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A Review on Aquaculture Development in Iran

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ABSTRACT Global aquaculture production has more than tripled during the last 15 years, and aquaculture is expected to account an increasing share in global seafood production. There are large differences among countries in the rate of growth and development of aquaculture. This review tries to explain the progress and problems of aquaculture during three last decades in Iran. The total production of Iran from aquaculture was 25,800 tons in 1994, approximately 8 percent of the total fisheries production. However, by 2008 it increased to more than 154,000 tons; 27% of total fisheries production. During the last decade, production share of different species in Iran has been variable. In the years 1998 and 2008 the highest percentage of aquaculture production was belonged to silver carp *Hypophthalmichthys molitrix* (50%) and rainbow trout (*Oncorhynchus mykiss*; 40%), respectively. The results showed that culture of rainbow trout has grown noticeably in the past two decades. At present, Iran has been acquired the first rank of rainbow trout culture in fresh water of the world. But in contrast, in recent decade shrimp aquaculture industry has failed due to white spot syndrome. Coastal and inland waters of Iran have more potential for aquaculture development. Recently, great sturgeon *Huso huso* and some species of barbus family have aroused interest from government and private enterprises for potential aquaculture use. Although aquaculture of Iran has shown a significant growth in the last decade, but it is concluded by introducing new species and overcome to present aquaculture problems in the country, the aquaculture production will be increased to several times.

Key words: *Aquaculture development, Aquaculture statistics, Freshwater, Iran, Rainbow trout*

1 INTRODUCTION

Fish is a valuable part of a healthy diet (Adam and Standridge, 2006). It is an important source of a number of nutrients, particularly protein, retinol, vitamin D and vitamin E. It is also rich in the following: iodine, selenium and the essential long-chain polyunsaturated fatty acids (PUFA), i.e. Eicosapentaenoic acid (EPA) and Docosahexaenoic acid (DHA) (Naylor *et al*., 2000; Welch *et al*., 2002).

It is recommended that fish and seafood products take a prominent position in the human diet, due to their beneficial effect on chronic degenerative diseases. The consumption of fish may protect against cancers (Caygill *et al*.,1996; Fernandez *et al*., 1999) and cardiovascular diseases (Simopoulos, 1999; Nestel, 2000; Kris-Etherton *et al*., 2002).

These advantages reveal cause of increased demand for seafood consumption, whereas

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marine resources diminish and even in some areas are completely discharged. Therefore, we must find new sources for the seafood supply.

A solution for this issue is the use of aquaculture that has high potential to supply seafood. For this purpose, in recent decades, the aquaculture sector has been gaining a lot of attention. Aquaculture is the farming of aquatic organisms, including finfish, shellfish and seaweeds by individuals, groups or corporations using interventions (e.g., feed, medications, controlled breeding, and containment) that enhance production.

The Islamic Republic of Iran is located in the Middle East between latitudes of 25° 00' and 39° 47'N and longitude of 44° 02' and 63° 02' E. The total area of the country is 1,648,195 km^2 which includes 1,636 million km^2 land area and 12,000 km^2 of water surface. The coast line stretches for 2,700 km to the south in the Persian Gulf and Oman Sea and in the north along the Caspian Sea.

Weather conditions differ greatly across Iran allowing a range of different types of aquaculture to be practiced. Fish farming in Iran is initiated with fish stock enhancement in the Caspian Sea and then continued for the semi-intensive aquaculture, utilizing Chinese carp species, rainbow trout, Indian white shrimp and recently white leg shrimp and giant freshwater prawn.

To date, a full report about aquaculture development in Iran has not been reported. So the purpose of the present study was to explain the progress and problems of aquaculture in Iran. Our analysis has focused on aquaculture trends in the past 30 years. We limit our study to finfish, bivalves and crustaceans and seaweed production in Iran. Also some countries that have similar species for aquaculture, like Iran, have been discussed.

For this review we used data from the comprehensive database and yearbooks of FAO and calendar statistical Iran Fisheries Organization. In order to manage information and access to Fishery statistics of various sorts that we needed, Fishstat Plus software (Version 2.3, Universal software for fishery statistical time series produced by FAO) was used. Microsoft office Excel 2003 used in order to produce statistical work and charts.

1.1 Aquaculture development in the world and Iran

Aquaculture, or underwater agriculture, is an art that has been practiced for some 4,000 years. Largely within the past three decades, it has developed into a science (Stickney, 1990). Because the worldwide decline of ocean fisheries stocks has provided impetus for rapid growth in fish and shellfish farming, or aquaculture (Naylor *et al*., 2000).

Fisheries and aquaculture play, either directly or indirectly, an essential role in the livelihoods of millions of people around the world. Aquaculture, while not the total answer to providing food for a hungry planet, will continue to make an important contribution. Aquaculture accounted for 47 percent of the world's fish food supply in 2006 (FAO, 2009).

More than 220 species of finfish and shellfish are farmed; the range includes giant clams, mussels, carps and salmon (Naylor *et al.*, 2000). World aquaculture has grown at an average annual rate of 8.8% from 1950 to 2004. Latin America and the Caribbean region have the highest average annual growth of 21.3%, mainly with salmonids and shrimps (Alfaro-Montoya, 2010).

Aquaculture now accounts for 76 percent of global freshwater finfish production and 65 percent of mollusks, and diadromous fish production (FAO, 2009). The contribution of aquaculture to global supplies consisting of fish, crustaceans, mollusks and other aquatic animals has continued to grow, increasing from 3.9 percent of total production by weight in 1970 to 36.0 percent in 2006. While total inland water catches increased significantly in 2005

and 2006, total global marine capture production has remained fairly stable since 2002 between 74.3 and 75.3 million tons. Global marine capture production was 81.9 million tons in 2006 (FAO, 2009).

Aquaculture activity records in Asia go back thousands of years. Asia accounts for roughly 90% of global aquaculture production, and China alone contributes more than two-thirds of the total (Naylor *et al*., 2000). The production of carp has increased markedly in Asia for local or regional consumption by relatively low-income households. In contrast, increased volumes of salmon, shrimp and other high-value species have been marketed mainly in industrialized countries (Naylor *et al*., 2000).

The Islamic Republic of Iran, however, has only given serious attention to this activity during the last three decades (Figure 1) where investment in aquaculture development began in the early 1980s along the Caspian Sea coasts regions and in some of the south-western provinces.

The first aquaculture experiment was conducted with rainbow trout culture near Tehran in Mahisara (Karaj) in 1959. The first farm for warm water aquaculture was established in Giulan Province (Sefidrud company-Rasht) and the Abzi Company in Khuzestan Province (Shooshtar) in 1971. The industry has developed very rapidly over the past seven years and great progress has been made (Shakouri, 2003).

In the past two decades aquaculture has had good growth in Iran. Figure 1 shows comparison between aquaculture and capture production in Iran.

The main types of aquaculture activities in the Islamic Republic of Iran are: Warmwater fish culture of Chinese carps, coldwater culture of rainbow trout, shrimp culture and culture-based fisheries and juvenile production for stock enhancement; For instance five species of sturgeon (*Acipenser guldenstaedti*, *A. persicus*, *A. stellatus*, *A. nudiventris* and *Huso huso*) and Kutum (*Rutilus kutum*) are artificially propagated in the government hatcheries and their fingerlings stocked into the Caspian Sea for the rehabilitation of their respective fisheries.

Total aquaculture production and value in Iran fish ponds in 1995 and 2008 are shown in the Table 1.

The total production of Iran from aquaculture was 25,800 tons in 1994, approximately 8 percent of the total fisheries production (308,100 tons). However, by 2008 it increased to more than 154,000 tons or 27 percent of total fisheries production (Figure 1) (IFO, 2008). In 2005, national production from both aquaculture and inland fisheries was 134,100 tons of which 22,179 tons derives from national and artificial water bodies and 73,396 tons from carp farming, including 63% silver carp, 25% common carp, 7% grass carp and 5% bighead carp, 34,760 tons from rainbow trout farming and 3,829 tons from cultured shrimp (Salehi, 2007).

During the last decade, production share of different species in Iran has been variable. In the years 1998 and 2008 the highest percentage of aquaculture production belonged to silver carp (50%) and rainbow trout (40%), respectively (Table 2).

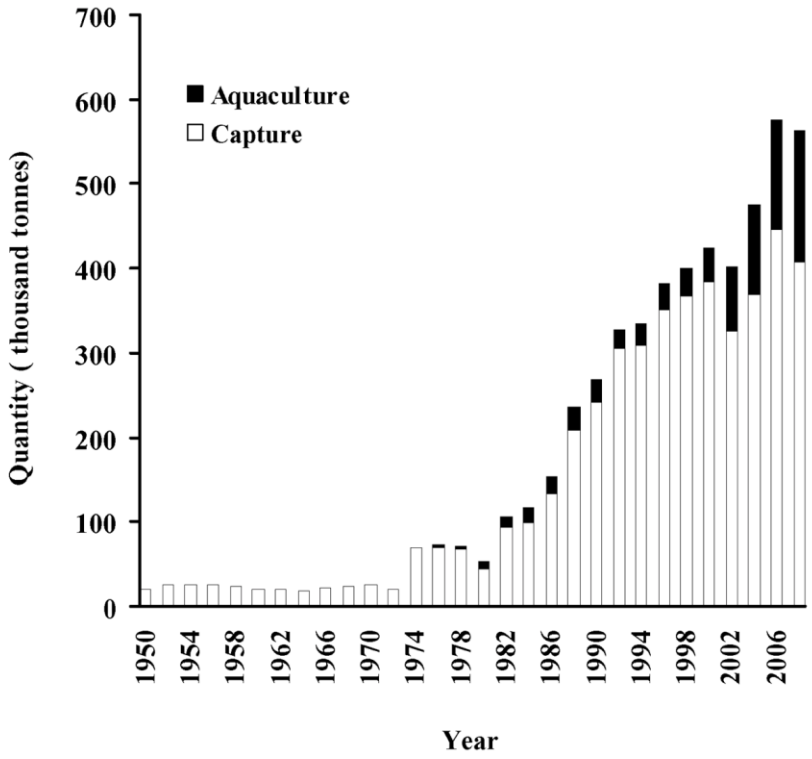

Figure 1 Comparison between aquaculture and capture production in Iran from 1951 to 2008 (FAO, 2008; IFO, 2008).

Table 1 Total aquaculture production and value in Iran in 1995 and 2008 (FAO, 2008; IFO, 2008).

Family	Environment	1995		2008	
		Quantity (t)	Value (1000USD)	Quantity (t)	Value (1000USD)
Cyprinidae	Freshwater	27,000	71,439	87,679	232,349
Salmonidae	Freshwater	1,500	4,500	62,630	187,890
Penaeidae	Brackish& marine water	136	884	4,372	26,232
Other	Freshwater	-	-	298	2,284
Total		28,636	76,823	154,979	448,755

Table 2 Comparison of production percentage of farmed fishes and shrimps in the years 1998 and 2008 in Iran (FAO, 2008; IFO, 2008).

Species	1998	2008
	Production (%)	Production (%)
Common carp (*Cyprinus carpio*)	16.0	14.0
Grass carp (*Ctenopharyngodon idella*)	12.0	8.8
Silver carp (*Hypophthalmichthys molitrix*)	50.0	31.0
Bighead carp (*Aristichthys nobilis*)	4.1	2.9
Rainbow trout (*Oncorhynchus mykiss*)	15.0	40.0
Acipenser spp. (i.e. *Huso huso*)	-	0.01
Indian white prawn (*Fenneropenaeus indicus*)	2.6	1.2
Giant fresh water prawn (*Macrobrachium rosenbergii*)	-	0.1
Pacific white shrimp (*Litopenaeus vannamei*)	-	1.6

There are different systems of culture in Iran that are:

- **Extensive aquaculture:** extensive aquaculture is practiced in inland lakes, dam and reservoirs across the country. There are many dams in Iran, which provide excellent conditions for aquaculture based fisheries. Most of the reservoirs along the Caspian Sea coasts are stocked mainly with Chinese and common carps.
- **Semi-intensive aquaculture:** Carp production in earthen ponds is the main form of semi-intensive production encountered, with 97,000 tons produced in 2007 from 33,790 ha of ponds.

Production of rainbow trout takes place in raceways with the average production being approximately 20 kg/m². Shrimp farming in the Islamic Republic of Iran also falls within the semi-intensive category of production. In 2004 the average production per hectare was 2.17 tons.

- **Intensive and super intensive aquaculture:** Over the past few years, 108 licenses have been issued to the private sector for the development of recirculation production systems. Of this Figure, thirty-two farms with a capacity of 2,400 tons are operational and a further 22 farms are under construction. Total production of rainbow trout using this method was 430 tons in 2002 or 3 percent of the total production of rainbow trout. The lack of adequate equipment and design has led to lower productivity levels than predicted using this system while still incurring higher production costs compared to raceway systems.
- **Integrated farming systems:** Integrated farming systems (utilizing waterfowl, rice and fish culture) are not common. Over recent years, however, the IFO has received funding to introduce new techniques to increase the productivity of both water and soil resources in the agriculture sector. Fish culture in paddies (following the harvesting of rice) and irrigation reservoirs have brought about considerable benefits to rural families including food security. Around 13 percent or 2,100 tons of the total rainbow trout production is produced using integrated systems as are 740 tons of Chinese carp (1.3 percent of total production). With regard to the extensive rice paddies found in the northen part of Iran, it seems that further

development and expansion of this system is feasible.

1.2 Human resources and aquaculture research

The IFO which governs all fisheries activities in the country is responsible for fisheries development including both the aquaculture and fisheries industries. It is affiliated to the Ministry of Jihad-e-Agriculture. The main responsibilities of the IFO within the aquaculture sub-sector are: Aquaculture development research and implementation, planning and preparation of the national development plans, identification and training in the aquaculture sector, improvement of existing farmer's knowledge, promotion of new culture systems, fish stock enhancement programs and investment in aquaculture infrastructure.

The total number of people employed in fisheries has risen from 82,400 in 1992 to 174,000 by 2008 (IFO, 2008). The number of registered fishers in the Caspian Sea increased only slightly, from 11,600 in 1994 to 12,900 in 2007, due to resource limitations, but in the Persian Gulf of Oman Sea fisheries increased from almost 75,000 in 1994 to more than 129,300 in 2007, due to deep sea fishing developments and increased opportunities for fishers. Employment in aquaculture and inland fisheries increased from almost 11,000 in 1994 to more than 31,000 in 2007. Shrimp culture plays an important role in the alleviation of poverty and the creation of job opportunities along the southern coast of the country.

The Iranian Fisheries Research Organization (IFRO) formerly established in 1917-1918 and the name of organization changed in 1971, covers most fisheries research activities. The objective of IFRO is performing the scientific applied researches regarding to the related subjects to aquatic organisms and their environment for approaching the best protection and stocks recovering and sustainable exploitation from live resources in Iranian waters. There is also an additional research institute that deals exclusively with the sturgeon resources of the Caspian Sea. The International Sturgeon Research Institute aims to concentrate on encouraging scientists from around the world to conduct research on the Caspian Sea in Iran. The outcome of research projects are submitted to the Fisheries Organization who in turn apply the results, where appropriate, to fisheries development and improvement; subsequently pilot projects are run and modified accordingly.

Since 1970 the Ministry of Science, Research and Technology has organized a fisheries science course within Iran's university program. At present, more than 20 open universities offer bachelor courses, master and post-graduate courses in various fields related to fisheries and aquaculture. The Universities of Tehran, Gorgan University of Agricultural Sciences and Natural Resources (Golestan Province), The University of Guilan, and Tarbiat Modares University are the oldest universities in the field of fisheries science. Universities have an extensive capacity for research activities; however, as yet there is no proper systematic link between the universities and industry.

1.3 Aquaculture activities of Iran in compare to pioneer countries

1.3.1 Warmwater fish culture

The culture of carp is an ancient activity. Total world aquaculture production of Carps, Barbels and other cyprinids was 12,774,000 tons in 1998 that increase to 18,944,000 tons in 2007 (FAO, 2007).

China continues to dominate global aquaculture with 63.4% of the world’s aquaculture production in 1995. China accounted for 70.4% of Asia’s production in 1995, but only 47.3% of its value, due to the

relatively low value of cultured species, mainly carps (FAO, 1997). Aquaculture production of Cyprinidae in China and India was 14,609,000 and 3,200,000 tons that have the first and second rank in the world in 2008, respectively.

In Iran, Carp farming was started about more than 40 years ago, initially as an attempt at hatching of Chinese carp (Azari Takami, 1984). Carp farming activities expanded quickly in close provinces to the Caspian Sea and other provinces like Khuzestan (Salehi, 2007).

In Iran, warmwater fish farming is based on the common, silver, grass, and bighead carps. These carps with different feeding habits, are cultured together, also have capability to breed in a large number of hatcheries and distributed to farm and open waters. As total carps seed production in the country in 2000 was 116 million which increased to 146 million in 2009.

The usual earthen pond depth varies between 1.8 to 2.5 m with a production time of approximately 5-8 months depending on the temperature and type of feeding regime in place. Average production is around 3 metric ton per ha, which is low compared to other states in Asia. The combination of the four carps species varies depending on climatic conditions and the farm management system being implemented. The most common combination is as follows: common carp 15-20 percent, grass carp 5-10 percent, silver carp 60-70 percent and bighead carp 5-10 percent.

It has undoubtedly seen great success over the last fifteen years, production from both carp farming and inland fisheries rising from less than 9,000 tons in 1980 to more than 87,000 tons in 2008 (Figure 2). Rank of total carp culture of Iran in the world was the 13 in 1980, but further improved to the rank of 8 in 2008. The total area that was used for warmwater fish farming was 23,270 ha and 33,790 ha in 2002 and 2007, respectively. This information shows approximately 45% increase in the area under cultivation for warmwater fish farming during a five years span. The provinces of Mazandaran, Guilan, Khuzestan and Golestan are the main geographical areas where warmwater fish farms are located. In Guilan and Mazandaran harvesting starts in September, but in Khuzestan it may be two or three months later. The standard marketable size for carp is about 1 kg in weight and some farmers may delay their harvesting up to November, or even December to achieve larger sizes and potentially better prices (Salehi, 2007). Salehi (2007) indicated that carp farming is a profitable activity with an average of 12% rate of farm income in 2001.

There are, however, several problems in warmwater fish farming including low production per hectare and extensive fish production, low water and feed quality, lack of technical knowledge, low cultural warm water species diversity, fish disease, and improper feeding and fertilizing management.

1.3.2 Coldwater fish culture

Salmon farming makes a small, but economically and environmentally significant contribution to global aquaculture production volumes (Pelletier and Tyedmers, 2007). The production of rainbow trout has grown exponentially since the 1950s, especially in Europe and more recently in Chile. This is primarily due to increased inland production in countries such as France, Italy, Denmark, Germany and Spain to supply the domestic markets, and mariculture in cages in Norway and Chile for the export market. Chile is currently the largest producer. Other major producing countries include Norway, France, Italy, Spain, Denmark, USA, Germany, Iran and UK (FAO, 2009).

The Islamic Republic of Iran has an established coldwater fish culture industry in both the private and public sectors. In Iran coldwater fish farming includes the rearing of rainbow trout in raceways (Dorafshan *et al*.,

2010). Rainbow trout has been introduced to Iran from several countries including the United Kingdom, Italy, Norway and France. Trout farms are distributed across the centre, north-western and western parts of the country, mostly in mountainous areas characterized by cool summers and cold winters. The farming system consists of simple raceway made of concrete through which water flows continuously. An increased number of farms, about 306 to 1200 with improving farming techniques and facilities has boosted annual production of trout from 280 tons in 1978 to more than 62,000 tons by 2008 (Figure 3). Also total annual production of larval rainbow trout in 2000 was 115 million which increased to 199 million during 2009 (IFO, 2008). Furthermore, trout was reported to be produced on non-licensed farms in Iran that the amount of fish produced via this method is not clear.

In Iran, production of rainbow trout takes place in raceways with the average production being approximately 20 kg/m^2 that is low compared to production levels obtained in Europe. Rainbow trout are grown to a market size of 250-300 g in trout farms of Iran (Johari and Kalbassi, 2004).

The total area utilized for rainbow trout farming is about 162.6 ha with the aim being to increase average production up to 30 kg/m^2 by the end of the fourth 5-year plan.

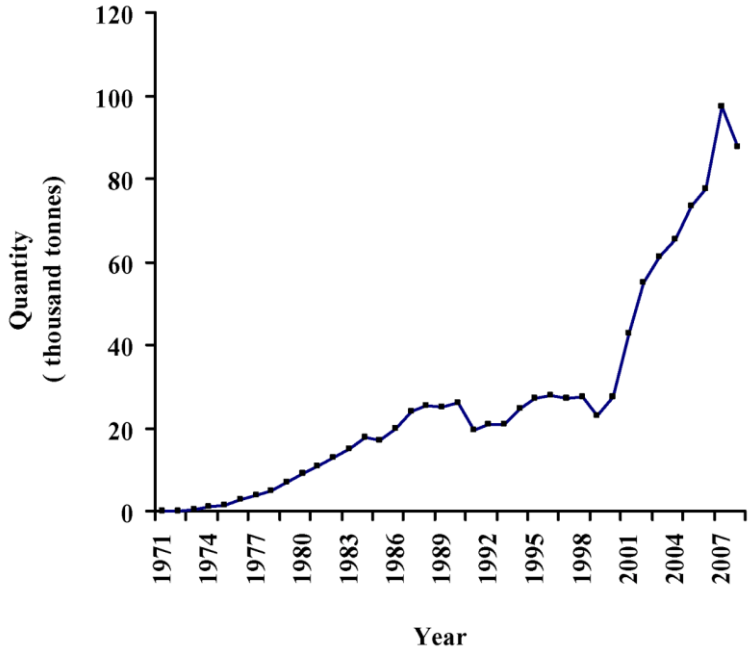

Figure 2 Culture of warm water fish in Iran from 1971 to 2008 (FAO, 2008; IFO, 2008).

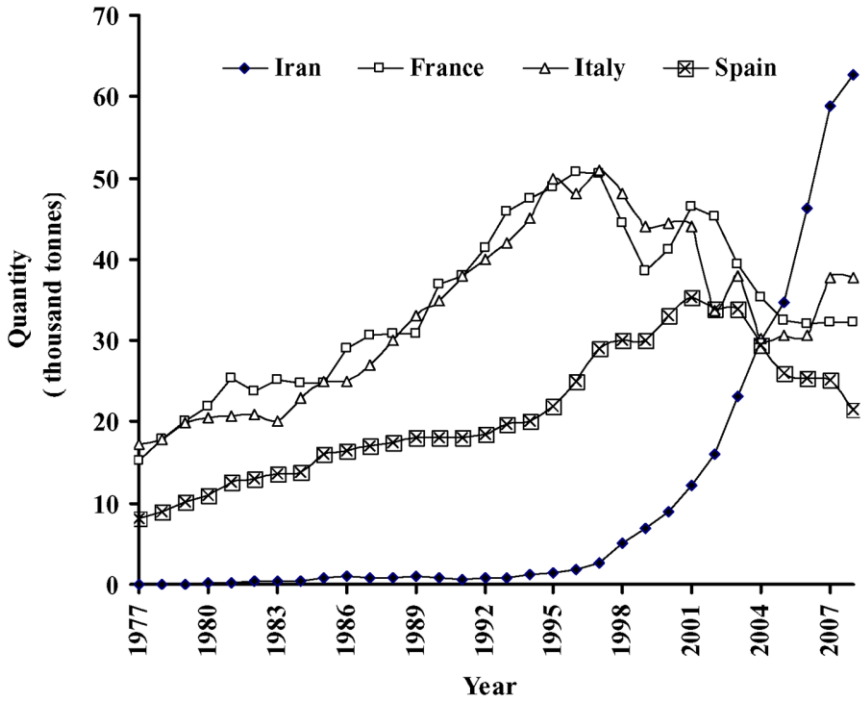

Figure 3 Culture trend of rainbow trout in fresh water in Iran, Italy, France and Spain from 1977 to 2008 (FAO, 2008; IFO, 2008).

The production of rainbow trout take place in Charmahal va Bakhtiari (17%), Lorestan (10%), Fars (6.5%), Mazandaran (14%), Kohkilouyeh (8%) and West Azerbaijan (8.5%) provinces, (IFO, 2008).

Demand for trout in Iran greatly exceeds domestic production. Consequently the government is currently supporting a major programme to increase salmonid output, both by building state-owned hatcheries and on-growing units and by providing licenses, land and juvenile fish to private farmers.

The main problems facing trout farmers in Iran are a lack of knowledge about up-to-date technologies and culture practices, disease, low density, unsuitable feeding and feed quality especially for starter diets, insufficient information on and supply of good quality feeds, hygiene and disease control issues, low water quality, and the absence of a scientifically based strategy for genetic improvement of the fish stocks.

1.3.3 Status of shrimp and prawn culture

Marine shrimp is one of the highest demand seafood items in the world (Wyban and Wyban, 1989). Shrimp have only recently been cultivated by man and it is only been in the last twenty to thirty years that the cultivated populations of some species, which are easily reproduced in captivity, have been isolated from wild populations. Consequently, most populations of cultivated shrimp have only had a relatively short period to evolve and adapt to intensive cultivated production systems (Cock *et al*., 2009).

In general, the global shrimp farming industry had a rapid growth in the 1980s mainly due to technological breakthroughs such as hatchery and feed causing a high demand for

shrimp, resulting in high price and high profit of shrimp farming, and public support. However, its growth has slowed down since 1991. Total global shrimp and prawn's aquaculture was equal to 985,890 tons in 1998 that increased to 3,399,000 in 2008.

Shrimp is a species with high economic value that are used mainly in developing countries like Iran usually as export to other nations.

Many species of shrimp such as *Penaeus monodon, Litopenaeus vannamei, Fenneropenaeus chinensis, Marsupenaeus japonicus, F. merguiensis* and *F. indicus* are reared in different areas of the world. China, Thailand, Vietnam Indonesia, Ecuador, Mexico and India have the highest production of shrimp farming in the world in 2007, respectively. Mainly, a major portion of shrimp aquaculture belongs to the species of *Litopenaeus vannamei* and *Penaeus monodon* (approximately 80 percent of total shrimp and prawn aquaculture).

The first rank of cultural shrimp was related to *P. monodon* until 2002, but in the last decade the amount of culture it had was fixed or even less. FAO data shows a rapid increase in production up to over 1,386,000 tons in 2004, due to the recent rapid spread of this species in Asia (FAO, 2006), the production of *L. vannamei* reached to approximately 2 million tons in 2007, so that it became the first rank of shrimp farming.

F. indicus (formerly *Penaeus indicus*), was the cultural shrimp of Iran in the past years as it was reared in the semi-intensive earthen ponds. Other countries such as India, Vietnam and Saudi Arabia also culture this species.

A semi-intensive ponds are stocked with hatchery produced seeds at the rate of 20-25 post larva/m² which production levels of 2,500 to 5,000 kg/ha are achieved. In Iran total annual production of post-larvae (PL) in 2000 was approximately equal to production in 2009 (532 million PL). Major shrimp aquaculture is produced in the southern Iranian provinces including: Sistan and Baluchestan (sometimes two times a year), Bushehr, Hormozgan and Khuzestan.

Serious outbreaks of shrimp diseases have been reported in most of the major producing countries. Viral diseases have reduced shrimp production (Shang *et al*., 1998). Unfortunately, due to occurring white spot syndrome in Iran aquaculture production of shrimp was greatly reduced in the last decade (Figure 4). Diseases that remain at a low level of incidence in natural populations may reach epidemic levels in intensive cultivation systems (Cock *et al*., 2009).

Asia leads the world in cultivated shrimp production with export earnings ranging in the number of billions of US dollars per year. Despite this success, annual production decreased in the latter nineties because of widespread epidemics (epizootics) caused by new viral pathogens. Although these viruses were no cause for alarm to human health authorities, they were economically crippling for Asian shrimp farmers (Flegel, 2006).

White spot syndrome virus (WSSV) is the causative agent of white spot disease of shrimp. During the last decade, the worldwide shrimp culture industry was beset with diseases mainly caused by viruses, particularly species with WSSV and suffered significant economic losses (Mohankumar and Ramasamy, 2006). Now this virus is the most serious threat facing the shrimp farming industry in Asia (since 1992) and Latin America (since 1999) (Briggs *et al*., 2005).

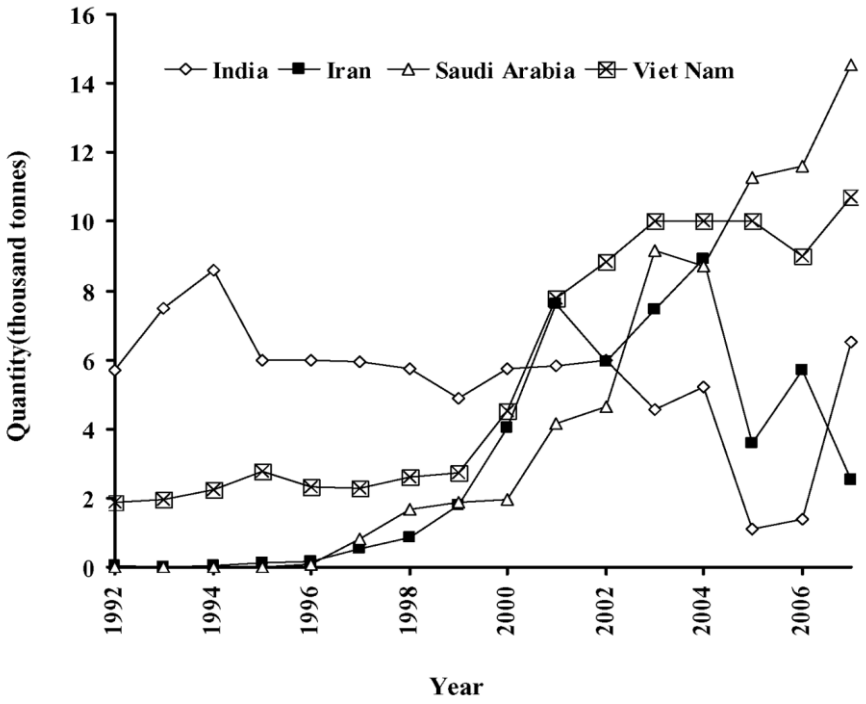

Figure 4 Culture of Indian white prawn in Iran, Saudi Arabia, India and Vietnam from 1992 to 2008 (FAO, 2008; IFO, 2008)

F. indicus is one of the major commercial species of shrimp aquaculture in Asia endemic to Indian waters and the most caught Indian species found in the wild, that it is susceptible to WSS (Manjusha *et al*., 2009). Due to economic losses of WSS, Iranian Fisheries Organization decided to replace Indian white shrimp by *L. vannamei.* Fortunately, today this new species have good results in Iran.

The giant freshwater prawn (*Macrobrachium rosenbergii*) is one of the most important crustacean species produced in inland aquaculture and in many tropical and subtropical countries worldwide. In 2004, the total amount for world farming of *M. rosenbergii* reached more than 194,000 tons, with an estimated market value that exceeded US$ 810 million, 99% of which, was produced in Asia (Thanh *et al.,* 2009), but recent years this species cultivated at low levels in Iran. Total aquaculture production of giant freshwater prawn in Iran was only 275 tons in 2008 (IFO, 2008).

Overall, there are at least five major problems in shrimp aquaculture industry: 1) shrimp disease especially WSS, 2) low average production per hectare, 3) problem in production of SPF (Specific Pathogen Free) and SPR (Specific Pathogen Resistant) broodstocks of shrimp inside the country, 4) unsuitable shrimp feed management, 5) high costs of broadstock importing and financial problems.

1.3.4 Sturgeon and Iran's position in the Caspian caviar fishing

There are 27 sturgeon species living in the seas and rivers of the Northern hemisphere (Birstein *et al*., 1997). Sturgeons appeared on the earth 200–250 million years ago and established regular and abundant populations. Today, they

are mostly in danger of extinction (Carmona *et al*., 2009; keyvanshokooh and Gharaei, 2010).

Strong international demand for caviar, complicated by political and environmental difficulties, has prompted overfishing in the traditional sturgeon-producing areas such as the Caspian Sea, placing the vitality of these sturgeon fisheries in jeopardy (Logan *et al*., 1995).

Sturgeons are becoming extinct not because of accidents or because they cannot adapt to natural changes, but because of the unsuitable management by humans, which is driving them to extinction, especially the construction of dams to prevent water flowing to the sea, thus impeding sturgeon migrations. The little water that remains is contaminated by agricultural biocides and industrial wastes. Above all, fishing depletes the number of adults, without allowing them to reproduce, and repopulation is not undertaken.

Prior to 1951, commercial sturgeon fishing was concentrated in the Caspian Sea, and in the last decades, 80 to 90 percent of the world's sturgeon catch was taken from the Caspian Sea (Birstein *et al*., 1997).

In the Caspian Sea, there are five species of sturgeons including *Acipenser persicus* (Persian sturgeon), *Acipenser gueldenstadti* (Russian sturgeon), *Acipenser nudiventris* (Ship sturgeon), *Acipenser stellatus* (Sevruga), and *Huso huso* (Beluga). 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 (Abdolhay, 2004). Among the borders countries Russia has highest catch of the Caspian sturgeons.

Countries that have done the most sturgeons fishing include: Iran, Russia, the United States of America, Canada and Kazakhstan. The total share of Iran and Russia during 1988-2007 has been 107 million tons showing that Russia had exactly three times the catch in this period when compared Iran (Figure 5). In order to rebuild stocks of these fishes, Iran started to release sturgeon fingerlings at 1972, so that in total 142 million pieces of fish have been released in the Caspian Sea during 1994-2002 (IFO, 2008). Also, because Iran has suitable brackish and salt inland waters for rearing of *Huso huso*, Iran has been able to produce brood, caviar and meat.

In sturgeon aquaculture, where the main purpose is caviar production, a reliable method is needed to separate the fish according to gender. Males are separated to the meat market while females remain in culture for more years under conditions of optimal growth and development (Keyvanshokooh *et al*., 2009).

The availability of monosex populations of caviar-producing females would significantly enhance the economic viability of domestic caviar production systems (Keyvanshokooh *et al*., 2009).

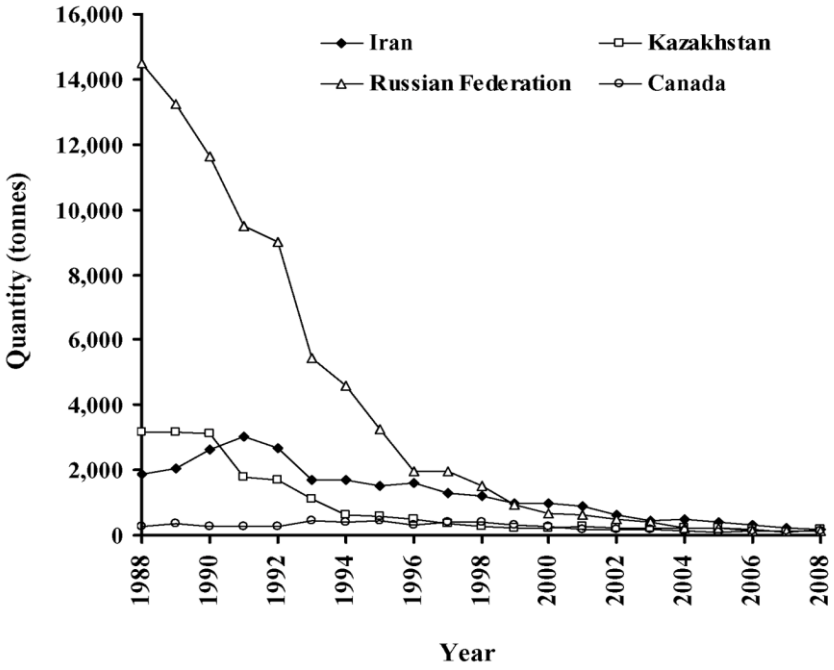

Figure 5 Capture trend of Acipenseridae species in Iran, Russian Federation, Canada and Kazakhstan from 1988 to 2008 (FAO, 2008; IFO, 2008)

2 CONSUMPTION

Capture fisheries and aquaculture supplied the world with about 110 million tons of food fish in 2006, providing an apparent per capita supply of 16.7 kg (live weight equivalent). In 2006, more than 110 million tons (77 percent) of world fish production was used for direct human consumption. Almost all of the remaining 33 million tons was destined for non-food products, in particular the manufacture of fishmeal and fish oil (FAO, 2009).

The average contribution of aquaculture per capita fish available for human consumption rose from 14 percent in 1986, to 30 percent in 1996 and to 47 percent in 2006. It can be expected to reach 50 percent in the next few years (FAO, 2009).

Significant variations in this overall trend are evident; for example Asia showed the strongest growth, while seafood consumption decreased in Africa and America. In Norway per capita consumption was 51.2 kg in 2000, an increase of 13% since 1990, but fish is not a popular part of the Iranian diet, especially in its central cities, which possess the main proportion of the population. Fish consumption in Iran is very low. Per capita consumption was only 1 kg in 1980, and had reached only 6.12 kg in 2003 and 7.32 kg by 2008 (IFO, 2008).

Expansion of aquaculture throughout the country, together with an increase in people's knowledge of fish as a healthy food, is helping to change people's attitude to fish and marketing campaigns. The IFO and Ministry of Health and Medical Education have also helped and encouraged to enhance fish consumption in the country.

3 FUTURE

Projecting the future growth of the world's population and resulting demand for fishery products has interested fish culturists. Although aquaculture production is not expected to feed the world's masses, it is expected to augment

the limited catch of marine and freshwater fish. Therefore the balance between farmed and wild-caught fish, as well as the total supply of fish available for human consumption will depend on future aquaculture practices (Naylor *et al*., 2000).

Accumulation of waste products is now the greatest obstacle to further increases in fish production. Culture of fish in intensively managed water reuse systems is expected to expand as groundwater supplies become more limited (Parker, 1989).

Iran's future fisheries development plans aim to increase fish production, improve the welfare of fishers and farmers, promote exports, increase fish consumption and provide greater food security. The per capita availability and consumption of fish is expected to increase to 10 kg/year and production will have to increase proportionately. Although aquaculture has been practiced for thirty years in the Iran, the major increase in production developed in the last 10 years.

Aquaculture is recognized as an important source to meet future fish demand. A number of schemes have been instituted by state and central sectors to increase brackish-water and mariculture and fish production from cages and ponds, and freshwater production from lakes, reservoirs and rivers. The private sector has emerged as a major player in aquaculture investment, particularly in shrimp and warm water farming.

Although in freshwater Iran has the first rank in production of rainbow trout during 2005 to 2008, inland waters of Iran have a lot more potential. On the other hand, using new photoperiod techniques on number of hatcheries have been able to meet alevins need farms at all seasons. Brown trout (*Salmo trutta*) has great potential as a suitable species for aquaculture (Quillet *et al*., 1992). In Iran, this species has attracted interest for aquaculture in cage and raceways in intensive culture systems, with emphasis on using triploid and gynogenetic populations, and also diploid and triploid hybrids between *Oncorhynchus mykiss* × *S. trutta caspius* (Kessler, 1877) (Hulata, 2001; Dorafshan, 2004; Kalbassi *et al.*, 2009).

Defeat of Indian white shrimp industry by white spot disease, led experts to enter the white leg shrimp which is more resistant against unsuitable environmental condition, so this enables them to produce white leg shrimp in a few numbers of farms. It is expected in the coming years, Iran is able to produce white leg shrimp in commercial scale.

The fish that have high production and economic potential for aquaculture in the sea and inland waters of Iran are shown in the Table 3. In the future Iran can cultivate these fish as a protein source while some of these species are produced (*Barbus sharpeyi* and *Barbus grypus*) in a few farms now.

Most fish cages are located in lakes and dams with rainbow trout production from cages being 350 tons in 2004. A development plan is underway in the Caspian Sea, Persian Gulf and the Oman Sea for the development of marine cage culture and a pilot project with 6 cages has been established at Qeshm Island in the Hormozgan province for experimental research into mariculture (FAO, 2010). The candidate species for mariculture development include groupers (Serranidae), cobia (*Rachycentron canadum*), silver pomferet (*Pampus argenteus*) and fourfinger threadfin (*Eleutheronema tetradactylum*). Also recently, the Caspian salmon, *Salmo trutta caspius* (Kessler, 1877), has attracted interest for aquaculture in cages and raceways in Iran, with emphasis on using triploid populations to omit problems associated with sexual maturation, which can reduce commercial benefits of salmonid culture, especially beyond the maturation phase (Dorafshan *et al*., 2008; Kalbassi *et al*., 2009).

Table 3 Fish that have high production and economic potential for aquaculture in the costal of Persian Gulf, Caspian Sea, and inland waters of Iran (Kalbassi *et al.*, in press).

Species	Description
Huso huso	This is a native species and it reaches to at least 1kg during a year. Culture environment: concrete, fiberglass and earthen ponds. The fish has maximum specific growth in brackish water
Barbus sharpeyi	Dependent on warm and freshwater. Feed: aquatic plants, aquatic insects and small fish Age of maturity: 2 years
Barbus grypus	This species is omnivores and compatible with different conditions. It is one of the most famous freshwater fish in Iran.
Abramis brama	This is feed on larvae of aquatic insects, crustaceans and diatoms. Culture environment: earthen pond
Stizostedion lucioperca	Feed: Larvae from zooplanktons and adults from other fish Age of maturity: 3-5 years
Cichlidae	This fish has a great tolerance to low water quality and uses a wide range of natural food. Many of them are euryhaline. Age of maturity: 6 months
Indian carps	These have been imported to Iran. Age of maturity: 2-3 years
Chanos chanos	The fish is euryhaline and remains alive in low oxygen and different temperatures (15-45 $^{\circ}$C) and it is distributed in Iran.
Rachycentron canadum	Young fish can be cultivated up to 4 kg of weight during 1.5 years. Euryhaline, Carnivorous
Coryphaena hippurus	Food: zooplankton, crustaceans, fish Age of maturity: 4-5 months Fish reached to 2 kg weight during 6 months.
Serranidae	The fish is found a lot in the Persian Gulf and Oman Sea and they are carnivorous.
Mugil cephalus	The fish has a distribution in the Caspian Sea. Age of maturity: 2 years (1-1.2 kg)
Other	*Acanthopagrus latus*t, *Sparidentex hasta, Pampus argenteus*, pearl-making oyster, Lobster, sea cucumber, pike, sturgeons, Crayfish

There is tremendous potential for expansion of aquaculture of brackish water and marine species along the coasts of Iran. The IFO has studied the potential for marine fish farming on the northern coast of the Persian Gulf and the Oman Sea, the results of which indicate good potential for cage culture in various areas. The study reveals that for an initial phase approximately 100,000 tons of fish could be produced in cages.

There are more than 130 species of seaweed found in the Iranian marine waters. *Gracilaria* spp., *Sargassum* spp. and *Eucheuma* spp. are some of the commercial seaweed species. Over the past four years several trials have been carried out on the farming of *Gracilaria* in ponds and the open sea and a pilot project has been initiated to develop commercial seaweed farming (FAO, 2010).

Persian Gulf pearls are well-known on the international markets, however, due to over fishing, oyster stocks have been reduced dramatically. IFRO has conducted various research projects for seed production and in 2004 successfully produced seed. Access to seed production technology could lead, in the future, to pearl culture activity (FAO, 2010).

4 CONCLUSIONS

In recent decades the share of aquaculture in total fisheries production has had good promotion in the world. When the role of aquaculture as a food producing sector is considered in combination with the importance of fish in the diets of many of the worlds' poorest nations, it would seem that aquaculture is assured a central role in efforts to meet the challenge to reduce poverty and hunger by half by 2015 (Sheriff *et al*., 2008).

Iran having abundant inland and marine waters, has a good potential for aquaculture, as shown above, in recent decades, fisheries of Iran have had good growth. Aquaculture contributions to past years have increased noticeably. Today, Iran in culturing rainbow trout in freshwater has the achieved the first rank in the world. Still, aquaculture in Iran is associated with various problems such as low density in fish and shrimp farming, lack of technical knowledge among farmers, diseases especially white spot disease in shrimp culture, unsuitable feed quality especially for starter diets, improper feeding management , low water quality in some of aquaculture sites, low hatching rate in larval production section, low quality seed production, improper brood stock production especially in shrimp aquaculture industry, financial problem, and low cultural species diversity.

For aquaculture production to increase, it is necessary to overcome the above mentioned problems. Slow growth rates of some fish species and losses due to disease are also major problems that currently limit expanded aquaculture production in Iran.

Although cage culture has many roles in world of aquaculture, it still not in a good position in Iran, suggestions that IFO pay more attention to cage culture section. It is clear that in order to ease fishing pressures on marine stocks, the production of marine species (especially finfish) through aquaculture must be accelerated (Tal *et al*., 2009). The farms are required to be equipped with modern equipment for improve fish density. As noted above, seafood has great benefits for consumers. We should be paying more attention to seafood contamination, because some species of fish may contain significant levels of methyl mercury, polychlorinated biphenyls (PCBs), dioxins, and other environmental contaminants (Penny *et al*., 2002).

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مروری بر توسعه آبزی پروری در ایران

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چکیده طی ۱۵ سال اخیر تولید جهانی آبزی‌پروری به بیش از سه برابر رسیده است و انتظار می‌رود سهم آبزی‌پروری در تولید جهانی شیلاتی افزایش یابد. در میان کشورهای مختلف در رابطه با میزان رشد و توسعه آبزی‌پروری تفاوت‌های زیادی وجود دارد. مقاله مروری حاضر سعی دارد پیشرفت‌ها و مشکلات صنعت آبزی پروی ایران در طی سه دهه اخیر را مورد بررسی قرار دهد. کل تولید آبزی پروری ایران در سال ۱۹۹۴ بالغ بر ۲۵۸۰۰ تن بود که تقریباً ۸ درصد کل تولید شیلاتی کشور را شامل می‌شد. در حالی که در سال ۲۰۰۸ این مقدار به بیش از ۱۵۴۰۰۰ تن رسید؛ این رقم معادل ۲۷ درصد کل تولید شیلاتی کشور در سال ۲۰۰۸ است. در طی دهه اخیر سهم تولید در بین گونه‌های پرورشی متفاوت بوده به طوری‌که در سال‌های ۱۹۹۸ و ۲۰۰۸ بالاترین درصد تولید آبزی‌پروری به ترتیب متعلق به کپور نقره‌ای *Hypophthalmichthys molitrix* (۵۰ درصد) و قزل‌آلای رنگین کمان *Oncorhynchus mykiss* (۴۰ درصد) بوده است. نتایج بررسی‌ها نشان می‌دهد که پرورش قزل‌آلای رنگین کمان در طی دو دهه اخیر رشد قابل توجهی داشته است. بنابراین ایران رتبه اول پرورش ماهی قزل‌آلا در آب شیرین را به خود اختصاص داد. در مقابل صنعت آبزی پروری میگوی کشور به دلیل بروز بیماری لکه سفید دچار بحران شد. در حال حاضر آب‌های ساحلی و داخلی کشور پتانسیل بالایی برای توسعه آبزی‌پروری دارند. اخیراً توجه دولت و بخش خصوصی برای آبزی‌پروری معطوف به گونه‌های ماهیان خاویاری نظیر فیل ماهی و باربوس ماهیان معطوف شده است. اگرچه صنعت آبزی‌پروری ایران رشد معنی‌داری طی دهه اخیر داشته اما به نظر می‌رسد با معرفی گونه‌های جدید و غلبه بر مشکلات حاضر صنعت آبزی پروری، تولید آبزی‌پروری ایران به چندین برابر رقم فعلی افزایش یابد.

کلمات کلیدی: آب شیرین، آمار آبزی‌پروری، ایران، توسعه آبزی‌پروری، قزل‌آلای رنگین کمان