Iranian Journal of Fisheries Sciences 7(2) 59-72 2008

Cost factor analysis of Caspian salmon (*Salmo trutta caspius* Kessleri, 1877) fingerling production and release in Iran

H. Salehi

hsalehi_ir@yahoo.com
Iranian Fisheries Research Organization, P.O.Box: 14155-6116
Tehran Iran

Received: September 2006 Accepted: May 2007

Abstract: Iran contributes to the stock enhancement of several economically valuable fish species, including the Caspian salmon, *S. trutta caspius*, by producing and releasing millions of fingerlings into the sea. This work was conducted to determine the production costs of the Caspian salmon fingerlings in the years 2002 and 2003. For this purpose, a questionnaire was prepared and filled in by an expert team using data available in the Kelardasht Caspian Salmon Hatchery and other related departments. Among various expenditures, on average, cost of labor (52%) and cost of feed (16%) had the greatest share. Results showed the average cost of production and release of a single fingerling in Iran was IRRls 6,685, (US$ 0.84) over the 2002-2003. The cost sensitivity of hatcheries production of the Caspian salmon shows that labor cost is the most sensitive, and a 50% increase in the cost of this item increases the total coast by more than 25% followed by feed cost.

Keywords: Economic Analysis, Caspian salmon, Costs, Stock enhancement, Iran

Introduction

Wild-population fisheries are seriously declining worldwide (Botsford *et al.*, 1997; Vitousek *et al.*, 1997; Pauly *et al.*, 1998). Several factors such as irregular fishing, dam construction, sand extraction from river beds, and various forms of pollution cause deterioration in aquatic habitats that affect fish stocks, including the Caspian salmon. Three methods are commonly used to attempt the replenishment of depleted stocks: (i) regulating fishing effort, (ii) restoring habitats critical to one or more life stages of the stock, and (iii) artificially supplementing the reproductive population through restoration or enhancement programs (Leber & Lee, 1997).

Although stock restoration or enhancement is gaining increased popularity and many countries are involved in stock enhancement or reconstruction of economically valuable fish stocks, it is generally not closely monitored or evaluated. Japan has a long history to support and rehabilitate resources of almost 80 species (Fushimi, 2001) with varying results. A major problem in justifying the expense and effort associated with stock enhancement is determining if it is successful. Leber (1999) points out that success has typically been measured by production levels and numbers of fish stocked. However, the success of a stock enhancement endeavor should be evaluated according to the goals of the project (Vea Salvanes *et al.*, 1995; Bell & Gervis, 1999; Kuwada *et al.*, 2000; Ashford & Danzmann, 2001; Rasmussen & Geertz-Hansen, 2001). The goals are often defined as the measurable contribution to the fishery or to the reproductive population.

Among the main issues that should be considered in any stock enhancement plan are the economic aspects in terms of costs and returns, which have been the object of several studies in recent years (Bartley, 1995 & 1999; Hansson *et al.*, 1997; Hilborn, 1998; Sreenivasan, 1988; Ahmad *et al.*, 1998; lorenzen *et al.*, 1998; Pruder *et al.*, 1999; Garaway, 1999; Kitada, 1999; Salehi, 1999, 2003_a, 2004 & 2005_b) and some researchers emphasized the profitability of stock enhancement and stressed that in some species the rate of return of investment was very high (Hansson *et al.*, 1997; Ahmad *et al.*, 1998; Lorenzen *et al.*, 1998; Garaway, 1999; Fushimi, 2001; Lorenzen *et al.*, 2001; Stickney & McVey, 2002). However, the economic analysis of all aspects of stock enhancement is very complicated, expensive, and takes long time to gain satisfactory returns.

Iran contributes to the stock enhancement efforts through artificial breeding of more than thirteen native species and releasing more than 500 million seedlings into the Caspian Sea and the Persian Gulf annually (Bartley, 1995; Shehadeh, 1996; Bartly & Rana, 1997; Abdolhay, 1998; Tahori, 1998; Salehi, 2003_a, 2004 & 2005_b). The natural maturation of the Caspian salmon in the south Caspian Sea seems to be facing serious problems, and there has been no evidence for natural maturation of the Caspian salmon so far (Razavi Sayyad, 1999). The total production of Caspian salmon was between 2-14 tons over the years 1995-2005,

however, it declined from 13 tons in 1995 to less than 3 tons by 2005 (Ghaninejad *et al.*, 2001; Sayyade Burani *et al.*, 2006; FAO, 2004; PDD, 2006). By considering the background of stock enhancement of the Caspian salmon and the result of fishing data, it seems the average catch of almost 6 tons per year over the 1995-2005 has probably been due to the stock enhancement program. Although the quality of the released Caspian salmon fingerlings has increased in the past few years, the quantity of fingerling production has remained constant in Iran, which averaged 350,000 fingerlings by 2003 (PDD, 2005).

Overall, for increasing the productivity and breeding procedure of hatchery production of the Caspian salmon in the Iranian reach of the Caspian Sea, including Guilan, Mazandaran and Golestan provinces, where the government has heavily invested over the last two decades as well as to help clarify the Caspian salmon fingerling production cost, input cost factor and their contributions, this study was carried out.

Materials and methods

The emphasis of the study was focused on selected preliminary investigations together with secondary data analyses. To determine the costs of production of the Caspian salmon fingerlings for the years 2002 and 2003, a questionnaire was prepared in 2004. An expert team comprising of economist, statistician and aquaculturist filled in the questionnaire using data provided by Kelardasht Caspian Salmon Hatchery. Other relevant documents available in different sections of the Iranian Fisheries Organization (IFO), especially accounting, budgeting and stock enhancement offices were also consulted. Secondary data were collected from IFO and its affiliated departments, Iranian Fisheries Research Organization (IFRO) and other organizations, such as FAO. Data were loaded into a Microsoft Excel spreadsheet and all the required functions, particularly the method for cost sensitivity analysis were used for analysis.

Results

Over the years 2002 and 2003, about 344,000 and 325,000 fingerlings of the Caspian salmon were respectively produced in Kelardasht Caspian Salmon Hatchery (Fig. 1). The total expenditure increased by 8% from IRRIs[1] 2,125 million in 2002 to 2,288 million in 2003. The total operation costs increased by 6% and averaged IRRIs 1,920 million over the same period. The two main operation costs were labor and feed that averaged IRRIs 1,152 million and 350 million, respectively (Table 1).

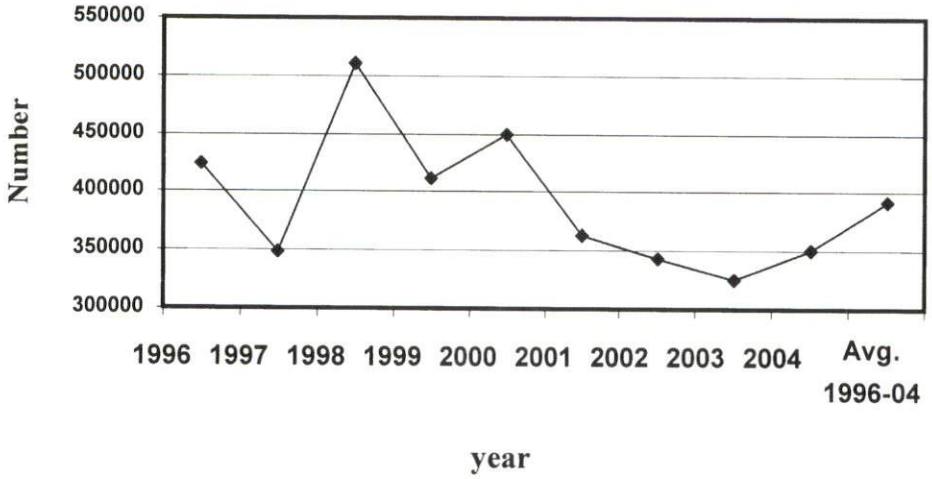


Figure 1: Number of Caspian salmon fingerling production and releasing over the years 1996-2004 in the South Caspian Sea.
Source: PDD, 2005.

1- On average, 1US$= IRRIs 8,000 over the 2002 and 2003.

Table 1: Total expenditures (IRRIs 1,000) of the Caspian salmon fingerling production over the 2002-2003 in Iran.

Year / Cost factors	2002	2003	Mean	SD[1]
Labor	1100910	1203304	1151783	72403
Feed	367678	331709	350830	25434
Maintenance	165774	155560	161073	7222
Energy	70135	121246	94879	36141
Handling & Releasing	76511	77780	77227	897
Chemicals & Drugs	27629	32027	28684	3110
Miscellaneous	51007	54904	52956	2756
Operation costs	1859644	1978818	1919638	84269
Depreciation	265664	308833	286842	30525
Total costs	2125308	2287651	2206480	114794

1- SD= Standard deviation.

2- Depreciation was calculated based on Planning and Management Organization and Aquaculture Department of Fisheries Organization of Iran methods for ponds, buildings and machineries and completed by Salehi, 1999 & 2005.

Over the years 2002 and 2003, the average cost per fingerling production increased by 14% from IRRIs 6,269 in 2002 to 7,123 in 2003. The total operation cost per fingerling production increased by 12% and averaged IRRIs 5,816 over the same period. Labor and feed costs per fingerling production averaged IRRIs 3,489 and 1,063, respectively. Depreciation and maintenance costs per fingerling production averaged IRRIs 869 and 488, respectively (Table 2).

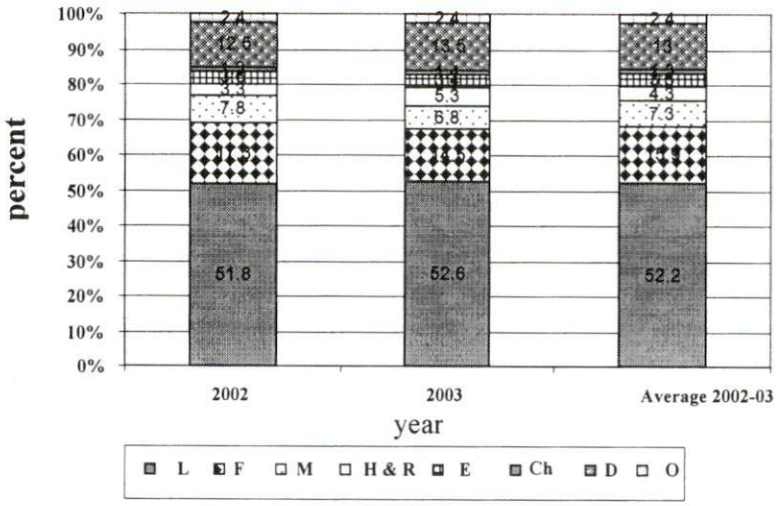
Table 2: Average costs (IRRIs per fingerling) of Caspian salmon fingerling production over the 2002-03 in Iran.

Year / Cost factors	2002	2003	Contribution costs (%)	SD
Labor	3247	3747	52	354
Feed	1085	1033	16	37
Maintenance	489	484	7	4
Energy	207	378	4	121
Handling & Releasing	226	242	11	11
Chemical & Drugs	81	100	1	13
Miscellaneous	150	171	3	15
Operation costs	5485	6161	87	478
Depreciation	784	962	13	126
Total costs	6269	7123	100	604

SD= Standard deviation.

Contribution of the main costs of fingerling production over the years 2002 and 2003 is shown in Table 2. Among various expenditures, on average, the labor cost with 52% and feed costs with 16% of total costs have the greatest share; depreciation (13%), maintenance (7%), handling and releasing (4%), and energy cost (4%) are the other important cost factors (Fig. 3).

The differences between years in contributing cost factor for fingerling production in Iran were negligible (Fig. 2). Operation costs per fingerling production between the succeeding years of 2002-2003 increased by 15% (Table 2). As Table 2 shows, the contribution of feed cost per fingerling production declined from 17.3% of total costs to 14.5%, however the contribution of harvesting and releasing cost increased from 3.3% to 5.3% of total costs over the years 2002-2003.



L: Labor, F: Feed, M: Maintenance, H & R: Handling and Releasing, E: Energy, Ch: Chemical and Drugs, D: Depreciation and O: Other costs.

Figure 2: Contribution of the main costs of Caspian salmon fingerling production over the years 2002-2003 in Iran.

The cost sensitivity of hatchery production of the Caspian salmon shows labor is the most sensitive, which is shown by the shape of labor line and a 50% increase in the cost of this item increases the total cost by more than 25% followed by feed cost (Table 2).

Discussion

Stock enhancement has many socio-economical and environmental advantages and many researchers have discussed the positive effects of stock rehabilitation of sturgeon and bony fishes in Iran (Razavi Sayyad, 1995; Abdolhay, 1998; Danesh, 1998; Tahori, 1998; Hosseini, 1998; Pourkazemi, 2000; Salehi, 1999 & 2003_a; Keyvan, 2002) and other countries (Sreenivasan, 1988; Bartley, 1995 & 1999; Hansson *et al.*, 1997; Leber & Lee, 1997; Ahmad *et al.*, 1998; Lorenzen *et al.*, 1998; Welcomme & Bartley, 1998; Garaway, 1999; Kitada, 1999; Stoner & Davis, 1994; Leber *et al.*, 1996; Leber *et al.*, 1998; Leber, 1996; Lorenzen *et al.*, 2001). To measure the success of Pacific threadfin (*Polydactylus sexfilis*) stock enhancement programe, American researchers in Hawaii considered the increases in its percentage share in fishermen's creels (Ziemann, 2003). Japanese researchers used increases in the catch statistics versus number of seeds released to measure the bay scallop (*Argopecten irradians*) stocking success (Kitada & Fujishima, 1997). In 1999, 30% of the harvested commercial salmon in Alaska was hatchery reared (Stickney & McVey, 2002).

Fish landing data after the establishment of various hatcheries along the Iranian part of the Caspian Sea clearly indicate the success of stock enhancement programs over the last two decades in Iran. This success was also noted for sturgeon by the beach seiners co-operatives (Abdolhay 1998; Tahori, 1998; Fadaee, 2002). In any way, all these important matters were noted to require the sensitivity and foresight of the researchers and fishery managers.

The estimated production cost for the Caspian salmon fingerling (IRRls 6,269 and 7,123 for the years 2002 and 2003, respectively) (Table 2) was higher than the corresponding costs for the sturgeon (IRRls 1,753 and 2,028) and kutum (IRRls 54 and 121) (Salehi, 2005_b & 2006_a). The main reason for higher production cost of

the Caspian salmon fingerling might be the lack of brood stock, the lower quantity of production and the scale of hatchery. As shown in this study (Fig. 2), the major cost in hatchery was labor cost, which averaged IRRIs 3,489 ($US 0.44) for each fingerling, followed by feed, averaging IRRIs 1,063. Compared with cultivation of other aquatic organisms, contribution of labor cost in Caspian salmon fingerling production was also very high; for instance, it was higher than in carp farming by 12% (Salehi, 1999), trout farming by 13% (Salehi, 2005_a), shrimp farming by 17% (Salehi, 2003_b), shrimp hatcheries by 26% (despite employing foreign experts), and sturgeon fingerling production in Iran (Salehi, 2005_b, 2006_b) and sturgeon farming in USA (Katherine *et al.*, 1985) by 32% and 12%, respectively. If the depreciation cost is omitted, the costs of labor and feed may increase to almost 60% and 18%, respectively. It seems the main reason for this higher labor cost can be attributed to the inactivity of the hatcheries during a few months off season, which could be reduced by adopting extra activities in such hatcheries. The cost sensitivity of hatchery production of the Caspian salmon shows labor is the most sensitive, and a 20% decrease in labor cost will lead to a total cost reduction by almost 12% though, reduction in these two major costs may increase productivity of the Caspian salmon hatchery and farm management. Current production and enhancement of the Caspian salmon fingerling and the huge investment suggest that this sector might be expected to become increasingly important in coming years. Future fingerling productions vary widely and will be, to a large extent, dependent on the ability to obtain brood fish from the Caspian Sea as well as government potential investment. Overall, the Caspian salmon rehabilitation industry may benefit from research aimed at developing technically viable production and enhancement systems as did before, improved nutrition, genetic improvement, disease prevention, water quality and industry management.

As for the fish return, it has been estimated that only 0.5% of the Caspian salmon fingerlings released annually return (Sayyade Burani *et al.*, 2006) at age 3-4 years (Karimpour & Hossienpour, 1988), which is 50% lower than the return rate for the Atlantic salmon (Krayushkina, 1999). Considering even the 0.5% return for the Caspian salmon, almost 1,720 fish of 334,000 released fingerlings over the

years 2002-2003 might be expected to return over the years 2006-2007. With an average weight of 2.5kg for each Caspian salmon (Sayyade Burani *et al.*, 2006), the total catch might be valued around IRRls 375 million (US$ 41,625). However, from the economic point of view, the positive effect of stock enhancement of the Caspian salmon in Iran is clear, and it might be necessary to promote low-cost methods for hatchery production as well as providing institutional and policy support to gain satisfactory returns.

Acknowledgment

We would like to gratefully acknowledge the assistance of Fisheries Organisation, Department of Hatching and Releasing, Fisheries Research Organization, and especially Mr Pashazonosi, the head of Kelardasht Hatchery.

References

Abdolhay, H., 1998. Artifical hatching for stock rehabilitation. The 7th National Fisheries Conferences, Responsible Fisheries (in Persian), Shilat, Tehran, Iran, pp.187-205.

Ahmed, I., Bland, S.J.R., Price, C.P. and Kershaw, R., 1998. Openwater stocking in Bangladesh. Experiences from the third fisheries project. FAO Fisheries Technical Paper. No. 374, pp.351-370.

Ashford, B.D. and Danzmann, R.G., 2001. An examination of the post-planting success of hatchery brook char possessing different mitochondrials DNA haplotypes. Journal of Fish Biology. **59:**544-554.

Bartley, M.D., 1995. Marine and coastal area hatchery enhancement programmes: Food security and Conservation of Biological Diversity, Paper prepared for Japanese/FAO Conference on Fisheries and Food security Kyoto, Japan, Dec. 1995, 15P.

Bartly, M.D. and Rana, K., 1997. Stocking inland waters of the Islamic Republic of Iran, FAO. 5P.

Bartley, M.D., 1999. Marine ranching: current issues, constraints and opportunities. In Marine ranching; FAO Fisheries Circular., No. 943, pp.28-43.

Bell, J.D. and Gervis, M., 1999. New species for coastal aquaculture in the tropical Pacific: Constraints, prospects, and considerations. Aquaculture International. **7:**207-223.

Botsford, L.W., Castilla, J.C. and Peerson, C.H., 1997. The management of fisheries and marine ecosystems. Science. **277:**500-515.

Danesh Khoosh Asl, A., 1998. The role of stock enhancement of kutum on quality and quantity of resources in the Caspian Sea. The 7th National Fisheries Conferences; Responsible Fisheries. Shilat Company, Tehran, Iran, pp.207-219. (in Persian).

Fadaee, B., 2002. The survey of probability role of beach seine net on sturgeon resources. International Sturgeon Research Institute, Rasht, Iran, 25P. (in Persian).

FAO , 2004. FISHSTAT, FAO Organization, Rome, Italy.

Fushimi, H., 2001. Production of juvenile marine finfish for stock enhancement. Japanese Aquaculture, **200:**33-53.

Garaway, J., 1999. Small water body fisheries and the potential for community-led enhancement: Case study from the Lao PDR, PhD Thesis, University of London, 414P.

Ghaninejad, D., Moghim, M., Sayyad Burani, M., and Abdulmaleki, S., 2001. Stock enhancement evaluation, Bony Fishes Research Center, Rasht. 98P. (in Persian).

Hansson, S., Arrhenius, F. and Nellbring, S., 1997. Benefits from fish stocking experiences from stocking young-of-the year pikeperch to a bay in the Baltic Sea. Fisheries Research, **32:**123-132.

Hilborn, R., 1998. The economic performance of marine stock enhancement projects. Bulletin of Marine Science, **62:**661-674.

Hosseini, M., 1998. The end of unresponsible sturgeon fishing. The 7th National Fisheries Conferences; Responsible Fisheries, Shilat Company, Tehran, Iran, pp.115-128 (in Persian).

Karimpour, M. and Hossienpour, N., 1988. Caspian Salmon. IFRO. 134P. (in Persian).

Katherine, J., Shigekawa, S. and Logan, S., 1985. Economic analysis of commercial hatchery production of sturgeon. Aquaculture, 51;299-312.

Keyvan, A., 2002. Introduction to biotechnology of cultured sturgeon, Azad University Lahijan, Iran, 270P. (in Persian).

Kitada, S., 1999. Contribution of hatchery enhancement and comperehesive fishery resource management. Marine ranching: global perspective with emphasis on the Japanese experience, FAO. Fisheries Circular. **943:**98-130.

Kitada, S. and Fujishima, H., 1997. The stocking effectiveness of scallop in Hokkaido. Nippon Suisan Gakkaishi. **63:**686-693.

Krayushkina, L.S., 1999. The survey of osmoregulation system of fishes. Translated by Danesh Khosh Asl, A. and Moradi, M. 1999. Bony Fishes Research Center, Rasht, Iran, 83P. (in Persian).

Kuwada, H., Masuda, R., Shiozawa, S., Kogane, T., Imaizumi, K. and Tsukamoto, K., 2000. Effect of fish size, handling stresses and training procedure on the swimming

behavior of hatchery-reared striped jack: implications for stock enhancement. Aquaculture. **185:**245-256.

Leber, K.M., 1999. Rationale for an experimental approach to stock enhancement. *In*: Stock enhancement and sea ranching (B.R. Howell; E. Moksness and T. Svåsand, eds.), Blackwell Science Ltd., Oxford, UK. pp.63-75.

Leber, K.M. and Lee, C.S., 1997. Marine stock enhancement potential with striped mullet, *Mugil cephalus*, in Hawaii. Bulletin of National Research Institute for Aquaculture, **3:**117-134.

Leber, K.M., Arce, S.M., Sterritt, D.A. and Brennan, N.P., 1996. Marine stock enhancement potential with striped mullet, *Mugil cephalus*, in Hawaii. Fisherie Bulletin, **94:**452-471.

Leber, K.M., Brennan, N.P. and Arce, S.M., 1998. Recruitment patterns of cultured juvenile Pacific threadfin, *Polydactylus sexfilis* (Polynemidae), released along sandy marine shores in Hawaii. Bulltin of Marine Science, **62:**389-408.

Lorenzen, K., Juntana, J. and Tourongruang, D., 1998. Assessing culture fisheries practices in small water bodies: a study of village fisheries in Northeast Thailand, Aquaculture Research, **29:**211-224.

Lorenzen, K., Amarasinghe, U.S., Bartley, D.M., Bell, J.D., Bilio, M., De Silva, S.S., Garaway, J.C., Hartmann, W.D., Kapetsky, J.M., Laleye, P., Moreau, J., Sugunan, V. V. and Swar, D.B., 2001. Strategic review of enhancements and culture-based fisheries. Aquaculture in the third millennium, Subasinghe R., Bueno P., Phillips M., Hough C., McGladdery S. and Arthur R., NACA/ FAO, Bangkok, Thailand, 2001, pp.221-237.

Moghim, M., 1999. Final report of statistics and biologic of sturgeon fish. Mazandaran Research Centre. 98P. (in Persian).

Planning and Development Department (PDD), 2005. Annual report of Shilat. Shiat Company, Tehran, Iran, 40P. (in Persian).

Planning and Development Department (PDD), 2006. Annual report of Shilat. Shiat Company, Tehran, Iran, 63P. (in Persian).

Pauly, D., Christensen, V., Dalsgaard, J., Froese, R. and Torres, F.J., 1998. Fishing down marine food webs. Science. **279:**860-863.

Pourkazemi, M. , 2000. Management and enhancement of sustainable resources. Aquaculture Department, Tehran, Iran, No. 18. pp.17-30. (in Persian).

Pruder, G.D., Ziemann, D.A., Leber, K.L., Lotz, J.L., Hawkins, W.E. and Conquest, L.D., 1999. U.S. Gulf of Mexico marine stock enhancement five-year program: 1999-

2004. Program management for planning, execution, review, and evaluation. Bulletin of National Research Institute for Aquaculture. **1:**89-99.

Rasmussen, G. and Geertz-Hansen, P., 2001. Fisheries management in inland and coastal waters in Denmark from 1987 to 1999. Fisheries Management of Ecology. **8:**311-322.

Razavi Sayyad, B., 1995. Kutum fish0. IFRO.Tehran, Iran, 165P. (in Persian).

Razavi Sayyad, B., 1999. Introduction to ecology of the Caspian Sea, kutum fish. IFRO. Tehran, Iran, 90P. (in Persian).

Salehi, H., 1999. A strategic analysis of carp culture development in Iran, PhD thesis, University of Stirling. Stirling, UK, 328P.

Salehi, H., 2003a. Economics analysis of kutum (*Rutilus frisii kutum*) fingerling production and releasing in Iran. Iranian Journal of Marine Science, pp.35-45. (in Persian)

Salehi, H., 2003b. The needs of research on aquaculture economics in Iran, Iranian Journal of Fisheries Sciences, IFRO. Tehran, Iran, pp.75-96. (in Persian).

Salehi, H., 2004. An economic analysis of carp culture production costs in Iran, Iranian Journal of Fisheries Sciences, IFRO., Tehran, Iran, pp.1-24.

Salehi, H., 2005a. An economic analysis of trout farming production in Iran, World Aquaculture 2005, May 2005, Bali- Indonesia, 35P. (unpublished).

Salehi, H., 2005b. An economic analysis of fingerling production of sturgeon in the south Caspian Sea over the years 2002-03. The 5th International Symposium on Sturgeon, Ramsar, 9-13 May, Iran, pp.319-324.

Salehi, H., 2006a. Comparative economics of kutum (*Rutilus frisii kutum*) fingerling production and releasing over the 2001-2003 in North of Iran. 13P. (in press).

Salehi, H., 2006b. Economics analysis of sturgeon fingerlings production in Iran, Iranian Journal of Fisheries Sciences. IFRO. Tehran, Iran, pp.67-80. (in Persian).

Sayyade Burani, M., Abtahi, B., Bahmani, M., Kazemi, R., Dazhandian, S., Daghigh Ruhi, J. and Amiri, A., 2006. Effects of weight on osmoregulatory ability of *Salmo trutta caspius* juveniles. Iranian Sientific Fisheries Journal, Vol.14, Winter 2006, pp.81-96.

Shehadeh, Z.H., 1996. Major trends in global aquaculture production and summary overview of the Gulfs (Persian Gulf and Gulf of Oman) area (1984 to 1994), TOFC Committee for development and management of the fishery resources of the Gulfs, Cairo, Egypt, 1-3 October, 8P.

Sreenivasan, A., 1988. Fish stock enhancement in larger Indo-Pacific inland water bodies using carps and tilapias, FAO Fisheries Reports, No. 405, pp.6-33.

Stickney, R.R. and McVey, J.P., 2002. Responsible marine aquaculture, CABI Publishing, Wallingford, Oxen, UK.

Stoner, A.W. and Davis, M., 1994. Experimental outplanting of juvenile queen conch, *Strombus gigas*: comparison of wild and hatchery-reared stocks. U.S. National of Marine Fisheries Service, Fisheries Bulletin. **92:**390-411.

Tahori, B.H., 1998. Sturgeon hatching in South Caspian Sea. The 7th National Fisheries Conferences, Responsible Fisheries. Shilat Company, Tehran, Iran, pp.221-244. (in Persian).

Vea Salvanes, A.G., Aksnes, D., Helge Fossa, J. and Giske, J., 1995. Simulated carrying capacities of fish in Norwegian fjords of Fisheries Oceanography, 4:17-43.

Vitousek, P.M., Mooney, H.A., Lubchenco, J. and Meilillo, J.M., 1997. Human domination of earth's ecosystems. Science. **277:**494-499.

Welcomme, R.L. and Bartley, D.M., 1998. Current approaches to the enhancement of fisheries. Fisheries Management and Ecology. **5:**351-382.

Ziemann, D.A., 2003. Impact of hatchery releases on the recreational fishery for Pacific threadfin (*Polydactylus sexfilis*) in Hawaii. UJNR. Technical paper report, No. 30, pp.75-86.