# Mine Water Aquaculture as an Economic Development Strategy: Linking Coal Mining, Fish Farming, Water Conservation and Recreation

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**ABSTRACT.** This study involves a comprehensive economic analysis of mine water aquaculture. First, the costs and benefits are quantified using standard enterprise budgeting and feasibility techniques. Next, a price analysis is conducted to determine the underlying probability distribution and generate confidence intervals for use in planning purposes. Then, the relationships between mine sites and unemployment, and mine sites and tourism, respectively, are illustrated using a spatial analysis. Finally, the potential economic development impacts of growth in the aquaculture industry on statewide output, income, and employment are estimated. The results have implications for entrepreneurs and the aquaculture and coal industries in Appalachia and other parts of the US where coal mining can be linked to fish farming, water conservation, and recreation. 

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## *INTRODUCTION*

The aquaculture industry, traditionally concentrated in the Southern United States, is rapidly growing in other areas of the country. As the use of conventional water sources such as springs, streams, and ponds approach their production limits, alternative water sources for raising fish become more attractive. One such non-traditional source is mine water. Appalachian states including West Virginia (the study area) have several active and abandoned mine sites that have plentiful water supplies potentially suitable for raising trout, arctic char or other aquaculture species. The technical feasibility of raising fish in mine water for food or recreational purposes has been demonstrated (Miller et al. 2004; Simmons et al. 2001); in addition, ongoing bio-assay studies have shown that food safety of fish raised in mine water is within acceptable limits, which, in turn, is likely to enhance consumer acceptance of this product. However, the economic feasibility of raising fish in mine water for commercial purposes has not been fully explored. The objective of this paper is to examine the economic feasibility of mine water aquaculture and to illustrate the possible economic development impacts.

Although no prior studies focusing on the economics of mine water aquaculture are documented in the literature, studies evaluating the culture of various aquaculture species in non-traditional environments do exist. For example, Rhodes (1993) examines the feasibility of culturing hybrid striped bass in a dredged material containment area. A special issue of a journal published by NOAA (1999) is devoted to articles exploring the use of non-traditional water environments such as Lake Superior as a strategy to promote sustainable development in the coastal basin. Other authors have investigated the recreation (angling)-related costs, benefits, and economic development impacts of streamflow restoration (Stevens et al. 2000), and provided a description of the ingredients and infrastructure needed to make mine water aquaculture successful in a coal-mining state such as West Virginia (Simmons et al. 2001). In addition, previous analyses have looked at the economics of farm based aquaculture in the study area (Fidler 2000) and the economics of processing in the study area (Fincham 2000). Our analysis builds on the latter two studies in particular.

Central to the determination of economic feasibility is a cost-benefit analysis. In terms of costs, since government regulations require mine water to be treated before it is discharged, additional costs incurred in aquaculture production from mine water are predominantly limited to items such as feed, labor and tanks or raceways. Benefits can accrue to mining companies, the aquaculture industry, and to statewide economic development. To the extent that scarce water resources are conserved for use in an additional production activity, society can benefit as well.

West Virginia makes an ideal study area for several reasons: (a) there is a relative abundance of high flow (> 1,000 gallons per minute on average) mine water sources; (b) the temperature and purity of the water (which sometimes–but not always–needs to be treated by the mine company before discharge) is optimal for raising trout and other cold-water species; and (c) there is an existing processing infrastructure and proximity to East coast population centers. The results have implications for entrepreneurs and the aquaculture, coal and recreational industries in other areas of Appalachia. In addition, the economic development results should be useful to policy makers in Appalachia and other parts of the country where coal mining can be linked to fish farming, water conservation, and recreation.

## *METHODS*

A comprehensive economic assessment requires a variety of techniques. First, conventional enterprise budgeting and feasibility techniques such as net present value are used to quantify the costs and benefits of mine water aquaculture. The latter are calculated using the EXCEL spreadsheet program. To capture economies of size, we assume two different hypothetical production facilities, producing 50,000 lbs and 100,000 lbs of food-size fish per year.

Next, a price analysis is conducted to determine the underlying probability distribution and confidence intervals for alternative fish species, information that can be used in business financial planning and risk management. The software package *@RISK* (Palisade Corporation, 2002) is used for this purpose.[1] Three fish species are examined, rainbow trout, *Oncorhynchus mykiss*; hybrid striped bass, *Morone chrysops* × *M. saxatilis*; and channel catfish, *Ictalurus punctatus*. Although cat-

1. Use of trade or manufacturer's name does not imply endorsement.

fish requires warmer waters and therefore is not a suitable candidate for mine water aquaculture in this area of the country, it has a long history in the US, and is included for perspective to show expected variability in prices (and therefore market risk) over an extended time period.

Finally, the geographical information systems (GIS) software package ArcView (ESRI 1998) is employed to capture the spatial relationships between mine water supply sources and unemployment and tourism, respectively, information that in turn can illustrate potential economic development impacts from the development of mine water aquaculture resources.

As part of the economic development analysis, the economic development multipliers are also estimated through an input-output analysis. The software package IMPLAN (MIG 1999) is used to illustrate the potential impacts of growth in the aquaculture industry on statewide output, income and employment.

Data for this analysis come from both primary and secondary, published, sources. Primary sources include mine water site visits and formal and informal producer surveys, while secondary sources include Agricultural Statistics and other reports by US Department of Agriculture, North Carolina Department of Agriculture, and West Virginia Department of Agriculture (WVDA).

## *RESULTS*

### *Financial Feasibility*

Central to this analysis is determining whether mine water aquaculture is profitable in the study area under the conditions assumed. These results are summarized in Table 1. The values in this table are derived through a sensitivity analysis of an EXCEL spreadsheet. In general, mine water aquaculture is profitable (from the viewpoint of the aquaculture producer) under a wide range of production level, time period and interest rate combinations. We find that the large (100,000 lbs) hypothetical production facility examined is more profitable in all scenarios examined. In addition, regardless of the size of the operation, the greater the time period of operation, the more profitable is the facility (as expected, these results are primarily because fixed costs are spread over a greater volume and/or time period). This information can be used to plan the length of the lease.

TABLE 1. Financial feasibility analysis for alternative mine water trout production levels, time periods, and interest rates.

*(a) 50,000 lbs Annual Production Level*

| Time period (years) | Net present value ($) | | | Internal rate of return (%) |
|---|---|---|---|---|
| | 7% | 9% | 11% | |
| 5 | 32,217 | 28,363 | 25,112 | 5 |
| 10 | 35,735 | 29,956 | 25,498 | 10 |
| 15 | 38,583 | 31,465 | 26,275 | 12 |
| 20 | 40,460 | 32,392 | 26,737 | 13 |

*(b) 100,000 lbs Annual Production Level*

| Time period (years) | Net present value ($) | | | Internal rate of return (%) |
|---|---|---|---|---|
| | 7% | 9% | 11% | |
| 5 | 54,424 | 48,460 | 43,379 | 12 |
| 10 | 69,231 | 58,543 | 50,200 | 19 |
| 15 | 77,818 | 63,638 | 53,242 | 21 |
| 20 | 82,613 | 66,080 | 54,502 | 22 |

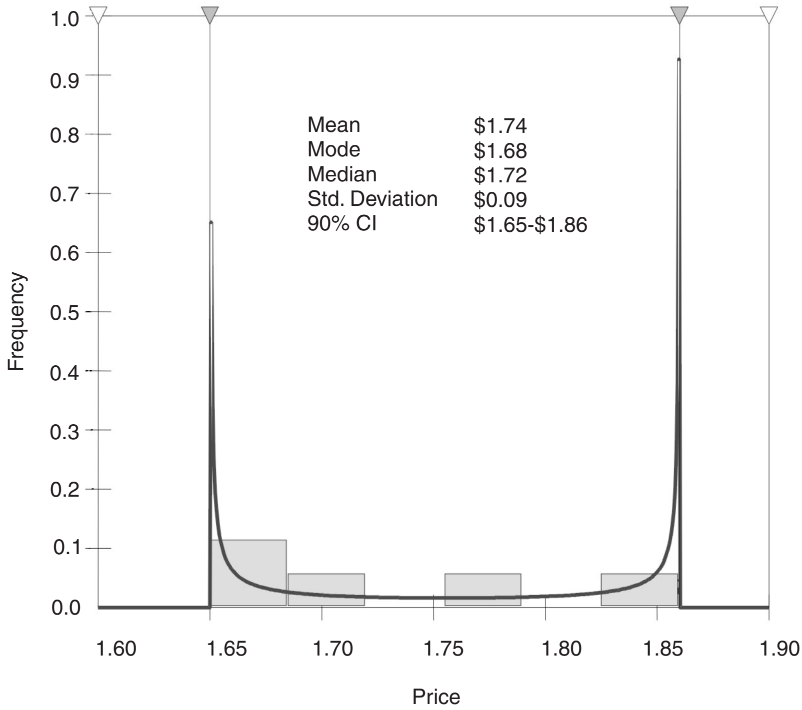
Net present value (NPV) is defined as the discounted value of a project's net annual cash flows less the initial investment cost. The internal rate of return (IRR) is basically the compound interest rate of the investment. Like the NPV, the higher the IRR, the more desirable the investment.

Tangible economic benefits can accrue to the mining company, as well in the form of the lease payment and to the extent that aquaculture production at the mine facility can reduce mine site reclamation costs. The latter are beyond the scope of this study.

### *Price Analysis*

The results of the price analysis are shown in Figures 1-3. The purpose of this analysis is to illustrate farm-gate price variability for various species (for which historical price data are available), which, in turn, can provide an indication of the degree of market risk that confronts producers (or even processors). Three different species are examined: rainbow trout, hybrid striped bass (HSB) and channel catfish. The results show that in terms of expected prices (current, not deflated, prices are used in this analysis), among the species examined, HSB is the most valuable (of course, one must compare both prices and costs to ultimately determine profitability)–such profitability analyses are contained in Fidler (2000) and San et al. (2001) for rainbow trout, and North Carolina Department of Agriculture for HSB, for example. In

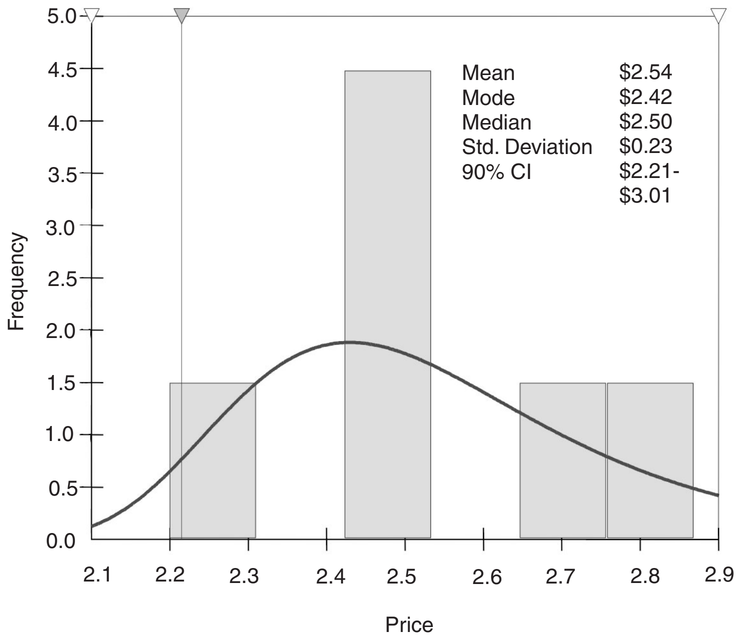
FIGURE 1. Beta general distribution of food-size trout weighted average farm-gate prices received, West Virginia, annual averages, 1997-2001 (West Virginia Department of Agriculture 2002).




terms of price variability, HSB also has the greatest price risk, both in terms of the standard deviation (23 cents) as well as the coefficient of variation (9.05), followed by rainbow trout, and channel catfish (the latter, incidentally, has both, the lowest price as well as the least price risk). While additional time series data on both prices (particularly for rainbow trout and HSB) and costs of production (in hill country) are needed to confirm these risk-return relationships, our preliminary conclusion is that the theoretical relationship between risk and return (i.e., the greater the risk, the greater the *potential* return) is confirmed.

It should also be noted that other species such as Arctic char, *Salvelinus alpinus*, command high farm-gate prices and are potentially suitable candidates for a mine water production system. However, data constraints preclude a more detailed analysis at this time. The 90% confidence intervals presented in Figures 1-3 can provide baseline information for producer

FIGURE 2. Extreme value (or Gumbel) distribution of hybrid striped bass farm-gate prices, Mid-Atlantic region, annual averages, 1992-1997 (North Carolina Department of Agriculture 2000).

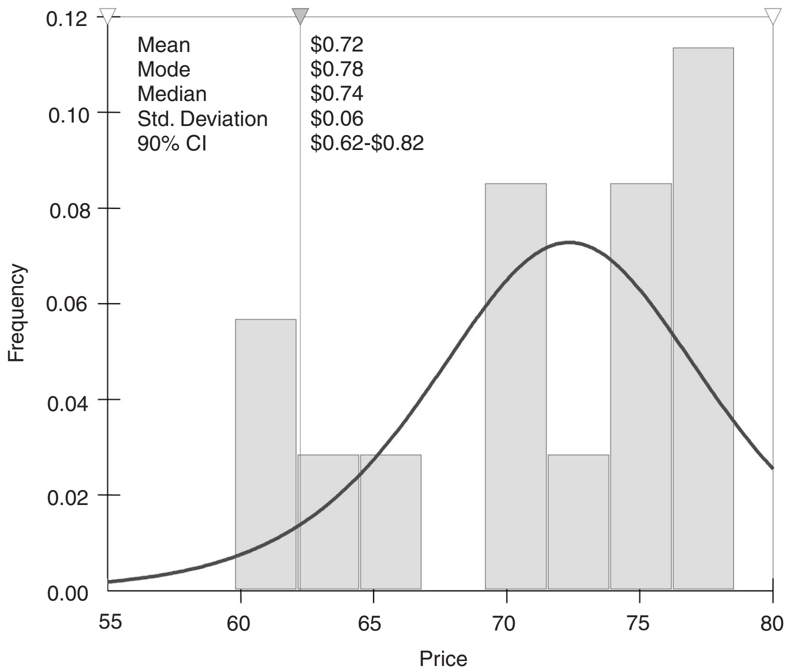



risk management, which, ultimately, is best accomplished through a diversification strategy (both, in terms of species produced as well as marketing outlets).

## *Spatial Analysis*

The spatial relationships between (i) high flow mine sites in WV (those with average flows exceeding 1,000 gallons per minute) and tourist trips, and (ii) between high flow sites and unemployment are shown in Figures 4 and 5, respectively. In both cases, it is revealing that the high flow mine sites coincide in many cases with counties that have high unemployment and/or high levels of tourism. The implication is that development of mine water sites for aquaculture can stimulate jobs, growth and tourism-related income in economically depressed areas. The impacts are quantified in the following sub-section.

FIGURE 3. Logistic distribution of catfish farm-gate prices, US annual averages, 1986-2000 (USDA 2002).

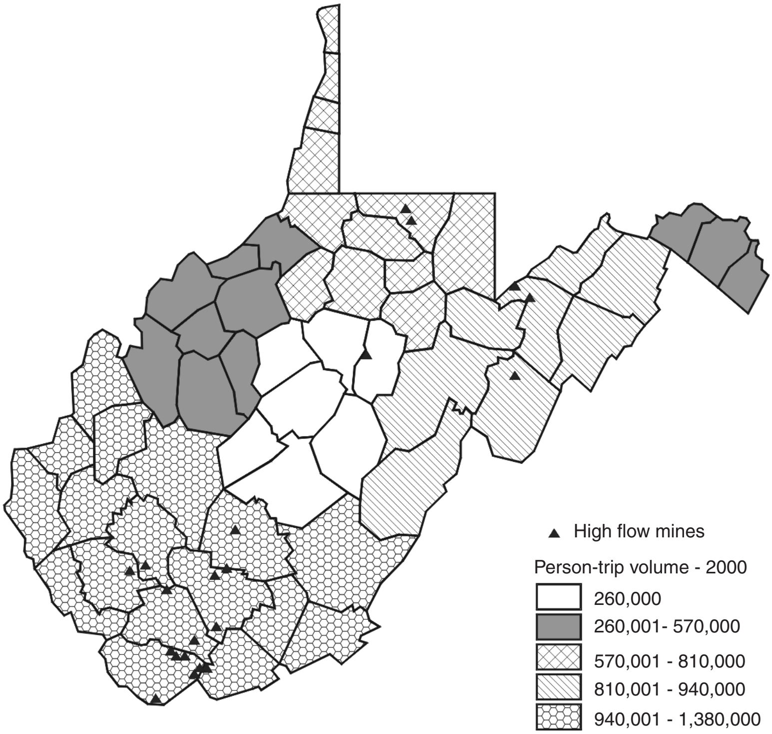



### *Potential Economic Development Impacts*

According to the WVDA, commercial food fish sales (mostly sales of rainbow trout to processors) across the state amounted to over $800,000 in 2001, a 35% increase from the previous year. An additional $1.4 million of rainbow trout was stocked for conservation and recreation, making the aquaculture production sector in WV an over $2 million annual activity. By virtue of its linkages with other sectors of the economy, an input-output analysis concludes that a $1 million increase in annual aquaculture production increases total output in the state by an estimated $2 million annually, generates an additional $1 million in income and business taxes, and adds 55 jobs.

In terms of recreational impacts, results suggest that for every 20,000 additional anglers, or an equivalent number of additional visits by existing anglers,[1] statewide output will increase by $2.5 million, income by

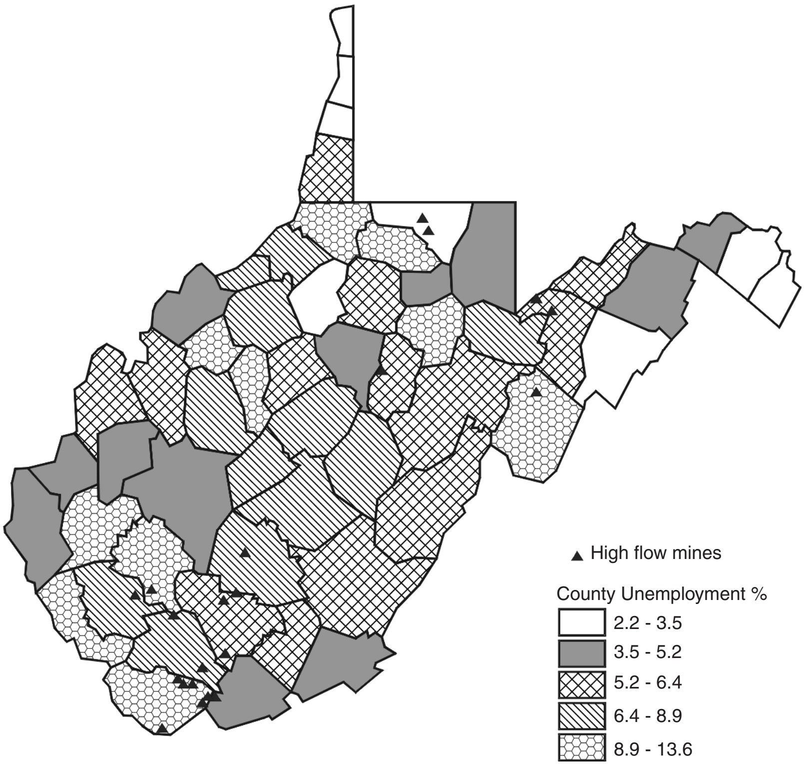
FIGURE 4. Location of high flow mine sites related to regional tourism, West Virginia, 2000.




$1.5 million, and 59 jobs will be created. A simple flow-chart showing how linkages among various sectors contributes to economic development is shown in Figure 6.

There are an estimated 25 mine sites around the state which meet water quality and quantity requirements for fish production. The estimated aggregate water flows from these sites is 50,400 gallons per minute (gpm) amounting to 73 million gallons per day. Assuming a production stocking density of 100 lbs per gpm, the total maximum fish production possible at these sites is 4-5 million lbs annually. Clearly not all these sites will be used for aquaculture. However, it provides an estimate of the possible upper bound, and, when used in conjunction with the economic multipliers noted previously, illustrates the magnitude of possi-

FIGURE 5. County unemployment relative to high flow mine water sources, West Virginia, 2000.

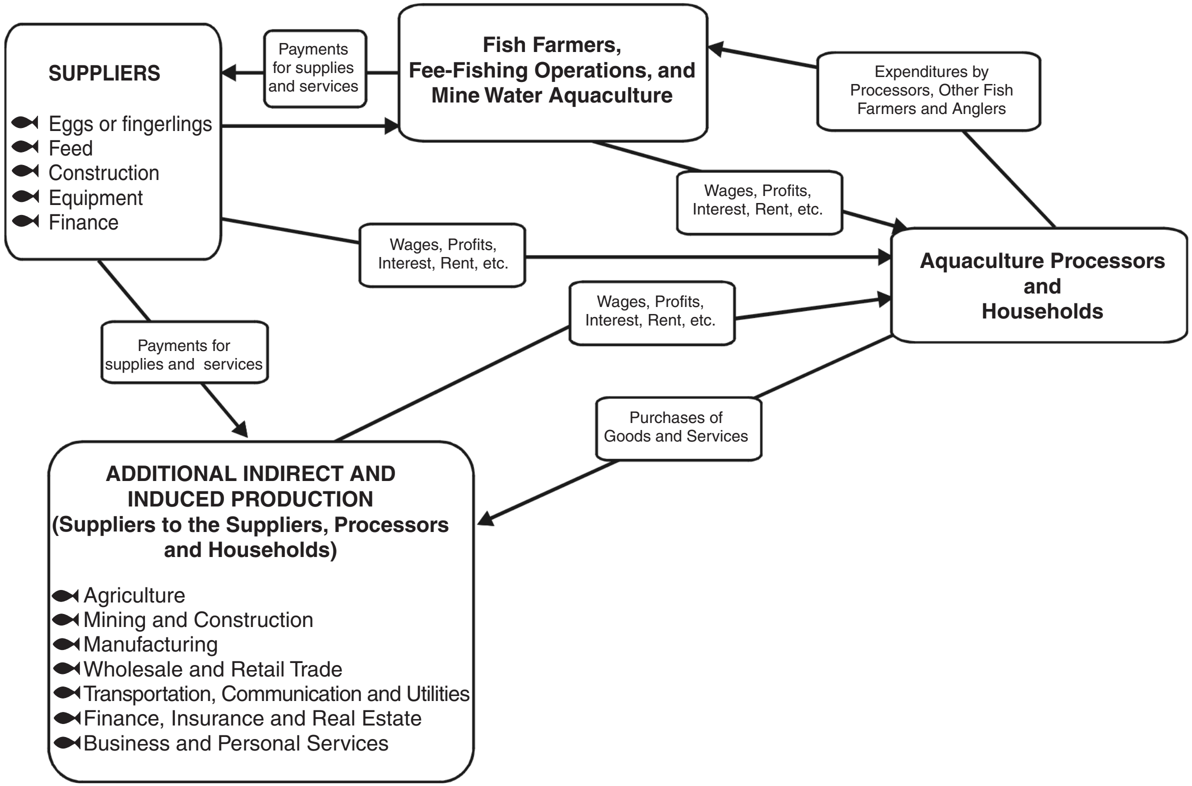



ble statewide economic development impacts ($10 million in additional total output, an added $5 million in income and business tax revenue to the state, and over 250 new jobs).

## *DISCUSSION AND IMPLICATIONS*

Ultimately, mine water aquaculture can be viewed as a special case of farm-based aquaculture, with adjustments made for unique circumstances regarding ownership of property (water and land) rights and government regulations regarding issues such as water treatment and

FIGURE 6. How aquaculture or fish farming creates jobs and income (adapted from Shifflet 2000).



permitting (which, essentially, are the responsibility of the coal mine). Thus, like a farm-based aquaculture operation, the operation of a given mine water facility can include one or more species (e.g., rainbow trout and arctic char) and/or one or more sales outlets (e.g., sales to processors; fee fishing outlets; and fingerlings). Although more than one species can be produced, practical considerations often preclude this arrangement. Diseases, water temperature differences, etc., can all play a major role in this decision. For example, although rainbow trout and Arctic char can be grown in the facility, ideally, char needs temperatures that average 4°F less than rainbow trout.

It should be noted that while the type of leasing agreement will be subject to tremendous variation, a suggested way to set up the lease is for the mining company to charge a flat rate for the facility or per pound if aquaculture production occurs (an analysis such as this can assist in determining the amount), but to waive this fee during seasons with a production failure (possibly defined as a loss in excess of 50%) that is a consequence of factors beyond the aquaculture operation's control (such as a situation that results in lower than normal pH levels or higher than acceptable $CO_2$ levels in the mine company's polishing pond, typically, the source of water for the aquaculture operation).

In general, while mine water aquaculture is found to be profitable under the conditions investigated and can be a potent economic development strategy, like other types of aquaculture, it is risky. Theoretically, a combination of species and sales outlets is a desirable diversification (or risk reduction) strategy; once more data become available, we can investigate the profit-risk relationships of different combinations. In addition, studies are needed to document consumer acceptance of fish produced in mine water environments.

In conclusion, mine water aquaculture can be a win-win situation from the viewpoint of the individual aquaculture entrepreneur, the mining company and statewide economic development. The potential benefits to entrepreneurs and the statewide economy have been quantified; the mining company also stands to benefit because of lower reclamation costs and invaluable positive publicity that inevitably results from linking production to conservation, recreation, and economic development.

## NOTES

1. According to survey data collected by the West Virginia University College of Business & Economics, this represents an approximately 10% increase over the existing estimated total of 204,379 in-state anglers and 370 out-of-state anglers. For purposes of this survey, anglers were defined as those holding either a sportsman package license (hunting + fishing) of a fish-only license.

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