

Nitrogen and phosphorus loading values in rainbow trout (*Oncorhynchus mykiss*) farming system in marine floating cage in the Southern Caspian Sea

Abstract

The aim of this study was to determine the loaded amounts of nitrogen (N) and phosphorus (P) in the Rainbow trout farming system in the floating cage in the south of the Caspian Sea in 2018-2019. Two weight groups of fish (Group 1: 120g; Group 2: 300g) with 30,000 pieces were introduced to each floating cage. The offshore farm had three cages for group 1 (G1) and two cages for group 2 (G2). The fish culture period was 165 days and started in December and ended in May. At the end of the fish farming period, in groups 1 (G1) and 2 (G2), the weights were 780grams and 1450grams, respectively. The fish feed was semi-submerged extruded. The feed conversion ratio for G1 and G2 was determined 1.1 and 1, respectively. Fish survival rate was 95%. The consumption of fish feed in G1 and G2 was 21 tons and 33 tons, respectively in each cage. The N content of the feed was 6.4% and the amount of feed P was 1.25%. The amount of N and P in dry fish was 10% and 3.2%, respectively. The amount of N and P loaded per 21ton and 33ton of fish feed in G1 and G2 was 873.75 and 1292.6 kg N and 112.02 and 150.3kg P respectively. Also, the percentage of N and P in fish feed loaded in G1 and G2 was 65 and 61.2% N and 42.4 and 36.4% P, respectively. Therefore, in this marine farm, with the production of 149.34 tons of Rainbow trout, 5206.45kg N and 636.66kg P were loaded in the environment around the cage. These data are representing average conditions.

Keywords: marine cage culture, caspian sea, nutrient load, rainbow trout (*Oncorhynchus mykiss*) nitrogen and phosphorus loading

Volume 10 Issue 3 - 2021

SM Vahid Farabi, M Golaghaei Darzi, M Sharifian, H Nasrollahzadeh Saravi

Department of Aquaculture, Iranian Fisheries Science Research Institute (IFSR), Caspian Sea Ecology Research Center (CSERC), Iran

Correspondence: Golaghaei Darzi, Department of Aquaculture, CSERC, IFSRI, Iran, Email smv_farabi@hotmail.com

Received: April 22, 2021 | **Published:** June 29, 2021

Introduction

The ecosystem of the Caspian Sea is unstable against environmental and human changes. Enclosed coastal waters are subject to deterioration and eutrophication. Therefore, it is necessary to carry out any kind of human activity in the coastal area in the Caspian Sea region with environmental issues and political challenges.¹ The marine cage culture began in the last decade (Since 2010) in the southern Caspian Sea region.² Following this development, marine fish cage culture has been accused as a potential source of serious environmental impacts on its surrounding aquatic environment.³⁻⁵ In the other hand, The Caspian Sea region is the world's third largest reservoir of oil and natural gas after the Persian Gulf and Russia. Thus, management of its coastal waters requires efforts by all littoral countries¹. For this reason, the establishment of environmental quality objectives and standards should be an integral part of any framework plan for aquaculture development.⁶ The marine fish farming cages are having usually a high degree impacts interaction with environment. This system produces wastes that are released directly into the environment. Excess feed and fish waste are discharged from the farms and, if they accumulate, may alter the chemical processes of decomposition and nutrient assimilation. These wastes that are rich in organic matter and nutrients (nitrogen: N and phosphorus: P) that released into coastal region. Additions of nitrogen and phosphorus to natural waters can cause eutrophication.⁷

Marine cage aquaculture operations are a recognized source of nitrogenous discharge released in the form of uneaten food, feces and metabolic wastes including ammonia and urea.⁸ The trend of increasing nitrogen levels in coastal waters due to anthropogenic sources is a concern worldwide, especially because it may contribute to algal

blooms and eutrophication.⁹ Eutrophication effects of fish farming can be considered at several different scales, from local effects in the immediate surroundings of the fish farm to the contribution to large scale eutrophication¹⁰, e.g., in the entire south of the Caspian Sea.

Research has determined the amounts of nitrogen released from marine fish cages and the potential water quality and environmental effects of dissolved nitrogen.¹¹ Recently, Norði et al.¹² calculated that about 63% of nitrogen fed at a Rainbow trout *Oncorhynchus mykiss* farm in the Faroe Islands was lost as dissolved nitrogen.¹² Olsen et al.¹³ constructed a mass balance estimate of nitrogen flow from a hypothetical Norwegian salmon farm producing 1000 metric tons (annual loading of 44kg of nitrogen) of fish per year.¹³

The aim of this study was to determine the loaded amounts of nitrogen (N) and phosphorus (P) in the Rainbow trout farming system in the floating cage in the south of the Caspian Sea in 2018-2019.

Materials and methods

This study was carried out in an offshore fish farm in the southern region of the Caspian Sea (36°, 47', 12" N and 51°, 7', 50. 2" E) with a distance of 5.6 km from the coast. Water depth is 30m. (Figure 1).

The offshore farm had 5 circular polyethylene floating cages with a diameter of 20meters and a net height of 7 meters (volume is about 2200m³) in 2018-2019. Two weight groups of fish (Group 1: 120g; Group 2: 300g) with 30,000 pieces were introduced to each floating cage. The marine farm had three cages for group 1 (G1) and two cages for group 2 (G2). The fish culture period was 165 days and started in December and ended in May. In this study used semi-submerged extruded fish commercial feed Faradaneh Company of Iran (Table 1).



Figure 1 The South of Caspian Sea included in this study (A: fish farm).

Table 1 Chemical composition of fish commercial feed (Faradaneh Company, Iran)

Chemical composition	Ratio (%)
Crude protein	40
Crude lipid	15
Crude fibre	3
Ash	9
Moisture	8
Nitrogen	6.4
Phosphorus	1.25

The analysis of nitrogen and phosphorus for feed and fish were carried out kjeldahl and vanadomolybdophosphoric acid methods, respectively.¹⁴ The Rainbow trout are 25% dry matter that contains 10% nitrogen (N) and 2.7% phosphorus (P). Nutrient loads to a production system can be estimated as the amounts of nitrogen and phosphorus in feed, minus quantities of these two nutrients in fish at harvest.⁷

After 165 days of feeding experiment the fish were counted to determine the survival rate (SR) according to the following equation in each cage (Eq. 1):

$$SR(\%) = \frac{\text{Number of Fish at the End of rearing}}{\text{Number of Fish introduced to the cage}} \times 100$$

The weight of the fish was measured with a scale of 1 gram at the beginning and end of the rearing period in each cage.

The average weight gain (AWG) were determined with the difference between the mean of initial and mean of final weights of fish at 165 days of rearing period in each cage, according to the following equation¹⁵. (Eq. 2):

$$AWG(g) = \text{initial Mean weight}(g) - \text{final Mean weight}(g) \text{ (Eq. 2)}$$

The feed conversion ratio (FCR) was calculated according to the following equation in each cage.¹⁶ (Eq. 3):

$$FCR = \frac{\text{Feed given}}{\text{Average Weight Gain (AWG)}}$$

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$$\text{Phosphorus Inputs in Feed (PIF)} = \text{Feed} \times \text{FeedP}$$

Nutrient removal in fish:

$$\text{Nitrogen Removal in Fish (NRF)} = (\text{Fish} \times 0.25) \times \text{FishN}$$

$$\text{Phosphorus Removal in Fish (PRF)} = (\text{Fish} \times 0.25) \times \text{FishP}$$

The equations for nitrogen and phosphorus loads are given in (1) and (2).

$$\text{Nitrogen load (kg of N)} = (\text{NIF} - \text{NRF})$$

$$\text{Phosphorus load (kg of N)} = (\text{PIF} - \text{PRF})$$

Feed: feed given; Feed N: percentage nitrogen content of feed; Feed P: percentage phosphorus content of feed.

Fish: Average Weight Gain; Fish N: percentage nitrogen content of fish; Fish P: percentage phosphorus content of fish.

Results

The Performance and feed utilization for G1 and G2 was determined (Table 2). A total of 149.34 tons (G1: 66.690 tons and G2: 82650 tons) of fish were caught from this site after 165 days.

The amount of N and P loaded per 21ton and 33ton of fish feed in each cage in G1 and G2 was 873.75kg and 1292.6kg N and 112.02kg and 150.3kg P respectively. The Table 3 has been showed estimates of nitrogen and phosphorus released per 1000kg feed in Rainbow trout marine cage culture systems in the south of the Caspian Sea.

Therefore, in this marine farm, with the production of 149.34 tons of Rainbow trout, 5206.45kg N and 636.66 kg P were loaded in the environment around the cage. These data are representing average conditions.

Table 2 Performance and feed utilization of Rainbow trout in marine cage culture systems in south of Caspian Sea

	Group 1	Group 2	Total
Initial mean weight (g)	120±12	300±18	-
Final mean weight (g)	780±23	1450±65	-
Average Weight Gain of fish:AWG (g)	660	1150	-
fish introduced to the cages (number)	90000	60000	-
Number of cage	3	2	5
Harvested in fish (number)	85500	57000	142500
Survival Rate: SR (%)	95	95	-
Harvested in fish (ton)	66.69±0.3	82.65±0.5	149.34
Total AWG (ton)	56.43	65.55	121.98
Total feed given (ton)	63	66	115.42
FCR	1.1	1	-

*These data are representing average conditions

Table 3 Estimates of nitrogen and phosphorus released per 1000 kg feed in Rainbow trout marine cage culture systems

Type of fish culture	Feed		FCR	Whole Body composition		System nutrient loads			
				(Dry Matter Basis)		(kg/1000 kg Feed)		(% Feed Input)	
	N%	P%		N%	P%	N	P	N	P
G 1	6.4	1.25	1.1	10	3.2	41.6	5.3	65	42.4
G 2	6.4	1.25	1	10	3.2	39.17	4.55	61.20	36.4

Discussion

The feeds applied in commercial aquaculture increase nutrients value in the environment. Actually, the resolving discharge of nutrients from aquaculture operations is an issue for conservation of environment. In the last decade, due to the increase in nutrients, unusual phenomena have occurred in the southern region of the Caspian Sea. Harmful algae blooms, mullet disease, Gobiidae death are some of the important cases of these emerging phenomena. On the larger scale, the anthropogenic nutrient load in south of the Caspian Sea is in most cases dominated by agricultural runoff and municipal sewage.²

Although this should not be used as a reason to allow unusual emissions from fish farms sea cage, it makes it is difficult to distinguish the large-scale eutrophication effects of fish farms Sea cage from that of other nutrient sources in the south of the Caspian Sea.³ The more important effects are found on the local and region scales, where fish farms in many cases are the dominating nutrient sources effective.¹⁹

In Europe, considerable attention has been given to limiting inputs of nitrogen and phosphorus in feed to fish cages as a means of reducing environmental loads. Little can be done to lessen loads nutrients other than improve feed conversion efficiency or reduce nitrogen and phosphorus concentrations in fish feeds.⁷

There are cases that, salmon fed diets with partial fish meal replacement by plant proteins reduced loads nutrients, but, decreased

growth rates and reduced nutrient digestibility and gut health compared to standard fish meal-based diets.^{19,20,21} Thus, there is a limit to how much nitrogen and phosphorus concentrations can be reduced without sacrificing feed quality.⁷

In addition to the above, the results of this study showed that another strategy can be used to reduce nitrogen and phosphorus loading into the environment. Because, in cage culture or any other fish culture, all nutrients not retained in fish enter the surrounding water and some nutrients are used to grow and increase the weight of fish.

Recently, Norđi et al. like this research (G1: 65%; G2: 61.2%) calculated that about 63% of nitrogen fed at *Oncorhynchus mykiss* farm was lost as dissolved nitrogen.¹² This study has shown that by selecting fish with higher weights at the period of cage rearing, it is possible to reduce the nutrients to the environment during rearing (Table 3).

Pulatso²² has been showed that in *Oncorhynchus mykiss* cages in which extruded feed was used, the nitrogen load was estimated to be between 33.47 and 25.97kg t⁻¹ of fish produced, and the phosphorus load was estimated to be between 7.32 and 7.96 kg t⁻¹ of fish produced.²² But, in this study was estimated nutrient loading less than Pulatso (2008) study (Table 3)²², Because the FCR was determined in this study (1 and 1.1) less than the Pulatso study (1.25-1.38).²² Therefore, feed conversion ratio is the most important factor in the rate of nutrient loading in fish farming.

However, the weight of each of the fish in G1 and G2 increased 6.5 times and 4.8 times the weight of the fish, respectively. But the final biomass production in G2 was higher than G1 and the amount of food consumed G2 was less than G1.

On the other hand, in fish weighing more than one kilogram (1450grams to 780grams) the price of fish meat is higher in the market. It seems that introducing higher weight fish to the marine cage culture system is also more economically appropriate.

Conclusion

The Caspian Sea is a closed sea and is very fragile. In recent years, unusual phenomena such as algal blooms and the groups' death of some wild fish have occurred in the sea. Therefore, in this sea, it is necessary that any human activity, especially fish farming in cages, which affects the ecosystem of the environment, be done with caution and environmental considerations. As a result, the data of this research can be used to management of fish production plan in the southern region of the Caspian Sea.

Conflicts of interest

The authors declare no conflict of interest.

Acknowledgments

None.

Funding

None.

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