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TECHNICAL COMMUNICATION

Using Aquaculture as a Post-mining Land Use in West Virginia

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Abstract Using aquaculture as a post-mining land use has resulted in financial savings in site reclamation, increased positive media attention for coal companies, and new biosecure water sources for commercial aquaculture operations in the West Virginia coal region. Large underground coal mines in Appalachia have created numerous gravity flow sources of water. These mine water sources are often nearly ideal in temperature, alkalinity, and pH for trout and have the additional value of being devoid of any serious fish pathogens. At one site, modifying the post-mining land use permit to allow the water flowing from the portal of a closed mine to be used to produce commercial rainbow trout for the recreational market reduced site reclamation costs by nearly $450,000 (US). At another site, an acid mine water treatment plant was converted into a quality public fishing park with healthy warm water species (channel catfish, largemouth bass, and bluegill sunfish). The county park is now being used for educational and recreational purposes to the benefit of the whole community.

Keywords Appalachia · Aquaculture · Biosecure · Coal · Post-mining land use · Reclamation · West Virginia

Introduction

Large volumes of water are discharged from old and new mining operations in West Virginia. This mine water is consistently cool (12–14°C) and, depending on water quality, sometimes suitable for commercial aquaculture (Jenkins et al. 1995). Using mine water for aquaculture is a practical way to avoid pathogens and their hosts (snails, worms, birds, and other fish) that continually threaten fish farms that use surface water. This paper discusses a facility in southern West Virginia that uses mine water to produce nearly 8,000 kg of trout annually, and another site (Dogwood Lake, in northern West Virginia) raises trout using water from a 5 ha reservoir that receives treated water from a passive acid mine drainage treatment plant (Tierney 2002). While the analytic concentrations of many divalent and trivalent ions of this water source far exceed the accepted tolerance levels for rainbow trout, the ionic concentrations were actually below such limits (Viadero and Tierney 2004).

Current Trends

Public and private producers have used surface water for trout production in concrete raceways due to ease of handling and harvesting, and the ability to reuse the water. These large-scale production facilities are operated by state and federal agencies to stock large areas for public recreational fishing. One problem with this type of facility is that animals in the source water are often carriers of serious diseases that are easily spread to other fish (Kowalski and Bergersen 2003; Mitchell 2002; Modin and Veek 2002). The concrete tanks are also costly to install, are not easily modified or moved, and time consuming to clean; in addition, the concrete erodes the soft fins of the fish. Within the past decade, state and federal hatcheries have come under increased pressure to reduce nutrient and pathogen

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discharges as well as to reduce the cost of production. This has resulted in the closing of some hatcheries, reduced production in others, and led to the purchase of trout from private producers to reduce the cost of stocking public waters used for recreational fishing (Hulbert 2000; Westers 2000). However, purchasing trout has also been problematic, due to an outbreak of viral hemorrhagic septicemia (VHS) in the Great Lakes region of the US and Canada; recently imposed transportation restrictions now require fish producers to be certified disease free for many different viral and bacterial diseases if they are to transport fish to other states.

Private trout producers usually have smaller water sources than larger public facilities and, therefore, have less production. The volume of a water source for commercial fish production should be at least 1,800 L/min during the lowest flows of any given year. As more private suppliers provide fish for stocking public streams for recreational fishing, there is a growing need for biosecure water sources to provide these fish for recreation. Donovan and Leavitt (2004) projected the extent of future mine flooding and mine discharge locations through the year 2015 along the boarder of PA and WV (Fig. 1). This information can be used to integrate aquaculture with the development of water treatment plants, as done successfully at the Mittiki mine site in Maryland (Ashby and Dean, Treated mine drainage effluent benefits Maryland and West Virginia fisherman, http://www.p2pays.org/ref/14/13905.htm), where a state hatchery has been operating successfully for 14 years. Wolkersdorfer (2008) discusses various examples of some problems associated with using mine water for aquaculture. Semmens and Miller (2003) discuss Appalachian regional examples of successful fish production using mine water.

Much of this paper refers to research conducted at the Robinhood Mine research site in northern West Virginia, but some other success stories are included to illustrate that the approach can be used at a range of sites. Unlike many mine discharges in the area, the water source used did not have acid or iron problems because there was very little pyrite associated with the coal seam. The water discharge from the Robinhood Mine, which ended operations in 2000, is located about 25 m above a 0.5 ha settling pond with an 8% slope leading to the pond. A simple bioassay conducted in 2002 demonstrated good survival and growth of rainbow trout receiving untreated drainage directly from the mine.

A 2-year study of water discharges indicated flows from 500 to 4,100 L/min. Temperatures were stable at 13°C and the pH was in the low 7s. The volume of the raceways (7,500 L) is suitable for flows of 500–1,350 L/min, which provides an acceptable exchange rate of at least 4 times per hour.

First Try

The first design used a commercially produced plastic dome-shaped product (turned upside down) used to store runoff from parking lots or buildings. The device is manufactured in sections of just over 2 m that can easily be joined together to make a long narrow trough. With an end cap on each end and a liner cut to length, a relatively inexpensive tank was made. The lightweight material allowed for easy installation and removal if necessary. The U-shaped lined tanks were 10 m long, 1.5 m wide and 0.8 m deep. Eight of these tanks were installed in series at the portal area of an inactive coal mine operated by Eastern Associated Coal Co. in southern West Virginia. The US Office of Surface Mining Reclamation and Enforcement (OSMRE) approved the post-mining land use of aquaculture after careful review.

Approximately 950 ten-cm rainbow trout fingerlings were stocked in each of the tanks in March 2004. An electrified 2 m high chain-link fence was installed to exclude black bears and poachers from the production area. Growth rates averaged 2.53 g/day during the 233 production days. Harvest weights averaged just over 600 g with a condition factor ($\times$100) of 1.69 (Miller 2006). Flesh analysis for toxins indicated no eating restrictions. In addition, unlike fish produced in concrete raceways, the lack of fin erosion was noted as soon as the first trout were harvested from the plastic tanks (Fig. 2).

The liners used in the first set of tanks began to cause production problems when heavy rains caused mud and water to accumulate between the liners and the plastic tank, significantly reducing production volume. This problem was resolved by using a siphon with a small hose to drain the water between the liner and the tanks. There is a 1 m vertical drop between each tank, which aids in re-aerating the water for the lower tank.

Savings in mine site reclamation, as of November 2004, amounted to more than $450,000. This was a major incentive for the mining company to use aquaculture as a post-mining reclamation activity. It should be noted that Eastern Associated Mine Co. used some of the larger trout from the 2004 growth trial to stock a local stream. This drew considerable positive media attention in the region and set the stage for improving the plastic tank design.

Second Try: Northeast Regional Aquaculture Center Grant

In 2006, the Northeast Regional Aquaculture Center (NRAC) and Eastern Associated Coal Company funded West Virginia University to develop an improved version of the original tanks. The NRAC project focuses on

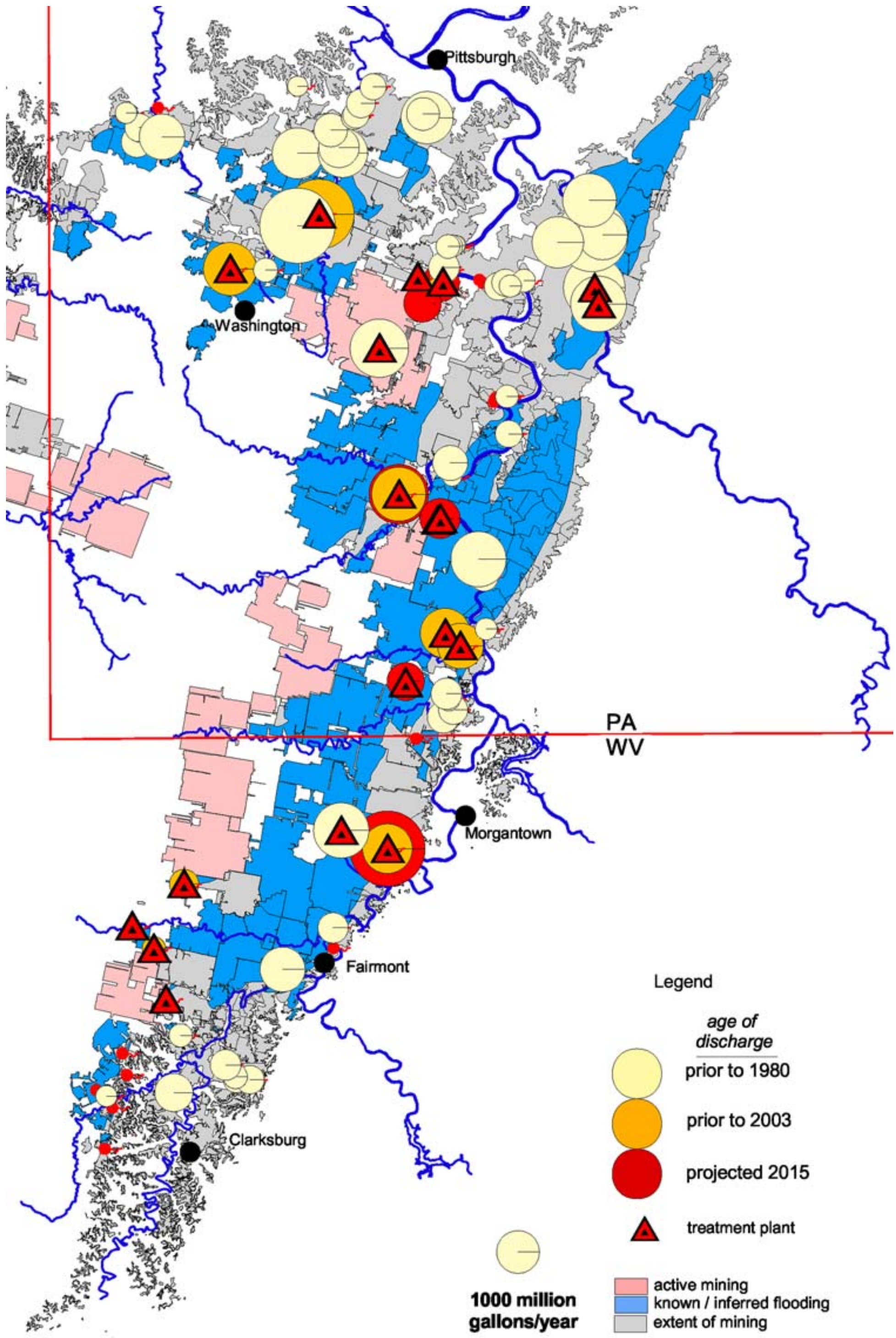

Fig. 1 Projected mine discharge locations and magnitude for year 2015. Base of mine outlines from year 2003 mapping (from Donovan and Leavitt 2004)

measuring the costs to purchase, install, and operate the plastic tanks compared to the traditional flat-bottomed concrete raceway system that is the industry standard. This research is attempting to reduce the fixed and variable costs for small to medium (<40,000 kg/year) sized fish farms.

Both the old and new versions of this plastic tank have a production volume of 7,500 L (2,000 gallons) and a carrying capacity of approximately 500 kg, depending on the flow of water. The new NRAC tanks were installed in autumn, 2006. Two populations of trout from the same hatchery using the same batch of eggs were placed in concrete and plastic tanks. Approximately 1,000 ten-cm rainbow trout fingerlings were stocked in each tank and were grown to market size (0.5 kg). Bird netting protected

Fig. 2 Good fin condition in rainbow trout harvest

both sites; the fish were fed a commercial, high energy trout diet, principally using demand feeders. Temperature and oxygen data were recorded at both sites to assure that the parameters were within the recommended culture conditions for trout.

Solid waste removal from concrete raceways continues to be a rather labor intensive chore. Excessive waste build-up in the quiescent (settling) zone can cause poor water quality and disease issues. A special manifold system was tested to remove the solid waste from the settling zone at the end of each plastic tank (patent pending). It is a simple system using a valve that allows the solid material to exit each tank along a waste pipe that parallels the tank system. Initial data indicate that the manifold system will significantly reduce labor costs for waste removal compared to the system used in concrete facilities. This will translate into reduced operational costs and a lower cost of production for the producer. The initial cost of materials and installation for the plastic tanks were found to be 47% less than that of a comparable concrete raceway system. Lower production costs will encourage more small to medium sized fish farmers to make the investment in this alternative raceway design. The plastic tank life expectancy is estimated to be 20 years.

Water Treatment Plant Infrastructure Used for a Fishing Park

The Tygart River Mine is located in northern West Virginia just south of Fairmont. In the mid-1980s, a water treatment plant was constructed to treat the acid mine drainage from the nearly 3,000 ha underground mine. Sodium hydroxide was used to boost the pH and a flocculent was added to speed the settling of the precipitating iron. Two 378,000 L (100,000 gallon) settling basins were built and three ponds were used for this water treatment process. The water then flowed out of the basins into the middle and lower polishing ponds before discharging into Guyses Run. Martinka Coal Co. discontinued operation of the water treatment plant at Guyses Run in September 1999, following construction of a new water treatment plant nearby. The mine water sludge that remained in the polishing ponds was removed and in October 2001, after encouraging results with fish survival in the basins, a revision to the post-mining land use permit was approved by the West Virginia Department of Environmental Protection (WVDEP). This revision allowed Martinka to leave infrastructure in place and divert some of the surface water runoff into the lower ponds for fish production. The diversion of this runoff into the pond also helped reduce the solids that would have reached the stream during heavy rainstorms.

Multiple analyses were done on the pond sediments and toxins (mercury and PCBs) were found to be extremely low. Today, this site is open to the public and providing the county children and adults with an exceptional catch per unit effort. The first Kids Fishing Day tournament resulted in 65 kids catching over 900 fish in only 4 h.

With the transfer of the deed from the mining company to the county commission, the park is in the process of becoming one of the premier county fishing parks in the state. This allowed the mining company to save considerable effort and cost in reclaiming the site. Once the safety and comfort improvements are completed on the site, Guyses Run will be open to the public for educational and recreational purposes. This project has been an example of cooperation between a mining company, West Virginia University (Davis College of Agriculture and the Extension Service), and the local government for the development of a natural resource, resulting in improved outdoor recreational activities for everyone in the region.

Arkwright Mine Site: a.k.a. Dogwood Lake

Nearly 5 years of research have been conducted at the Dogwood Lake mine site, owned by Consol Energy. The benefits to Consol have been limited to demonstrations and occasional publicity about the fish being raised at the site. The unique characteristics of the water, which is very high in dissolved ions, have allowed scientists to test the water on a variety of fish including rainbow trout, brown trout, and hybrid stripped bass. All three of these species grew and survived well under commercial densities in a raceway system that received a portion of the outflow from the reservoir that serves as the polishing basin. The most recent stocking was nearly 6,000 brook trout, and they are doing great.

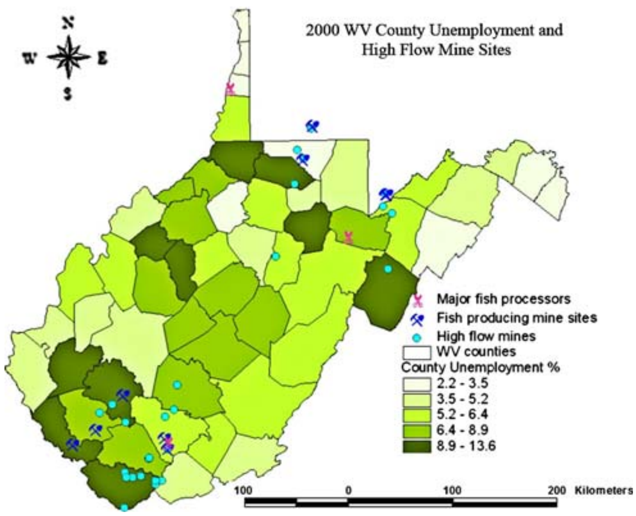

Fig. 3 High volume mine water discharges and unemployment in West Virginia (year 2000)

The mining industry has benefited from this post-mining land use in a number of ways. By converting a mine site into a productive aquaculture facility, a positive image was garnered by the fact that sensitive game fish are being commercially produced from mine facilities. These same facilities have often been associated with negative impacts on the aquatic life in a receiving stream.

Another advantage to using aquaculture as a post-mining land use is the potential savings in reclaiming the land. The Extension Service at West Virginia University has successfully aided the mining industry in converting the two mine sites mentioned in this article into productive aquaculture sites. In both cases, the result was reclamation savings in the range of a quarter to half million dollars (US). Federal and state regulatory agencies approved the post-mining land use permits within 1 year. D'Souza et al. (2004) showed how the relationship between high volume mine discharges and high unemployment in southern West Virginia (Fig. 3) could be used to increase tourism using an economic development strategy. Aquaculture as a post mining land use provides numerous opportunities for cooperation between diverse organizations. This cooperation has led to economic and social benefits for all of the involved organizations.

References

Donovan JJ, Leavitt BR (2004) The future of mine water discharges from underground coal mines of the Pittsburgh Coal Basin, WV-PA. In: Proceedings of national meeting of the American society of mining and reclamation and the 25th West Virginia surface mine drainage task force meeting, Morgantown, WV. ASMR, Lexington, pp 518–528

D'Souza G, Miller D, Semmens K, Smith D (2004) Mine water aquaculture as an economic development strategy: linking coal mining, fish farming, water conservation and recreation. J Appl Aquac 15(1/2):159–172

Hulbert PJ (2000) Phosphorus reduction at Adirondack hatchery: is the end in sight? In: Proceedings of 3rd East Coast Trout management and culture workshop. American Fisheries Society, Southern Div Trout Committee

Jenkins MR, Wade EM, Fletcher JJ, Hankins JA (1995) Economic analysis of non-traditional water resources for aquaculture in West Virginia. The Conservation Fund's Freshwater Institute, p 95

Kowalski DA, Bergersen EP (2003) The toxicity of Baylucide and TFM to *Tubifex tubifex*: implications for chemical control of the Oligochaete host of *Myxobolus cerebralis*, the causative agent of Whirling disease. N Am J Aquac 65(3):171–178

Miller D (2006) Trout culture as a post mining land use in West Virginia—a case study. Abstracts, Annual Meeting of the World Aquaculture Society, Florence, AQUA 2006, p 613

Mitchell AJ (2002) A copper sulfate-citric acid pond shoreline treatment to control the rams horn snail *Planorbella trivolvis*. N Am J Aquac 64(3):182–187

Modin JC, Veek TM (2002) Biological control of the parasitic copepod *Salmoncola califoriensis* in a commercial trout hatchery on the Lower Merced River, California. N Am J Aquac 64(2):122–128

Semmens KJ, Miller DJ (2003) Utilizing mine water for aquaculture. In: Proceedings of international water conference, Pittsburgh, IWC-03-24

Tierney AE (2002) The technical feasibility of using treated mine water to rear rainbow trout, *Oncorhynchus Mykiss*. MS Thesis, West Virginia University, Morgantown. https://eidr.wvu.edu/files/2575/tierney_aislinn_thesis.PDF

Viadero RC, Tierney AE (2004) Development of treated mine waters for aquaculture: non-ideal water chemistry effects at Dogwood Lakes. In: Proceedings of national meeting of the American society of mining and reclamation and the 25th West Virginia surface mine drainage task force meeting, Morgantown, WV. ASMR, Lexington, p 1960

Westers H (2000) The case of Michigan's Platte River salmon hatchery—a fourteen year dispute about phosphorus effluent contribution and its impact on Platte Lake: a precedence for public fish hatcheries? In: Proceedings of 3rd East Coast Trout management and culture workshop. American Fisheries Society, Southern Division Trout Committee

Wolkersdorfer C (2008) Water management at abandoned flooded underground mines—fundamentals—tracer tests—modelling—water treatment. Springer, Heidelberg, p 466