FEASIBILITY OF UTILIZING WASTE-HEAT FOR FISH PRODUCTION IN NORTH DAKOTA

Randall S. Anderson and Jay A. Leitch

Aquaculture is a unique form of agriculture involving the rearing of aquatic organisms under controlled or semicontrolled conditions. Although aquaculture is usually associated with production of food fish for human consumption, it also includes production of fishes used for establishing or enhancing sport and commercial fisheries, production of bait fishes, and aquatic plant production.

Aquaculture in the United States is a recent development in comparison to other areas of the world where husbandry of aquatic organisms has been practiced for 3,000 to 4,000 years. Aquaculture in this country first began with the culture of oysters in the 1850s and development of salmon hatcheries in the 1870s (Avault, 1980). In recent decades, more interest has focused on production of fish for table food.

Total U.S. harvest of edible fish and shellfish in 1982 was 3.3 billion pounds, of which 395 million pounds (11 percent of the total) was produced by aquaculture (Joint Subcommittee on Aquaculture, 1983). Most U.S. aquacultural production of food fish has concentrated on two fish species in two major geographic locations. Over 85 percent of all farm-raised trout originate from Idaho's Snake River Valley (USDA, 1982). The southern states of Alabama, Arkansas, and Mississippi produce over 90 percent of all farm-raised catfish.

Aquatic species used in aquaculture systems are cold-blooded, so their growth is dependent upon the temperature of their environment. Optimal conditions for rapid growth and food conversion for most cultured species occur between 50 and 86 degrees F. This has limited most successful aquaculture ventures to areas with warm climates (e.g., catfish in the South) or to areas with abundant natural geothermal spring waters (e.g., trout in Idaho).

Aquaculture activity in the United States has recently been increasing for several reasons. Aquatic organisms are more efficient food converters in comparison to terrestrial food animals. Fish are also becoming more recognized as an all-purpose protein food that contains no carbohydrates, little fat, and is leaner than most meats (Lovell, 1980). Per capita consumption of fish has been increasing over the past 25 years from 10.5 pounds in 1955 to 13.5 pounds in 1980 (USDA, 1981). At the same time, natural fish supplies have decreased due to overharvest, pollution, and loss of habitat.

There has recently been considerable interest regarding the feasibility of using industrial waste-heat for creating optimal rearing conditions in areas normally unsuitable for aquaculture. Coal-fired electrical generating plants discharge large volumes of heated water as part of their operation. This warm water has been used in aquaculture facilities worldwide.

The major objective of this study was to examine the biotechnical and economic feasibility of a year-round, waste-heat aquaculture venture at North Dakota coal-fired electrical generating plants.

CONCEPTUAL FRAMEWORK

This analysis incorporated elements of technical, biological, and financial feasibility. The technical feasibility analysis consisted of a review and selection of potential waste-heat aquaculture sites in North Dakota. Criteria used in site selection were based upon power plant operating characteristics and other on-site variables applicable to waste-heat aquacultural use.

The biological feasibility analysis included a review and selection of species with potential for aquacultural use at a selected power plant site. Criteria based on cultural characteristics and market factors were established to facilitate selection of potential species.

After a potential site and species were selected, a hypothetical aquaculture facility and production scenarios were developed. The economic analysis involved estimating investment requirements and total production costs per pound for each scenario.

RESULTS AND DISCUSSION

Seven coal-fired electrical generating stations were evaluated for potential aquacultural use (Figure 1). The Leland Olds Station (LOS) operated by Basin Electric

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Anderson is research assistant and Leitch is assistant professor, Department of Agricultural Economics.

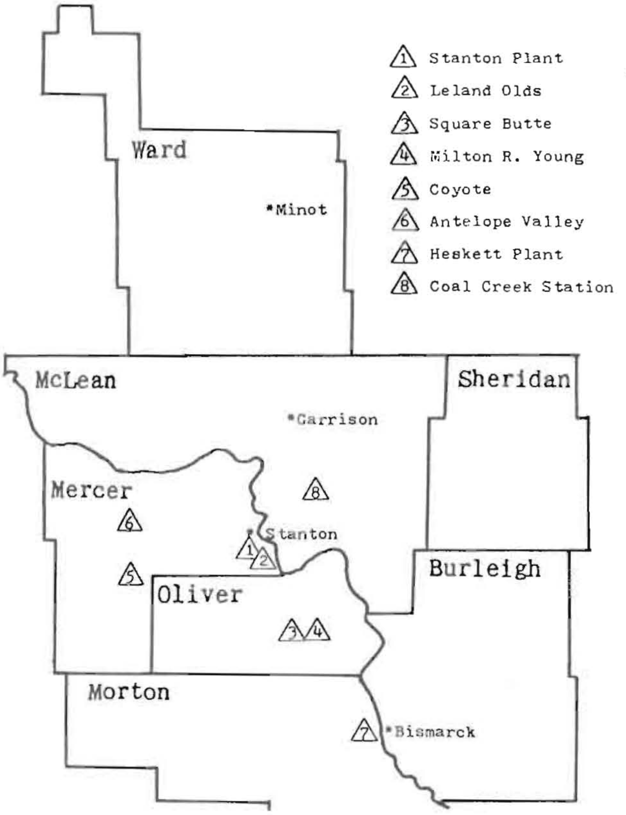

Figure 1. Major Coal-Fired Electrical Generating Stations in West Central North Dakota

Power Cooperative was selected as the best site due to the following characteristics:

- Life expectancy of the generating station should allow a minimum of 10 more years of continued operation.
- The station utilizes a single-pass condenser system which has several aquacultural advantages over closed-cycle systems.
- Leland Olds Station consists of two generating units and thus has two separate thermal effluents providing greater reliability of continuous warm water flow.
- Location of LOS adjacent to the Missouri River provides access to an adequate supply of cooler water needed to temper the thermal effluent.

Aquatic species reviewed for potential use at LOS were freshwater prawn (*Macrobrachium* sp.), American eel (*Anguilla rostrata*), yellow perch (*Perca flavescens*), walleye (*Stizostedion vitreum*), salmon (*Oncorhynchus* sp.), striped bass (*Morone saxatilis*), tilapia (*Sarotherodon* sp.), rainbow trout (*Salmo gairdneri*), and channel catfish (*Ictalurus punctatus*). Rainbow trout and channel catfish were selected as the best species for the following reasons:

- Cultural requirements and techniques for both species are well known.
- Environmental requirements for optimal growth are obtainable at LOS.
- Use of a cold-water and a warm-water species will allow maximum utilization of the thermal effluent during different times of the year.
- Both species are popular food fish.

A hypothetical aquaculture facility and two production scenarios were developed based on parameters of the Leland Olds site and cultural requirements of rainbow trout and channel catfish.

> **Production Scenario I:** rear rainbow trout from November-April and channel catfish from May-October. Trout and catfish would be stocked at a size of 6 inches and harvested at weights of 12 and 20 ounces, respectively.
>
> **Production Scenario II:** rear rainbow trout on a year-round basis. One-inch fingerlings would be stocked four times each year. Trout would be harvested 12 months later at an average of 12 ounces. Both scenarios have an annual live-wieght harvest of 100,000 pounds.

Investment requirements for the proposed facility fall into five major categories: (1) water supply equipment ($21,970), (2) production raceways ($35, 640), (3) water and waste discharge facilites ($27,950), 4) feeding equipment ($7,300), and (5) miscellaneous equipment ($24,600). Total capital investment required for 100,000 pounds/year is $117,460.

Annual fixed costs include amortization of capital funds ($20,220)[1], management costs ($24,800), and insurance ($3,000). Annual operating costs include fingerlings, feed, labor, transportation, electricity for pumping, repairs and maintenance, interest on operating capital, and miscellaneous expenses (Table 1).

Total annual cost per pound of harvested trout was $1.53 for Production Scenario I and $1.26 for Production Scenario II (Table 2). Total annual cost per pound of catfish harvested was $1.17. Changes in costs of the three largest cost components comprising total annual costs (management, fingerlings, and feed) had only a minor effect on total per-pound costs of production.

CONCLUSIONS

Results of this study indicate that year-round aquaculture is biotechnically feasible in North Dakota by utilizing thermal effluent from a coal-fired power plant. Several power plant sites and aquatic species have potential for aquacultural development.

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[1] Based on 100 percent external financing of $117,460, 10-year repayment, and 12 percent interest.

Table 1. Annual Variable Aquaculture Production Costs, Leland Olds Station, 1983

Item	Production Scenario	
	I	II
	dollars	
Fingerlings		
Rainbow trout	$20,834	$ 8,333
Channel catfish	6,000	NA
Feed		
Rainbow trout	19,453	44,939
Channel catfish	16,406	NA
Labor	7,072	7,072
Repairs and maintenance	2,349	2,349
Pumping costs	5,879	7,839
Transportation	589	589
Miscellaneous expense	3,929	3,556
Interest on operating capital	4,126	3,734
Total		
Rainbow trout[a]	52,259	78,411
Channel catfish[a]	34,378	NA

NA = Not Applicable.

[a] For Production Scenario I, the total cost of labor, repairs and maintenance, pumping, transportation, miscellaneous expense, and interest on operating capital have been divided equally among rainbow trout and channel catfish.

Table 2. Catfish and Trout Production Costs, Scenarios I and II, Leland Olds Station, 1983

Item	Production Scenario	
	I	II
	dollars	
Total Annual Costs	$134,657	$126,431
Annual fixed cost	48,020	48,020
Annual variable cost (trout)	52,259	78,411
Annual variable cost (catfish)	34,378	NA
Total Cost Per Pound (Trout)[a]	1.53	1.26
Fixed cost per pound	0.48	0.48
Variable cost per pound	1.05	0.78
Total Cost Per Pound (Catfish)[b]	1.17	NA
Fixed cost per pound	0.48	NA
Variable cost per pound	0.69	NA

NA = Not Applicable

[a] Based on an annual harvest of 50,000 pounds for Production Scenario I and a harvest of 100,000 pounds for Production Scenario II.

[b] Based on an annual harvest of 50,000 pounds.

Economic feasibility is not easily determined. Trout and catfish production costs at the proposed facility are substantially higher than the average prices received by producers in the major aquaculture production regions ($0.60 - $0.70/pound). However, higher prices have been received by producers in other states. The potential for profit exists if these higher prices could be received in North Dakota through promotion as a specialty or locally-raised product.

Success of any large-scale commercial venture will depend upon solving marketing and economic problems more than biotechnical ones. Prior to any aquacultural development, potential markets need to be identified or created. Addition of a major fish wholesaler to the venture would certainly help in this area.

LITERATURE CITED

Avault, J.W., Jr. "Aquaculture," **Fisheries Management,** pp. 379-411, edited by R.T. Lackey and L.A. Nielsen, John Wiley and Sons, Inc., New York, 1980.

Joint Subcommittee on Aquaculture. **National Aquaculture Development Plan,** Vol. I, Washington, D.C., 1983, 67 pp.

Lovell, T. "Nutritional Value: A Marketing Asset," **Aquaculture Magazine** 6(5):36, 1980.

United State Department of Agriculture. **Aquaculture - An Overview,** Agricultural Issues Overview No. 1, National Agricultural Library, 1981, 30 pp.

United States Department of Agriculture. **Aquaculture Outlook and Situation,** Economic Research Service AS-3, April 1982, 16 pp.

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The world's agriculture is entering an era of high technology driven by the computer chip and the basic science of genetic engineering. If we think that our farms have changed in the past 20 years, I'd submit that we "haven't seen anything yet." Our new plant varieties will have genes "engineered" for disease and insect resistance; and still other genes for salt and drouth tolerance; and still other traits for high yield under irrigation. We will use variable seeding, herbicide and fertilizer rates on a given field guided by an on-board computer that will follow a seeding plan programmed on a "floppy disk," planned by the micro computer on the kitchen table. All of this will lead North Dakota farmers to an increasingly important position in U.S. agricultural production.

Space age agriculture will challenge us all in terms of keeping pace with our real world potential. Our challenge as operators of North Dakota's research establishment is the implementation and management of research programs that will keep North Dakota farmers on the leading edge of farm production technology. This means we must be prepared to compete for the best trained minds to man the scientific research laboratories of our research organization. If we continue to reach for a more agressive research program in North Dakota, our agriculture will not only survive the present period of financial stress, but we will be in a position to lead American agriculture to a period of greater future prosperity.