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A Comparative Study on Productivity of Salmon Aquaculture in Conventional and PLC-equipped Ponds

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Abstract

Population growth and insufficient food particularly high-quality protein resources over recent decades have led to greater attention paid to consumption of aquatic species. In this respect, Lorestan provides a huge potential for rearing coldwater fish especially salmons. This comparative study revolves around the productivity of salmon aquaculture in conventional and PLC-equipped ponds across several Lorestan towns including Khorramabad, Selseleh, Dalfan, Azna and Aligudarz. For that purpose, there were three major concepts involved in this study; production function, efficiency and total factor productivity. The results demonstrated that water consumption was steadily lower in the PLC-equipped ponds, thus cutting down on costs. The mortality rate in this method was low and the final yield was high due to several factors including 1) production per unit (hectare) was 2365, whereas it was at most 2078 in the conventional method, 2) the daily growth rate was averagely higher, so that fish body weights reached 350 g at the end of each period, 3) the survival percentage in this method was 100 in case of numerous ponds, suggesting the desirability of such method. Therefore, it can be stated that productivity of fish rearing ponds is remarkably higher supported by PLC methods as compared to the conventional methods. In order to measure the total factor production, the Cobb-Douglas function was employed to find out labor, fish fry, water flow rate, useful area and food left a positive impact on the fish production function by 17, 28, 29, 43 and 49 percent, respectively. Efficiency is another aspect of comparing the two methods. It can be divided into three components including technical, allocative and economic efficiency. Moreover, the PLC-equipped ponds are more efficient than the conventional methods.

Keywords: salmons; PLC-equipped ponds; production function; productivity; efficiency.

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Introduction

The ever-increasing world population growth has made food supply and access to nutritional sources a major preoccupation for humans today. Pisciculture is a common method of supplying protein needs for humans (Abdollah-Mashaei, 2007). As an essential source of animal protein right next to rice, fish constitutes the nutritional diet for low-income families in many developing nations. The soaring world population inevitably leads to higher demands for fish production (Alibeigi, 1996). Statistics suggest that pisciculture has experienced the fastest growth as compared to other food production industries. According to the FAO report (2004), the total aquaculture production in 1996 was 7.26 million tons, whereas it went up to 37 million tons later in 2001. Such growth rate can be associated with a combination of several factors as follows: World population growth, declining traditional fishing (Caddy, Griffiths, 1995), changing production patterns in developed countries (Lem, Shehadeh, 1997; Tacon, 1997). Over 36 million people around the world are directly employed in the fishery and aquaculture sector, where 200 million people directly benefit from the revenues (Garcia, Newton, 1997).

The aquaculture industry has developed strikingly over the last 50 years, to the extent the production rate currently amount to a total of 60 million tons, worth of 70 million dollars (FAO 2006). Iran has an excellent capacity for developing fishery and aquaculture. Roughly 2700 kilometers of the blue border across north and south of Iran, housing several lakes, rivers and freshwater springs, can provide a great potentiality for aquaculture in the country. The aquaculture products have dramatically grown throughout the world. Being no exception to the rule, Iran experienced 440 tons per year production of salmons in 1990, which went all the way up to 73624 tons per year later in 2010. These figures are indicative of an increase in fish production over the last 20 years (FAO, 2012).

This study attempted to compare the productivity rate in conventional fish rearing methods and PLC-equipped methods supported by CCTV systems smartly monitoring all the physical and chemical properties of water. In fact, the major objective was to evaluate how effective the later method is in aquaculture performance.

The Programmable Logic Controller (PLC) refers to a digital computer transferring an engineering program to conductors or relays through a circuit or interface, thereby launching and controlling certain machines under the predesigned program.

Materials and methods

This study focuses on Lorestan province in Iran, covering several towns such as Khorramabad, Selseleh, Delfan, Azna and Aligoudarz, where the largest fish rearing farms can be found. In this research, the productivity in conventional methods and PLC-equipped modern methods was assessed through three basic factors below: 1. Water consumption. 2. Fish mortality rate. 3. Final Yield.

The data were collected through a field and desk review as well as questionnaire. The sample size was determined through the Cochran's formula as follow (Cochran, 1977):

$$n = \frac{z^2.p.q.N}{d^2.(N-1)+z^2.p.q}$$

Where:

N represents the statistical population size at 1.96, *Z* represents the normal value of standard unit at confidence level of 95%, and *n* represents the sample size.

d=0.05 is the allowable error, p=0.5 is the attribute size in the population q=0.5 is the percentage of people without that attribute.

In order to measure the total factor productivity, the Cobb-Douglas function was employed as follow:

Y= F(L,K)

Where *Y* represents the true economic yield, *L* represents the number of hired labor, and *K* represents the capital to work ratio per unit of time. Moreover, the production function is assumed as a continuous function along with first order positive, partial and differentiable derivatives. The Cobb-Douglas production function desirably depicts the relationship between products and certain inputs, thus demonstrating the production factors contributing to outputs. The validity of this function was confirmed by several studies such as that conducted by Lindert (1999) and Deng et al. (2005). The Cobb-Douglas production function was employed for the purpose of this study as follow:

$$q = AL^{a1}wg^{a2}De^{a3}AC^{a4}FO^{a5}u$$

From the logarithm of the above equation we have:

$$q = a_1 Ln(AL) + a_2 Ln(wg) + a_3 Ln(De) + a_4 Ln(AC) + a_5 Ln(Fo) + Ln(u)$$

Where:

L is labor per people/day, *Wg* is the fish fry indicator (number multiplied by average weight), and *q* is the production function.

De stands for the pool water flow rate (liter per second), *Ac* is the pool useful area (square meter), and *A* is the constant

Fo represents the food intake per kg, *a1* to a5 are the elasticity of production to production factors ration, and *U* is the disruption term.

After rearing and harvesting the fish, the coefficient of conversion, survival percentage, production per unit of area (hectare), average body weight, average daily growth and daily nutritional diet were processed through SPSS, while the statistical difference was obtained through ANOVA. Moreover, the one-way variance analysis and the Duncan's multiple range test were employed. The measurement error level was $P \leq 0.05$. The physical and chemical properties of water include: Water temperature, oxygen and PH were measured twice a day (morning and evening), while other parameters such as salinity, clarity and water depth were measured once a day. In this procedure, the oxygen was measured by Oxygouar and the water PH was measured by WTW-330i. The salinity of water was measured by WTW-320, while the water clarity was measured by a Secchi disk in the afternoon.

Conclusions:

The results of this research demonstrated that

- The gender of fish farmers were: 21 male and 4 female.
- Age of fish farmers: 2 people under 20 years old, 3 people between 21 and 30 years old. 8 people between 31 and 40 years old, 8 people between 41 and 50 years old, and 4 people over 50 years old.
- The education of fish farmers: High-school diploma and lower (9 people), college associate degree (8 people), bachelor's (5), and master's (3 people).
- The amount of dissolved oxygen in water during the 90-day period ranges from 5.5 to 7.8. Dissolved oxygen plays a crucial role in fish growth, so that the optimum level of dissolved oxygen is close to saturation. The amount of dissolved oxygen in consecutive pools declined from an average 7.8 to 5.5 mg/L. This is consistent with the finding obtained by Shepherd and Bromage (1992) who pointed out oxygen level decreases from 2 to 3 mg/L as water flows through a workshop.

Inferential analysis of the hypothesis

Hypothesis: There is a difference between productivity of aquaculture conventional ponds and PLC-equipped ponds.

H0: There is no difference between productivity of aquaculture conventional ponds and PLC-equipped ponds.

H1: There is a difference between productivity of aquaculture conventional ponds and PLC-equipped ponds.

The Mann–Whitney U test was employed for hypothesis testing. As a nonparametric test, the Mann–Whitney U evaluates the difference between the independent groups in terms of a certain variable entailing either ordinal or nominal data. The productivity rate in the conventional method of pisciculture is 67.38, while it is 77.62 in the PLC-equipped ponds. The significance level of Mann–Whitney U test is lower than 5%, thus there is a difference between productivity of aquaculture conventional ponds and PLC-equipped ponds. For evaluation of such difference in productivity, both methods were assessed through several factors as follows: water consumption, mortality rate and final yield.

Water consumption rate

With regard to the obtained results, water consumption in the conventional methods involves a great deal of fluctuation, i.e. the lowest and highest rates were 2.1 and 9 L/sec, respectively. Hence, the program would be further challenged. Water consumption in the PLC-equipped methods is nearly predictable, i.e. the lowest and highest rates are 5.5 and 7.2 L/sec, respectively. In fact, this method involves an average water consumption rate.

Mortality rate

The mortality rate in the conventional methods is relatively high and unsteady. On average, the maximum and minimum mortality rates were reported to be 310 and 178 fish, respectively. The mortality rate in PLC-equipped methods is lower than the former. The maximum and minimum mortality rate drops to 214 and 100 fish, respectively.

Final yield

This involves three components: 1. Production per unit 2.Average daily growth 3. Survival percentage

Production per unit

In the conventional methods, an average 1500 to 2000 units of fish per hectare are reared. The production rate depends on numerous factors. The minimum and maximum production rates in each hectare are 1254 and 2078, respectively. In the PLC-equipped methods, that figure rises to roughly 2400 fish per unit of area. Moreover, the minimum and maximum numbers of fish are 1556 and 2356, respectively.

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Average daily growth

Naturally, the fish growth ascends over the 90-day period. In the conventional method, the progress is slow during the first few days, but it intensifies halfway through until peaking at the end of the period, i.e. 305 grams on average. In the PLC-equipped methods, the same procedure takes place, except for the final 20 days, when the maximum average growth reportedly hits 340 grams.

Survival percentage or number of fish fry kept alive until the end of the period and final production phase: In the conventional methods, the average survival percentage in 25 examined ponds was 89.68. In the PLC-equipped ponds, however, the survival percentage rose to 93.2, i.e. the PLC-equipped pools experienced almost no mortality.

Efficiency of PLC-equipped methods versus conventional methods

Efficiency is another aspect of comparing the two methods. The total efficiency is divided into three components; technical and managerial and scaling. The technical efficiency in the PLC-equipped ponds was 0.809, whereas it was 0.612 in the conventional method. As for the average allocative efficiency, the conventional and PLC-equipped methods scored 0.55 and 0.62, respectively. Finally, the economic efficiency for the conventional method was 0.73 while it was 0.954 for the PLC-equipped method. In general, the total average efficiency for the conventional method was 0.63, where it was 0.794 for the PLC-equipped method. It can therefore be concluded that the PLC-equipped ponds are more efficient than the conventional methods. With regard to results of data analysis, the average total factor productivity at the fish rearing units varied from 79 to 63 percent. Similar results were obtained by Martinez, Leung (2004) who examined the shrimp rearing units in Brazil, and also Kaliba et al. (2007) who examined the catfish rearing units in the United States, which altogether signified the fact that technical efficiency was higher than technical growth in the fish rearing units under study.

Calculation of production function

In order to measure the production function, the Analysis of variance (ANOVA) was employed to find out labor, fish fry, water flow rate, useful area, and food left a positive impact on the fish production function by 17, 28, 29, 43, and 49 percent, respectively.

Calculation of elasticity in production function inputs

In order to determine the total productivity of production factors, the Cobb-Douglas function was employed. In this research, the elasticity of production inputs was scored for labor (ranked first), pool useful area (ranked second), food (ranked third), fish fry (ranked fourth) and water flow rate (ranked fifth.) A review of literature revolving around productivity and estimation of production function in aquaculture around the world covers the study done by Martinez-Cordero et al. (2004) on shrimp rearing in Brazil. Furthermore, another study by Cinemre et al. (2006) focused on salmon aquaculture in Turkey, finding out that several factors negatively contribute to productivity such as fish diet and farm size. In an additional study by Roy et al. (2002), the relationship between farm size and its effect on productivity was examined. The data obtained from this research revealed that there was a relatively strong and positive relationship between farm size and productivity.

Summary

A CCTV-equipped aquaculture system involves water re-consumption and higher fish density in rearing pools. According the estimations, water rehabilitation and providing a favorable living environment in pools, the water consumption can be remarkably reduced, which in turn would transform the aquaculture and promotion across farms with restricted water and land. For instance, the water flow required by a salmon aquaculture farm with a capacity of 50 tons is 500 L/sec, where the pools stretch 50 thousand square meters. In contrast, a circulating-water system with the same capacity requires water flow at only 7 L/sec, where the pools shrink down to 250 square meters.

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