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On the Environmental Impact of Freshwater Fish Farms in Greece and in Iceland

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Authors' contributions

All authors contributed equally in the design of this work. Author TM performed the literature review, collected and analyzed the data from Fish Farms in Iceland and Greece and wrote the first draft of the manuscript. Author HT contributed in writing up of the manuscript and in the methodology. Author MT collected the data from Greece and revised the first draft. Author CN contributed in writing up the first draft of the manuscript and in the literature review. All authors read and approved the final manuscript.

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ABSTRACT

In the present study, we focused on the nitrogen and phosphorus levels generated by open flow freshwater fish farms in Greece and Iceland where salmonid fish are cultivated. There are several differences in the legislation and regulation of the aquaculture sector in Greece and in Iceland. Nevertheless, in both countries, environmental protection agencies need accurate information for nutrient processes in order to evaluate the environmental influence on surrounding waters by salmon aquaculture. Data were collected from surveys of 21 freshwater fish farms in Greece and 9 in Iceland. The surveyed farms practiced intensive production methods. The concentrations of

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nitrogen and phosphorus in farms' discharges were used to estimate organic load generated. The collected data were compared with data from the literature for the production Salmonids for species cultivated in Iceland (Arctic charr, Atlantic salmon) and in Greece (Rainbow trout). The results of the analysis indicate that in both countries the highest concentrations of nitrogen and phosphorus discharges of fish farms exhibits a variability which can be attributed to the total biomass of produced fish, fish feed and feeding management protocols used, species cultivated and ambient temperature. During the last 30 years, there was a significant reduction in the amount of nutrients generated by fish farms, which to a great extent is a result of lower levels of protein content in fish feeds and improved feed conversion efficiency. It is estimated that over the past 30 years, the combined effect of reduced nitrogen and phosphorus content and the improvements in Feed Conversion Efficiency, resulted in about 50% reduction in the nutrients generated by every Kg of farmed fish produced. Nevertheless, this significant improvement was easily offset by and increased production of fresh water fish farms exhibited in both countries. It seems possible that legislative measures combined with improvements in technology and feed management of fish farms will continue to be good option of minimizing the environmental impact of fish farms in the future.

Keywords: Aquaculture pollution; salmonid fish; Greece; Iceland.

1. INTRODUCTION

An important factor for estimating the nutrients impact of fish farms on the freshwater system is the rate of the nutrients discharge [1]. For example, the rate of the Nitrogen and Phosphorus discharges can produce models to estimate the dispersion of them and thus to assess the current ecological situation and future prediction. National and local authorities may control and impose limits on the amount of nutrient levels in the outflows of freshwater fish farms. Aquaculture units generate organic and nutrient-enriching products which originate from fish faeces and uneaten food particles [2,3]. There are several methods which can be used to estimate and monitor the nutrient load generated by fish farms. This estimation and monitoring is crucial for assessing the environmental impact of the Aquaculture industry and the regulation of the industry by local and national agencies and stakeholders [4,5]. Environmental assessment of Aquaculture sites may include monitoring the chemical parameters which indicate the chemicals and the organic load released in the environment and the ecological changes occurred in the surrounding aquatic ecosystem [6,7]. A robust monitoring programme should consider the natural conditions of the area and assess the environmental impact of the fish farm. It is crucial to adopt a monitoring strategy which will distinguish between the natural inputs of organic material (e.g. leaf litter), human inputs that are not related to aquaculture (e.g. agricultural run-off) and the aquaculture generated inputs. If these inputs are not acknowledged, then aquaculture could be

unfairly blamed for environmental degradation [2]. For example, the levels of organic load in an aquatic ecosystem may originate from dissolved nitrogen and phosphorus discharged from freshwater fish farms but this can vary according to several parameters [8]. National and local authorities may control and impose limits on the amount of nutrient levels in the outflows of freshwater fish farms.

In the present study, we focused on the nitrogen and phosphorus levels generated by open flow freshwater fish farms in Greece and Iceland where salmonid fish are cultivated. Fish farms may have an environmental impact, but also be subjected to environmental pollution generated by other activities creating an interaction between environment and the health status of growing fish and the final quality of the product [9,10]. There are several differences in the legislation and regulation of the aquaculture sector in Greece and in Iceland. Nevertheless, in both countries, environmental protection agencies need accurate information for nutrient processes in order to evaluate the environmental influence on surrounding waters of fish farms that cultivate salmonids.

2. MATERIALS AND METHODS

Data were collected from surveys of 21 freshwater fish farms in Greece and 9 in Iceland. The surveyed farms practiced intensive production methods. The concentrations of nitrogen and phosphorus in the feed labels and in the water discharges of the fish farms were used to estimate organic load generated.

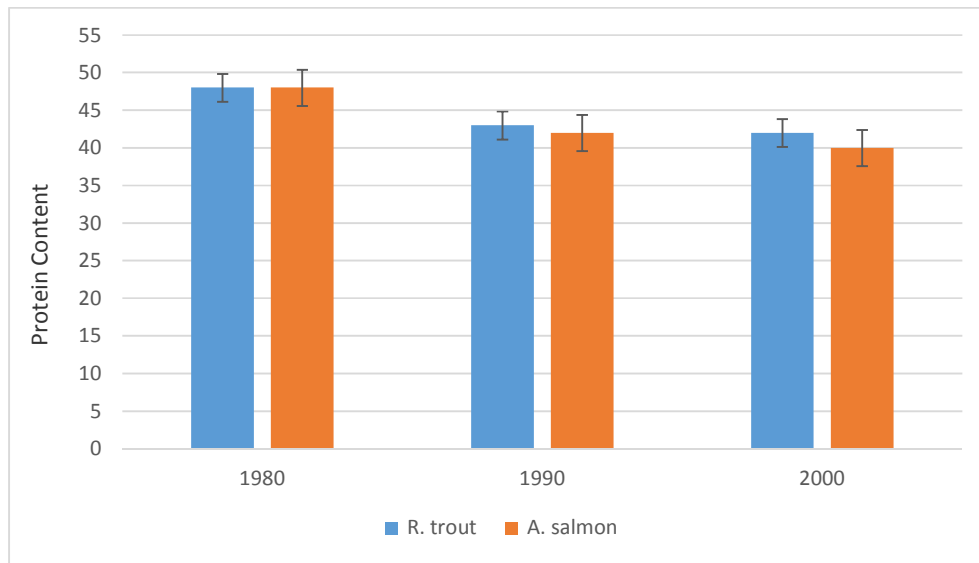


Fig. 1. Historical trend in the reduction of protein content (% dry weight in aquaculture feed) in the fresh water fish farm feeds used in Greece and Iceland for the farming of *Oncorhynchus mykiss* (R. trout) and *Salmo salar* (A. salmon) respectively

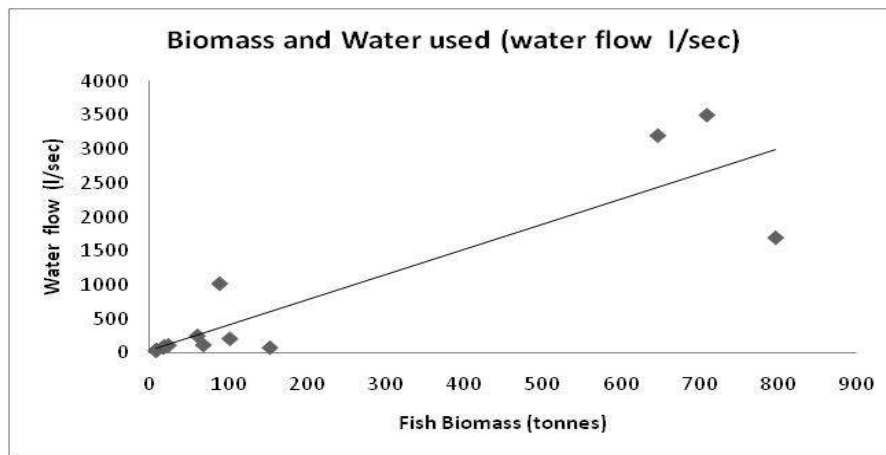


Fig. 2. Water flow rate and fish biomass of fish held in land based salmonid fish farms (Pearson correlation coefficient=0.65, $P < .005$ calculated from annual average data from eight fish farms Greece and nine from Iceland)

The data collected from the local aquatic ecosystems after the tested farms and included the nutrients release, (nitrogen and phosphorus concentrations in $\mu\text{mole/l}$) which been calculated to the annual release. The farming parameters were also recorded and included the biomass production, the feed amount used and the water flow into the farms. For Icelandic ecosystems, the methodology for obtaining these measurements and calculations came from the protocols outlined at Bergheim & Braaten [11] and the procedures coming from Wang et al.

[12]. For Greek ecosystems, the Sampling and Analytical Procedures came from Kotti et al. [13] and Kagalou et al. [14]. The collected data were compared with data from the literature for the production of Salmonids for species cultivated in Iceland for *Salvelinus alpinus* and *Salmo salar* (Arctic charr and Atlantic salmon) and in Greece for *Oncorhynchus mykiss* (Rainbow trout). Then, the nutrients were brought against the years to test the historical trend and the relationship between the water flow and the biomass also tested. Microsoft Excel was used to calculate the

Pearson correlation between water flow and fish biomass of Fish farms.

3. RESULTS AND DISCUSSION

The historical reduction of Protein content of fish feeds used in salmon and trout aquaculture is presented in Fig. 1, where there is a reduction over time. *Salmo Salar* protein content values appear to present a higher reduction rate than *Oncorhynchus mykiss* and they have significantly decreased the last twenty years. It is seen the 20 years trend reduced from 47 to 43 g/kg feed for R trout (8.6%) and from 47 to 40 g/kg feed (15%) for A. salmon.

The water requirements of the Fresh water fish farms increased as the biomass of the fish increased (Fig. 2), which is natural, as more

oxygen is needed for the fish to breathe when the biomass is increasing [15].

The results suggest a historical trend in the reduction of Nitrogen content in the Fresh Water Fish farm feeds used in Greece and Iceland for the farming of rainbow trout and Atlantic salmon respectively (Fig. 3).

There is also a historical trend in the improvement of Feed Conversion Rate (FCR) of Fresh Water Fish farm feeds in Greece which farm rainbow trout (Fig. 4). Data for Atlantic salmon are estimates from published reports of the Atlantic salmon industry. Data of R. trout are representative mean values of fish farms in NW Greece which provide an indication of the evolution of FCR from historical records.

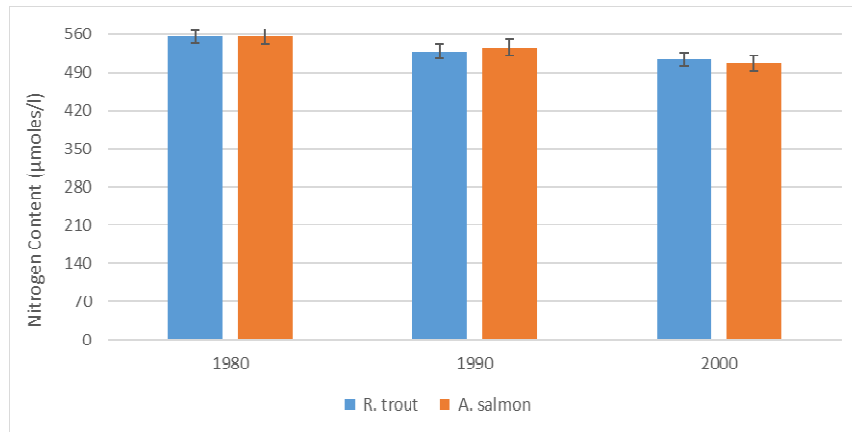


Fig. 3. Historical trend in the improvement of the Nitrogen content expressed in µmoles/l of F.W. Fish farm feeds in Greece which farm *O. mykiss* (R. trout) and *S. salar* (A. salmon)

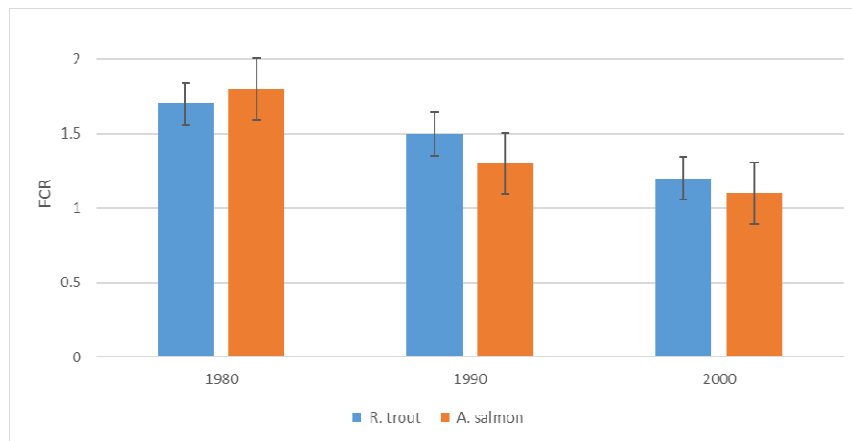


Fig. 4. Historical trend in the improvement of Feed Conversion Rate (FCR) of fresh water fish farm feeds in which farm *Oncorhynchus mykiss* (R. trout) and *Salmo Salar* (A. salmon) respectively

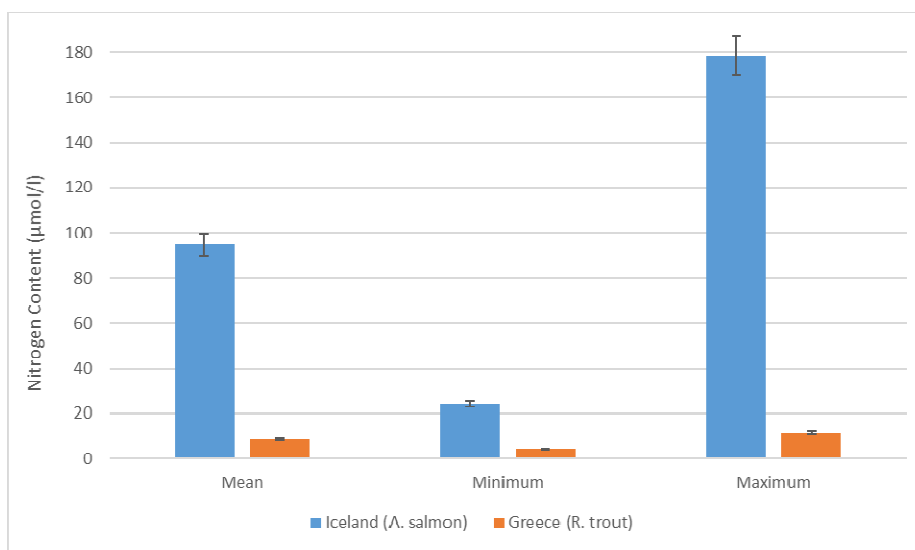


Fig. 5. Currently average, minimum and maximum values of nitrogen content ($\mu\text{moles/l}$) of water effluents from salmonid fish fresh water fish farms in Greece (rainbow trout fish farms, $n=20$) and in Iceland (Atlantic salmon fish farms, $n=10$)

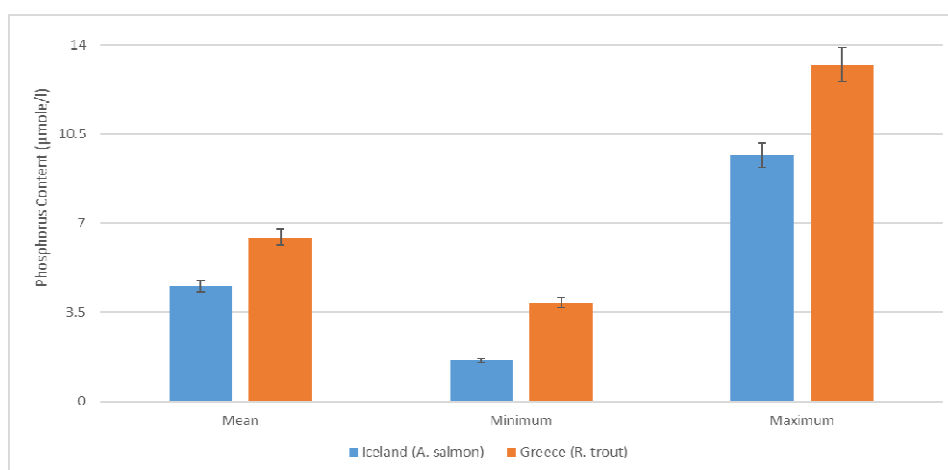


Fig. 6. Currently average, minimum and maximum values of phosphorus content expressed ($\mu\text{moles/l}$) of water effluents from salmonid fish fresh water fish farms in Greece (rainbow trout fish farms) and in Iceland (Atlantic salmon fish farms)

The nitrogen and phosphorus content of the water effluents of Fresh water fish farms in Iceland exhibited higher values. This can be explained by the different water flow to biomass ratio of A. salmon fish farms and trout fish farms in Greece (Figs. 5 and 6) [15].

4. CONCLUSION

The results can be used to improve the sustainability of the aquaculture sector, which depends on this type of research as the

environmental impact can either limit or slow down the growth of this sector. The control and monitoring of water quality is of vital importance to the success or failure of the aquaculture production. It is therefore necessary to develop new research applications focused on reducing the negative impacts of aquaculture effluents on the environment. A very important issue is to improve feed quality, with a greater bioavailability of phosphorus and proteins, reducing the amount of fish excreta.

The sustainability of the aquaculture sector depends on minimizing the environmental impact generated by aquaculture farms. The management of exploitation / environment interactions is one of the major axes of aquaculture production. One obvious way to reduce the quantity of discharged waste is to improve the feed management. The development of high-energy diets with increased fat content, reduced carbohydrate levels, reduced protein levels, and improved digestibility has significantly decreased waste production in salmonid farming.

During the last 30 years, there was a significant reduction in the amount of nutrients generated by fish farms, which is a result mostly due to lower levels of protein content in fish feeds and improved feed conversion efficiency. This is important for the land-based farms as they can use Flow through systems without high nutrients release. Using historical data, it is estimated that the combined effect of reduced nitrogen and phosphorus content and the improvements in Feed Conversion Efficiency, resulted in about 50% reduction in the nutrients generated by every Kg of farmed fish produced. Nevertheless, this significant improvement was easily offset by and increased production of fresh water fish farms exhibited in both Greece and Iceland.

Future policies could employ feed based regulation in industry, to improve the control of nutrient discharges of fish farms and prompt the utilization of feeding management practices and adaptation of technology, which can improve feed composition and feed conversion efficiency. The introduction of Recirculating Aquaculture (filtering) systems (RAS) would also improve dramatically the nutrients release in the adjacent ecosystems.

It seems possible that legislative measures combined with improvements in technology and feed management of fish farms will continue to be good option of minimizing the environmental impact of fish farms in the future.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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