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A glance on sturgeon farming potential of Turkey

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Abstract

The author reviewed the aquacultural history, potential of marine, freshwater finfish and sturgeon in Turkey and gives examples on the other countries. Also this review gives information about legal status, previous studies and projects, origins of the seedlings, natural distribution area, restocking studies and aquaculture opportunities. Since a long time, sturgeon is known as valuable caviar production in Turkish Black Sea region. Turkish Black Sea coast is approximately 1685 km long. There were the six indigenous sturgeon species known in the Black Sea; but last studies shows that only three species (*Huso huso, Acipenser stellatus, Acipenser gueldensteatdii*) are frequently found. These data shows that the other three species (*A. ruthenus*, *A. sturio*, *A. nudiventris*) are in poor existence in the Black sea. The sturgeons are nearly become an extinct because of the over fishing, water pollution and dam & dike constructions on the way of spawning areas. Aquaculture is the only way to increase and protect the natural stocks of this species all over the world.

Keywords: Sturgeon, Aquaculture, Turkey, Farming potential

Introduction

Sturgeons are of the primitive fishes in the world. They are called as ancients or fossil fish by most of authors. Hosting last 250 million years in the world, shows that this species has a big tolerance to the climate and ecological changes. Dams, dikes and the water pollution were the main problems for migrating fish. Building dams, dikes and hydroelectric power dams to the rivers without fish passage ways affects the population of sturgeons like other migrating fish in the Black sea. There are four big rivers flowing to the Black sea including Sakarya, Yeşilırmak, Kızılırmak and Çoruh, which have the feeding and the spawning area for Black sea sturgeons.

Aquaculture was implemented in Turkey with rainbow trout in 1970's and Sea bass and Sea bream in 1980's. Turkish aquaculture of marine and fresh water species has been growing rapidly every year (Okumuş and Deniz 2007). According to the statistics of 2009, the economical value of aquaculture production was over 620 million $ with 158,729 tones/year in Turkey (SSI 2010). European Sea bass (*Dicentrarchus labrax*) (29.3%), Sea bream (*Sparus aurata*) (17.9%) and rainbow trout (*Oncorhynchus mykiss*) (47.6%) are the mass aquaculture products of Turkey. In addition, 17 fish species have newly been introduced to aquaculture and found place on fish markets with over 2,200 tones/year (SSI 2010).

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Nowadays, many fish farms which have hatcheries and adaptation units, are working on these 17 new species that can be adapted to farming conditions. Sturgeon is one these fish. This ancient fish has long time been hunted by Black sea fishermen for its caviar. This review gives information to the fish farmers who understand the absence of this valuable fish, and reveals the potential of aquaculture in Turkey.

Current status of world sturgeon culture and countries

There are many studies done on the current status of sturgeon culture in the world (Williot et al. 1993, 2001; Williot and Bourguignon 1991). Further, the rapid growth of this new branch of the aquaculture industry was possible only after a long lead-time in research on cultivation of these species, not only because of the Russian research (e.g. Burtsev 1969) but also because of pioneering and extensive research efforts in the 1980's in North America and Europe (Williot and Rouault 1982; Doroshov et al. 1983; Doroshov 1985; Williot 1986; Williot et al. 2001; Williot et al. 2007; Arlati et al. 1988).

World sturgeon aquaculture production was only 1297 tons in 1996 and 2706 tons in 1999 (FAO Database 2001; Raymakers and Hoover 2002). Data provided by Bronzi et al. (1999) suggest that these figures might be at least 50% lower than the actual production. It is believed that China has become the largest country sturgeon aquaculture in the world as of 2000 (Wei 2002; Wei and Yang 2003).

About the year 2000, China started to rear sturgeons at a large scale, targeting the national consumer market (Bronzi et al. 2011). A large number of fertilized sturgeon eggs or prelarvae were also imported from Russia, France and Hungary (Sun et al. 2003; Wei and Yang 2003). After only six years, the Chinese productions started to contribute substantially to the total world production of sturgeon meat. At around 2007, the total aquaculture sturgeon meat production was estimated to be around 29,300 tons annually. This estimation was based on the FAO (2009) statistics, and supplemented with information gained through various regional and personal contacts which helped to partially track the rapid and continuous investments made in recent years (Bronzi et al. 2011; Wei et al. 2011).

In 2008, the global production of farmed caviar was estimated to be 110–120 tones, mostly originating from some 80 farms in 16 countries. However, this figure is changing rapidly. At least 12 sturgeon species contributed to the aquaculture production while a substantial part is coming from at least six hybrids. All of them are farmed in more than 30 countries, including some outside the range states (e.g. South America). The most commonly used species is the Siberian sturgeon (*Acipenser baerii*) which is presently reared in 22 countries reaching a total production of about 8800 tons per year, followed by the Russian sturgeon (*Acipenser gueldensteadtii*) cultured in about 16 countries, while the sterlet (*Acipenser ruthenus*) is produced in 15, and the stellate sturgeon (*Acipenser stellatus*) is presently cultured in 12 countries. A total of 35 countries involved in sturgeon aquaculture for meat and caviar are presently known to us (Williot et al. 2009; Bronzi et al. 2011).

World caviar market and prices, for future prospects

Caviar is still considered as a luxury product in many regions and fetches high prices. The economic crisis in 2009 surprisingly little affected this niche market. The 500 tons of caviar traded in 1970's and 1980's as the average capacity of the market at the price level (180 US$ per kg wholesale *vs*. income level in the early 1980's) can be considered as a realistic target for today too. Therefore, a 400% increase in production seems feasible based on the 2008 data (Bronzi et al. 2011).

The latter point has to be taken with caution. As already noted earlier (Raymakers 2006), the prices for caviar have generally increased at the beginning of the new millennium, however, pricing has become highly variable, depending on the source of caviar (wild *vs.* farmed), the assessed quality of the product, the trade name and type of presentation, but also depending greatly on the species (Gessner et al. 2002a, b, 2003).

The future effects of these developments on consumer behavior are difficult to assess. However, traditional consumers who are able to pay high prices for image and social status will continue to be among the core customer groups of the sturgeon caviar trade. It is, therefore, not surprising that the rarest beluga caviar with the highest quality is sold more than 10,000 € per kg at retail market, while the caviar of commonly farmed species may be sold for prices around 10% of this level (Bronzi et al. 2011).

Presently price levels range from around 300 US$ per kg in North America to around 600 € per kg in European countries with the retail prices reaching up to 2000 € per kg for *A. transmontanus* in Italy (Bronzi et al. 2011). According to the above described developments, expert opinions anticipate a caviar production scenario that is eventually guarded by several drivers defining their markets for a variety of sturgeon products (Bronzi et al. 2011).

Based on the quick development of the sturgeon aquaculture industry in China, further improved domestic management approaches for sturgeon farming and caviar processing are needed, and attention towards the development of a sustainable sturgeon-culture industry as well as solid species conservation programs are necessary (Cui et al. 2006).

Therefore, published information related to sturgeon farming is updated, new strategies are discussed, and the most likely course taken for a sustainable sturgeon aquaculture industry are highlighted, and the perspectives for further research and development are presented (Wei et al. 2011). With the declining production of caviar from wild sturgeon, and the rapid increase in the quantity of caviar from farmed sturgeons, it is believed that there will be a considerable caviar market, and farmed caviar will replace the wild one in the future (Wei et al. 2011). In the foreseeable future, there may be very little wild sturgeon products on the world market, as aquaculture production will be the major contributor to the caviar trade (Wei et al. 2011).

Alternative markets on sturgeon except meat and caviar

The cultured sturgeons have not only been used as food for human consumption, but also developed to derive at medical products, leather and other uses (Wei et al. 2011). While meat (including Semi-finished products, finished products, smoked products) and caviar will dominate in terms of production volume, products traditionally obtained from the skin, swim bladder, intestine, cartilages and viscera will be increasingly seen on the markets while eventually the entire fish will be utilized more effectively, including the extraction of highly priced specific substances applied in health products, pharmaceuticals, cosmetics, industrial glue, leather and other value-added products (Bronzi et al. 2011; Wei et al. 2011). In this regard, it is believed that diversification of products will increase in the future, serving more than one market and contribute to the sustainability of the industry (Wei et al. 2011)

Legal status of sturgeon fisheries and advices for future in Turkey

Several measures have been taken by various national, regional and international organizations to slow this downward trend. A major step was the listing of the sturgeon species on Annex II of CITES in Harare 1997 (Bronzi et al. 2011).

In Turkey, protection of sturgeon started when sturgeon stocks decreased in the entire Black sea coasts. The sturgeon fishing is restricted in the Turkish waters since 1971. Beluga was then included in the sturgeon fishing ban in 1997 and its legal fishery was completely forbidden (Çelikkale et al. 2004). However, sturgeon fishing is still being reported from Turkish fishermen in the Black sea region. The Turkish government gives financial supports for aquaculture farms. For new species the support amount is 1 TL/kg (0.55 $/kg). But new strategies have to improve labeling systems for standardization sturgeon aquaculture, processing and trade to ensure a sustainable development of sturgeon aquaculture (Rosenthal et al. 2006; Zhu et al. 2008; Wei et al. 2011).

According to Wei et al. 2011, sturgeon guild or co-operatives are the key point for finding market to exporting the meat and caviar. It will help the farmers to reach better profitability while also promoting quality control in an attempt to prevent companies from purchasing fish with potential problems from any irresponsible individual farmer.

Also, a national action plan should be promptly worked out for the conservation of Turkish natural stocks. China faced serious problems with importing exotic sturgeon species and their hybrids for aquaculture. It negatively impacts native sturgeon species, sturgeon biodiversity and sturgeon ecosystems (Wakeford 2001; Shortnose Sturgeon Recovery Team 1998). They believe that it is unnecessary to import non-native sturgeons; it is possible to provide enough fry for aquaculture through captive breeding of native species. Hatcheries should also be very cautious with open-water rearing of sturgeons in net cages, even if this culture mode greatly reduces rearing costs (Wei et al. 2004).

Exotic sturgeon escapes may cause severe ecological problems, including threatening native sturgeons once these exotics become established or hybridize with native sturgeons. Net cage culture operations should be restricted to closed waters which has native stocks (Wei et al. 2004). Sturgeon aquaculture can be used as a tool not only for economic development to meet the demand for products from these species, but also for restocking (Barannikova 1987; Birstein 1993; Burtzev 1999; Rosenthal et al. 2006).

Previous projects held on sturgeon in Turkey

There were some studies on sturgeon starts at 1989, “Turkey Appraisal of the Sturgeon and Sea trout Fisheries and Proposals for a Rehabilitation Programme” which was sponsored by FAO (Akbulut et al. 2011). Edwards and

Doroshov (1989), underlined the aquaculture potential area for sturgeons in the Black sea region; and also gave advises for fish passage ways which was during the planning stage of the building dams on the flowing rivers to the Black Sea. The results of the project show that the sturgeon aquaculture could be done in Turkey. First sturgeon aquaculture studies started at the end of 1990's in Turkey. In 1996, first attempt on aquaculture was implemented with 75-days old *A. baeri* fingerlings which were imported from France to Ankara University (Köksal et al. 2000; Atar et al. 2008). There were some studies done on growth performance and feeds. Since then, the spawning of this fish has not been successful yet.

In 2001, the Fisheries Faculty of Istanbul University imported *A. gueldensteadtii* fertilized eggs from Federal Center of Selection and Genetics for Aquaculture, Krasnodar, Russia, for restocking and aquaculture studies (Ercan et al. 2002; Çelikkale et al. 2003). Russian sturgeon was hatched and released to the Sakarya River. Some of specimens were kept for aquaculture studies. Adaptation, cage culture and growth performance studies have been carried out, while broodstock and cryopreservation studies are ongoing.

In 2006, Central Fisheries Research Institute of Ministry of Agriculture and Rural Affairs of Turkey made a project on "Research on Present Status of Sturgeon Population and Rearing Possibilities" in collaboration with 3 Universities (Akbulut et al. 2011). At the end of this project the fishermen in the region participated in the sturgeon conservation studies. They help the project team in tagging and releasing of studied sturgeon to the Black sea. In this study, the researchers tried to get eggs and sperms from wild caught sturgeons by injected of pituitary hormones to them. However, none of the eggs were fertilized.

In 2008, a FAO-TCP project namely "Recovery of sturgeon population in Turkey: habitat assessment and restocking" was conducted by the Central Fisheries Research Institute (CFRI), Ministry of Agriculture and Rural Affairs (MARA), Ministry of Environment and Forestry (MEF) and the General Directorate of State Hydraulic Works (SHW) with Turkish Universities. *A. stellatus* and *A. gueldensteadtii* fertilized eggs were imported from Federal Center of Selection and Genetics for Aquaculture, Krasnodar, Russia. High rates of incubation occurred in the hatchery. Most of the hatched fingerlings were tagged and released to the Black Sea. Also some thousands of these specimens were given to the fish farms of the region to give impulse on sturgeon aquaculture. In 2009, Istanbul University started to keep the wild sturgeon by catching fingerlings and adapting them to the farm conditions (Memiş et al. 2011).

Potential regions for sturgeon aquaculture in Turkey

Most sturgeons are anadromous bottom-feeders, spawning upstream and feeding in river deltas and estuaries. While some are entirely freshwater, very few venture into the open ocean beyond near coastal areas (Url3 2011). Indeed, at present with the exception of *A. sturio* (Williot et al. 2007, 2009), all farmed sturgeon species, whatever their ecology, are raised in fresh water. About this tolerable characteristic, sturgeon aquaculture can be done in many different water resources (fresh, marine and brackish waters). Turkey is a rich country for having many different water resources for aquaculture purposes. Also the climate can be an advantage for this species for early maturation in open systems. Having many different water resources gives an opportunity to the aquaculture farms to save in their costs. The species distribution can also be changed based on the water reservoir conditions of the different regions of Turkey.

Eggs and fingerlings of three sturgeon species (*A. baerii*, *A. stellatus* and *A. gueldensteadtii*) were imported into Turkey from 1996 to 2009. According to the species a series of experiments, it has been shown that aquaculture of sturgeons could be successful in the warm waters and cages (Çelikkale et al. 2002, 2005). Sturgeon farming in Turkey has improved in popularity since 2001 after Istanbul University got successful data (Çelikkale et al. 2002, 2005; Memiş et al. 2007).

At present, the gynogenesis technology to obtain monosex female populations in several acipenseriform species (Van Eenennaam et al. 1996; Mims et al. 1997; Fopp-Bayat 2007) is in progress and will improve the economic efficiency of caviar production as well as can be used as a valuable tool to the restoration of endangered and extinct species (Wei et al. 2011). For culturing the sturgeon species for meat or caviar, the biological characteristics should be taken into consideration. The culturing systems will be different depending to the species characteristics. Choosing a closed-cycle system for maintaining captive broodstock may provide the quality control needed for the foundation of sustainable sturgeon farming, and also serving as a tool for the preservation of the gene pool of endangered sturgeon species (Chebanov et al. 2002; Williot et al. 2007; Williot et al. 2009).

Raising sturgeon in net cages has many advantages such as lower operational costs, less disease and better product quality. Net cages also provide a huge capacity for sturgeon culture. However, net cage culture poses some risks, such as unforeseen potential for escapement and disease outbreaks in long-term growing cage cultures as well

as pollution from own and other activities (Wei et al. 2004). According to these reports, Turkey has a big chance for sturgeon culture since it has natural sturgeon population and years of experience in fish aquaculture.

Black sea region

Black sea (Fig. 1) has 1895 km coastal zone. This sea is the natural distribution area of the six sturgeon species. The temperature of so many freshwater resources as well as sea water is lower than 22 ^{0}C (Url1 2011). Based on the 2009 Fisheries statistics, this region was producing 15,130 tons/year sea bass (*Dicentrarchus labrax*), trout (*Oncorhynchus mykiss*) in raceways and sea cages. However, since the coast line is open to the high waves, it's hard and expensive to make cage culture in this area. Also, there are a few sheltered bays and areas that give some opportunities for cage culture. Some farms have been settled in these coasts.

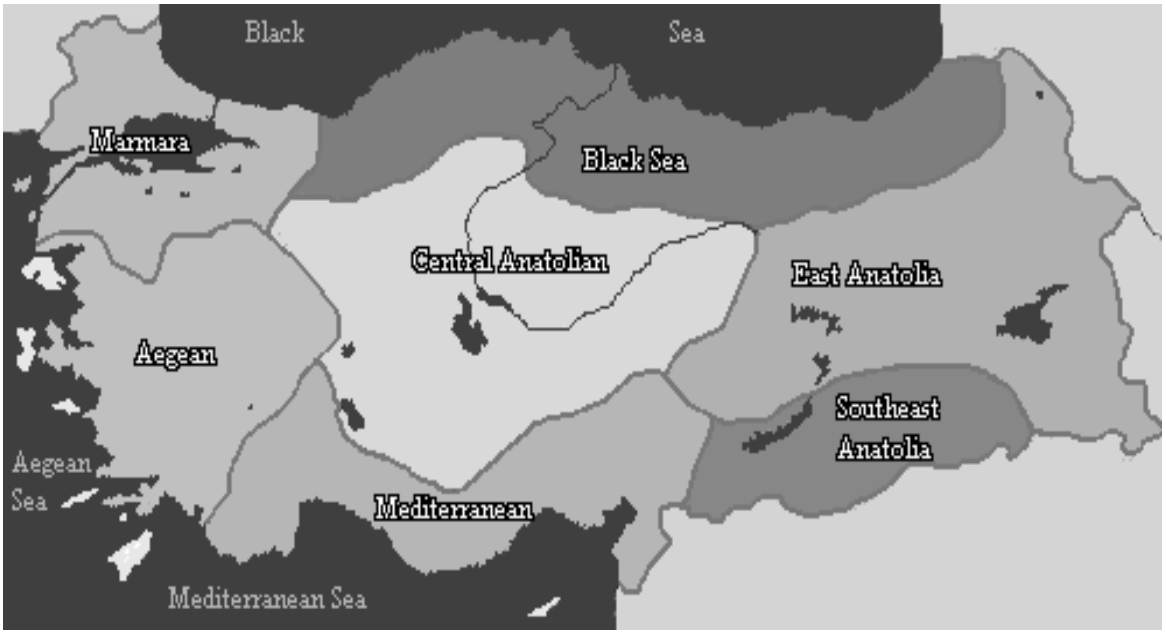

Fig. 1. Geographical regions of Turkey (from: Url2 (2011))

Aegean region

Aegean coasts (Fig. 1) are so curved shape and convenient for cage aquaculture. This region is the capital of Turkish marine aquaculture. Sea bass, sea bream, trout and the new species are being cultured in this region. In 2009, 94,950 tones/year of total marine and inland finfish production was produced in this region, of which 73,815 tone/year were marine species (sea bass, sea bream and other species) and 19,477 tones/year were trout (SIS 2010). The climate conditions and seawater temperature is very suitable for marine and freshwater aquaculture. This region is also important for tourism. Every year over 3 million people visit the holiday resorts. Nowadays tourism and fish farms have faced problems. Touristic firms do not want to see the cage fish farms in the inner bays. So the government has prepared some regulations for cage farms. Now the fish farms have to be 1 mile away from mainland and have 1 m/s flow rate around the cage sides and minimum 30 m deep waters. They have to install off-shore fish cages and since it is expensive, most of the small farms have sold their production quotas. The small fish cage farmers have intension to invest in the ponds to produce marine fish.

Mediterranean region

The climate and water sources of the Mediterranean Sea (Fig. 1) are good for aquaculture, but its salinity is high for this species. There are some fish farms for breeding the tuna fish. Also nearly 15,500 tones of marine fish and 13,000 tones/year trout are being cultured in this region. As an advice, inland sturgeon aquaculture could be done in this region. Also, an investment for a freshwater sturgeon farm to produce meat and caviar has been made by a private company in this region from 2009.

Anatolian region

The climate is not suitable in the winter time. Geothermal water bodies can be an alternative for sturgeon farming. Cage culture could be an opportunity at the dam reservoirs. The trout farmers prefer to install their farms in this region. After finishing the new cage fish farm investments, over 75,000 tones/year is going to be produced in this region. It is nearly the total trout production amount of today.

Conclusions

There are six indigenous species of Acipenseriformes in Turkey, all of which are endangered because of various human activities. Commercial farming of sturgeons has become popular nowadays. There are the three species presently cultured, including imported species from Russia, France and Germany. Sturgeons are not a traditional food of the average Turkish people, imported fish meat and caviar has found market on luxury restaurants.

Turkey has many different (warm/cold, fresh, brackish and marine) water resources that can be used for sturgeon farming. The technology and the know-how of Turkish aquaculture could be forced and be used on sturgeon farming for future of sturgeon. By help of last 15 year academic studies on sturgeon, aquaculture industry of Turkey has gotten an opinion on this potential. Nowadays, Turkey has one private sturgeon farm on the Mediterranean region; also there are more than 10 fish farms that have sturgeon fingerlings, except universities and institutes. Universities have a big role for advertising this fish in the media (news papers, TV, etc.) for pushing efforts to the fish farms.

Turkey should not be dependent to the other countries regarding the importing of fertilized egg and fingerlings and some regulation has to be configured for getting broodstocks from natural populations of Turkey. Turkey has to create their natural broodstocks to protect the gene pool of the natural species. By getting own population sturgeon eggs, Turkey can get the independence for sturgeon aquaculture. It is necessary for sustainable sturgeon aquaculture. Also, exotic sturgeon escapes may cause severe ecological problems, including threatening native sturgeons once these exotics become established or hybridize with native sturgeons (Wei et al. 2004).

According to Wei et al. (2011), a key issue is to make a complete use of resources through product diversification in order to reduce the breeding costs. Presently, the profit generated by sturgeon aquaculture is very low because of the long culture period compared to teleost species. Therefore, efficient culture (grow-out) methods are required because of the relatively long time needed to reach market size. For example, pond aquaculture, reservoir aquaculture, culture in large water resources as well as cage culture can reduce the production cost and should be advocated in an environmentally compatible manner. This would permit to reduce the high energy consumption for intensive facilities requiring temperature controls and oxygen supply. Especially culturing in large water resources in cages can encompass new fisheries growth, and even can intensify the sturgeon aquaculture industry if operated in an environmentally compatible manner (Sun et al. 2003). Safeguarding standards as to the carrying capacity and environmental compatibility need to be developed for this.

Wei et al. (2011) also adverted that we need to pay much more attention to disease prevention and to minimize treatment (prophylaxis rather than treatment with antimicrobials). Furthermore, guidelines need to be developed for production systems that avoid environmental pollution (for example, use the herbs and natural plant products for disease control; implement the provisions of withdrawal periods for drugs; limit licenses to approved drugs only; define organic environmental loads released from sturgeon farms). While developing these strategies, one should try to achieve a win-win situation for both, food safety and environmental protection. There is a need to enhance the research on adequate feeds suitable for sturgeon aquaculture. In Turkey there are over 20 fish feed manufacturers. So it is possible to find and formulate suitable feeds for sturgeons.

Artificial reproduction of the sturgeon species is probably the only way to ensure a rapid increase in sturgeon stocks. In order to preserve sturgeon stocks, it will be necessary to coordinate efforts of all countries surrounding the Black Sea. Turkish aquaculture has a power and experiences to invest on sturgeon aquaculture.

References

Akbulut B, Zengin M, Çiftçi YC, Tiril SU, Memiş D, Alkan A, Çakmak A, Kurtoğlu IZ, Aydin I, Üstündağ E, Eroğlu E, Serdar S. 2011. Stimulating sturgeon conservation and rehabilitation measures in Turkey: an overview on major projects (2006-2009). J Appl Ichtyol 27: 415-419.

Arlati G, Bronzi P, Colombo L, Giovannini G. 1988. Induced breeding of the Italian sturgeon (*Acipenser naccarii*) reared in captivity. Riv Ital Acquacol 23: 94-96.

Atar HH, Bekcan S, Keskin E. 2008. Cultivation techniques of Siberian sturgeon (*Acipenser baeri*) larvea at hatchery and production. Paper presented at International workshop on Protection Strategy and Production of Sturgeons, Samsun, Turkey.

Barannikova IA. 1987. Review of sturgeon farming in the Soviet Union. J Ichthyol 35: 62-71.

Birstein VJ. 1993. Sturgeons and paddlefish: threatened fishes in need of conservation. Cons Biol 7: 773-787.

Bronzi P, Rosenthal H, Arlati G, Williot P. 1999. A brief overview on the status and prospects of sturgeon farming in western and central Europe. J Appl Ichthyol 15: 224-227.

Bronzi P, Rosenthal H, Gessner J. 2011. Global sturgeon aquaculture production: an overview. J Appl Ichthyol 27: 169-175.

Burtzev IA. 1999. The history of global sturgeon aquaculture. J Appl Ichthyol 15: 325.

Burtzev IA.1969. Obtaining offspring from intergeneric hybrid between beluga, *Huso huso* L., and the sterlet, *Acipenser ruthenus* L. In: Genetic, selection and hybridization of fishes. Moscow, Nauka, pp. 232–242, (in Russian).

Çelikkale MS, Memiş D, Ercan E, Çağıltay F. 2005. Growth performance of juvenile Russian sturgeon (*A. gueldenstaedtii*) at two stocking densities in net cages. J Appl Ichthyol 21: 14-18.

Çelikkale MS, Memiş D, Ercan E. 2003. Sturgeon culture in Turkey. Paper presented at International symposium of fisheries and zoology, Istanbul, Turkey.

Çelikkale MS, Timur M, Memis D, Ercan E. 2002. A study on acclimation to the cold water of juveniles Russian sturgeon (*A. gueldenstaedtii*). Turk J Fish Aquat Sci 2: 137-140.

Çelikkale MS, Okumus I, Memis D. 2004. Contemporary status of Turkish sturgeon (Acipenseridae) stocks, conservation measures and recent studies. Symposium on Aquaculture Development – Partnership between Science and Producer Associations, European Inland Fisheries Advisory Commission (EIFAC), Wierzba, Poland.

Chebanov MS, Karnaukhov GI, Galich EV, Chmir YN. 2002. Hatchery stock enhancement and conservation of sturgeon, with an emphasis on the Azov Sea populations. J Appl Ichthyol 18: 463-469.

Cui E, He JX, Zheng WZ. 2006. The status analysis and development suggestion on sturgeons in China. Chin Aqua 6: 8-10 (In Chinese).

Doroshov SI, Clark WH, Lutes PB, Swallow RL, Beer KE, McGuire AB, Cochran M D. 1983. Artificial propagation of the white sturgeon, *Acipenser transmontanus* Richardson. Aquaculture 32: 93-104.

Doroshov SI.1985. Biology, culture of sturgeon, Acipenseriformes. In: Recent advances in aquaculture 2. JF Muir and RJ Rogers (Eds). Westview Press, Boulder, pp. 251-274.

Edwards D, Doroshov S. 1989. Appraisal of the sturgeon and sea trout fisheries and proposals for a rehabilitation program. FAO Field Document I.TCP/TUR/8853: pp. 38.

Ercan E, Memiş D, Çelikkale MS, Timur M, Sümer A. 2002. A modified system for sturgeon incubation and larvea rearing. Paper presented at International workshop on Advanced Techniques in Larviculture of Sturgeon Fish, Urmia, Iran.

FAO 2009. Aquaculture production: quantities 1950–2005. FISHSTAT Plus – Food and Agriculture Organization of the United Nations. Universal software for fishery statistical time series.

Fopp-Bayat D. 2007. Spontaneous gynogenesis in Siberian sturgeon *Acipenser baeri* Brandt. Aqua Res 38: 776-779.

Gessner J, Wirth M, Anders E, Arndt GM, Wurtz S, Kirschbaum F. 2003. Storaufzucht und Kaviarproduktion – wirtschaftlicher Stand und Perspektiven. (Sturgeon culture and caviar production – economic status and perspectives.). Fischer und Teichwirt 12: 449-453, (In German).

Gessner J, Wirth M, Kirschbaum F, Kruger A, Patriche N. 2002b. Caviar composition, the influence of food sources and husbandry practice. J Appl Ichthyol 18: 665-672.

Gessner J, Wirth M, Kirschbaum F, Patriche N. 2002a. Processing techniques for caviar and their effect on product composition. Int Rev Hydrobiol 87: 645-650.

Köksal G, Rad F, Kındır FM. 2000. Growth performance and feed conversion efficiency of Siberian sturgeon Juveniles (*Acipenser baerii*) reared in concrete raceways. Turk J Vet Anim Sci 24: 435- 442.

Memiş D, Ercan E, Yamaner G. 2011. Acclimation to farm conditions of wild caught sturgeon species as by-catch from the North-West Turkish Blacksea coasts. J Appl Ichthyol 27: 433-435.

Memiş D. 2007. Sturgeon Aquaculture, In: Marine Aquaculture in Turkey (ed. By A Candan, S Karataş, H Küçüktaş, İ Okumuş), pp. 1-10, Turkish Marine Research Foundation, Pub. Number: 27, Istanbul, Turkey.

Mims SD, Shelton WL, Linhart O, Wang C. 1997. Induced meiotic gynogenesis of paddlefish *Polyodon spathula*. J World Aqua Soc 28: 334-343.

Okumuş İ, Deniz H. 2007. Past, Present and Future of the Marine Aquaculture, In: Marine Aquaculture in Turkey (ed. By A Candan, S Karataş, H Küçüktaş, İ Okumuş), pp. 1-10, Turkish Marine Research Foundation, Pub. Number: 27, Istanbul, Turkey

Raymakers C, Hoover C. 2002. Acipenseriformes: CITES implementation from range states to consumer countries. J Appl Ichthyol 18: 629-638.

Raymakers C. 2006. CITES, the conservation on international trade in endangered species of wild fauna and flora: its role in the conservation of Acipenseriformes. J Appl Ichthyol 22(Suppl. 1): 53-65.

Rosenthal H, Pourkazemi M, Bruch R. 2006. The 5th international symposium on sturgeons: a conference with major emphasis on conservation, environmental mitigation and sustainable use of the sturgeon resources. J Appl Ichthyol 22(Suppl. 1): 1-11.

Shortnose Sturgeon Recovery Team 1998. Final recovery plan for the shortnose sturgeon (*Acipenser brevirostrum*). US Dept. Commerce and Nat. Mar. Fish. Serv., NOAA, 104 pp.
SSI 2010. Fisheries statistics. State Institute of Statistics of Prime Ministry, Ankara, Turkey.
Sun D, Qu Q, Ma G. 2003. The status of sturgeon culture in China. J Dalian Fish Univ 18: 216-221, (In Chinese).
Url 1. 2011. Marine aquaculture in Turkey and Potential finfish species. Paper presented at Chieam: Options Mediterranneennes, by Deniz H. http://ressources.ciheam.org/om/pdf/c47/00600637.pdf.
Url 2. 2011. http://www.welcome2worldholidays.com/turkey/index.htm.
Url 3. 2011. http://m.panda.org/what_we_do/endangered_species/sturgeon.
Van Eenennaam AL, Van Eenennaam JP, Medrano JF, Doroshov SI. 1996. Rapid verification of meiotic gynogenesis and polyploidy in white sturgeon *Acipenser transmontanus* Richardson. Aquaculture 147: 177-189.
Wakeford A. 2001. State of Florida conservation plan for gulf sturgeon (*Acipenser oxyrinchus desotoi*). Florida Marine Research Institute Technical Report TR-8:100 pp.
Wei Q, He J, Yang D, Zheng W, Li L. 2004. Status of sturgeon aquaculture and sturgeon trade in China: a review based on two recent nationwide surveys. J Appl Ichthyol 20: 321-332.
Wei Q, Yang D, 2003. Conservation and management of sturgeons and paddlefishes in China and their industrialization. Freshwater Fish 33: 3-7, (In Chinese).
Wei Q, Zou Y, Li P, Li L. 2011. Sturgeon aquaculture in China: progress, strategies and prospects assessed on the basis of nation-wide surveys (2007–2009). J Appl Ichthyol 27: 162-168.
Wei Q. 2002. On the direction of sturgeon industry of China. Sci Fish Farm 151: 3-4 (In Chinese).
Williot P, Rouault T. 1982. Compte rendu dune premiere reproduction en France de lesturgeon sibererien *Acipenser baerii*. (Report on the first artificial reproduction in France of the Siberian sturgeon *Acipenser baeri*.). Bull Fr Piscic 286: 255-261.
Williot P. 1986. Lelevage des esturgeons. In: Aquaculture. G. Barnabe´ (Ed.). Lavoisier Technique et Documentation, Paris, France, Aquaculture, pp. 713-738.
Williot P, Bourguignon G, 1991. Production d'esturgeons et de caviar, état actuel et perspectives. In: ACIPENSER, P. Williot (ed), Cemagref, Antony, pp. 509-513.
Williot P, Bronzi P, Arlati G. 1993. A very brief survey of status and prospects of freshwater sturgeon farming in Europe (EEC). In: Aquaculture of Freshwater Species (except salmonids). P. Kestemont and R. Billard (eds). Europ Aqua Soc 20: 32-36.
Williot P, Rouault T, Pelard M, Mercier D, Jacobs L. 2009. Artificial reproduction of captive endangered European Atlantic sturgeon, *Acipenser sturio*. Endang Spec Res 6: 251-257.
Williot P, Rouault T, Pelard M, Mercier D, Lepage M, Davail-Cuisset B, Kirschbaum F, Ludwig A. 2007. Building a broodstock of the critically endangered sturgeon *Acipenser sturio* L.: problems associated with the adaptation of wild-caught fish to hatchery conditions. Cybium 31: 3-11.
Williot P, Sabeau L, Gessner J, Arlati, G, Bronzi, P, Gulyas, T, Berni, P. 2001. Sturgeon farming in Western Europe: recent developments and perspectives. Aquat Liv Res 14: 367-374.
Zhu B, Que Y, Yang Z, Chang J. 2008. A review on genetic studies in sturgeons and their trade control in China. J Appl Ichthyol 24(Suppl. 1): 29-35.