The Use of a High Energy Feed for the Improvement of Trout Farm Effluents

Justin Eric Nyland

Thesis manuscript submitted to the Faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

Masters of Science
in
Environmental Sciences and Engineering

Dr. Gregory Boardman, Chair
Dr. George Flick
Dr. John Little

August 26, 1999
Blacksburg, Virginia

Keywords: Aquaculture Effluents, High Energy Feed, Suspended Solids, Nitrogen

The Use of a High Energy Feed for the Improvement of Trout Farm Effluents

Justin Eric Nyland

ABSTRACT

The aquaculture industry has experienced a great expansion in recent years. Along with this growth, increased regulatory attention has been directed towards aquacultura effluents. The problem with the majority of these discharges is the solids and nutrien spikes that occur during times of high farm activity. Several studies have proven tha these discharges have the potential to adversely affect downstream water quality. Although several treatment options are currently in use, the use of Best Management Practices (BMPs) has been recommended in recent years to improve the quality of these discharges. The implementation of one of these BMPs, the use of a high energy feed, was the focus of this study. In two separate experiments at trout raising facilities, the effluents of basins receiving a high energy feed were compared to similar basins receiving a standard trout grower feed. The water quality parameters of main concern were total suspended solids, total Kjeldahl nitrogen (TKN) and total ammonia nitrogen (TAN). The results of these studies showed that the effluents of basins receiving a high energy feed generally contained significantly lower concentrations of TSS, but higher amounts of TKN, than those receiving a standard grower feed.

GRANT INFORMATION

This research was sponsored by the Virginia Department of Environmenta Quality through the 604(b) Water Quality Management Planning Grant Program.

AUTHOR’S ACKNOWLEDGEMENTS

The cooperation and assistance from each of the farms’ personnel was wonderful and greatly appreciated. The project team would also like to thank the following people for their helpful suggestions and input throughout the stud : Larry Hough, Willia Kregloe, Kemper Lloyd, and Dwight Sours of the VDEQ; Steve Summerfelt of the Freshwater Institute in Shepherdstown, West Virginia; George Duckwall from the Virginia Department of Game and Inland Fisheries; and, Todd Powless from Zeigler Brothers, Incorporated.

AUTHOR'S NOTE

While the majority of this study focuses on the use of a high energy feed for the improvement of trout farm effluents, it must be noted that a joint effort was conducted on the part of Vince Maillard and myself to survey four trout farms in Virginia. Between August of 1997 and April of 1998, Vince Maillard and myself made several visits to each of the four facilities. Here, the quality of the influents, effluents, and raceway water of each facility was examined in great detail. During this time, the applicability of several treatment alternatives was also investigated. The results and conclusions of these studies are referenced within the Executive Summary.

In February of 1998, the majority of my efforts were directed towards analyzing the use of a high energy feed and its impacts on effluent water quality at two of the four facilities. At this time, Vince Maillard concentrated his efforts towards characterizing water quality and sludge in raceway systems and analyzing treatment options for these facilities.

Although the preliminary surveys and experiments conducted at these facilities are not discussed in the body of this text, the conclusions and recommendations made in this study could not have been made without the aforementioned joint effort

EXECUTIVE SUMMARY

Surveys conducted by the Virginia Department of Environmental Quality (VDEQ) revealed that the benthic aquatic life of receiving waters was impacted by discharges from several freshwater trout farms. In general, these facilities are comprised of several raceways in series, all discharging to one localized area of a receiving stream. One general characteristic of these facilities is their high flow rates, which would require large-scale treatment systems. This presents a problem for a majority of the facilities, where both economic and space constraints exist. Thus, the goal of this project was to identify practicable treatment options, which would improve water quality, both within the facilities and in their discharges to receiving waters. In March of 1997, the VDEQ provided Virginia Tech with a grant to accomplish this goal.

The Virginia Tech project team consisted of: Dr. Gregory D. Boardman, Professor of Civil and Environmental Engineering, Dr. George J. Flick, Professor in Food Science and Technology, Dr. George S. Libey, Director of the Virginia Tech Recirculating Aquaculture Center, Justin Nyland, M.S. Candidate in Environmental Sciences and Engineering, and Vincent Maillard, M.S. Candidate in Environmental Engineering.

During the first stage of the project, initial visits to two trout farms were made. Meetings were conducted with each facility owner/superintendent to provide additional insight into where problem areas existed and possible solutions. Each basin at these facilities was characterized. This included general measurements for basin dimensions, volumes, and flows. Temperature and dissolved oxygen (DO) were also measured to establish a trend for these two parameters within each facility. Structural and operational differences between these two facilities were noted, as well. One facility had concrete basins and demand feeders installed, whereas raceways at the other were manually fed and made of either concrete or earth.

An additional objective of these initial visits was to observe the effects of daily activities (feeding, harvesting, general cleaning) on effluent water quality. Based on a review of literature, a significant increase in suspended matter was expected during these events. Site observations confirmed these findings, because a difference was immediately apparent.

During this time, an extensive literature review was conducted. Several journals and articles addressing treatment methods were obtained. Although several treatment alternatives and management strategies were presented, the majority of these options were not applicable for the farms under consideration. This review was supported by phone interviews with aquaculture facility operators nationwide, including Dr. Randy MacMillan and Gary Fornshell of Clear Spring Foods, Inc. in Buhl, Idaho, and Jim Parsons of Blue Lakes in Twin Falls, Idaho. The project team also met with Steve Summerfelt of the Freshwater Institute in Shepherdstown, West Virginia. A great amount of additional literature was obtained through this correspondence. The Virginia Pollutant Discharge Elimination System (VPDES) permits for each facility were obtained in order to outline the water quality parameters that were currently under regulation.

In September 1997, a sampling and monitoring protocol was designed for the two trout farms. Sampling was conducted on a bi-weekly basis. The water quality parameters of main concern were DO, temperature, total suspended solids (TSS), total organic carbon (TOC), and 5-day biochemical oxygen demand (BOD_5).

Another effort made during this initial phase was to determine accurate flow measurements both through the facilities and within individual basins. This was accomplished by obtaining accurate dimensions and measuring current velocities through each basin. The current velocities were measured with a hand-held current velocity meter. Problems arose when it was discovered that the majority of the flow velocities were below the detection limit of the instrument. Although the influent and effluent flows could be measured, the distribution throughout each basin could not be quantified. In order to address this problem, a standard, empirically-derived hydraulics equation was used which relates the heights of influent weir readings to basin flow rates. This procedure avoided the problems encountered with the current velocity meter. When the two methods were compared by measuring influent flows, both produced similar results. From this, it was determined that using weir readings to determine flow rates was adequate.

In late September, 1997, a third trout farm was selected by the project team. Initial efforts were directed at characterizing basins within the facility in a manner similar to the other two farms. A sampling and monitoring protocol for this facility was soon established. At this point, results from the first stage of sampling were evaluated. Although no facilities exceeded the TSS discharge standards in their VPDES permits, certain sampling events at each facility revealed high spikes of suspended matter. As suspected in the early stages of the project, these high levels of TSS could often be correlated to either high activity in the vicinity of the sampling point, and/or a high fish density within the basin.

In order to establish correlations between farming activities, fish densities and solids concentrations, documentation of practices at each facility was needed. The project team frequently communicated with the facility managers from October of 1997 until the end of the project in order to keep track of a number of variables (stocking, harvesting, movements within raceways, feeding rates). Fish densities of designated basins were tracked on a daily basis.

In November of 1997, a meeting with the Regulatory Services Engineers of the VDEQ (Valley Regional Office) was held to discuss possible solutions to the problems encountered with aquacultural effluents. A review of each of the participating facilities' VPDES permits was conducted. Although no major revisions were forecasted for these permits in the near future, the discharge of phosphorus is under consideration. An expansion of the current sampling and monitoring protocol to include total Kjeldahl nitrogen (TKN) and total ammonia nitrogen (TAN) was strongly recommended in order to determine the levels of both organically-bound and inorganic nitrogen in these waters.

The major focus of the discussion was the fact that although pollutants may fall under permit regulations, adverse effects were still being observed in receiving waters. One approach suggested to address this issue was the implementation of Best Management Practices (BMPs) at the facilities. Among the BMPs mentioned were the use of settling ponds and sludge thickeners, regular basin cleanings, and the use of a high energy feed. At this point, the efforts of this project branched out to include the treatability of wastewater and sludges from raceway system trout farms, and the use of a high energy feed for the improvement of aquacultural effluents.

Three trout farms were selected for the characterization of water quality and sludge of aquaculture facilities. These farms were considered to provide adequate representation of fish farms throughout Virginia. Monitoring and sampling was conducted at all three farms from September of 1997 to April of 1998. The parameters that were periodically measured included: DO, temperature, pH, TSS, settleable solids (SS), volatile suspended solids (VSS), total phosphate (TP), ortho-phosphate (OP), TKN, TAN, BOD_5, and dissolved organic carbon (DOC).
Three major experiments were also conducted at these facilities: a particle size analysis, an 8 day batch study, and an analysis of sludge accumulation. The results for all three studies, along with those for the periodic sampling and monitoring trips, are outlined below.

Sampling and monitoring at all three sites revealed that little change in water quality between influents and outlets occurred during normal conditions at each facility. The average concentrations of each regulated parameter (DO, BOD_5, TSS, SS, TAN) were well below their regulatory limit at each facility. Raceway water quality was threatened mostly during times of heavy facility activity (feeding, harvesting,cleaning). During these events, fish or employees within the raceways would stir up solids that had settled to the bottom. During a 5-day intensive study, a number of high TSS values were correlated with feeding events. Although the majority of samples taken during this study had relatively low solids concentrations, the high flows through these facilities posed a problem with regards to total mass loadings.

Particle size analyses were conducted on various effluents from these facilities. Effluents were analyzed on both a mass basis and total number basis. Although the majority of the particles were small in size (5-30 um), the large particles (>105 um) made a significant contribution to total solids content on a mass basis. This analysis was necessary to predict the solids removal efficiencies for different treatment processes.

From the 8 day batch study, particle degradation and settling of effluent solids were analyzed. Results from these studies were used along with the particle size analyses to assess the effectiveness of certain treatment options.

Once the aforementioned tests were completed, the treatability of aquaculture effluents could be properly assessed. The main objective of this assessment was to develop treatment schemes for a number of facilities that were both efficient and economically practicable. A number of options had to be considered due to the variability within farms. An in-depth survey of treatability options was conducted. The alternatives covered in this study included: settling ponds, sediment traps, microscreens, baffling, tube/plate settlers, dissolved-air flotation (DAF), foam fractionation, wetlands, ozone, swirl separators, and waste minimization.

This review provided sufficient information to narrow down the number of alternatives applicable for the four farms. Additional pilot studies were conducted to further investigate the effectiveness of certain options. On a purely economical basis, a number of treatment alternatives were questioned immediately. These included ozone, filter beds, microscreens, tube and plate settlers, and swirl separators. The applicability of other treatment options were seen as inappropriate based on the characteristics of the effluents and spatial constraints at each farm. Those removed from consideration included microscreens, DAF, foam fractionation, and wetlands.

Based on these conclusions, a number of studies were directed at determining the efficiencies of sediment traps and settling, in combination with baffling. In one study the solids removal efficiencies for a baffled settling basin at three different detention times were evaluated, while in another the accumulation rates within an existing sediment trap were measured.

A number of different sludge treatment and disposal options for the farms were analyzed in a similar manner. Upon consulting a number of literature sources, several different alternatives were presented and reviewed in detail. This review assisted the project team in selecting the proper sludge treatment option for each farm. The following alternatives were reviewed: landfilling, land application, composting, and the use of sludge drying beds.

Waste minimization is another practice that can aid in the reduction of aquacultural effluent solids. A number of simple actions can be taken to reduce waste feed and metabolic by-products entering the raceways. By maintaining accurate fish inventories, appropriate feeding rates can be calculated to eliminate overfeeding. This results in less solids being introduced into the system, in turn reducing the amounts of suspended matter found in effluents. Several methods for eliminating overfeeding and waste feed were reviewed in detail. The methods included the use of self-feeding units, feeding to satiation, elimination of feed fines, and the implementation of ultrasound and infrared technologies to detect waste feed. Another practice for reducing the amount of solids entering raceway systems is the use of a high energy feed. Since less high energy feed is needed per pound of fish production, solids input to the system is less.

Studies comparing the effluents from basins receiving a standard trout grower feed to those receiving a high energy trout feed were conducted at two farms. Effluent levels of TSS, TKN, and TAN were studied in great detail. Both studies showed that the effluents of basins receiving the standard trout grower feed generally contained higher levels of TSS than those receiving a high energy feed. Upon further analysis, the effluents of basins receiving the standard grower trout feed contained somewhat lower levels of TKN than those receiving a high energy feed. The TAN levels in each effluent were not significantly different

Another study conducted at one of the farms was designed to compare the amount of time needed for solids levels to subside in each type of basin during a cleaning event. This analysis proved that a basin receiving a standard grower feed required almost twice the amount of time for TSS concentrations to return to normal levels. The main reason for this was that a greater amount of solids accumulated at the bottom of the standard grower feed basin. This resulted in longer cleaning times, with higher solids concentrations in the effluents during the cleaning process. It was therfore concluded that impacts to receiving waters during cleaning events could be drastically reduced with the use of the high energy feed. If flow was only diverted to settling basins during times of these concentrated flows, the size requirements for settling basins could be dramatically reduced with the use of a high energy feed, resulting in a lower capital cost.

Each study outlines several options for the improvement of aquaculture effluent quality. Because of the individuality of each facility, no general solution is proposed. The results of these studies must be applied to each farm on a site specific basis in order to appropriately address each individual problem.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES