Iranian Journal of Fisheries Sciences 9(2) 245-254 2010

Effect of the selected physico-chemical parameters on growth of rainbow trout (*Oncorhynchus mykiss*) in raceway system in Iran

Moogouei R.[1*]; Karbassi A.R.[2]; Monavari S.M.[3]; Rabani M.[1]; Taheri Mirghaed A.[4]

Received: February 2008 Accepted: December 2009

Abstract

A study was conducted to evaluate the correlation between selected physico-chemical parameters of water and their effects on growth of Rainbow trout (*Oncorhynchus mykiss*) in raceway system in the area of Sarab Gerdu, Iran. The samples were collected from twenty raceways (270- day old fish, surface area 55m^2; flow rate 150 ls^{-1}; total production 15 T). Physico-chemical parameters were the fluctuations of total ammonia nitrogen, dissolved oxygen, turbidity, nitrogen (nitrates), phosphorous (phosphates), total dissolved solids, electrical conductivity, fluoride, boron, pH, temperature, total hardness, and alkalinity. Multivariate analyses were conducted employing three categories of parameters including A, B and C. The results of the study showed that temperature and pH variations were similar. Dissolved oxygen with negative similarity coefficient, _0.618 was located in the third category while positive coefficient, 0.479 of other parameters except for pH and temperature (second category) and dissolved oxygen (third category) was located in the first one. pH value was not in a standard range due to increase in water temperature. This, in turn had impact on other parameters, such as unionized ammonia, a toxic chemical, to fish. Our result demonstrated that nitrate concentration is the most significant chemical parameter for fish growth in this area. Similarity, increase in concentration of dissolved oxygen in the water (from 3.30 mgl^{-1} up to 12 mgl^{-1}) was necessary to promote productivity.

Keywords: multivariate analyses; raceway system; aquaculture; rainbow trout.

1-Islamic Azad University, North Branch of Tehtan, Faculty of Marine Sciences, Tehran, Iran.
2-Tehran University, Faculty of Environment, Tehran, Iran.
3-Islamic Azad University, Science and Research Branch of Tehran.
4-University of Tehran, Fish disease & health dept. Tehran,Iran.
[*]Corresponding author's email: r_moogoui@iau-tnb.ac.ir

[DOR: 20.1001.1.15622916.2010.9.2.5.9]

Introduction

Emphasis on aquatic protein consumption in the 4th national five-year economic, social and cultural development plans, due to human health benefits and food stuff values encourage supplement of terrestrial protein production systems with aquatic protein production facilities (Anon., 2005a). Water quality determines to a great extend the success or failure of a fish culture operation (Piper *et al*., 1982). Water is an essential requirement for fish farming, so any proper-prepared plan for aquaculture must describe the quality and quantity of water available for this purpose (Summerfelt, 2000). The achievement of rainbow trout as an aquaculture species is dependent on technological advances and production of fish with great amounts of high quality lean muscle (Johansen & Overturf, 2005, Cohen *et al*., 2005). Moreover it has lately been accepted that the welfare of farmed fish merits consideration, where welfare can be considered to represent the physical and mental state of animal is relative to its environment. Proper stocking density has been emphasized due to an apparent increasing on mortality in the likelihood of poor welfare at higher stock densities. Stocking density practices differed noticeably between individual farms with maximum densities varying from <20 to >80 kgm^{-3}. Stocking density was linked to type of production, with farms producing fish for the table market operated at higher densities than farms rearing fish for the restocking/fisheries market (Ellis, *et al*., 2002; North *et al*., 2006). The main source of ammonia in water of a high stocked density cultured pond occurred in the effluent of a raceway is excreted from fish, typically via their gills. Animals produce ammonia as a byproduct of protein metabolism (Hargreaves *et al*., 2005). What is measured by chemical analysis is called total ammonia nitrogen (TAN) because it includes two forms of ammonia: unionized form (NH_3), and ammonium ion ($NH4^+$). Unionized ammonia is toxic to fish (Summerfelt., 2000). In other words, studies on spatial changes in physical and chemical characteristics of water which is used for aquaculture by raceway system present essential information for best management options at all time. Moreover in restricted exchange environments, there is a risk of high levels of nutrients accumulating in one area, causing hypernutrification and potentially creating undesirable effects (Midlen & Redding, 1998; MacGravin, 2000; Carrol *et al*., 2003). The objective of this work was to evaluate important water physical and chemical factors in rainbow trout culture. Although the quantity of water available is of importance, only water quality parameters are considered here.

Materials and methods

The area of study is placed in Lorestan Province (Fig. 1). It lies between latitudes of 46°, 50́ to 50°, 01́ and longitudes of 32°, 40́ to 34°, 32́. Temperature of the area is between a maximum of 20.4°C and a minimum of

[DOR: 20.1001.1.15622916.2010.9.2.5.9]

7.6°C and average temperature is 14°C. Annual precipitation is 612.7 mm and average sunny hours per month is 268h. The number of icy days in the study field is 111 per year (Anon., 2005).

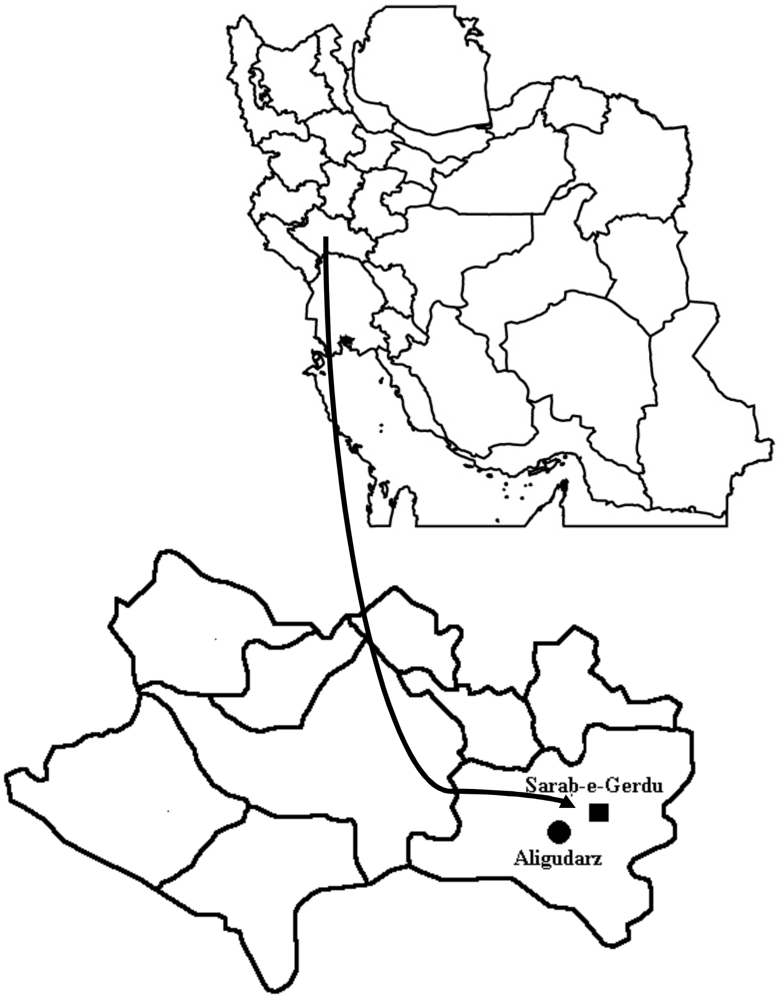

Figure 1: The area of Sarab Gerdu in Iran

Initially water flow delivered to the farm raceways was determined. Water samples were collected from four sites inside and outside raceways. Raceways were located in four rows up – down. The last station was in the river that receives aquaculture waste water. Selected parameters were: temperature, turbidity, total ammonia nitrogen, phosphate, alkalinity, dissolved oxygen, nitrate, free chlorine residue, total hardness, total dissolved solids (TDS), fluoride, boron, pH and electric conductivity (EC).which were measured according to APHA-standard method (Greenberg *et al.*, 1992). Temperature and pH were measured by YSI model.Nitrate was determined using the reduction column while ammonium was measured using Oriole model EA 940

Ion analyzer and 95-12 ammonia electrode, standard method 4500-NH_3. Level of PO_4^{-3} was determined using the standard molybdenum blue method. The determination of DO was carried out using the Winkler method according to Strickland & Parsons (1972) and Bryan and Williams (1976). In order to measure the amount of boron and fluoride, they were analyzed using ICP with mass spectrometry. Free chlorine residue was determined using chlorometer model 1000-PT. Total hardness was measured using APHA 3111B method while electrical conductivity (EC) was determined using APHA 2510B method. Alkalinity measured by titration. Furthermore TDS and turbidity were determined using APHA 2540C and APHA 1992 method. Each experiment was conducted in three replications. Statistical analyses (mean water quality parameters, standard deviations and correlation coefficients) were evaluated in Explore software package. Data were analyzed by weighted pair group multivariate Cluster analysis (Davis, 1973).

Result

Water sample analyses data were summarized in Table 1. Spatial variation of the parameters implied that the third row of raceways had more critical condition compared to the first row. The rate of change and similarity between the parameters were given in Fig.2. The measured parameters were compared with water quality standards (Table 3). Tables 1 and 2 showed the temperature in raceways varied between 13.00 °C up to 14.10 °C (13.80 ±0.51). The results of multivariate analysis are in Fig. 2. This dendogram separates dissolved oxygen from other parameters, showing its crucial role in raceway aquaculture. Temperature and pH in one group were placed next in importance. Finally nitrogen showed a small difference from other parameters. So after DO, temperature, pH, Cl and nitrogen can be recognized as an influencing parameter in raceway management. Other parameters were similar, therefore were considered as one group.

[DOR: 20.1001.1.15622916.2010.9.2.5.9]

Table 1: Summary of water quality data for aquaculture in the present study

Parameter:	Temperature (°C)	Turbidity (NTU)	Total Ammonia Nitrogen	Phosphorus (phosphate) (mgl^{-1})	Alkalinity (mgl^{-1})	Dissolved Oxygen (mgl^{-1})	Nitrogen (nitrate) (mgl^{-1})	Free Chlorine residue (mgl^{-1})	Total hardness (mgl^{-1})	Total Dissolved Solids (mgl^{-1})	Fluoride (mgl-^{1})	Boron (mgl^{-1})	pH	Electric Conductivity (dsm^{-1})
min valve	13.00	Very low	1.25	0.06	250	2.60	4.40	8.85	122.50	218.24	0.002	0.001	8.27	341
max valve	14.10	Very low	4.63	0.09	259	3.90	4.90	23.01	203.50	286.72	0.004	0.001	8.44	448
mean valve	13.80	Very low	2.20	0.07	255	3.30	4.55	17.70	154.30	237.28	0.0025	0.001	8.38	371
Standard deviation	0.51	0.00	1.62	0.01	13.98	0.57	0.24	6.29	34.58	33.11	0.001	0.00	0.07	0.05

Table 2: Comparison between water quality standards and measured values for rainbow trout culture in the present study (mgl^{-1})

Variable	Ground water[a]	Ground water in the Sarab Gerdu	Raceways (Sarab Gerdu)	Best exposure Levels[b]	Acceptable Continuous exposure levels[b]	Levels associated with fish kill[b]
Temperature (°C)	Varies latitudinal and by depth of well	13.0	13.95	15.0	10 to 16	>25.7
Turbidity[c]	Low(clear water)	Low(clear water)	Low(clear water)	Low(clear water)	<25	It has no significant effect
UIA	0	0.0800	0.0950	0	0.0125 to 0.0200	>0.32 0 to 0.02 tolerance level
Phosphate	<surface water	0.060	0.065			0.02 to 4 phosphorus 0.1 phosphate
Alkalinity	Low in granitic or shale, medium to high in limestone aquifers	250.0	253.5	181.0	20 to 300	
DO	<1	3.90	3.35	7 to 13	<16 to <6	<3
Nitrate	Variable	4.5	4.4	<0.55	<50	>1000
Total hardness	50 to 250	122.50	145.75	50 to 400	>20	>800
TDS	Variable	218.24	222.08		<400	>500
pH	<7	8.27	8.42	6.5 to 8.5	5.5 to 9	<5.5 or >9

a: summerfelt, 2000
b: Boyd & Tucker, 1998
c:Karim1997

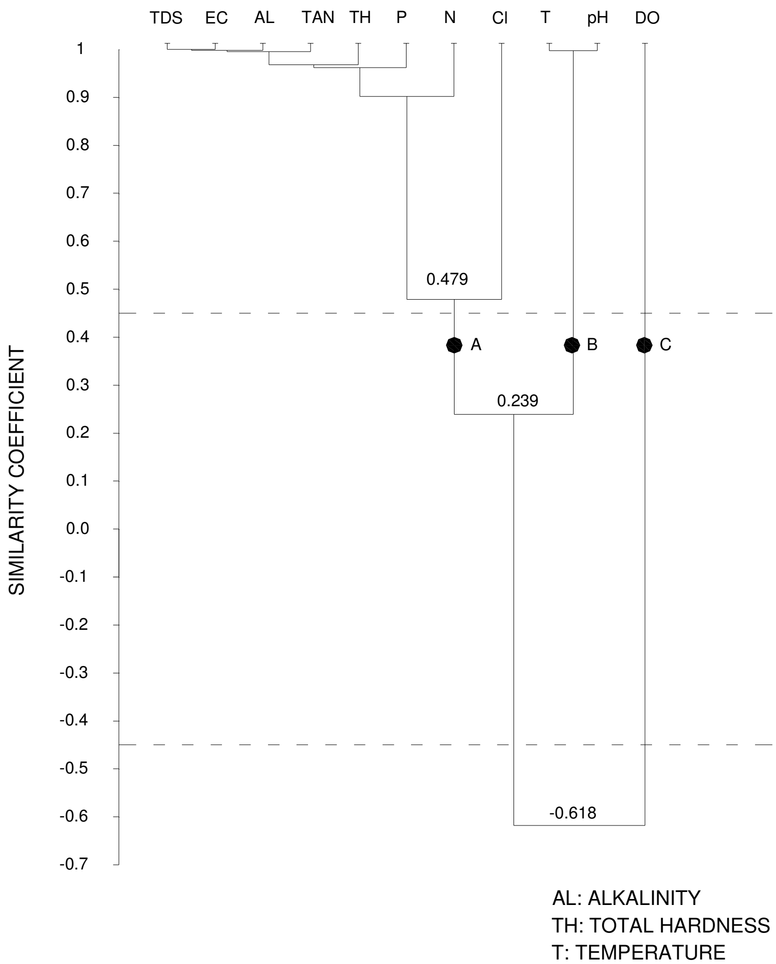

Figure 3: Dendogram of cluster analysis of raceway water quality parameters in the present study

Discussion

According to Boyd and Tucker (1998) best growth of rainbow trout occurs in a temperature range of 10 °C up to 16 °C. pH varied from 8.27 to 8.44. It seems that temperature is more critical than pH in water management of these raceways. DO concentrations need to be increased? Increasing in nitrates and phosphates due to their adverse impact in the environment also has to be monitored (Lin *et al*., 2001; Bricker *et al*., 2003; Ferreira *et al*., 2007). Turbidity is in allowable range while sun rays directly contact fish skin through the water. According to the dendogram in Fig.2, the similarity coefficient between EC and TDS was 1, which means EC changes due to environmental fluctuations the same as TDS. The similarity coefficient of alkalinity with these two parameters was 0.998. TAN with similarity

[DOR: 20.1001.1.15622916.2010.9.2.5.9]

[DOR: 20.1001.1.15622916.2010.9.2.5.9]

coefficient equal to 0.995 joints with previous parameters. As it is illustrated in Fig.2 the similarity coefficients of total hardness, phosphorous, nitrogen with previous parameters were equal to 0.968, 0.962 and 0.902 respectively. The similarity coefficient of chlorine was 0.479 which has a moderate coherence (not high) with seven previous parameters. These eight parameters gather together in a cluster named "A". In this analysis the similarity coefficient between pH and temperature was 0.997 and these two parameters made the second cluster named "B". pH and temperature have a high similarity coefficient and their response to environmental stimulus is very similar. The similarity coefficient of clusters "A" and "B" was 0.239 showing these two clusters do not have a noticeable similarity. In the third cluster there was only one parameter (DO), which had a negative similarity coefficient. The similarity coefficient of this cluster with other two clusters was _0.618. It could be implied that changes of DO concentration against the other environmental parameters is in a reverse phase, i.e., an increase in concentrations of the parameters in "A" and "B" clusters will cause a decrease in DO. Best pH is registered from 6.5 through 8.5 (Boyd, & Tucker, 1998). The reason behind presence of temperature and pH in one cluster is that an increase in temperature would enhance pH value and consequently pH can become out of recommended range. Sudden changes in pH of 1.7 would result in fish mortality (Summerfelt, 2000). Furthermore, many studies have been conducted to investigate the basic physiological requirements of fish seed including water quality management during transport. These compose lowering of temperature (Phillips & Brockway, 1954; Norris *et al*., 1960; Sing *et al*., 2004). Toxicity of other parameters such as unionized ammonia and chlorine would be affected by pH. Department of the Environment of Iran (DOE) standards allows a pH of 6 to 8.5 in agricultural waters (Anonymous, 2005b). The turbidity of water is minuscule in these raceways, therefore sun lights passed deeply through the water. For prevention of sunburn injuries to the fish stock, it was necessary to protect them from the direct sunlight, especially during the hot summer hours. The minimum concentration of DO for fish health is about 6 mgl^{-1} (Summerfelt, 2000). The results of the present study showed that the concentration of DO varied from 2.6 to 3.9 mgl^{-1} with an average of 3.3 mgl^{-1} and a standard deviation of 0.57. Mortality of rainbow trout may initiate below 3.0 mgl^{-1} (Summerfelt, 2000). It is essential to install aeration system in these raceways because the minimum dissolved oxygen was below the mortality limit. Lowering the stock density could prevent stress on fish. Furthermore correlation coefficient of DO with other parameters was negative. It means that increasing in concentrations of these parameters would decrease the concentration of DO. In fact concentration of DO was the most critical parameter for water quality management. Total ammonia nitrogen varied from 1.25 mgl^{-1} to 4.63

mgl^{-1} with an average of 2.20 and a standard deviation of 1.62. According to Iran's DOE standards for total ammonia nitrogen, the concentration of this parameter in waters that use for agriculture has to be 0 (Anonymous, 2005b). Continual cleaning of raceways from fish excretion cause fish stocks to be healthy. On the other hand, establishment of a proper waste water management system can decrease adverse environmental impacts of aquaculture in the area. Phytoremediation offers a safe alternative to conventional cleanup technique. Furthermore increase in ammonia, enhance the water pH and therefore pH could go out of allowable range. With an increase in these (pH or ammonia) parameters concentration of DO decreases and the condition can become hazardous for fish health. Alkalinity varied from 250 mgl^{-1} to 259 mgl^{-1} with an average of 255 and a standard deviation of 13.98. The best concentration of alkalinity for trout farming is reported to be 181 mgl^{-1} (Table 2), suggesting that there is no risk to the water quality as far as alkalinity is concerned. Total hardness varied from 122.5 mgl^{-1} up to 203.5 mgl^{-1} (with an average of 154.3 and a standard deviation of 34.58). The best total hardness for rainbow trout is equal to 50 up to 400 mgl^{-1} (Karbassi, *et al.*,2007). As it could be seen, hardness in the study area was more than ideal hardness, but results of the study showed that it is not considered to be a limiting parameter. TDS in the ground water which is used for aquaculture can be more than 1500 mgl^{-1} NaCl (Summerfelt, 2000). Results of the present study showed a TDS range from 218.24 mgl^{-1} to 286.72 mgl^{-1} with an average of 237.28 and a standard deviation of 33.11. Average concentration of fluoride was 0.0025 mgl^{-1} with standard deviation of 0.001 and average concentration of boron was 0.001 mgl^{-1} with standard deviation of 0.000. The necessary concentration of boron for rainbow trout culture is equal to 0.2 up to 0.6 mg per Kg weight of fresh fish (Eisler, 1990). According to the DOE standards of Iran allowable concentration of boron is equal to 1mgl^{-1} in water resources that are used for agriculture. As a result it could be determined that boron should be added to the fish food. The best concentration of EC for rainbow trout culture is equal to 432 dsm^{-1} (Karami, 1997) and results of the present study showed EC to be varied from 341 up to 448 dsm^{-1}(with an average of 371 and standard error of 0.05). The results imply that this resource initially is suitable comparing with other groundwater resources but dissolved oxygen concentration have to be increased in water. Moreover control of an increase in temperature and pH due to their adverse impact on fish health and their effect on other parameters is important.

Acknowledgements

The authors wish to thank Mr. A. Goroei and the Sabzazma Laratory for their field and lab assistance. Roshanak Moogouei prepared figures. Thanks are due to Fereshteh Heidari for editing the manuscript. Special thanks to Mr. Morteza Heidari for his technical assistance.

References

Anonymous, 2005a. Iran Management and Planning Organization, Statistic Year Book Of Lorestan Management and Planning Organization of Lorestan Province, 29P (In Persian).

Anonymous, 2005$_{b}$. Iran Environmental Protection Laws, Department of the Environment, Tehran, Iran, 61P (In Persian).

Boyd, C. E., and Tucker, C. S., 1998. Pond Aquaculture Water Quality Management, Kluwer Academic Publishers, USA. pp. 507-512.

Bricker, S.B., Ferreira, J.G., Simas, T., 2003. An integrated methodology for assessment of estuarine trophic status. Ecological Modelling 169 (**1**): 39–60.

Bryan, J.P., Williams, P.J., 1976. A Winkler procedure for making precise of oxygen concentration for productivity and related studies. Journal of Experimental Marine Biology and Ecology **21:** 191-197.

Carrol, M. L., Cochrane, S., Fieler, R., Velvin, R., White, P., 2003. Organic enrichment of sediments from salmon farming in Norway: environmental factors, management practices, and monitoring techniques, Journal of Aquaculture **226**: 165–180.

Cohen, J., Samocha, T.M., Fox, J.M., Gandy, R.L., Lawrence, A.L., 2005. Characterization of water quality factors during intensive raceway production of juvenile *Litopenaeus vannamei* using limited discharge and biosecure management tools, Aquacultural Engineering **32:** 425–442.

Davis, J. C., 1973. Statistics and data analysis in geology. Weily Intl., USA.

Eisler, R., 1990. Boron Hazards to fish, wildlife, invertebrates: A synoptic Review. U.S. Fish and Wildlife Service, Patuxent Wildlife Research Center, Maryland, USA.

Ellis, T., North, B., Scott, A.P., Bromage, N.R., Porter, M., Gadd, D., 2002. The relationships between stocking density and welfare in farmed rainbow trout. Journal of. Fish Biology **61:** 493–531.

Ferreira, J.G., Hawkins, A.J.S., Bricker, S.B., 2007. Management of productivity, environmental effects and profitability of shellfish aquaculture, the Farm Aquaculture Resource Management (FARM) model, Aquaculture **264:** 160–174.

Greenberg, A.E., Clesceri, L.S., Eaton, A.D., 1992. Standard Methods for the Examination of Water and Wastewater, 18th ed. American Public Health Association Publication (APHA), Washington DC.

Hargreaves, J.A., Tucker C.S., Thornton, E.R., Kingsbury, S.K., 2005. Characteristics and sedimentation of initial effluent discharged from excavated

Johansen, K., A., and Overturf, K., 2005. Sequence, conservation, and quantitative expression of rainbow trout Myf5, Comparative

Biochemistry and physiology, Part B. Elsevior Publishers, USA.

Karami, A., 1997. Water management and oxygen adjustment for cool water fishes, pp. 25-36. Aquaculture department, Iran fishery Organization, Tehran, Iran.

Karbassi, A., Monavari, S., M. and Moogouei, R., 2007. Strategic Management in the Environment, pp. 174. Kavosh Ghalam publication, Tehran, Iran.

levee ponds for channel catfish, Aquacultural Engineering **33:** 96–109.

Lin, K.C., Shrestha, M.K., Yi, Y., Diana, J.S., 2001. Management to minimize the environmental impacts of pond effluent: harvest draining techniques and effluent quality, Aquacultural Engineering **25:** 125–135.

MacGarvin, M., 2000. Scotland's Secret, Aquaculture, Nutrient Pollution, Eutrophication and Toxic Blooms. World Wildlife Fund, Perth, Scotland. 21P.

Midlen, A., and Redding, T., 1998. Environmental Management for Aquaculture. Chapman & Hall, London, UK. 223 P.

Norris, K. S., Brocato, F., McFarland, W. N., 1960. A survey of fish transportation methods and equipment. Calif. Fish Game **46:** 5-33.

North, B. P., Ellis, T., Turnbull, J. F., Davis, J., Bromage, N. R., 2006. stocking density practices of commercial UK rainbow trout farms, aquaculture **259:** 260-267

Phillips A. M., and Brockway, D. R., 1954. Effects of starvation, Water temperature and sodium amytal on the metabolic rate of brook trout. Fish-Cult. **16:** 65-68.

Piper, R. G., McElvain I. B., Orme L. E., McCraren J. P. , Flower L. G., and Leonard J. R., 1982. Fish hatchery management. U. S. Fish and widelife Service, Washington, D. C. USA.

Sing, R. K., Vartak, V. R., Balang, A. K., Ghughuskar, M., 2004. Water quality management during transportation of fry of Indian major carps, Calta calta (Hamilton), Labeo rohita (Hamilton) and Cirrhinus mrigala (Hamilton), Journal of Aquaculture, **235:**297-302.

Strickland, J. D. H. and Parsons, T. R., 1972. A Practical Handbook Of Seawater Analysis, second ed. Fisheries Research Board of Canada Bulletin, Ottawa, Canada.

Summerfelt, R. C., 2000. Water Quality Considerations for Aquaculture. Department of Animal Ecology, pp. 2-7. Iowa State University, Ames, USA.