WASTES/EFFLUENTS[8]

Termination Report for the Period
September 1, 2001 to August 31,
2005

NCRAC FUNDING: $195,000 (September 1, 2001 to March 31, 2005)

PARTICIPANTS:

Fred P. Binkowski	University of Wisconsin-Milwaukee	Wisconsin
Jeffrey A. Malison	University of Wisconsin-Madison	Wisconsin
Douglas J. Reinemann	University of Wisconsin-Madison	Wisconsin
Robert C. Summerfelt	Iowa State University	Iowa
Steven E. Yeo	University of Wisconsin-Milwaukee	Wisconsin
Industry Advisory Council Liaison:		
Harry Westers	Aquaculture Bioengineering Corporation, Rives Junction	Michigan
Extension Liaison:		
Fred P. Binkowski	University of Wisconsin-Milwaukee	Wisconsin
Non-Funded Collaborators:		
Michael Becker	Odbek Industries, Inc., St. Paul	Minnesota
Von Byrd	USDA Forest Products Laboratory, Madison	Wisconsin
Chuck Ehlers	Ehlers Enterprises, Manning	Iowa
Jae Park	University of Wisconsin-Madison	Wisconsin
Mark Raabe	REM Engineering, LLC, Evansville	Wisconsin
Todd Rogers	Odbek Industries, Inc., St. Paul	Minnesota
Roger Rowell	USDA Forest Products Laboratory, Madison	Wisconsin

[8]NCRAC has funded three Wastes/Effluents projects. The termination report for the first project is contained in the 1989-1996 Compendium Report; a termination report for one of the two objectives of the second project is contained in the 1998-99 Annual Progress Report, and a termination report for other objective of the second project, which was chaired by Fred P. Binkowski, is contained in the 1999-00 Annual Progress Report. This termination report is for the third Wastes/Effluents project which is chaired by Robert C. Summerfelt. It is a 3-year project that began September 1, 2001.

PROJECT OBJECTIVES

(1) Document the fate of aquaculture waste components (phosphorus, nitrogen, solids) relative to feed input into traditional and newly designed aquaculture systems.

(2) Evaluate the technical and economic feasibility of rapid solids removal/recovery appropriate for new aquaculture facility designs.

(3) Demonstrate economically sound processing methods for beneficial use of aquaculture waste.

(4) Provide workshops and fact sheets that address best management practices (BMPs) for waste control.

PRINCIPAL ACCOMPLISHMENTS

OBJECTIVE 1

Researchers at Iowa State University (ISU) estimated nutrient retention by largemouth bass (*Micropterus salmoides*), walleye (*Sander vitreus*), hybrid striped bass (aka sunshine bass, *Morone chrysops* & × *Morone saxatilis* %), and rainbow trout (*Oncorhyncus mykiss*) in five 39.2 m^3 (10,357 gal) 'Cornell type' dual-drain culture tanks of a commercial recirculating aquaculture facility in west-central Iowa (Ehler Enterprises, Inc., Manning). Walleye were cultured in two of the five tanks. Most of the rainbow trout (643 g; 1.4 lb) and walleye (497 g [1.1 lb] and 398 g [0.88 lb]) were market size whereas the largemouth bass (73 g; 0.16 lb) and hybrid striped bass (96 g; 0.21 lb) were fingerlings. A mass balance approach was used to calculate the increase in the dry weight of biomass from growth of the fish with nutrient nitrogen (N) and phosphorus (P) content of the dry weight of feed to each tank of fish. Nutrient retention was measured in two intervals of 27 days and 29 days. Over both intervals N retention in the cultured fish ranged from 10.6–48.5%, and P retention ranged from 11.9–56.5%. For walleye, nutrient retention was related to size, the smaller walleye had nearly twice the retention rates of the larger walleye. Market- size rainbow trout and walleye exhibited relatively slower growth and corresponding low levels of nutrient retention. Nitrogen and phosphorus retention was inversely related to food conversion ratio; thus, the higher, therefore, poorer food conversion resulted in lower nutrient retention. Total ammonia nitrogen (TAN) production (g/kg feed fed) was inversely related to nitrogen retention. Empirical values for TAN production ranged from 3.8–6.6% of daily feeding rate, higher than the 2–3% often used as a general guide. The findings demonstrate the importance of factors affecting feed conversion (i.e., feeding efficiency), as well as the interaction between fish age or size, growth rates, temperature, feeding rates, nutrient content, and protein retention. The findings provide strong evidence for caution in acceptance of any single generalized value for estimating TAN production from feeding rates alone.

OBJECTIVE 2

Objective 2 was carried out at both ISU and the University of Wisconsin-Madison (UW-Madison).

ISU researchers compared solids removal by the drum filter and a solids trap in a recirculating aquaculture system that uses 39.2 m^3 (10,357 gal) 'Cornell type' dual- drain culture tanks with sidewall and center drains. The water volume of the five culture tanks was 78.5% of total system volume (249.9 m^3; 66,024 gal) and the piping and treatment components 21.5%. The daily freshwater inflow (added makeup water per day) was only 1.9% of total system volume.

Recirculating flow to each culture tank (784 Lpm; 207 gpm) was about 1.2 exchanges per hour; i.e., a hydraulic retention time was 50 min through each tank. The diameter (i.e., 5.43 m; 17.8 ft) to depth (i.e., 1.69 m; 5.5 ft) ratio was 3.2:1. The sidewall drain carried 78.7% of flow and the center drain 21.3% of flow. Flow from the sidewall drain by- passed the drum filter and went directly to the sump where two 7.5 hp electric centrifugal pumps lifted the water through the fluidized-sand biofilter. The design and operation of the particular commercial facility differs in two unique ways from most other recirculating aquaculture systems: (1) the high flow from the side-wall drain of the culture tanks by-passed the drum filter; and (2) the center drain of each tank discharged into an external standpipe that contained three lengths of pipe (i.e., the triple standpipe [TSP]) that had a quiescent zone below the shortest standpipe that functioned as a simple sedimentation basin.

Ehler's RAS configuration had savings in capital and operating costs because the microscreen filter did not filter the total flow from the culture tank (most of the flow bypassed the drum filter) and the solids capture by the TSP reduces solids load on the filter from the center drain. The waste effluent from the culture building discharged to a septic tank (primary settler) with a perforated tile line that terminated in a pond (polishing pond). By volume, the two major effluents to the septic tank were from the drum filter (DF) backwash (40.5%) and the discharge from draining the TSP (59.4%). The DF operated 35% of the time but the TSP was drained manually only once per day for 10 seconds by pulling the shortest of the three standpipes, which emptied the TSP (0.34 m^3; 89.8 gal) and discharged solids that accumulated in the quiescent zone below the shortest of standpipe. TSP accounted for 83.2% biochemical oxygen demand, 71.4% total nitrogen, 82.1% total phosphorus, 66.1% suspended solids, 64.1% total dissolved solids, and 86.5% total suspended solids of the total volume of effluent discharging to the septic tank. The efficient function of the TSP allowed the system to operate with only a 21.5% of recirculating flow going to the drum filter and it reduced water loss from backflushing the drum filter. The TSP was a cost-effective, simple modification of an external standpipe for rapid removal of suspended solids derived from waste feed and fish feces from culture tank effluents of a recirculating aquaculture system.

The goal of UW-Madison studies was to evaluate the feasibility of using wood fiber filters to capture solids from raceway and pond effluents. Prior to designing the fiber filters, information on the particle size of solids in raceway and pond effluents was needed. The particle size of three types of effluents were characterized: (1) effluent from fingerling production ponds at the Lake Mills State Fish Hatchery (LMSFH). The effluent from the final 5% of the water was sampled during pond draining, because previous studies have shown that this portion of the effluent contains the highest concentration of solids. (2) Effluent from coho salmon production raceways at the LMSFH collected during "pump" cleaning (one commonly used method to clean raceways). (3) Effluent from coho salmon production raceways at the LMSFH collected during "pump" cleaning (another commonly used method to clean raceways).

A small-scale filter box (designed for a flow rate of 4–6 Lpm; 0.9–1.3 gpm) was designed and built by UW-Madison researchers and engineers from the USDA Forest Products Laboratory (FPL). The box was designed to accept 4–6 filters in a series flow design. Initial studies focused on flow dynamics, i.e., to minimize problems related to overflow and filter bypass. Once these problems were resolved, a set of graded "Nytex" screens were installed to measure particle size and distribution. The results indicate that pond effluent contained a higher percentage of small particles than raceway effluent. Approximately 60% of solids from pond effluent, and 75% of solids from "swept" or "pumped" raceway effluent were retained by a 75 µm screen. According to FPL engineers, these data suggested that it should be possible to design wood fiber filters to retain a high percentage of solids and at the same time permit high flow rates through the filters.

Three types of fiber filters were then manufactured: "random," made from 28% kenaf, 28% jute, 28% flax, 10% aspen, and 6% binder; "DW I," made from 90% juniper and 10% binder; and "DW II," made from 65% juniper, 15% aspen, 10% alfalfa, and 10% binder. Preliminary studies showed that all three-filter types were effective at retaining solids from aquaculture effluents. In repeated tests using pond effluent (which contains smaller particles, in general, than raceway effluent), three random and DW I filters in series retained more than 70% of the solids.

Flow rates through the filters have shown that fiber filters can be practically designed to accommodate flow rates typically associated with pump cleaning of large scale raceways (60–200 Lpm; 15.9–52.8 gpm). Fiber filters capable of effectively removing solids from pond effluent can be designed, but the large surface area required to permit the extremely high flow rates associated with pond draining (>1,500 Lpm; 376 gpm) may make the application of fiber filters for pond effluent less feasible than for raceway effluent. Therefore, final studies in 2004 (described below) were focused on the retention of solids from raceways.

UW-Madison researchers first constructed a large-scale filter box capable of handling flows of 60–200 Lpm (15.9–52.8 gpm). The size of the box was approximately 2.0 m L × 0.5 m W × 0.6 m H (6.6 ft L × 1.6 ft W × 2.0 ft H). This box was fitted with a set of six identical filters (0.5 m H × 0.5 m W; 1.6 ft × 1.6 ft W). The box was designed to allow the water to flow through all six filters, and then exit the box. The filters would eventually plug, and water would overflow each filter sequentially. The box reached its filtration capacity when all six filters were plugged.

A series of tests were conducted in conjunction with routine pump cleanings of coho salmon aceways at the LMSFH. For these cleanings, a gasoline-powered centrifugal pump is used to "vacuum" the settled solid waste from the bottom of the raceway. Under normal conditions, the pumping rate is 200 Lpm (52.8 gpm), and it takes an operator approximately 30 min of pumping to clean the ~ 425 linear meters (~1,394 ft) of raceway. The pump effluent was discharged through the box filter, and the concentration and total weight of the solids pumped from the raceway, the percentage of solids trapped by the filter box, the total weight of solids trapped by the filter box, and the percentage of phosphorus in the trapped solids were determined.

The random filters removed about 79% of the total solids in the pumped effluent until the box reached capacity. One set of filters reached capacity in about 10 min. The entire raceway cleaning operation could be conducted using 3 sets of 6 filters each. The filtration capacity of one set of filters was almost 400 g (.89 lb) (dry weight) of solids. The average concentration of phosphorus in the dry solid material was 0.66%.

OBJECTIVE 3

University of Wisconsin-Milwaukee (UW- Milwaukee) scientists investigated processing methods for beneficial use of aquaculture waste. Their work is categorized into two sub-objectives as follows.

Sub-objective A: Develop methods to recover and partially dewater biosolids from intensive yellow perch aquaculture for use as a feedstock for vermicomposting using red worms and warmer-temperature tolerant "cultured" nightcrawlers.

Using a combination of the settling of suspended solids and the use of the worm bed soil itself for dewatering, UW- Milwaukee investigators demonstrated that recirculating aquaculture system bead filter sludge could be successfully recovered and used as worm feedstock. Back-flushed waste solids from the bead filter/clarifier of UW- Milwaukee 25-m^3 (6,604-gal) recirculating aquaculture system, and to a lesser extent, some solids from a 3.3-m^3 (872-gal) circular flow-through tank of yellow perch fingerlings were obtained for use as worm food. A graduated conical-bottomed 560-L (148-gal) tank was used to separate the solids by settling from the remaining wastewater. Over the three year period of this study, three cohorts of perch fingerlings were produced in the UW-Milwaukee recirculating aquaculture system, the daily amount of settled sludge recovered from the bead filter varied widely with a mean volume of 41 L (10.8 gal) and a range of 254 L (67 gal) and a median value of 30 L (8 gal). The total settled sludge recovered was 31.4 m^3 (8,306 gal). The sludge was approximately 3.5% solid for an approximate dried weight of 1,099 kg (2,423 lb) of recovered solids consisting principally of fecal material, waste food, and some microbial floc and possibly small amounts of sand from the biofilter.

From January through October 8, 2002 during the first cycle of perch grow-out, approximately 973 kg (2,145 lb) dried weight of commercial fish feed was used to feed the perch in the recirculating aquaculture system. During that 280-day period, an accumulated total of 9.6 m^3 (2,536 gal) of settled sludge material (336 kg [741 lb] dried weight) was recovered from the bead filter back washings. This recovered sludge is approximately equivalent to 35% of the dried weight of the fish food (973 kg [2,145 lb] dried) used to grow out the approximately 10,000 perch fingerlings in the recirculating aquaculture system during this period of operation.

During a second cycle of perch grow out, from mid-December 2002 through October 10, 2003, biosolids from the bead clarifier were again recovered from the UW- Milwaukee recirculating aquaculture system. In this 302-day period, a total of 15.3 m^3 (4,036 gal) of settled sludge was collected from the recirculating aquaculture system and was potentially available for use as worm food. This recovered amount was equivalent to 28.3% of the dry weight of the fish food (1,651 kg [3,640 lb] dried) used during that period.

During a third perch grow-out cycle from October 30, 2003 to July 25, 2004, bead filter sludge (total 6.4 m^3; 1,691 gal) equivalent to 224 kg (494 lb) dry weight was recovered from the UW-Milwaukee recirculating aquaculture system. This recovery is approximately 19% of the dry weight of fish food used (1,174 kg; 2,580 lb) in the recirculating aquaculture system over that 268-day period.

In each succeeding perch grow-out cycle, there appears to have been a trend toward decreasing solids recovery. We believe that this may be due to the installation and operation of an ozone treatment system during the second and third perch grow-out trials, and/or to variations in feeding efficiency and food conversion between the trials.

Sub-objective B: Propagating worm stocks in continuous composting bins utilizing bead filter sludge as food. Seed stocks were obtained of two species of earthworms with recognized potential for vermicomposting of organic materials: “cultured” nightcrawlers, *Eudrilus eugeniae*, (approximately 400 totaling 0.384 kg [0.847 lb]), and red worms, *Eisenia foetida*, (approximately 500 totaling 0.081 kg [0.179 lb]).

In January 2002, these worm stocks were introduced into separate commercial continuous-vermicomposting bins. The surface area of each bin was 0.66 m^2 (7.10 ft^2). Draining the sludge through the worm bedding dewatered the bead filter sludge. The majority of the solids from the bead- filter sludge were retained in the upper layer of worm bedding and excess water dripped by gravity through the bed and collected in a drip pan. Feedings of settled sludge were measured volumetrically and poured from a 3.0-L (0.8-gal) graduated pitcher. Sludge feedings were applied in thin layers to cover only a portion of the bedding surface to insure that the worms could find a refuge from extreme conditions. Additional food was added when the previously added material had been worked over by the worm stocks. Accumulation of unused food was avoided to prevent anaerobic conditions, odor problems, and adversely high temperature conditions in the beds.

During 2002, worm populations in the bins were sampled at 2, 9, 14, and 23 weeks after stocking. Both species of worms prospered when fed the yellow perch RAS bead-filter sludge. Reproduction and cocoon deposition were observed in the first few weeks. The estimated worm initial stocking density (% by weight) in the bedding was 0.1% for the red worms and 0.5% for the nightcrawlers. The red worm bin population tended to increase steadily over the 23-week period both in terms of percent worms by weight (0.1–2.6%) and estimated number of worms (500 to ~13,000) in the bin. The nightcrawlers fluctuated in percent worm density by weight (range 0.5–6.4%).
Nightcrawler density increased to 4.6% due to rapid initial growth, but then decreased as the larger older individuals died off gradually through the first nine weeks and were replaced by an abundant cohort of young worms after 42–48 days. In the nine-week sample worm density by weight (1.9%) was less than half of what it was at two weeks, while the estimated number of worms in the bin had gone from an original 400 to approximately 12,000. By 14 weeks the nightcrawler bin had regained high worm density by weight (6.4%) and estimated numbers appeared to remain around 13,000. However, by 23 weeks the worm sizes were mixed and not as clearly dominated by a single cohort in both numbers (~4,000) and density by weight (1.8%). Variation between samples on a given sampling date was high and handpicking sub-samples was laborious. It is difficult to obtain accurate inventory of worm stocks in continuous batch culture in order to predict the numbers of harvestable bait-size worms.

From January through September 2002, the worms were fed a total of 837 L (221 gal) of sludge. Individual feedings were generally in 3.0 L (0.8 gal) increments and varied from 0–18 L (0–4.8 gal) per bin on a given date. Following the harvest of the perch at the end of September 2002, through mid-December 2002 commercial worm feed was used because sludge was unavailable from the recirculating aquaculture system until restocking with a new batch of fingerlings occurred.

Once the 2003 perch production cycle of the UW-Milwaukee recirculating aquaculture system was restarted in late December 2002 through October 2003, the worm bins were again maintained by feeding bead filter sludge. In that period, a total of 495 L (130 gal) of sludge was fed to the worms in the continuous compost bins.

The amount of recovered sludge from the recirculating aquaculture system proved to be far greater than the capacity of these composters to accept the waste without creating undesirable bedding conditions and odor problems. Observation of the worms feeding on a thin layer of sludge (3.0–6.0 L; 0.8–1.6 gal) applied to each bin (0.66 m^2 or 7.10 ft^2) and covered with a light covering of soil, indicated that when sufficient worm stocks are present the food layer could be worked over in 3–4 days at which time more sludge could be applied. Applying sludge at a rate similar to that used for these composting bins (approximately 4.5–9.0 L/m^2 [0.11–0.22 gal/ft^2] at 4 day intervals), a worm bed of 25–50 m^2 (269–538 ft^2) could be readily supported at the modal level of sludge production.

From June 1, 2003 through July 29, 2004 the red worm and African night crawler bins were each periodically harvested by handpicking the worms, separating them from the compost, then they were washed, drained and the total wet weight of the harvest from each bin was recorded. During this13 month period, six harvests were collected from each bin. A total of 3.2 kg (7.1 lb) of red worms and 3.6 kg (7.9 lb) of African nightcrawlers were harvested. During this period a total of 177 L (47 gal) of settled sludge (at 3.5% solid approximately 6.2 kg [13.7 lb] dry weight of sludge) and 0.44 kg (0.97 lb) of commercial worm feed was feed to each bin, or a feeding conversion efficiency ratio of approximately 2:1 on a dry weight of feed and wet weight of worms basis. (The commercial worm feed was used in late October and early November during the period when sludge was unavailable from the recirculating aquaculture system during the period following the harvest of one crop of perch and restocking with a new batch of fingerlings). On this basis, had the worm bins been scaled up to accept the total amount of sludge recovered (1,099 kg [2,423 lb] dried) the recirculating aquaculture system should have been able to support a potential production of 550 kg (1,213 lb) of worms. The sludge was approximately 96.5% moisture so 177 L (47 gal) of sludge represents 171 kg (377 lb) of water and only an additional 37 L (10 gal) of water was used to keep the beds moist during this period. During the harvest period there was little detectable water dripping through the worm bed and the majority of the water was lost through evaporation.

In the summer of 2002 UW-Milwaukee researchers compared bead filter sludge as a foodstuff for vermicomposting/vermiculture to a commercial worm diet. The influence of the addition of hardwood sawdust and shredded paper as worm bedding additives were also examined. This research was done with the assistance of an undergraduate participant in the National Science Foundation "Research Experience for Undergraduates" program from July through August 2002; an experiment was conducted using ventilated commercial production pails. Three worm feeding treatments (no supplemental feeding, commercial worm food, and bead filter sludge) were combined with three types of bedding ("black peat" soil alone [9.0 L; 2.4 gal]; black peat [6.0 L; 1.6 gal] plus sawdust [3.0 L; 0.8 gal]; and black peat [6.0 L; 1.6 gal] plus shredded paper [3.0 L; 0.8 gal]). Each treatment combination was assigned to a commercial production worm pail and 20.0 g (0.7 oz) (about 50 African nightcrawlers, or 70 red worms) batches of each worm species were randomly assigned to each of the nine pails. The treatment array was replicated three times on successive dates resulting in triplicate pails for each of the nine treatment combinations for each worm species (27 pails total for each species). Food treatments consisted of either
3.0 L (0.8 gal) of sludge, 29 g (1.0 oz) of commercial worm food followed by 3.0 L (0.8 gal) of recycle aquaculture system water, or no food followed by 3.0 L (0.8 gal) of recirculating aquaculture system water. The amount of commercial food fed to the worms (29 g; 1.0 oz) approximated the equivalent dried solids in 3.0 L (0.8 gal) of biosolids sludge. Growth and survival in each pail was evaluated at two and four weeks. Yellow perch recirculating aquaculture system bead filter sludge was found to be a suitable feedstock for both "cultured" nightcrawlers and red worms.
Buckets of nightcrawlers fed bead-filter sludge increased 489% in overall mass with a 96% survival after four weeks. After four

weeks, the weight of red worms fed bead filter sludge increased 224% percent with 73% survival. Between the second and fourth week several buckets of both sludge- fed and commercial food-fed red worms experienced some mortality. In this experiment, recirculating aquaculture system sludge as a worm feedstock was as successful as, or outperformed the commercial worm food. After four weeks, the weight of nightcrawlers fed commercial worm food increased 415% with a 99.8% survival. Red worms fed commercial worm food had a 63% survival rate and a worm biomass increase of 187% after four weeks. The fed worms grew much better than the worms without supplemental feeding; at four weeks unfed nightcrawlers increased only 154% with 100% survival and red worms increased 127% with 97% survival. All substrate types tested were successful in maintaining worm cultures. No differences in worm growth and survival could be attributed to the various substrates. However, preliminary results suggest that the addition of sawdust allows better drainage and drying of the bedding. Addition of sawdust would probably reduce the labor costs required for separation and picking of the worms from the substrate at harvest.

Samples of worms, bedding substances, and composts from both the continuous compost bins and the sludge feeding experiment were freeze-dried and prepared for isotope analysis and carbon:nitrogen ratio to characterize the alteration in the biosolids during the vermicomposting process. Although maintenance problems with the mass spectrometer have delayed completion of the carbon:nitrogen ratio (C:N) and isotope analysis, limited final results indicate that the freeze-dried sludge has a nitrogen content 5.0–5.7 % nitrogen and a C:N of 5:1 and the freeze dried compost has a nitrogen content of 2–3% and a C:N ratio of 14–15:1.

OBJECTIVE 4

On September 12, 2002, the U.S. Environmental Protection Agency (USEPA) released proposed rules for under authority of the Clean Water Act. The final USEPA effluent limitations guidelines and standards for the concentrated aquatic animal production (CAAP) Category rules are to be released by June 2004. To help producers understand the proposed USEPA rules and Best Management Practices (BMPs), ISU proposed to offer a workshop to provide an overview of USEPA guidelines and standards and BMPs for ponds, raceways, and recycle systems. In addition, ISU has been conducting a literature search of computerized databases to prepare an updated bibliography of aquaculture effluent related issues. When completed, findings of objectives 1, 2, and 3 of the current NCRAC project can provide guidance for development of BMPs. Information may be distributed in fact sheets and technical bulletins, and presented at conferences and workshops.

IMPACTS

OBJECTIVE 1

ISU researchers described nutrient (N and P) inputs in water and feed, and nutrient and solids outputs in the effluent of a commercial recycle aquaculture facility that has employs a septic tank to capture solids and nutrients from the effluent of the culture system. The findings demonstrate the importance of factors affecting feed conversion (i.e., feeding efficiency), as well as the interaction between fish age or size, growth rates, temperature, feeding rates, nutrient content, and protein retention. Values for TAN production ranged from 3.8–6.6% of daily feeding rate, higher than the 2–3% often used as a general guide. The findings provide strong evidence for caution in acceptance of any single generalized value for estimating TAN production from feeding rates alone. ISU's findings on nutrient retention address USEPA's requirement that a CAAP facility "employ efficient feed management and feeding strategies that limit feed input to the minimum amount ... in order to minimize potential discharges of uneaten feed and waste products to waters of the U.S."

OBJECTIVE 2

ISU research demonstrated design features of a recirculating aquaculutre system that facilitated rapid removal of solids as well as reduced costs for the microscreen (drum) filter, one of the most expensive components of a RA system. The culture system used dual-drain tanks that allow the operator to set the proportion of flow from the culture tank to sidewall and center drains. As operated, 79% of the flow from the culture tanks, which had the lowest concentration of suspended solids discharged through the sidewall drain, reduced the size and cost of the drum filter, a major capital cost. In addition, the findings demonstrate that the triple standpipe reduced the load of solids to the drum filter as well as facilitating rapid solids removal. Efficient solids capture and disposal is important to operating efficiency of the recirculating aquaculture system, water quality for the cultured fish, and waste management.

The findings of UW-Madison researchers demonstrated that wood fiber filters can be used as an innovative, cost effective method to remove a high percentage of solid wastes from the effluent from many typical flow- through aquaculture systems.

OBJECTIVE 3

UW-Milwaukee investigators demonstrated that fish waste sludge equivalent to approximately 18–35% of the weight of the food used to produce perch in recirculating systems is potentially a viable feedstock for worm culture. On pre-established worm beds the settled sludge can be directly applied in thin layers, without prior dewatering, and rapidly processed. This can be beneficial to aquaculture, especially recycle aquaculture systems, because vermicomposting can potentially decrease the amount of waste released by converting it to salable worms and organic compost to defray some of the high operating expense of recycle aquaculture system rearing.

Recently investigators at Virginia Tech have been investigating the use of vermicomposting in connection with waste recycling at Blue Ridge Aquaculture, a large tilapia recirculating aquaculture system production system in Martinsville, Virginia. However, investigators are unaware of any applications of this technique for aquaculture waste recovery in the NCR. In discussions with several Wisconsin recirculating system operators at the state aquaculture conference, they expressed interest in vermicomposting on a trial basis. Depending on the markets that may be developed for worms and vermicompost, these techniques will find application for aquaculture applications like recirculating aquaculture system that produce concentrated sludge.

OBJECTIVE 4

The proceedings of the NCRAC sponsored 2003 workshop, entitled “Aquaculture Effluents: Overview of USEPA Guidelines and Standards and BMPs for Ponds, Raceways, and Recycle Culture Systems,” integrated the scientific and experience- based knowledge on best management practices to reduce the impact of effluents of pond, raceway, and recycle aquaculture systems. It is an important source of information needed by commercial operators for understanding the scope and content of USEPA’s final regulation (i.e., rule) for the concentrated aquatic animal production industry as published in the “Final Effluent Limitations Guidelines and New Source Performance Standards for the Concentrated Aquatic Animal Production Point Source Category, August 2004.” The USEPA rules apply to the coldwater species category, which includes but is not limited to trout and salmon, and the warmwater category that includes but is not limited to catfish, sunfish, and minnow families of fishes. The coldwater category *"includes ponds, raceways, or other similar structures which discharge at least 30 days/year but does not include facilities which produce less than 9,090 harvest weight kilograms (about 20,000 pounds) per year; and facilities which feed less than 2,272 kilograms (approximately 5,000 pounds) during the calendar month of maximum feeding.*” The warmwater category *"includes ponds, raceways, or other similar structures which discharge at least 30 days/year but does not included: closed ponds which discharge only during periods of excess runoff; or facilities which produce less than 45,454 harvest weight kilograms (approximately 100,000 pounds) per year.*”

RECOMMENDED FOLLOW-UP ACTIVITIES

For recirculating (i.e., recycle) systems producing at least 100,000 pounds of aquatic animals per year, to meet USEPA's "nationally applicable effluent limitation guidelines and standards" plans for new or renovation of recycle systems should consider a design similar to that of Ehler's recycle system as described by ISU. The components and flow configuration of that system can reduce capital and operating costs, and reduce water consumption and address solids control. Interested parties are advised to contact ISU investigators for further information. They are available for presentations for state or regional fish farming workshops. Research designed to evaluate feeding strategies (e.g., feeding frequency) to achieve enhanced feeding efficiency would be valuable also.

UW-Madison investigators recommend that aquaculturists that are interested in using fiber filters to remove solids from aquaculture effluents should be advised to contact UW-Madison or FPL investigators for consultation and advice. There is a need for application of vermicomposting techniques by regional aquaculturists demonstrating its use on a commercial scale either to produce organic vermicompost or for vermiculture. Continuous vermicompost bins with mixed generations of worms would be suitable for sludge recycling by compost production. Approximately 4.75 $kg/m^2/yr$ (.97 $lb/ft^2/yr$) of worms were harvested by continuous vermiculture without any separation of cohorts or special fattening to grow them to bait size. Vermiculture, of appropriately sized baitworms, could potentially be increased by an approach that separates cohorts of worms by age and size, insuring better inventory control, avoiding problems with decreased growth rate at high worm density and separating harvestable-sized worms from the numerous smaller sized worms. At a commercial vermiculture operation in Racine, Wisconsin cultured nightcrawlers are grown in plastic pails (approximately10.0 L [2.6 gal] capacity). At about two-week intervals new cohorts of worms are established by separating cocoons from harvested adult worms. Use of modular bins and a cohort separation management strategy is advantageous for inventory control in an operation intending to produce predictable numbers of harvestable bait-sized worms. However, the smaller sized bed of the modular pails tended to dry more easily than and required closer monitoring than the larger continuous composting beds. Because worm growth appears to be slowed in the high density continuous composters, perhaps a hybrid rearing scheme using the continuous composting bed as the principle waste processing method and as a source for periodically harvesting several-week-old intermediate-sized worms that could be rapidly fattened and grown to bait size at lowered density using the modular bins, might be most advantageous for recirculating aquaculture system waste recycling.

PUBLICATIONS, MANUSCRIPTS, OR PAPERS PRESENTED

See the Appendix for a cumulative output for all NCRAC-funded Wastes/Effluents activities.

SUPPORT

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVER-SITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
2001-02	$80,766	$58,752	$299,980	$21,060		$379,792	$460,558
2002-03	$68,514	$59,059	$123,434	$21,918		$204,411	$272,925
2003-05	$45,720	$60,740	$128,173	$22,375		$211,288	$257,008
TOTAL	$195,000	$178,551	$551,587	$65,353		$795,491	$990,491