WASTES/EFFLUENTS[18]

Project Termination Report for the Period
September 1, 1992 to August 31, 1996

NCRAC FUNDING LEVEL: $153,300 (September 1, 1992 to February 29, 1996)

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Iowa DNR	Rathbun State Fish Hatchery	Iowa
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Michael Wyatt	Sandhills Aquafarm	Nebraska

REASON FOR TERMINATION
The objectives for this project were completed.

PROJECT OBJECTIVES
(1) Characterize aquaculture effluents from four types of aquaculture production systems: pond culture, flow through culture (raceway), cage culture, and recirculating systems.

(2) Generate a data base from these four types of production systems to help promote a reasonable choice of effluent discharge regulations by government agencies.

PRINCIPAL ACCOMPLISHMENTS
OBJECTIVE 1
POND PRODUCTION SYSTEMS
Fairport State Fish Hatchery, Iowa
Water quality was monitored in four culture ponds stocked with channel catfish, *Ictalurus punctatus,* fingerlings at Fairport State Fish Hatchery near Muscatine, Iowa during 1993. Data were collected during the culture season and at harvest to analyze pond and effluent water quality. During the course of the growing season, water temperature, nitrates, and total suspended solids levels decreased while dissolved oxygen (DO), ammonia, un-ionized ammonia and 5-day carbonaceous (organic) biological oxygen demand ($CBOD_5$) increased.

Analysis of data collected at harvest revealed that total phosphorus and total solid levels increased substantially in the pond effluents compared to those within the ponds. Towards the latter stages of fish harvest, $CBOD_5$ levels significantly increased within the ponds; effluent quality

significantly deteriorated, having increased levels of total phosphorus, total nitrogen, $CBOD_5$, total solids, and total suspended solids. Fish biomass was a positive influence on $CBOD_5$.

Kloubec Fish Farm, Iowa

Samples were obtained from Kloubec's channel catfish and hybrid sunfish ponds in early and late October 1993. During the sampling period, two ponds had elevated levels of nitrites and three ponds had elevated levels of nitrates compared to earlier sampling periods. However, $CBOD_5$ levels decreased in all ponds during this sampling period. The two ponds with the highest levels of $CBOD_5$ at this time had been harvested the previous month. The act of seining probably resulted in direct increase in $CBOD_5$ levels compared to those ponds that had not been harvested.

Ponds at Kloubec's Fish Farm had higher $CBOD_5$ levels than did the flow-through situation at the Rathbun State Fish Hatchery, but were similar to pond levels at the Fairport State Fish Hatchery. However, the nitrogenous compounds levels were low. The two ponds with the highest feed levels had the highest $CBOD_5$ levels.

RACEWAY (FLOW-THROUGH) PRODUCTION SYSTEMS

Rathbun State Fish Hatchery, Iowa

The effects of a flow-through aquaculture facility, Rathbun Fish Hatchery, Iowa, were assessed in 1993. Significant differences ($P = 0.10$) were determined in both water quality and invertebrate parameters at six sample sites. Sites closest to the culture facility had elevated levels of several nitrogenous and phosphorus compounds compared to sites at the water intake and Chariton River. Main production factors influencing water quality parameters at sites were those taking place within the main hatchery building (flow, fish biomass, feed quantity and quality). Invertebrate groups, both zooplankton and other macroinvertebrates, did not differ between the upstream and down-river stations.

The overall conclusion concerning this data set is that the effects of aquaculture effluents from this hatchery are minimal at best on both chemical and biological factors. High flows resulting from flood conditions caused increased dilution of aquacultural effluents. The 1993 field season had the worst flooding in the state's history. Thus, data collected during this period may not be representative of a typical year where some hatchery effects may have been seen under more normal conditions.

Sandhills Aquafarm, Nebraska

The goal of the University of Nebraska-Lincoln (UNL) research was to monitor key water quality parameters above and below Sandhills Aquafarm, a modern trout production facility on Whitetail Creek in western Nebraska. Whitetail Creek is a spring-fed, first order stream with relatively constant flow and good water quality. Sandhills Aquafarm consists of twelve 2.4- H 33.5-m (8- H 100-ft) raceways with total flows of 23.5 m^3/min (6,200 gpm) and annual production rates of rainbow trout of 77,100 kg/year (170,000 lb/year). Four sites were established above the facility and four below to obtain reliable, representative physicochemical measurements and water samples for laboratory analyses.

It was clear that several water quality parameters continued to differ consistently above versus below the aquaculture facility, particularly DO, pH, ammonium-nitrogen, total nitrogen, orthophosphate, and phosphorus. Total suspended solids and turbidity showed no consistent trends. While temperature and biochemical oxygen demand (BOD) appeared to exhibit relatively little difference above and below the facility (although even these differences were consistent), downstream decreases in DO and pH, and increases in ammonium-nitrogen, total nitrogen, total phosphorus, and orthophosphate were evident. These data clearly indicate that water quality was altered downstream from the facility in both 1993 and 1994.

Rushing Waters Fisheries, Wisconsin

Rushing Waters Fisheries is one of the most productive commercial rainbow trout hatcheries in Wisconsin. It has earthen raceways and ponds with a total flow approximately half that of the Nebraska Sandhills operation. As such, it is representative of the more typically sized private trout production facilities in the North Central Region (NCR). This facility is supplied by groundwater wells and springs of moderate conductivity (between 400-600 μS) and is located at the head of a small creek that is a tributary to Blue Springs Creek in Jefferson County, Wisconsin.

Alterations in water quality occurred in the effluents of the three chains of raceways as compared to the source waters entered at the head of each raceway chain, and the water quality of the combined effluent in the creek leaving the property. Increases in BOD, total suspended solids, total ammonia nitrogen, nitrite-nitrogen, soluble reactive phosphorus, and total phosphorus were evident. Under typical production conditions these changes were slight, but on at least one occasion raceway cleaning activities created more elevated conditions of total suspended solids and total phosphorus in the creek leaving the property.

The effluents from the earthen production raceways had slightly lowered levels of nitrate-nitrogen compared to the source water. It seems reasonable that the natural primary and secondary productivity in the earthen bottomed rearing units would utilize nitrate. Dissolved oxygen levels in the groundwater well sources tended to be slightly lower than in the effluents from the raceways. Use of aerating devices in the rearing units kept DO levels high, and the level in the newly pumped well water probably had not yet had enough contact with the atmosphere to reach full saturation before sampling. Source water samples were taken from an open reservoir rather than from groundwater wells, and water from this reservoir had slightly higher levels of solids, ammonia, and phosphorus than the well water sources. This difference was slight, however, in comparison to the general differences between the source waters and the effluents.

Alpine Farms, Wisconsin

Tank rearing of yellow perch and whitefish at Alpine Farms, Sheboygan Falls, Wisconsin was investigated to characterize the effluents produced by alternative regional aquaculture species. Yellow perch and whitefish tank effluents produced changes in water quality parameters similar in direction and magnitude to those of the other flow through rearing situations. Differences appeared to be controlled by production conditions (water exchange, loading, and ration level) rather than by the species reared.

Glacier Springs Hatchery, Wisconsin

The intended opportunity to examine the changes in effluent water quality during the renovation of a former hatchery that had been inactive for over a decade didn't materialize during the project period, due to changes in the owner's plans. A representative set of before renovation water quality data was gathered, which would be suitable for comparison if future renovation occurs. Emphasis was shifted to the Rushing Waters Hatchery study when plans for renovation were delayed.

CAGE CULTURE PRODUCTION SYSTEMS

Trout Culture

Freshwater Farms of Ohio's trout cage culture facility is located near Urbana, Ohio in an abandoned quarry. The site consists of four separate quarry lakes, two of which discharge into a third, which together with the fourth, discharge into the Mad River. A total of ten sampling sites were monitored, including spring inflow into two lakes, the cage culture site at two depths, the discharge from the production lake into a settling lake, the discharge into the Mad River from the settling pond, discharge from an unused lake into the Mad River, and the Mad River upstream and downstream from the discharges.

For all measured parameters, there were no significant differences. There was no negative impact of Freshwater Farms of Ohio's trout cage culture operation on the water quality of the quarry lakes or the receiving water of the discharge. In fact, in most cases significant improvement occurred due to the diluting effect of the quarry discharges.

Channel Catfish Culture

The Piketon Research and Extension Center (PREC-OSU) has a small demonstration cage culture operation in a 1.8-ha (4.4-acre) reservoir located at the facility. The cage culture operation reflects what a small farmer could easily build in a farm pond for the production of channel catfish and for trout grow out in the winter months. The system was lightly stocked over the spring months with trout and yellow perch fingerlings and then heavily stocked with channel catfish (850 kg; 1,874 lb) in mid-summer.

The impact of the small scale cage catfish cage culture operation at PREC-OSU is not easily characterized due to the input from the Center's wastewater treatment plant. Still most water quality parameters were typical of catfish production ponds.

RECIRCULATING SYSTEMS

The facilities studied at Illinois State University included two recirculating aquaculture systems (RAS) stocked with Nile tilapia (*Oreochromis niloticus*). The first system consisted of a 18,927-L (5,000-gal) culture tank, a settling tank particle filter, a vertical screen submerged media biofilter and an oxygen column. The second system consisted of a 170,343-L (45,000-gal) culture system, a drum microscreen particle filter, a submerged media biofilter and oxygen columns. The second system is similar in design, although smaller in scale, when compared to operating commercial systems found in the private sector. The second system was producing 226.8-453.6 kg (500-1,000 lb) of live tilapia each week during the time of these trials.

Data collected on two different RASs demonstrate that RAS effluents contain elevated levels of total solids, settleable matter, BOD, forms of nitrogen (excluding non-ionized ammonia), phosphorus, and reduced concentrations of DO, which agree with previous RAS studies.

OBJECTIVE 2

The combined data sets from these investigations have been tabulated and attached, along with an extensive bibliography concerning aquaculture effluents, as appendices to the Project Termination Report Part II. This data set and references provide a single source overview of effluent water quality from representative regional aquaculture production facilities.

IMPACTS

Data from the recirculating system study has already been used by a private sector aquaculturist in developing a new large recirculating system that meets USEPA compliance. It is anticipated that as this data base is made available to the industry, many more actual applications will occur. Aquaculturists can use this data to take a proactive stance in helping environmental regulatory agencies compose practical aquaculture discharge regulations. Aquaculturists may also use the data collected as baseline values in research to determine the efficiency of newer effluent treatments and best management practices (BMPs) designed to reduce the impact of effluent discharges. Practices that alleviate effluent problems may result in more efficient operation of the hatchery facility and economic savings, and also decrease environmental impacts. This information will help protect the quality of water resources and may alleviate the fears of the general public as to the perceived polluting aspects of aquaculture systems.

RECOMMENDED FOLLOW-UP ACTIVITIES

This work has measured the levels of solids produced by representative regional facilities as settleable solids, total suspended solids, and dried solids. The more dramatic changes in water quality from aquaculture operations are associated with clean out events for removal of settled aquaculture waste materials. Solid wastes are most easily removed from culture systems by conventional water treatment processes, while nutrients, once they become dissolved, require treatment technologies that are cost prohibitive. Strategies to improve commercial fish foods from the perspective of waste management need to be evaluated. Better understanding of the influence of commercial diet formulations on the integrity of fecal solids and the consequent impact on nutrient release, holds promise of reducing the release of phosphorus into aquaculture

effluents. This is one of the aspects of greatest regulatory concern due to its potential role in the eutrophication of receiving waters. The addition of fiber to the diet can potentially influence fecal durability in water and permit easier removal. The practicality of this strategy needs to be investigated and demonstrated.

In recirculating aquaculture systems the size distribution of suspended solids particles shifts to smaller sized particles that are the most difficult to remove, and more information is needed on the impact of such particulate solid matter on fish health and the performance of recirculating systems. Recycle systems also produce expectedly more concentrated waste, but they also permit more opportunities for innovative reuse or disposal. Efficient solids removal and management provides an avenue for the utilization of waste by-products as potentially beneficial resources in the context of integrated resource management plans.

Wise resource management calls for finding beneficial use for these concentrated aquaculture by-products. These types of practices can promote aquaculture as a beneficial or at least a benign influence on water resources when good stewardship is practiced. In this regard, comparison of real-life aquaculture production situations to other common land and water use practices will be helpful in arguing for realistic and just regulatory and permit situations. Comparing aquaculture waste production within the context of other contemporary land use practices with regard to impact on regional water quality, should be useful for demonstrating that current and prospective regional aquaculture is relatively benign environmentally.

Using the results of this project, a report needs to be prepared that contrasts the potential impact of regional aquaculture development with other contemporary agricultural, municipal, industrial, and natural resource land uses. There is a need for this information to be organized into an easily understood format so that normal aquaculture operating conditions can be viewed against the existing general background of water quality fluctuation and environmental impact. This report should also review and evaluate current research on alternative beneficial uses of aquaculture by-products, emphasizing integrated resource management and aimed at developing sustainable aquacultural practices. Options to be examined should include constructed wetlands, irrigation uses, hydroponics and even biogas production strategies. Often the situations and examples of such practices, as presented in the existing literature, deal with species, climates, and situations, which may or may not be applicable to the environmental and regulatory situations in our region. There is a need to review and present this information in relation to its relevance and application to aquaculture in the NCR.

PUBLICATIONS AND PAPERS PRESENTED

See Appendix.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1992-93	$77,064	$54,427	$15,000[a]			$69,427	$146,491
1993-94	$76,236	$43,261	$20,000[a]		$10,000[b]	$73,261	$149,497
TOTAL	$153,300	$97,688	$35,000		$10,000	$142,68	$295,988

[a]Glacial Springs Hatcheries
[b]Archer Daniels Midland

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Publication in Print

Rosati, R., P.D. O'Rourke, K. Tudor, and R.D. Henry. 1993. Performance of a raceway and vertical screen filter while growing *Tilapia nilotica* under commercial conditions. Pages 303-214 *in* J-K. Wang, editor. Techniques for modern aquaculture. Publication No. P-0293, American Society of Agricultural Engineering, St. Joseph, Michigan.

Papers Presented

Hinrichs, D., J. Webb, R. Rosati, and P. Foley. 1994. Effluent characterization from the production of *Oreochromis niloticus* in a modified Red Ewald-style recirculating system. 25th Annual Meeting of the World Aquaculture Society, New Orleans, Louisiana, January 12-16, 1994.

Rosati, R., P.D. O'Rourke, K. Tudor, and R.D. Henry. 1993. Performance of a raceway and vertical screen filter while growing *Tilapia nilotica* under commercial conditions. Techniques for Modern Aquaculture, Special Session at the Annual Meeting of the American Society of Agricultural Engineering, Spokane, Washington, June 21-23, 1993.

Rosati, R., J. Webb, D. Hinrichs, and P. Foley. 1993. Characteristics of the effluent from a recirculating aquaculture system. Proceedings of the 1993 annual meeting of the U.S. Chapter of the World Aquaculture Society, Hilton Head, South Carolina, January 27-30, 1993.

Rosati, R., D. Hinrichs, and J. Webb. 1994. Biofilter performance during the production of *Oreochromis niloticus* in a modified Red Ewald-style recirculating system. American Fisheries Society Annual Meeting, Halifax, Nova Scotia, August 21-25, 1994.

Smydra, T.M., and J.E. Morris. 1994. Characterization of aquaculture effluents from two Iowa hatcheries. American Fisheries Society, Iowa Chapter, Council Bluffs, Iowa, February 15-16, 1994.

Smydra, T.M., and J.E. Morris. 1994. Characterization of aquaculture effluents. 56th Midwest Fish and Wildlife Conference, Indianapolis, Indiana, December 4-7, 1994.