1998 SEMAC Mini Grant Program

Final Report

The Potential for Crayfish Production In Massachusetts

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Executive Summary:

Coonamessett Farm personnel have been working on methods of culturing native crayfish species in an economically viable manner. Culturing has been successfully accomplished for similar species of crayfish in other geographic locations. During this project it was demonstrated that crayfish can be successfully cultured as an additional crop in conjunction with other farm crop production activities. Crayfish culture can be accomplished with minimal investments and might be economically worthwhile if high value local live-markets can be developed in which to sell the crayfish.

INTRODUCTION

This mini-grant built upon work started under a project funded by the Department of Food and Agriculture's Environmental Technology Program to develop a greenhouse polyculture system. For purposes of continuity, some of the information from that study is included in this report. This mini-grant demonstration project continued the study of the potential for fresh water native crayfish production in Southeastern Massachusetts. Native crayfish may be a good choice for diversifying existing fresh water aquaculture ventures, cranberry operations, and greenhouse plant production facilities. Crayfish can be marketed live as a gourmet food, bait, and as aquarium specimens. They can be grown in conjunction with terrestrial and aquatic plants, bait fish, and ornamental fish. Southeastern Massachusetts enjoys significant advantages over southern crayfish producers because of the proximity to potential high value markets.

The research primarily took place at Coonamessett Farm. Coonamessett Farm is a twenty acre farming and research enterprise located on Cape Cod. Crops include small fruit, vegetables, bedding plants, and flowers. Research and technical consulting services are offered in small scale agriculture, aquaculture, and fisheries. In 1997, Coonamessett Farm received funding from the Massachusetts Agro-Technology Grants Program (Ag-Tech). The funding was to demonstrate the commercial viability of using available greenhouse plant growing systems for the production, holding, and marketing of aquatic crops as part of a polyculture system. As part of this polyculture project, we demonstrated a new technology from Japan, called Bio-Cord, that can be used to maintain water quality in these systems and other places on the farm. The Ag-Tech project was primarily directed at developing and demonstrating the polyculture system design.

The Coonamessett Polyculture System is very flexible. It can be operated in an ebb and flow manner for watering potted plants or hydroponic crop production. It can function at low flow rates/water levels for nutrient film technique (NFT) hydroponic growing or at high flow rates/water levels (up to 10 inches) for aquatic species holding. The system can function as two completely separate units in any combination of operating modes. Water quality monitoring and u/v sterilization are available.

From an environmental standpoint most greenhouse operations may ultimately be required to have recirculating water systems to eliminate chemical runoff. Water use in such systems has reportedly been cut by two-thirds and fertilizer use by up to three-quarters (Josko, 1991). The potential to use these systems to grow aquatic animal crops, as well as plant crops, in southeastern Massachusetts needs to be explored. Species such as ornamental fish, crayfish and bait fish (golden shiners, minnows, goldfish, etc) are potential candidates for this system. Many garden centers are now selling aquatic plants and ornamental fish for the rapidly expanding water garden market. Bait fish and crayfish are in high demand as bait for fresh water fishing. In addition, the restaurants to which we presently sell produce are interested in trying crayfish in addition to, or as a substitute for shrimp as a menu item. The demand for crayfish is increasing both domestically and overseas (Ladewig and Schaer, 1993). The feasibility of growing crayfish in a greenhouse environment in shallow trays has already been demonstrated (Culley et al, 1985).

The primary modification for raising aquatic species in standard ebb and flow table tops is raising the sides of the tables. In our system design we chose table top fiberglass tanks that are 8 x 4 ft with sides one foot in height. These tanks were originally designed for raising fishing worms. During1997 we successfully operated the polyculture system and demonstrated the commercial viability of raising greenhouse crops (primarily lettuce, greens, and herbs). In September, 1997 we stocked half of our system (five tanks) with about 200 crayfish, *Procambarus acutus,* caught in Weweantic Cranberry Bog. In January, 1998, most of these crayfish were alive and well. They have been molting, mating, and feeding. The Ag-Tech funding ended in March, 1998; the mini-grant started soon thereafter.

Bio-cord technology is being used to maintain water quality in this closed system. The cord is basically a core covered with many rings of thread. This provides a large surface area for the attachment of microbes. Interestingly, crayfish and bait fish feed on micro-organisms. Besides maintaining water quality, the presence of the Bio-Cord may provide an alternate food source for the aquatic crop.

In the 1997 Ag-Tech funded project we did not raise the green and aquatic crops in the same tank simultaneously but in a rotational manner. This was to avoid the problems associated with trying to integrate different growing requirements. Crayfish can easily be integrated into agricultural crop rotation (Bretonne and Romaire, 1990) and grown simultaneously with bait fish (Alon and Dean, 1985). The goal is to expand and diversify production using the same equipment (the same capital investment) for both types of crop, thus creating increased farmed products, increased use of equipment and increased profits. In this mini-grant project we used part of the Coonamessett Polyculture System to rear and hold crayfish in conjunction with golden shiners and plants. The cross-fertilization of technologies between agriculture and aquaculture should promote the use of these self-contained technologies (because the systems can be used during down time in plant farming) thus making investment in the required equipment economically rewarding.

Crayfish production

The polyculture project described above has provided Coonamessett Farm with an excellent experimental facility for raising and studying crayfish. We originally chose local crayfish to demonstrate our polyculture system because they were native in this area and did not require deep holding tanks. There is a vast amount of scientific literature written about crayfish production. Although the literature primarily concerns pond culture in the south and mid-west for species other than the White River crayfish, *Procambarus acutus,* much of the information is directly applicable.

In the controlled conditions of the greenhouse the crayfish can be fed special diets to improve flavor and color and/or be harvested as soft shells upon molting. We also plan a catch-you-own bait activity as part of Coonamessett Farm's expansion into on-farm entertainment. Our preliminary review of the literature leads us to believe that with very little modification cranberry bogs can be used for crayfish/bait fish culture. Future work could include the intensive use of transformed ebb and flow tables in greenhouse growing systems as part of a cranberry bog based crayfish production system utilized for final grow out and/or holding.

CULTURING REQUIREMENTS

Native Massachusetts crayfish may be a good choice for diversifying existing fresh water aquaculture ventures, cranberry operations, and greenhouse plant production facilities. They grow fast, reproduce rapidly, and are very tolerant of low water quality. Crayfish can be marketed live as a gourmet food, bait, and as pets. They can be grown in conjunction with terrestrial and aquatic plants, bait fish, and ornamental fish. The species this project focused on was the white river crayfish, *Procambarus acutus*. This species has recently been renamed as *Procambarus zonangulus*. The high abundance of this crayfish in Southeastern Massachusetts cranberry bogs, streams, and ponds indicates that there is significant potential for culturing this species in large quantities that could have significant and positive economic impact. Massachusetts enjoys significant advantages over southern producers because of the proximity to potential high value markets.

Crayfish are commercially produced in the USA by establishing perpetuating populations in ponds or rice fields. There are a limited number of semi-intensive growing systems used for either raising juveniles for pond stocking or for producing soft-shell crayfish using pond stock. There is also an increasing demand by the aquarium trade.

One potential market is the fish bait trade. Small crayfish, 2.5-3.5 cm (1-1.5 inches) make excellent bait for yellow perch and bluegill sunfish. Larger crayfish, 2.5-3.5 cm (1.5-2.5 inches) have a reputation as great bass bait. The price range for crayfish as bait is dependent on size. Prices run between $0.25 and $1.00 each. Another potential market is soft shell crayfish for the white tablecloth restaurant trade. These crayfish, about 30 to the pound, receive farm gate prices of about $6.00/lb and retail to the restaurants at $11.00/lb. The desirable market size for hard-shell crayfish is about 30 grams.

Culturing crayfish requires an understanding of how to keep crayfish alive and growing. In some cases the culturist will also want to have crayfish successfully reproduce. Crayfish increase their size by molting. The rate at which they grow is dependent on how often they molt and the size increase at each molt. Factors that affect growth include water temperature, water condition, photo period, nutrition, crowding, and stress. It is assumed that improved conditions of space, feed, and water quality should greatly enhance growth compared to the wild.

Optimum temperature for the species of interest in this project, *Procambarus acutus*, is from 20-25 degrees Celsius (68-77 F). It is possible that this species held in this temperature range during long-day photo periods could molt every 6-10 days and reach lengths of 75 mm in three months.

Other water quality parameter recommendations for crayfish are dissolved oxygen greater than 3 ppm, total hardness greater than 100 ppm, pH from 6.5 to 8.5, carbon dioxide less than 5 ppm, and ammonia less than 1 ppm. Water hardness of 100-150 ppt has been recommended for pond culture. Calcium uptake is impaired when pH is below 5.75.

Crayfish are opportunistic omnivores; they will eat most anything. Most of their diet in the wild is believed to be microbially enriched detritus. Macro invertebrates and seeds may be important food sources in the wild as well. Crayfish need calcium to grow which can be supplied from the water or from the feed. Sinking fish pellets are suitable for feeding crayfish however they rapidly disintegrate in the water requiring close attention to maintenance of water quality. Feeding rates should be about 3% of body weight for growing juveniles and about 1% for adults. In the cold winter months feeding can be reduced. High protein (40 percent) floating trout pellets have been used in shallow water holding tanks at the rate of 3-4 pellets per crayfish. There is still considerable discussion on what is the best diet to maximize growth in crayfish. Some studies suggest zooplankton is very important for juvenile growth. *Daphnia* as a feed has been shown to cause considerable weight gain in crayfish compared to plant-based feeds. Population density is the most important factor for limiting growth in crayfish.

Bottom cover and shelter are important to the growth and survival of crayfish. It has been reported (Brown et al, 1995) that stocking densities above 5 individuals per square meter results in significant mortalities. In intensive culture systems shelter has been shown to increase the survival of crayfish, but not growth, with stocking densities of 20-25 crayfish per square meter. Survival was depressed with stocking densities of 100 per square meter. Growth and survival can be increased by layering the tank bottom with window screening or onion bags.

North American crayfish species exhibit significant resistance to disease. There are few disease or parasite problems associated with their culture. However, high mortality has occurred in earthen ponds and confined holding systems from vibriosis.

Breeding

Density of brood stock should be about one to two animals per square foot of tank (8-20 per square meter). Sex ratio of 1:1 is desirable. Water depth does not need to exceed 6-8 inches. Feeding should be minimal to preserve water quality. Water exchange/replacement can be minimal. Raising water temperature in January-February can induce egg laying and hatching up to three months earlier than in the wild.

The red claw crayfish, *Procambarus clarkii*, is the better known southern cousin of the white river crayfish. Red claw females lay their eggs within 2-8 weeks of copulation when water temperatures are around 22 degrees C (72 F). The eggs are extruded onto the swimmerets and take a couple of days for the attachment to firm. The berried females than can be held individually or in communal tanks with plenty of shelter. The young crayfish when hatched can be held at densities of 9-18 per square foot (100-200/sq m) for about a month.

Soft-shell Production

Crayfish, after molting, have a soft-shell stage that lasts for about 12 hours and a paper-shell stage that lasts 36-48 hours. Soft-shelled crayfish have a much higher market value than hard-shelled crayfish both as a food item and as bait. Soft-shell crayfish can be almost entirely eaten compared to only the 12-15% of the tail meat of the hard shell animal. Red swamp crayfish have been the most suitable for soft-shell production; white river crayfish do not do as well in shedding systems down south. The soft-shell crayfish production industry, for the gourmet food market in the southeastern states, has not shown itself to be economically viable due to high production costs.

Crayfish can be held in shallow tanks for the purpose of harvesting and selling the newly molted soft-shell animal. Research in Louisiana focused on this technique in the 1980's. Stocking densities of small (<2 in) pre-molts initially did not exceed four animals per square foot. Larger crayfish (3-4 inch) were stocked at densities of about one per square foot of tank bottom. More recently stocking densities of 24-30 crayfish (about 1 lb) per square foot of tray surface has been used successfully. The tanks should be light colored and well lighted for ease of identifying molting crayfish. The sides of the tanks need to be at least six inches high to prevent the crayfish from escaping.

The Louisiana system, set up in a 35' x 96' greenhouse uses trays that are 3 feet wide by 9 feet long placed about 30 inches above floor level. Water flow rates were 15 gallons an hour. The tanks held 2 inches of water, about 40 gallons, thus there was a complete water exchange every 3 hours. Partitions were used in the tanks to separate the crayfish for easy inspection. Two foot square sections held up to 40 crayfish and inspections for molts were conducted at 12 hour intervals.

Systems have evolved to where a typical operation might operate 48-60 trays, 8 feet by 3 feet with water depths of six inches. The trays, when used for shedding, have water levels of only ½ to 1 inch maintained by spraying the water over the crayfish. Water flows of 1 to 3 g.p.m. are enough to maintain dissolved oxygen levels above 5 mg/l and ammonia below 0.5 ppm. The trays are tilted so the water flows out one end through a screened outlet. It has been found that 90% of the molting takes place during daylight so frequent inspections are made during the day to harvest the freshest molts.

Baitfish and Ornamentals

Freshwater finfish culture can be either integrated with hydroponic plant and crayfish production or conducted in rotation using the same facilities. Integrating the fish culture and plant production has many additional problems associated with the process than when performed separately. In Louisiana, research has been conducted on using soft-shell crayfish production facilities, during the off-season, to hold and raise koi carp and goldfish. Finfish and crayfish can be cultured together but there are some additional management problems related to water depth and disease.

The Coonamessett Farm polyculture system design includes the ability to hold small finfish species such as baitfish and ornamentals. This category includes golden shiners (*Notemigonus crysoleucas*), fathead minnow (*Pimephales promelas*), goldfish (*Carassius auratus*), and koi carp (*Cyprinus carpio*). These species are regularly grown in intensive culture and have well developed feeding programs. This project did not focus on breeding requirements for these species.

There are several additional requirements for small finfish holding that are not needed for crayfish. Additional sources of water aeration would be very useful to insure against oxygen depletion. Automatic feeders would be essential to avoid the need for frequent hand feeding. There also needs to be more effort expanded to filter out particulate matter to prevent ammonia toxicity.

PROJECT RESULTS

Five tanks, referred to as System Two, were set up in an aquatic species holding mode. The water level was maintained at eight inches by the use of stand pipes on the tank outlet drain hole. The water was constantly recirculated with an exchange rate of once every four hours. The U/V sterilizer was on line in System Two treating water recirculated from the pump back to the filter tank. A Bio-cord filter with 20 meters of material was located in the filter tank.

On September 26, 1997, 72 crayfish were captured by Linda Rinta in her Weweantic cranberry bog. The crayfish were apparently migrating from the bog into a marsh area. We have identified the crayfish as *Procambarus acutus*; commonly called white river crayfish. Additional crayfish were captured during a two week period bringing the total to 173. The lengths and tank distribution of the crayfish are given in the attached Appendix Table (Dated 10/4/97).

The crayfish were initially being maintained on a diet consisting of greens, dried dog food, trout pellets, chicken feed, and assorted other food stuffs. We located a source of inexpensive sinking fish feed which became the primary feed from December to the present. Less than 50 grams per week were being fed to the entire crayfish population over the winter months. Activity started to pick up in March and feeding was increased to 50 grams per day. The crayfish were observed molting and mating frequently through December and this activity resumed in March. A pre-molt crayfish is usually very dark in color. Just before molting the crayfish lays on its side. The shell splits between the carapace and tail and the crayfish exits the old shell. We had placed into the tank a number of structures to provide shelter and hopefully to reduce lethal interactions between the animals. The structures include sections of PVC pipe and inverted 1020 plant trays covered with Biocord.

Initially, we routinely cleaned the bottom of the crayfish tanks every few weeks using a siphon. By December 1997 we decided this was too much work and we stopped cleaning the tanks. A hydroponic crop of lettuce and greens was established in the crayfish tanks in January, 1998. A sheet of Styrofoam floats on the surface of each tank into which the plants are inserted using plastic mesh baskets. Chemical nutrients, Hydrosol and Caltrate, were routinely added to the water for hydroponic growing maintaining an EC of about 2.0. PH was usually between 7.0-8.0. A temperature recorder was located in Tank 7 and the resulting temperature profile is presented in the Appendix. The crayfish were often found hanging from the plant roots which were frequently cut short by this activity. The plants did not seem to suffer by this root pruning.

On March 11, 1998 a crayfish inventory, totaling 138 individuals, was taken and is presented in the Appendix Table dated 3/11/98. Overall, the initial crayfish population suffered about a 20% mortality over the winter period. An unknown portion of the mortality may be due to escapees as very few bodies were ever recovered. Crayfish have been found on the floor of the greenhouse routinely. The crayfish also were capable of moving between tanks making it difficult to keep tank inventories straight. By June, 1998, we gave up on trying to keep specific crayfish restricted to specific tanks. Regardless of these tank inventory problems, the data indicates virtually no growth took place over the winter period.

Sometime in the spring several golden shiners were added to the tank system by Dr. Dale Leavitt of SEMAC. These fish spawned a number of times and many golden shiners, some up to three inches in length, existed throughout the tank system during the project period. Crayfish were observed successfully catching and eating the golden shiners. The shiners were fed a diet of fish flakes.

At least one crayfish spawned sometime in late spring. Appendix Table dated 6/25/98 presents the results of our inventory at that time. Sixty-eight larger crayfish were left from the original stocking. An additional thirty were sold to a restaurant leaving forty missing-in-action. One hundred and sixty-eight new crayfish were inventoried with a size range of 12-40 mm. The length modes would indicate two age groups in these new crayfish.

The tanks were again inventoried on 7/24/98 and contained 178 crayfish; 25 large and 151 of the new 1998 year class. The data indicates that both size groups in the 1998 year class grew about 20 mm during July. On October 3, 1998, a berried female was observed in Tank 9. Two days later the eggs were gone and many tiny crayfish, 1-2 mm, were observed in the tank thus we initiated an inventory. The crayfish born in the spring of 1998 had reached sizes of 60-80 mm which approximates what researchers have identified in other intensive culture systems. The original crayfish were mostly dead or missing. The high disappearance of the adult crayfish during the summer may have been due to an increased incentive to leave the tanks for some biological reason.

On 10/17/98, one gallon of organic fish emulsion was added to the 500 gallon hydroponic system to augment nitrogen as part of another research effort. Overnight, virtually all the crayfish and golden shiners died ending the project. The cause of death most likely was oxygen depletion.

Economic evaluation

We have found potential markets for the crayfish as food, bait, and as pets. We received a Class 3 Aquaculture Permit for a Type A Facility that initially only listed golden shiners since crayfish are unregulated. However, this became a Catch 22 because we could not sell crayfish without an aquaculture permit (buyers were uncertain of the legality). Finally, the permit was modified to list crayfish to overcome potential problems.

The polyculture system proved that it can hold crayfish through this period but limited data hinders economic analysis for evaluating crayfish as a crop. Research in Louisiana on soft-shell crayfish production systems indicated that 1440 square feet of tank space can produce about $13,252 worth of crayfish in four months ($6.00/lb base price). This is about 2200 pounds of crayfish which at 30 count means upwards of 65,000 crayfish were processed through the facility (about 20,000 at any one time). This type of system requires a continuous source of pre-molts. Crayfish are then sold through middlemen who receive $11.00/lb at the restaurant door. Our conversation with chefs on Cape Cod lead us to believe that $8.00/lb would be an acceptable delivered price for gourmet quality soft-shells. If a demand develops this could go higher.

However, we are uncertain to the quantity of crayfish that would be available for holding for soft-shell production and of the sourcing problems. We thus took a more conservative approach assuming that a one-time load of crayfish would be held for the bait market. A facility with 1280 square feet of tank space can probably hold 5000 bait size crayfish with a market value of $2,500. A baitfish crop can also be held in conjunction with the crayfish but this is beyond are capabilities to examine at this time.

It is also difficult to compare this system to single purpose systems such as ebb and flow benches, hydroponic tables, or large aquatic holding tanks. The polyculture system costs more than each one of these type systems viewed separately, however, it can perform the tasks of all three. The best method to evaluate the potential for crayfish production at this time is to assume that a system already exists for the production of a crop, for example, hydroponic lettuce that is capable of holding crayfish. We then would need to evaluate what the additional costs would be to grow crayfish and what would be the anticipated return on investment. The only two costs that we have identified is the cost of the original stock and the cost of feed.

Commercial farm sources of crayfish are expensive; adult red river crayfish prices range from $50.00 to $100.00/hundred plus shipping. If adult crayfish can be routinely harvested in the fall by trapping in cranberry bog systems the price should be much lower. At the catch per unit effort for wild harvest in the fall of 1997 that we attained; a price of $0.25 per adult crayfish would be an acceptable rate. Our attempts to harvest crayfish in 1998 met with failure but we are on a low point in the learning curve.

Adult crayfish harvested in the fall would be used as a spawning stock for the spring as well as for sale during the summer. Any offspring produced would be marketable as bait the following winter and used for spawning stock the following spring/summer. The holding facility, in our case a greenhouse, would primarily serve as a live warehouse for retailing the crayfish. The crayfish do not need any purchased feed but their diet could be augmented with fish food. An economic evaluation per 100 fall harvested crayfish may be as follows:

Cost per 100 from wild harvester = $25.00
Mortality over winter spring holding period = 20%
Sale of crayfish to restaurant; 80 @ $0.50 each = $40.00
Cost of feed; 20 weeks x 50 grams/week = 2 lbs of feed @ $1/lb = $2.00
Gross Profit per 100 crayfish (no labor) = $13.00

The incidental cost of labor to take care of the crayfish will mostly be associated with feeding and removing the crayfish from the tanks for market. Maintenance of the system and delivery to market are incidental to the main crop; in our case lettuce. If we estimate an hour per week dedicated to crayfish that would amount to 20 hours @ $8.00/hour = $160.00. This would mean the facility would have to produce a minimum of 1200 crayfish to break even.

CONCLUSION

There does not seem to be any major technical obstacles to crayfish culture in our area. The need is to either develop an abundant wild stock for economies of scale or to sell the crayfish at a higher unit value. As a food item it is hard to conceive of the crayfish price ever exceeding $0.75 each; the price of fancy Tiger shrimp. Bait prices seldom approach $1.00 each and the pet market is very small. This leaves the requirement to hold large numbers of crayfish as an adjunct crop to be worthwhile. Our original premise of using cranberry bog systems for stock production and intensive holding facilities for marketing still seems viable.

REFERENCES

Alon, N.C. and J.M. Dean. 1980. Production guidelines for crawfish farming in South Carolina. Special publ. USC-B1-80-1.71 pp.

Bretonne, L.W. and R.P. Romaire. 1990. Crawfish production systems. SRAC Publ. No. 241. January, 1990. 4 pp.

Bretonne, L.W. and R.P. Romaire. 1990. Crawfish production, Harvesting, marketing and economics. SRAC Publ. No. 242. January, 1990. 4 pp.

Bretonne, L.W. and R.P. Romaire. 1990. Crawfish culture, Site selection, pond construction and water quality. SRAC Publ. No. 240. Fact sheet 9043. 4 pp.

Culley, D.D., M.Z. Said, and E. Rejmankova. 1985. Producing soft crawfish: a status report. Louisiana Sea Grant. 16 pp.

Engle, C.R., L.W. Dorman, and D.L. Gray. 1988. Baitfish production enterprise budget. SRAC Publ. No. 122. November 1988. 4 pp.

Gray, D.L. 1988. Baitfish. SRAC Publ. No. 120. November 1988. 2 pp.

Gray, D.L. 1988. Baitfish, feeds and feeding practices. SRAC Publ. No. 121. November 1988. 3 pp.

Gross, M.L. 1989. A bibliography on the culture of baitfish. Minnesota Extension Service. September, 1989. 4 pp.

Homziak, J. 1993. Producing soft-shell crawfish in off-season catfish hatcheries. Aquaculture Magazine, September/October 1993:58-65.

Huner,J.V. 192. Culturing ornamental cyprinid fish in crawfish culture systems. Aquaculture Magazine, September/October 1992:30-39.

Josko, D.L. 1991. Ebb and flow saves money-and grows great crops. In Grower Talks, September 1991: pp23-24.

Ladewig, K.F. and S.L. Schaer. 1993. Crawfish, A healthy Choice. SRAC Publ. No. 243, September, 1993. 4 pp.

Rivara, G. 1992. Industry profile: Integrated aquaculture and hydroponics. Northeastern Aquaculture. Vol 4, No. 2,3. :1-4.