes showed significant differentiation between the two (Rezvani, 1997). This result was in contrast with that obtained in a study based on the mtDNA 100-bp region of Russian sturgeon from the South Caspian Sea, where no significant differentiation among populations from four wide regions was observed by Pourkazemi in 1996 (Rezvani, 1997). Overall, these data suggest that the Russian sturgeon populations in the South Caspian Sea comprise at least two stocks.

Russian sturgeons enter the rivers Volga, Ural and Terek for reproduction. The largest stocks occur in the Volga, up to the Volgagrad dam. Fish reach 200–210 cm in length with a weight of 60–65 kg, and can live up to 40 years. Males reach sexual maturity at the age of 7 years and females at 8 years. Maximum size for most males occurs at 14–17 years, and for females at 18–21 years. Russian sturgeon are found in coastal shallows at depths from 2 to 100–130 m with large numbers at depths of less than 50 m.

Ship sturgeon (Acipenser nudiventris)

Kazancheev (1981) identified two reproductively isolated groups known as the North and South Caspian ship sturgeon populations. These populations differ slightly from the typical form from the Ural Sea. At the present time, because of the drying of the Ural Sea, *A. nudiventris* as well as other species have become extinct in the wild there.

The ship sturgeon is a large fish; at maturity individuals grow to over 200 cm and 75 kg. For breeding it enters the rivers Kura, Ural and Sefidroud, but it is rarely found in the Volga. Most of the males mature at the age of 9–13 years, and females at 13–16 years. It forages mainly in the middle and South Caspian Sea, along the western shores at depths of 11–25 m, and feeds on fish and bottom invertebrates. Fishing for the ship sturgeon is now prohibited in the Ural River because of depletion of stocks. The ship sturgeon is of relatively minor significance for Caspian catches.

Karyotype

Studies of sturgeon karyotype provide information about both the evolution and the polyploidization event in this group on ancient fish. The karyotype of the sturgeon is among the most complicated of the vertebrates and has not yet been studied in sufficient depth. In most sturgeon species a large number of chromosomes are present, about half of which are microchromosomes (Vasiliev, 1980, and references cited in Birstein and Vasiliev, 1987). Sturgeon can be divided into two groups based on the number of chromosomes.

First group: species carrying 120 chromosomes or tetraploid (e.g. *Huso huso*, *H. dauricus*, *A. ruthenus*, *A. stellatus*, *A. nudiventeris*). Second group: sturgeon with 240 chromosomes or octoploid (e.g. *A. naccarii*, *A. gueldenstaedti*, *A. baeri*, *A. persicus*).

The chromosome numbers of five sturgeon species of the Caspian Sea are given in Table 14. Study of sturgeon genome size using flow cytometry methods has revealed that there is a correlation between the number of chromosomes and genome size (DNA content per nucleus). In *H. huso* ($2n = 120$), the DNA content reaches 3.6 pg per nucleus, whereas in *A. naccarii* ($2n = 240$) DNA content = 5.7–6.3 pg per nucleus (Fontana, 1976). Birstein (1993) studied the DNA content in ten Eurasian sturgeon species using flow cytometry methods. They concluded that the average DNA content in tetraploid sturgeon ranges from 3.17 to 4.04 pg and in octoploid sturgeon species (*A. gueldenstaedti*) from 3.17 to 8.31 pg. The DNA content in Sakhalin sturgeon (*A. medirostris* = *A. mikadoi*) is estimated to be twice as high as in the octoploids, 13.93–14.73 pg, and they concluded that the ploidy level of Sakhalin sturgeon may be 16n and number of chromosomes could be 500 (Birstein, 1993).

TABLE 14. Chromosome numbers of sturgeon in the Caspian Sea

No.	Species	Chromosome no. (2n)	References
1	*Huso huso*	118 ± 2	Birstein and Vasiliev (1987)
2	*A. stellatus*	118 ± 2	Birstein and Vasiliev (1987)
3	*A. nudiventeris*	118 ± 2	Sokolov and Vasiliev (1989)
4	*A. gueldenstaedti*	250 ± 8	Birstein and Vasiliev (1987)
5	*A. persicus*	250 ± 10	Norouz Fashkhami, Poukazemi and Baradan Noveiry (1998)