Agricultural Innovations
Practical applications for sustainable agriculture
Fact Sheet
Sustainable Agriculture Research & Education

Polyculture and Reservoir Ranching: Sustainable Aquaculture Strategies for Paddlefish *(Polyodon spathula)* Production

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Reservoir ranched paddlefish.

Inside this fact sheet:

SARE Agricultural Innovations are based on knowledge gained from SARE-funded projects. Written for farmers and agricultural educators, these peer-reviewed fact sheets provide practical, hands-on information to integrate well-researched sustainable strategies into farming and ranching systems. The articles are written by project coordinators and published by SARE.

Geographic Range:

South, Midwest and North Central regions of the United States. Temperate climates globally.

Introduction

Aquaculture is the farming and caring of aquatic organisms including fish, mollusks, crustaceans and aquatic plants under individual or corporate ownership. Aquaculture has been almost entirely responsible for the expansion of available food fish since 1988, with production doubling in inland waters over the last decade. However, the majority of the expansion in aquaculture production is from Asian countries, largely from China.

Aquaculture in the United States ranks 11th in the world in terms of total production and value. As a result, the United States imports a majority of its aquatic foods, which contributes to our nation's trade deficit as well as an uncertainty of supplies and product quality (1). Further, aquaculture in the United States is expected to face strong competition from both the continued growth of imports of aquacultural products globally and from domestic poultry and livestock industries (1). Species diversification, modernization of traditional production systems, and the development of innovative production methods should be practiced to increase efficient use of water resources and lower production costs (2).

Traditional aquacultural species in pond culture are expensive because of the high costs for land, pond construction and feed. To compete, the U.S. must produce high-value species in production systems that use existing water more efficiently, minimize waste of nutrients, maximize the use of natural foods derived from solar energy (i.e. photosynthesis), enhance water quality, and increase fish productivity of existing waters (3). The purpose of this fact sheet is to describe two production systems, polyculture and reservoir ranching, that show promise of becoming popular

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methods for increasing fish production and profits in inland waters compared to a traditional monoculture system. We also examine the usefulness of paddlefish as a high-value, emerging species that grows well in polyculture with channel catfish or in reservoir ranching.

Paddlefish

Paddlefish, closely related to sturgeons, are filter feeders throughout most of their life and the only member of the family Polyodontidae on the continent (4). Paddlefish have a mostly cartilaginous skeleton guaranteeing no bones in the meat. Paddlefish grow rapidly, up to 0.75 pounds/month, and can be easily harvested by seining or gill netting. Paddlefish reproduction can be induced with hormones to propagate; and fingerlings can be raised intensively up to stocker size of more than 12 inches in the same season. Mature female fish (about 20 to 70 pounds) can produce about 15 percent of their body weight in roe (3 to 10 pounds). However, there are some disadvantages to paddlefish and their production. They have poor tolerance for low dissolved oxygen (<2 ppm), and show handling stress when water temperatures are higher than 70° F. Artificial propagation and fingerling production are complex procedures and fingerlings are vulnerable to bird predation (5).

Paddlefish have long been an alternative to sturgeon as a source of meat and caviar. Formerly abundant in the Mississippi River basin and adjacent Gulf Coast drainage, natural populations of paddlefish were commercially harvested for their high-valued, boneless meat and roe sold as caviar. Continued loss and alteration of natural spawning habitat, organochlorine (i.e. chlordane and PCB) contaminants, and overexploitation by commercial fishing are believed to be the main reasons for declining populations.

The listing of sturgeon and paddlefish species by the United Nations Convention on International Trade in Endangered Species (CITES) greatly restricts the importation of sturgeon products from the Caspian Sea area, the major source for the world's supply of caviar and sturgeon meat products. As a result, there is an increasing gap between the demand and supply of those products. In some markets, wild-caught paddlefish have been substituted for sturgeon because of their similarity in taste and quality. Producing cultured paddlefish in the United States would help to meet the consumer demand and, at the same time, reduce the pressure on natural paddlefish/sturgeon populations.

Extensive water resources suitable for growing paddlefish exist in the United States, including millions of acres of private and public reservoirs throughout the United States built

Polycultured paddlefish.

for flood control management and/or hydroelectric production. Most of those reservoirs are managed exclusively for sport fish. However, if paddlefish were permitted to be stocked at 10 fish/acre in just 2,000 acres/year and with a 75-percent harvest rate, it is predicted that enough meat and caviar per year (after an initial waiting period of at least seven years) could be produced to impact the economy by as much as $7 million a year. Further, with catfish production being the largest segment of U.S. aquaculture, there are over 175,000 acres of existing catfish ponds in the southern region (1) where paddlefish could be raised also.

High feed cost is one of the major factors limiting the income of catfish farmers. However, excess feed and excrement from catfish make these ponds nutrient-rich and abundant with zooplankton. Polyculture of catfish with a filter feeding species such as paddlefish could take advantage of the zooplankton in catfish ponds to increase the fish yield per acre without adding to the feed cost. Though bighead carp, a filter-feeding fish native to China, have been introduced into catfish ponds and have demonstrated yields of 300-500 kg/ha (6), meat from this species is not well accepted by American consumers because it has small bones and a strong fish taste, causing a low market value for this product. However, paddlefish, a native filter feeding species, provides a more valuable meat with no bones, a mild flavor and a firm texture (5).

Polyculture of Paddlefish and Catfish

Polyculture of paddlefish with channel catfish is a system designed for producing yearly harvest of paddlefish for meat. Paddlefish should be stocked large enough so as not to be preyed on by the catfish. In production ponds, more than 12

inches is the recommended size. In catfish fingerling ponds, less than 12 inches is suitable.

Since paddlefish feed on natural zooplankton, there is a certain carrying capacity of fish that can be grown per surface area of the pond based on the amount of natural food present. Ponds that are more than five years old typically have an established food base favorable to paddlefish; newer ponds should be assessed before stocking. For example, in Kentucky, we had an average fish survival of 29 percent in ponds that were only two years old as opposed to 75 percent in ponds that were six years or older. Paddlefish stocked at 100 fish/surface acre should exhibit a growth rate of about 0.5 pounds/month producing 5- to 6-pound fish in a year with about a 75-percent survival rate.

Polycultured paddlefish.

Paddlefish can be harvested using the same net or "seine" as catfish. Seines are typically large enough to encircle the entire area of the pond. In the middle of the seine, there is an attachment known as the "sock," which is 10 to 15 feet long and allows the fish to congregate. Socks are of different mesh sizes to permit the grading of fish, allowing small fish to be released back into the pond and larger fish to be harvested and processed. During this grading process, paddlefish can be easily removed by hand sorting. The fish are relatively docile, and the paddle provides a convenient handle to catch the fish. In catfish fingerling ponds, using a seine with one-inch mesh will permit the release of small catfish and only retain the paddlefish. Paddlefish can be held in holding nets in the pond then loaded onto hauling truck for transport to the processing plant.

Catfish ponds are not recommended for growing mature female paddlefish for roe. Catfish ponds present a higher level of risk for caviar production than reservoir ranching due to possible mortality from frequent handling of the paddlefish during catfish harvest or low dissolved oxygen (<2 ppm). However, some producers have taken the risk and have been successful in producing caviar and meat by careful water quality management and infrequent harvests. Farmers who have raised paddlefish for several years in the same pond use gill nets to selectively remove only the paddlefish. Gill nets of four-inch mesh or larger will usually not catch catfish, and the paddlefish are easy to remove alive. This method is easy, but the gear may need special permitting by state officials for use as aquaculture harvesting equipment.

See table 1 for a comparison of two production strategies for paddlefish.

Advantages and Disadvantages of Polyculturing Paddlefish with Channel Catfish

Paddlefish between 5 and 6 pounds grown with catfish in ponds should increase production yields by 300-500 pounds as well as profit margins between $100 to $200/acre compared to growing only catfish in ponds. Paddlefish are docile and relatively easy to harvest and sort from catfish. Farmers have

Table 1. Biological and Economical Comparison of Paddlefish Polyculture with Channel Catfish and Reservoir Ranching: Two Sustainable Production Strategies.

	Pond Polyculture with Catfish	Reservoir Ranching
Product(s)	Meat	Meat and Caviar
Stocking	100 Fish/acre	5-10 Fish/acre
Culture Duration	12 Months	7-9 Years (sexual maturity)
Potential Revenue	$100-200/acre[1]	$500-1000/acre[2]

[1]Based on 75% survival, fingerling purchased at $3 each, and meat sold as whole fish at $1/lb. at the pond bank.
[2]Based on 50-75% of the fish harvested, at least 3 females/acre, 4 pounds of roe/female and caviar sold at $100/lb.

reported better water quality such as lower ammonia and nitrite levels with paddlefish stocked in catfish ponds. Test markets have demonstrated a strong acceptance for paddlefish meat, which provides a new fish product for market diversification.

There are some disadvantages to using paddlefish in polyculture with catfish. Large numbers of stocker fingerlings (>12 inches) are currently not available. Because of the limited supply, prices of fingerlings are high (> $3). Paddlefish can not tolerate low dissolved oxygen (< 2 ppm). They are vulnerable to bird predation, especially at night, when the fish has a tendency to swim near the water surface. Markets are not well established because of lack of consistent supplies of cultured paddlefish.

Reservoir Ranching

Reservoir ranching is an extensive, sustainable, non-polluting production system in which young fish (more than 12 inches in length) are stocked into lakes or reservoirs, permitted to forage on the natural food supply and harvested (7). They can be harvested as a meat fish after two or more years, or be permitted to grow to maturity of seven to nine years and harvested for their meat and roe. Paddlefish are usually over 10 pounds after two years, and females will usually reach maturity when the fish is over 30 pounds. To catch meat fish, 4- to 5-inch bar mesh gill nets will catch 10- to 30-pound fish. For catching mature females usually over 30 pounds, 6-inch bar mesh nets are best suited. Gill nets should be 150 feet long and 18 to 24 feet deep. They should be set perpendicular to the shore and left overnight if the water temperature is below 50ºF. When the water temperature is over 50ºF, nets need to be checked every couple of hours to prevent fish mortality.

Paddlefish can be stocked in lakes and reservoirs that are managed for sport fishes such as hybrid striped bass and walleye. They should not be stocked in reservoirs stocked with striped bass or tiger muskie, large predator fish that could consume them or could get entangled in gill nets at harvest. This system is very economical for paddlefish caviar production, requiring only the purchase of young fish, an existing body of water, seven to nine years of waiting for sexual maturity and harvesting.

Reservoir ranched paddlefish.

Reservoir Ranching Demonstration

A reservoir ranching demonstration was implemented in 1996 using a private 68-acre "strip pit" reservoir (surface-mined for coal in the mid-1950s) in southern Indiana. Four hundred paddlefish were initially stocked. In the winter of 2004, 6-inch bar mesh gill nets (about a total of 900 feet) were set for two 24-hour periods. About 200 paddlefish averaging 33 pounds were captured. The fish were processed, providing about 1.75 tons of whole-dressed (de-headed and eviscerated) fish and 180 pounds of processed caviar. Another harvest from this reservoir in the winter of 2006 will be attempted to further assess survival. Initial cost of fish was $1,200 and harvest/processing costs were $3,600. Gross revenue was over $35,000 for the caviar sold at $150/pound and meat sold at $2.50/pound.

Pros and Cons of Reservoir Ranching in Large Reservoirs (>2000 acres)

Use of large reservoirs could permit large numbers (i.e. 20,000 fish in 2,000 acres) of paddlefish to be stocked for grow-out. At least half of the fish could be females, which

Table 2. Potential Revenue from Paddlefish Harvested from a Hypothetical 2,000-acre Reservoir.

Harvest rate Mature fish	No. of Fish [1] Captured	Gross Revenue[2]	Returns above Variable Cost[3]
25%	5,000	$1435,000	$1,391,500
50%	10,000	$2,599,000	$2,339,100
75%	15,000	$3,885,000	$3,496,500

[1] 50% of the fish are predicted to be mature females with about 4 pounds of processed caviar.
[2] Based on fillet meat@ $5.99/lb and caviar@$100/lb.
[3] Fish and harvest costs are predicted to be about 10% of the gross revenue.

would assist in generating revenue from a domestic supply of high-quality meat and caviar (table 2). Paddlefish will not reproduce in static water, so the number of fish would never increase.

Survey of caviar taste test (top). High-end restaurant with paddlefish caviar and meat (bottom).

Small family farms could produce and supply young paddlefish for stocking a local reservoir. Moreover, aquaculture infrastructure such as the hatchery and processing plant could increase employment in rural areas. At harvest, large mesh gill nets (6 inches in bar mesh) that are selective for large paddlefish will not capture most sport fish as long as the reservoir is not stocked with striped bass or tiger muskie. Some of the money generated from the harvest would sustain the program for re-stocking. Overall, the estimated economic impact from 2000 acres with 75 percent of the fish recovered is estimated to be around $7 million.

There are some disadvantages to using large reservoirs for paddlefish production. Most large reservoirs are considered public water and would have to be approved for production through government bureaucracy. Some reservoirs in the fall or during heavy rains have rapid draw downs to lower the water level that could permit the fish to escape. Poaching could be a possibility and would require better security around the reservoir. Total harvest is not possible, which would leave some of the large fish in the reservoir to be removed later.

Currently, there are no states that practice paddlefish reservoir ranching as a business in public waters. However, the Kentucky legislature mandated that its citizens be surveyed for their opinion on reservoir ranching of paddlefish in selected public reservoirs. The majority of the results (about 70 percent) gave positive acceptance by the public to permit this type of production with paddlefish. Recently, the Kentucky Department of Commerce started to evaluate the potential of a pilot project. For more information, email smims@kysu.edu

Summary

Raising paddlefish in ponds with channel catfish or in reservoir ranching is both sustainable and economically promising in temperate climates. The fish grows fast by filter feeding on zooplankton and is valuable for its boneless meat and black roe processed as caviar. Currently, there are only a few hatcheries that produce stocker paddlefish, and supply of the fingerlings is limited, which inversely effects the price (≥ $3). Chefs at high-end restaurants indicated that the meat was versatile, with many ways of preparation, and that the caviar was a suitable substitute for the more pricy sturgeon caviar.

However, inconsistent supply of these products has slowed its market development. To develop this industry and increase supply, existing bodies of water are needed to produce paddlefish. Catfish farmers and land owners should consider stocking paddlefish into their ponds and private reservoirs. Federal and state governments need to consider changing regulations to permit the stocking and harvesting of paddlefish in selected public reservoirs.

SARE Research Synopsis

The SARE project Enhancing Farmers' Income through Polyculture of Paddlefish with Catfish in the Southern Region was conducted from 1999-2002. Paddlefish were stocked in commercial catfish ponds (five acres or larger) at 50 and 75 fish/acre located in Kentucky, Alabama and Oklahoma. These states represent low catfish production in the United States and often lower profit margins with monoculture of catfish. Survivals ranged from 70 to 85 percent in both densities for all three locations. Mortalities were attributed to stocking stress in transport and/or bird predation, not to low dissolved oxygen or poor water quality. The growth model for this regional project gave significantly greater average weight gains of fish in KY (6.pounds) and AL (5.5 pounds) than fish in OK (4.9 pounds). The addition of paddlefish to a catfish pond demonstrated an increase in production of over 300 pounds/acre, which could contribute to farm income. Estimated profits could range from $100 to $200/acre when farmers purchase fingerlings at $3 each and sell fish at $1/pound at the pond bank. Overall, the polyculture system gave similar results in paddlefish growth and survival despite wide geo-

graphical distances among the states tested, demonstrating the versatility of this fish to adapt to varying climatic and water quality conditions.

Fresh fillets were test marketed and chef surveyed at high-end restaurants in Louisville and Lexington, KY. Market survey responses were scored on a scale of 5, with 1 equaling strongly disliked or undesirable and 5 equaling strongly liked or desirable. The taste, texture, color and overall product averaged 3.8, 4.1, 4.3 and 4.1, respectively. The chefs indicated that the product was very versatile because they were able to cook it many different ways such as baked, broiled, smoked, fried, etc., mainly due to its firm texture. Further, the chefs said that the product was unique, providing their customers with a new experience that was highly desirable and well received by high-end clientele. Chefs preferred fillets fresh, not frozen. Chefs were willing to purchase the fresh fillets at prices between $7.99 and $8.99 a pound.

This fact sheet is based on a SARE-funded project.
For more information, please visit www.sare.org > Project Reports > Search the database for project # LS99-104

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