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Aquaculture

Crayfish Aquaculture Demonstration in Minnesota Rice Paddies

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Introduction

Crayfish culture is the largest aquaculture industry in the United States in acreage, and is second only to catfish in total production. In Louisiana alone, 140,000 acres produce an average of 500 to 600 pounds each, yielding about 77 million pounds per year. In Minnesota, crayfish aquaculture is still relatively undeveloped, but has potential. The papershell crayfish (*Orconectes immunis*), a native and widespread Minnesota species (Helgen 1990), has become so abundant in wild rice paddies that rice yields have fallen, according to local growers. Methods to reduce crayfish populations have been unsuccessful, while the economic viability of wild rice culture has been impaired by competition from California. As a result, Minnesota paddy wild rice growers in areas affected by crayfish have expressed an interest in exploring crayfish culture.

Should crayfish culture and marketing prove feasible, vacant wild rice paddies offer commercial-scale opportunities quickly and with small investment. This project was designed to explore this unique opportunity. The primary objective was to raise crayfish to a marketable size (for either bait or food) by the end of the first growing season. The secondary objective was to see if a production level could be achieved that would make crayfish culture economically feasible.

Project Description

An existing rice paddy was divided into three one-acre paddies. In 1990, berried (egg-laden) female crayfish were obtained from nearby rice paddies, and placed in cages. The cages were designed to hold the adult females but allow young crayfish to escape when they were ready to leave the female. In 1991, berried females were stocked directly in the paddies without using cages. A supplementary experimental crayfish diet of 20 percent crude protein and 6.0 percent crude fat (donated by Zeigler Brothers) was used to enhance growth rate.

Quadrat samples were used to estimate standing stock and harvest potential (1991 only) because no commercial harvest was conducted. The number of crayfish per sample, sex, maturity, and length (carapace length, CL, in cm) were recorded.

By mid-August, no crayfish were found more than one meter from the shoreline. Standing stock was estimated by multiplying the average number of crayfish in shoreline quadrat samples by the length of the shoreline. Overhanging terrestrial grasses prevented quadrat sampling along some shorelines. Dip net samples, however, showed that these areas held many more crayfish than quadrat sampled areas. To adjust for this, standing stock for each paddy was calculated by estimating that there were 1.5 to 2 times as many crayfish in areas with heavy vegetation as in sampled areas. All estimates of standing stock and harvest potential are reported as a range based on this estimate.

1990 Season

Three, one-acre paddies were filled with water by April 26, and approximately 20 lbs of berried females, carrying a total of about 174,000 eggs, were put into cages in each paddy. The cages were each stocked with approximately five pounds of crayfish. Stocking was complete by April 30. Young crayfish (0.4 cm CL) were first observed on May 31.

An episode of low dissolved oxygen killed a number of the adult females early on. Densities of young crayfish in all ponds were low during 1990, indicating there was also significant mortality among the young. Water temperatures, which were colder than normal and fluctuated significantly during the spring of 1990, may also have contributed to mortality. This could have delayed hatching and increased the stress on the females. No supplementary food was given

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to the females during captivity (April 30 to May 30), and it is unknown if this resulted in cannibalism of the eggs or young.

Few young crayfish were found in traps and dip net samples. Also in 1990, aquatic macrophyte production was heavy, another indication crayfish density was low. As a result, supplemental feeding was not conducted.

Growth was monitored throughout the summer. Young crayfish grew rapidly during June and July, and typically had very new and soft, or brittle, shells, indicating frequent molting and growth. The young crayfish grew to an average size of 3.4 cm (CL) by mid-August (Table 1), ranging from 3.25 to 3.95 cm. The average size did not increase after August 9.

The ponds were drained in mid September and few crayfish burrows were observed. Predation had clearly been a problem. Otters had been observed feeding in the paddies and substantial amounts of crayfish shells were found in otter feces throughout the summer. No estimate of standing stock was made in 1990.

1991 Season

The three paddies were flooded on May 2-3, and approximately 30 lbs of berried females were stocked in each by May 16 (approximately 260,000 eggs per acre). Young-of-the-year crayfish were first captured in dip net sweeps on May 10, and averaged 0.5 cm (CL). Seven to 24 young crayfish were captured per sweep, indicating that survival of young crayfish was much higher in 1991 than in 1990.

Early in the season, aquatic vegetation was very thick. By mid-July, almost none was left. Floating bits of aquatic macrophytes were observed on all the paddies on June 18. This floating material looked similar to the rice clippings found in wild rice paddies that have been damaged by crayfish. Only scattered clumps of wild rice were growing by July 11, and they were in the center of the ponds.

Table 1. Average size (CL cm) attained in 1990 and 1991 in three demonstration paddies.

	1990	1991
Paddy #1	3.34	3.30
Paddy #2	3.58	2.46
Paddy #3	3.38	3.18
Combined	3.39	2.84

Each paddy was fertilized in late May. Two 50 lb bags of 5-45-5 (N-P-K) granular fertilizer were cut open and sunk along the windward (western) shore of each paddy. In addition, several bales of discarded hay were added to each paddy. Throughout June, approximately 50 lbs of feed were fed per paddy twice per week. Feed quality was likely reduced because it had been stored at room temperature for a year. The manufacturer still recommended its use because it was meant only as a supplemental feed. Beginning July 11, the crayfish were fed 50 lbs per acre every other day.

Growth varied as a function of density. Paddy #2 had the smallest crayfish (Table 1) and the highest standing stock (Table 2). Growth and density in the other two paddies (paddies #1 and #3) were similar to one another, but crayfish were larger and less abundant than in paddy #2. The average size of young crayfish in all three paddies (2.8 cm CL) was less than that attained in 1990 (3.5 cm CL) when densities were much lower. Even though supplemental artificial food was provided in 1991, it apparently was not sufficient to compensate for the higher densities.

The number of crayfish estimated per acre ranged from 10,414 to 35,560 and averaged 19,558 for the three paddies combined. The average individual weight in paddies #1, #2, and #3 was 11.2g (41 crayfish per lb), 5.8g (79 crayfish per pound), and 10.2g (45 crayfish per lb), respectively. Estimated standing stock ranged from 287 to 562 lbs per acre, with an average of between 375 to 450 pounds per acre.

Discussion

In both years of the study, crayfish seemed to vanish from the paddies during September. Considerable burrowing activity, especially in the levees, was observed beginning in mid-August, at

Table 2. Adjusted Standing Stock and Harvest Potential, August 15, 1991

	Adjusted Standing Stock (Pounds/acre)[1]	Harvest Potential (Pounds/acre)[2]
POND #1	387 to 465	580 to 697
POND #2	506 to 562	759 to 843
POND #3	287 to 345	430 to 517
AVERAGE (three ponds)	375 to 450	562 to 675

[1] Quadrat standing stock estimates were adjusted to take into consideration higher densities of crayfish in areas not able to be sampled by the quadrat sampler. There were two areas in pond #1 and #3 and one area in pond #2 that had an estimated 1.5 to 2.0 more crayfish than the sampled locations.

[2] Harvest potential was estimated as 1.5 times the adjusted standing stock to take into consideration such things as crayfish lost to cannibalism, predation, emigration and lost growth potential because crayfish were not harvested and were food limited.

the same time crayfish densities began to decline. When the water was drawn down in paddies #2 and #3 (the drain in paddy #1 was not functional) on September 25, very few crayfish were found, and few additional burrows were found. The onset of burrowing may be related to declining water temperatures or to reproduction.

The number of burrows observed, however, didn't seem to account for the entire population that had previously been present. Intense predation, cannibalism, and emigration may have accounted for much of the loss. Predators found in or near the experimental paddies included raccoons, otters, mink, skunks, and great blue herons. The remains of crayfish exoskeletons were abundant in raccoon and otter feces found around the paddies. The impact of predators on our one acre paddies was likely much higher than it would be for commercial sized paddies.

If harvesting had been done during the season, more crayfish would have been harvested than remained for the August standing stock estimate. For example, had it begun in July when the crayfish were two inches long (suitable for some soft- and hard- shell bait markets), fewer crayfish would have been lost to predators and cannibalism. In addition, reduced densities would have allowed the remaining crayfish to grow more quickly. Given this, it may be estimated that the 1991 potential harvest from the experimental paddies was 1.5 times the August 15 standing crop (Table 2). Therefore, the estimated potential harvest for the 1991 season was between 560 and 675 lbs per acre.

This potential harvest compares well with the yield of *Procambarus clarkii* and *P. zonangulus* from Louisiana ponds. The USDA (1991) estimated that the average annual harvest of crayfish from Louisiana ponds in 1990 was 587 lbs. Lorio, Avery and Lutz (1991) reported an average production of 506 lbs per acre for the same year. The potential harvest in this study was higher than the 46-352 lbs per acre of *O. immunis* produced in New York ponds (Forney, 1957; Tack 1941), but was slightly less than the 689-810 lbs per acre of *O. immunis* harvested in a Michigan pond (Lydell,1938). The crayfish in Lydell's study were harvested at intervals throughout the summer. Although unclear, the crayfish in the New York studies may have been harvested when the pond was drained, which would result in an estimate of standing stock rather than harvest potential.

While the size of *O. immunis* produced in our experimental paddies was smaller than the *Procambarus* species produced in Louisiana ponds, the size achieved here was larger than that of the *O. immunis* produced in the New York and Michigan ponds cited above. Pond-raised Louisiana crayfish are typically harvested and marketed at a size of slightly larger than 30 per lb. (12.5 to 14.0 gm each) (*Seafood Leader*, 1989), which translates into crayfish about three inches long (approximately 3.8 cm CL) The crayfish from the experimental paddies in 1991 averaged 62 per lb. (7.3 gm each) and were approximately 2 3/8 inches long (2.8 cm CL). Crayfish from the four New York ponds described by Tack (1941) averaged smaller than 230 crayfish per lb.(1.9 gm each). Crayfish from the Michigan pond reported by Lydell (1938) were nearly as small, averaging 195 per lb. over three years, and crayfish from the New York study reported by Forney (1957) ranged from 99 - 253 per lb. (4.6 to 1.8 gm each).

In 1990, crayfish grew to an average length of 3.4 cm CL, better than in any of the ponds during 1991. Because 1990 densities were very low, growth was probably near maximum for extensive culture in central Minnesota. If crayfish had been removed during the 1991 growing season as they reached bait-market size, the average size at the end of the growing season would likely have been higher.

Conclusion

Based on the results of this study, crayfish can attain a size suitable for the soft- and hard- shell bait market by the end of July and can attain a marginal food size by the end of the first growing season. Identification of reliable markets is of critical importance if crayfish culture is to develop. Midwestern markets currently exist for bait crayfish, but are unreliable and present logistical problems. Crayfish cannot be sold live for bait in Minnesota or most areas of Wisconsin and must therefore be transported live to Illinois, Indiana, Ohio, New York, West Virginia, and other states.

O. immunis are currently nonexistent in the food market. If an efficient mechanical tail meat peeler could be developed, the potential of young-of-the-year *O immunis*. for the food market would increase. A second growing season would likely improve market potential for whole boiled crayfish but may also reduce economic viability.

The next steps in the development of crayfish aquaculture should focus on the development of reliable markets and on incorporating commercial-scale crayfish culture into wild rice production. Paddy rice producing areas that currently do not experience crayfish problems should not consider crayfish culture at this time because of the threat crayfish pose to rice production if they become established. *O. immunis* can also pose severe problems for fish production and should not be introduced without thought to future pond use. In areas where crayfish already cause problems, however, crop rotation or polyculture of crayfish with another aquatic crop (wild rice, minnows, etc.) may produce a greater economic return per acre than a single crop. Much more information regarding life history, behavior, and natural population fluctuations in wild rice paddies needs to be collected before a bona fide industry can emerge.

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